Forecasting the benefits from providing an interface between cycling and public transport

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Abbreviations and acronyms

ARTA	Auckland Regional Transport Authority
BaR	bike and ride
BART	Bay Area Rapid Transit (California, US)
BCR	benefit-to-cost ratio
BoB	bikes on board
EEM	*Economic evaluation manual* (NZTA)
FHWA	Federal Highway Administration (US)
MTD	[Santa Barbara] Metropolitan Transport District
NPV	net present value
NZTA	New Zealand Transport Agency
PT	public transport
TMIF	Transport Monitoring Indicator Framework (Ministry of Transport, New Zealand)

Contents

Executive summary

This research refers to ‘cycle-PT’ as the introduction of secure storage at public transport stations/stops (bike and ride) and racks on board buses, carriages or ferries (bike on board). Cycle-PT enhances and expands public transport patronage by catering to a wider array of users, both those for whom it is too far to walk to public transport as well as those who prefer to use a bicycle as part of their trip.

The research outcomes are guidance for New Zealand practitioners on forecasting the use and benefits of cycle-PT initiatives in various contexts in New Zealand and in making an economic evaluation of the benefits of introducing cycle-PT into New Zealand.

The research methodology was to examine the types of cycle-PT systems in use around the world and identify relevant examples to inform the likely uptake of cycle-PT in New Zealand. On analysis of various examples, it was decided that North American data from both the United States and Canada was the most applicable to the New Zealand context. This is due to similar mode share for cycling and a similar historical approach to the provision of cycling facilities.

Various initial approaches to the research methodology failed to satisfactorily derive cycle-PT forecasts but the final refined research methodology created a model to forecast cycle-PT demand based on:

- overall cycle-PT demand as a portion of public transport patronage
- the number of cycle-PT users who would shift away from the private car
- the demand for secure locker storage.

A Monte Carlo based simulation was set up to model the range of values of each variable and the resulting number of cycle-PT users. This produced forecasts as a range of values including an average as well as a 95th percentile low and high range. The model will allow practitioners to adjust the forecasts for each examination of cycle-PT demand within the range, according to local context.

The information produced by the forecast models was used to perform an economic evaluation to assess a benefit-to-cost ratio using the NZ Transport Agency’s *Economic evaluation manual.*

Six significant urban areas within New Zealand were assessed for their potential to integrate cycle-PT into their existing public transport service. For every area, the benefit-to-cost ratio exceeded 1, especially for cities with higher levels of congestion.

The economic analysis indicated that the introduction of either the full cycle-PT option including secure storage, or the bikes on board option alone, would produce favourable economics.

The study also concluded that there would be other benefits and advantages to the general community with the introduction of cycle-PT.

Abstract

The integration of cycling and public transport (cycle-PT) can provide additional transport modal choice and flexibility in the use of existing public transport and also increase cycling trips and transit patronage. A model was developed for forecasting demand for bike racks on board public transport and secure storage at stations and terminals in different contexts and for different public transport modes. The NZ Transport Agency's *Economic evaluation manual* was used to calculate the economic justification in terms of a benefit-to-cost (BCR) ratio for implementing cycle-PT in New Zealand's larger centres. Cycle-PT is economically justified in New Zealand with BCRs from 2 to more than 10 depending on the centre and the scenario. The implementation of cycle-PT in New Zealand's six largest centres could produce more than 1.7 million cycle-PT trips per annum. This research has provided sufficient analysis for practitioners to be able to systematically plan and evaluate the demand and economics for cycle-PT schemes in New Zealand.

1 Introduction

1.1 Scope of research

The objective of the research was to assess international experience in providing storage facilities for bicycles at public transport stops/stations/terminals and providing for cyclists to take their bicycles on public transport. Based on this assessment, the research has developed guidance on the potential demand for and the economics of cycle-PT initiatives in New Zealand.

The results of the research will sit alongside any separate examination of New Zealand trials of cycle-PT integration.

The outcomes of the research study were stated as the:

- estimation of the likely level of use of bike-and-ride (BaR) secure storage facilities in particular locations
- estimation of the likely level of use of bike-on-board (BoB) facilities on public transport
- calculation of additional benefits for any project costs related to providing secure storage or taking bicycles on public transport services
- estimation of intangible benefits of related increased public transport usage through reduced CO_2 and other greenhouse gases from transport activities
- demonstration of a high-level review of the benefits to enable the appropriate prioritisation of funds to be spent on secure bicycle storage and bike racks on-board public transport services.

1.2 Research methodology

The following is a summary of the stages involved in developing the final refined methodology:

1. An international literature review to determine a likely range of mode share for different cycle-PT initiatives.
2. The development of a methodology to forecast the likely uptake of cycle-PT in New Zealand for various situations and urban areas.
3. Identification of the increases in patronage on public transport services through cycle-PT and what this is likely to require in terms of infrastructure (eg secure lockers, cycle racks).
4. Evaluation of the economics of cycle-PT and whether cycle-PT initiatives should be further pursued.
5. Development of a method for the evaluation of cycle-PT initiatives compatible with the *Economic evaluation manual* (EEM), volume 2 (NZTA 2010b).

The literature review for this project identified data from a range of individual cycle-PT systems including likely value ranges for each factor affecting cycle-PT demand. Due to the range in data for each factor from different cycle-PT installations and in some instances a low sample size of data, the range for each factor was incorporated into the estimates of cycle-PT demand.

This involved:

- For each component of demand for cycle-PT, a likely value as well as an estimated standard deviation were derived from the high and low bounds for that value. The calculations assumed a particular statistical distribution for each factor.

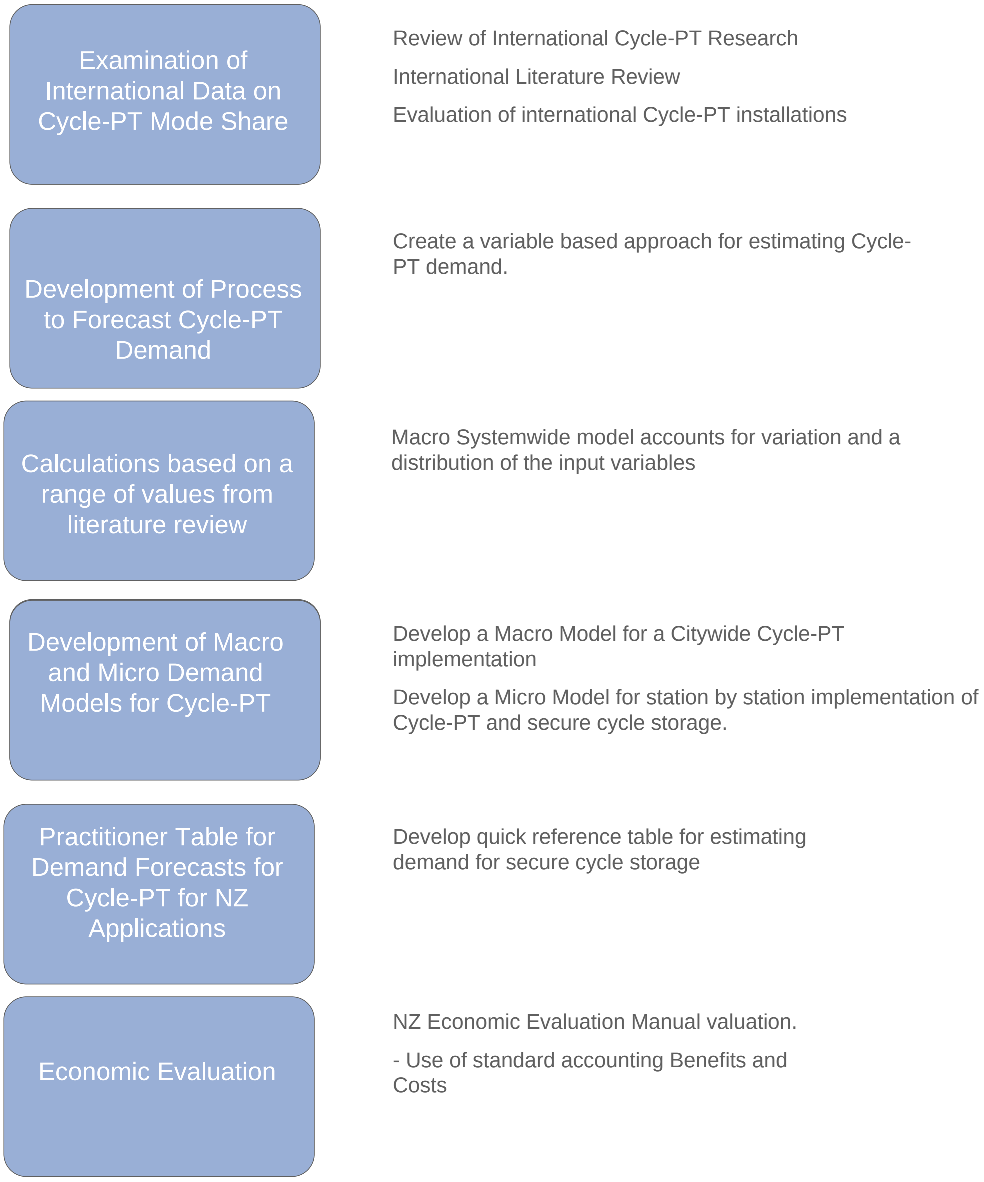
- A Monte Carlo simulation was performed using the distribution of the variables to test an output range of demand rather than a single value.

The above allowed factors to be incorporated into the calculations even where there were few data points recognising that there was variability in each factor.

Some initiatives and pilots of cycle-PT integration have already been implemented in New Zealand but these were not taken into account as the objective of this research was to forecast the use of cycle-PT integration based on the longer-term rates of cycle-PT experienced overseas. Schneider (2005) describes how initial patronage is sensitive to short-term factors, the level of marketing and education and the proportion of the network covered.

The methodology is summarised in figure 1.1.

Figure 1.1 Research methodology outline



Review of International Cycle-PT Research

International Literature Review

Evaluation of international Cycle-PT installations

Create a variable based approach for estimating Cycle-PT demand.

Macro Systemwide model accounts for variation and a distribution of the input variables

Develop a Macro Model for a Citywide Cycle-PT implementation

Develop a Micro Model for station by station implementation of Cycle-PT and secure cycle storage.

Develop quick reference table for estimating demand for secure cycle storage

NZ Economic Evaluation Manual valuation.

- Use of standard accounting Benefits and Costs

2 Examination of international cycle-PT systems

2.1 Introduction

The primary focus of the research methodology was to use international data to provide guidance for practitioners in forecasting the use and benefits of cycle-PT initiatives in various contexts in New Zealand.

The review of international data covered multiple forms of public transport including buses, ferries and various types of commuter rail services.

The literature identified two primary methods of cycle and public transport integration:

- **Bike and ride (BaR):** a cyclist uses a bike to reach the public transport facilities and then parks the bike there.
- **Bike on board (BoB):** a cyclist uses a bike to reach the public transport facilities and carries the bike onto the public transport service. The bike can then be used at the latter end of the service to reach the final destination.

Some other key findings from the search of international literature on cycle-PT were:

- The economics of cycle-PT initiatives appear to be positive and there are successful operations continuing internationally.
- Previous research has not been able to develop a process to forecast the preference for bicycle locker usage or secure bicycle storage where it was possible to carry bikes on public transport.
- The provision of cycle-PT integration increases the effective catchment area for public transport and will lead to increased public transport patronage.
- While cycle-PT occurs in various parts of the world, North American research and cycling characteristics may be best suited to forecasting cycle-PT demand in New Zealand due to similar transport networks, car ownership rates and modal splits.

2.2 Increase in public transport catchment with cycle-PT

Research and surveys in a number of countries have found that the time required to reach a public transport service is a dominant factor in public perception of public transport as a viable mode choice. One of the key benefits of cycle-PT is the ability to increase patronage on existing public transport services due to the increased catchment area (number of people) who could cycle to public transport from areas too distant for walking. Table 2.1 summarises the findings from seven sources referring to catchment area studies.

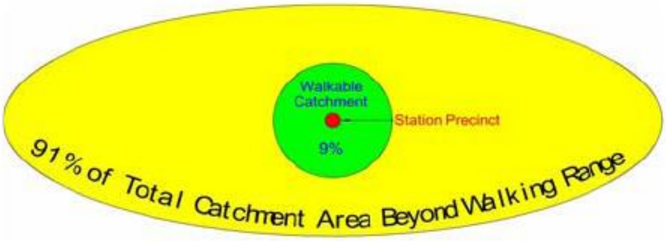
Table 2.1 Public transport catchment areas for walking and cycling used for analysis

Source/study area	Walking	Cycling
USA, Canada (Robinson 2003)	0.25 miles (0.4km)	3 miles (4.8km); 12 times walking distance
Netherlands, Germany, UK (Martens 2004)	-	2–5 km
UK Department of Transport 2004)	10 minutes; 0.8km	3.2km; 4–15 times walking distance
USA (Victoria Transport Policy Institute 2010)	10 minutes	3–4 times walking distance
Scotland (Scottish Executive 2000)	-	2–5km
China (Lu et al 2003)	500m	20 minutes
Australia (Pedal Power ACT 2005)	700m; 10 minutes	3–4 times walking distance (2.1–2.8km)

Despite the variety of countries undertaking catchment area studies, the ratios between walking and cycling catchments are on a similar scale. Typically patrons are prepared to spend 10 minutes walking (800m at 1.3m/sec) or 10 minutes cycling (3.2km assuming four times the walking speed).

Figure 2.1 displays an example from Western Australia rail transit of an increased catchment area.

Figure 2.1 Catchment area example



Source: Martinovich (2008)

Considering the increase in travel distance by integrating cycling and public transport, the public transport catchment area could potentially increase more than 10-fold over walking, and a geographic information system (GIS) analysis of the particular geography of Auckland and Wellington confirmed this.

This helps explain why public transport patronage increases when cycle-PT is introduced. However there is insufficient information available on the number of potential patrons outside the walking catchment who would be attracted to cycling to a public transport service. To collect this information would require a substantial survey effort and for this reason the research focused on using only long-term observed cycle-PT rates from relevant urban contexts and public transport mode shares.

2.3 Applicability of overseas cycle-PT data to New Zealand

Two specific elements were examined in more detail to determine the applicability of overseas data to cycle-PT usage and hence demand in New Zealand. These were:

- similar mode share for cycling
- effect of climate and topography.

2.3.1 Cycling mode share

It was important that the results of overseas experience used in this research were from areas with similar mode share.

The literature review typically produced data and reporting from Europe and North America.

The long tradition of cycling in Europe combined with greater investment in cycling with urban design and transit facilities incorporating cycling infrastructure mean that in European cities up to 20%–30% of urban journeys can be made by bicycle. In the USA, the national average is closer to 1% (Komanoff and Pucher 2003) which is similar to major urban areas in New Zealand where typical cycling mode share is less than 3%[1].

Although some level of bike and bus integration is common throughout Europe, it is a relatively new development in North America. Federal legislative changes starting in the early 1990s provided specific bicycle funding collected through petrol usage tax to local and state government authorities for the purposes of implementing cycle facilities and BoB programmes (Clarke 2003). The success of BoB programmes has meant that, since 1991, more than 80 operators across the United States have adopted a BoB programme, with more than 15.5 million BOB trips per year (Boyle and Spindler 1999).

This in turn has led to a body of research that is valuable in a New Zealand context, as it describes the results of cycle-PT in highly motorised cities with historically low cycle mode share.

2.3.2 Relevance of climate and topography

New Zealand cities are relatively spread out, often lack adequate cycle facilities and in some cases have wet and windy weather and hilly topography.

Climate and topography have little overall effect on cycle usage when compared with the effects of the level of investment in cycling infrastructure. In North America the trend is for the more northern cities to have a higher cycle mode share despite generally difficult cycling climate conditions.

The city of Seattle has a population of 560,000, a hilly topography and often poor cycling weather conditions. It also has one of the highest cycle rates (ranked 3rd among the 70 largest cities) in the USA, with a high level of integration between cycle and public transport. The BoB programme is complemented by the provision of cycling lanes, bicycle parking, pavement surface maintenance and public promotion of cycling. The result of this cycle investment has been the rise of a 'cycle culture' within a traditionally car-friendly nation, with more than 20% of the population cycling regularly and more than 300,000 BoB trips being undertaken annually (Boyle and Spindler 1999).

Different topography and weather conditions (specifically those experienced across North America) do not appear to affect cycle-PT rates.

2.4 Case studies of two North American cities

Two cities, one large and one small, were examined to provide a comparison between typical situations in the USA and New Zealand. The study illustrated the similarities between USA and New Zealand contexts

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[1] 2001 and 2006 New Zealand Census data. Note Christchurch and Nelson urban areas are >6% cycling mode share from the 2006 Census.

and also provided expectations on the scale of the effect of investing in cycle-PT integration in New Zealand.

2.4.1 Santa Barbara – 200,000 population

Santa Barbara[2] is located in California, USA, about 100 miles north-west of Los Angeles. The city is located on the coast of the Pacific Ocean and in the foothills of California's Coastal Ranges. The local bus service has a service area population of about 200,000 people. It is completely independent of any larger urban area (ie it is not a suburb) has both hilly terrain and seasonal wet weather and is a good benchmark for smaller New Zealand cities.

The city began implementing a bike on bus programme in 1995, and has bike racks installed on 70 of its 90 buses (about 80%). Santa Barbara has a public transport mode share of 6.2% and a bicycle mode share of 4.5% (Hagelin 2005).

Santa Barbara's BoB usage was 1% of total patronage in 2003. Santa Barbara Metropolitan Transit District (MTD) has provided figures indicating that in 2006 this had risen to about 1.3%. The Santa Barbara MTD also indicated that the cost of purchasing the bike racks was about $US700 per bus and that they were inexpensive to maintain, therefore providing a cost-effective addition to their services. The Santa Barbara MTD has been pleased with the success of the programme.

Of the 82 North American public transport services used in the analysis that have a BoB programme, Santa Barbara is ranked midway (35th) in terms of the proportion of passengers carrying bikes on board public transport services.

Given the varying topographical and weather conditions and similar population size to smaller New Zealand cities, Santa Barbara is a relevant benchmark comparison for New Zealand.

2.4.2 Santa Clara – 1.7 million population

Santa Clara[3] is located on the San Francisco Peninsula in California and is a good benchmark for larger New Zealand cities.

Since 1996 Santa Clara has allowed BoB for both train and bus services. Santa Clara's Caltrain service has the highest proportion of BoB riders of the 82 services used in the analysis. (The 6% figure for trains has been used as an upper range of what might be possible in New Zealand.)

Santa Clara Valley Transport Authority's investment strategy included equipping all of its 540 buses with bike racks, as well as modifying train carriages to carry cycles, for a combined cost of $US500,000. The investment in cycle-PT has produced an average observed BoB of 2% for the bus system and a bicycle mode share of 1.6%[3].

Santa Clara was one of the first operators in America to institute a BoB programme when it began to purchase Japanese rolling stock in the mid-1990s which was built to accommodate cycle passengers. Since 2000, Santa Clara has adopted a carriage purchasing policy that includes cycle considerations. The success of its programme has meant that bicycle rack capacity constraints have been a recurring issue, with some cycle commuters having to wait for the next train to arrive.

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[2] Information for this section has also come from /bikesontransit and santabarbara.com

[3] Information for this section has been drawn from Jenkins (2001); vta.org and caltrain.com

It should be noted that the 6.2% figure for Santa Clara only includes actual BoB trips. The proportion of people cycling to public transport is likely to be higher, as secure bicycle lockers are available at all Santa Clara train stations and they have a large bicycle infrastructure network.

2.5 Cycle-PT mode share in the USA

From the literature on North American cities, it would appear that about 1% of the population cycle to work even where no cycle facilities exist. The largest bicycle friendly cities in the USA achieved an average mode share of 1.51% estimated in 2008, versus a US average cycle mode share of 0.93% in the largest metro areas (United States Census Bureau 2008).

Cities that have recently begun to integrate cycle and public transport combined with bicycle lanes, bicycle parking and promotional activities, have developed a cycle journey-to-work mode share greater than 5% within the last 15 years. Canadian cities with a greater investment in cycle infrastructure also see a higher proportion of people journeying to work on bicycles, particularly in areas where bicycles and public transport have been well integrated. Integration between public transport and cycling has been found to stimulate both modes. The result has seen some Canadian cities develop up to four times the cycling mode share of cities that lack such investment (Pucher and Buehler 2005).

Transit agencies report that the introduction of cycle-PT services increased patronage by attracting new users and encouraging existing users to ride more often, and this was affirmed by a survey of BoB users (Hagelin 2005).

Tables 2.2 and 2.3 identify the percentage of total public transport patronage that is BoB across a range of North American transit authorities, with table 2.2 showing bus cycle-PT and table 2.3 showing light rail and train cycle-PT.

Table 2.2 Mode share for BoB cycle-PT in North America – bus only

Number of transit authorities with data	Range of annual patronage	Average percentage of patronage that is BoB	Maximum percentage of patronage that is BoB	Some similar cities in New Zealand
22	Less than 4 million	1%	5%	Tauranga, Dunedin, Hamilton
19	6 to 20 million	1%	4%	Christchurch
11	30 to 60 million	1%	2%	Wellington, Auckland
10	60 to 350 million	0.5%	0.8%	-

The percentage of BoB patronage as a percentage of total patronage is a steady 1% over the range of annual patronage that is relevant to New Zealand. The most attractive systems in North America attract no more than 4% to 5% of patronage as BoB. The BoB percentages tend to reduce as bus patronage increases but at patronage levels many times greater than any region in New Zealand.

For commuter rail, Wellington and Auckland are the only relevant regions in New Zealand. Table 2.3 identifies the BoB mode share from the North American data.

Table 2.3 Mode share for BoB cycle-PT in North America – light rail and train only

Number of transit authorities with data	Range of annual patronage	Average percentage of patronage that is BoB	Maximum percentage of patronage that is BoB	Some similar cities in New Zealand
7	Less than 10 million	3%	6%	Wellington, Auckland
11	10 to 250 million	0.1%	0.5%	–

2.6 Extension to New Zealand

Table 2.4 below is based on North American data.

The operation of buses as rapid transit (BRT) on separated facilities such as Auckland's Northern Busway is expected to be closer to rail as they have similar catchments on exclusive right-of-way corridors which are typically unavailable to cyclists. Also, the further the stations/stops are apart the greater the impact of increasing the catchment radius from 800m to 3km; catchments of local bus stops overlap heavily as they are often less than 800m apart.

Based on the analysis of US data, the average and likely ranges of BoB in the New Zealand context are shown in table 2.4.

Table 2.4 Bike on board percentages relevant to New Zealand

Mode	Average BoB %	Typical range of BoB %	Relevant cities
Bus	1.2%	0.5%–3%	All
Train, ferry	3%	1.5%–6%	Wellington, Auckland

3 Public transport and cycle-PT patronage in New Zealand

3.1 Introduction

The models developed in this research forecast cycle-PT demand from existing public transport patronage. This section of the report identifies the public transport mode shares and total patronage figures for New Zealand's largest metropolitan areas.

The use of public transport and non-vehicle based modes varies between the major centres of Auckland, Wellington and Christchurch, as shown in table 3.1.

Table 3.1 Normal means of travel to work – percent of work trips (2006 Census data)

Region	Public Bus	Train	Bicycle	Walked or jogged
Auckland	9.4%	1.3%	1.6%	8.4%
Christchurch	5.0%	0.0%	6.4%	5.6%
Wellington	11.3%	7.4%	2.1%	12.4%
Dunedin	3.7%	-	2.0%	11.7%
Hamilton	2.0%	-	3.1%	6.2%
Tauranga	1.0%	-	2.6%	4.3%
New Zealand	5.2%	1.7%	2.6%	6.7%

Ferry as a mode of transport for journey to work was not listed as an explicit choice in the 2006 Census. The category 'Other' may pertain to ferry trips, but could also include other modes.

The majority of major centres in New Zealand have seen increases in public transport patronage since the 2006 Census. The patronage figures assumed for the modelling in this research project are based on the Ministry of Transport's Transport Monitoring Indicator Framework (TMIF)[4] which has patronage data by region for most recently the 2008/2009 year.

The assessment of cycle-PT accounts for those who may use a service during congested commuting periods and those who use cycle-PT during non-congested periods. The benefits as outlined in section 7.4 include a separate 'decongestion' benefit that accrues to users who shift from private cars to public transport during the peak periods. All assessments of cycle-PT demand include estimates of peak users and off-peak users and this is based on a typical hourly profile of patronage on a weekday.

3.2 Auckland region

The TMIF figures show that bus patronage was around 46.3 million trips in 2008/09, ferry patronage around 4.2 million trips, and train patronage around 7.2 million trips. This gives an assumed total for public transport trips per year in Auckland of 57.7 million. This is shown in table 3.2 overleaf.

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[4] Data available from www.transport.govt.nz/ourwork/tmif/

3.2.1 Auckland bus services

There are approximately 46.3 million bus trips annually in the Auckland region. There are no facilities for BoB, and limited facilities for BaR are provided at some stations on the rapid transit network (bus and rail). Private third-party bicycle storage services have begun operation in two areas of the city CBD. These provide cycle services (eg repair, showers, clothing storage) and secure bicycle storage primarily on the work end of a home-to-work cycle trip.[5]

3.2.2 Auckland rail services

Table 3.2 demonstrates how patronage targets for trains are intended to grow as the region invests in improving the quality and frequency of services to match patronage levels experienced in similar sized cities to Auckland. It is expected that commuter rail's share of public transport trips will increase over time.

Table 3.2 Comparisons with Auckland rail patronage levels (ARTA 2006 and Ministry of Transport TMIF 2010)

City	Population (million)	Rail length (km)	Rail patronage
Perth, WA	1.3	95	33 million
Portland, USA	1.3	70	33 million
Calgary, Canada	1.1	32	52 million
Auckland, 2005/06	1.3	94	5 million
Auckland, 2008/09	1.3	94	7 million
Auckland target (2030)	1.6 (projected)	94+	30 million

The Auckland train system charges $1.00 for bringing a bicycle on the train although BoB is discouraged during peak periods. Therefore usage is largely outside of peak commuter periods which probably limits the overall observed demand.

From data provided by the Auckland Regional Council and shown in figure 3.1, bike on train patronage has increased significantly over the years with approximately 0.5% of patrons carrying bicycles on trains. This compares to the 3% figure adopted for rail BoB from North American data (table 2.4) suggesting that the use of BoB on the Auckland rail system has the potential to expand approximately three-fold with better integration and support.

A possibility for increasing cycle-PT for rail patronage would be to increase BaR lockers at the stations across the network. The current cycle-PT figures only represent those bringing their bicycle on the train.

Figure 3.1 shows the absolute numbers of cycle BoB users and proportion of cycle users to the total rail patronage. The chart also displays the seasonal variation of cycle-PT use which shows that during the summer months the percentage of cycle-PT riders generally increases.

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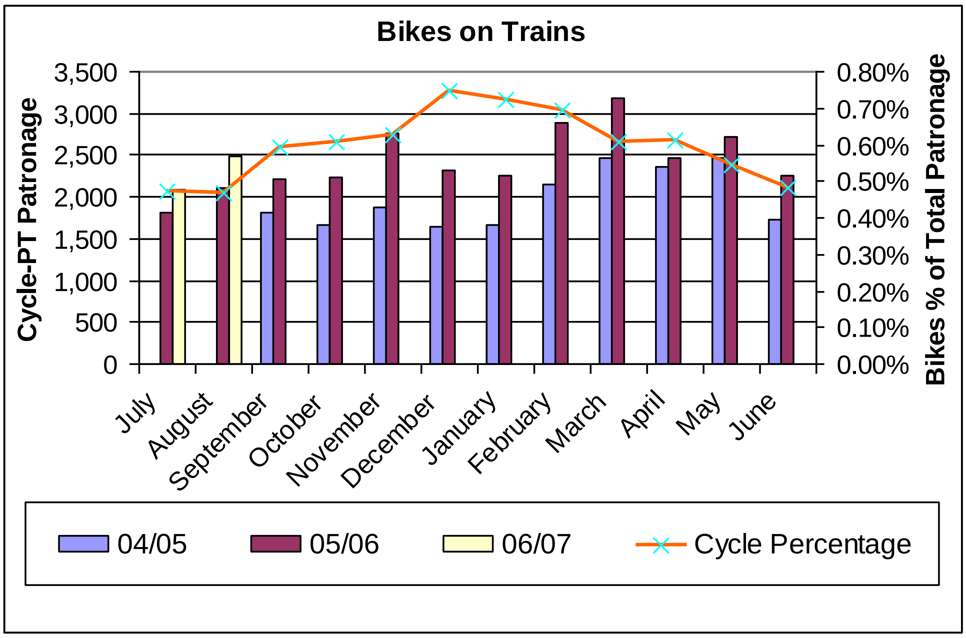
[5] www.bikecentral.co.nz is one example.

Figure 3.1 Bikes on train numbers in Auckland region



Source: ARTA train patronage data (ARTA 2006)

3.2.3 Auckland ferry services

As there was no US data for BoB on ferries, the observed BoB patronage from Auckland's ferry services was analysed to determine whether the rates for rail and BRT were also the most relevant for ferries.

Based on cycle-count surveys at the Auckland central ferry terminal next to Britomart (the Waitemata Harbour Ferry Terminal) and ferry boarding information received from Fullers Ferries, the bicycle count and total ferry boarding are listed below in table 3.3.

Table 3.3 One-day passenger counts at Auckland central ferry terminal, November 2006

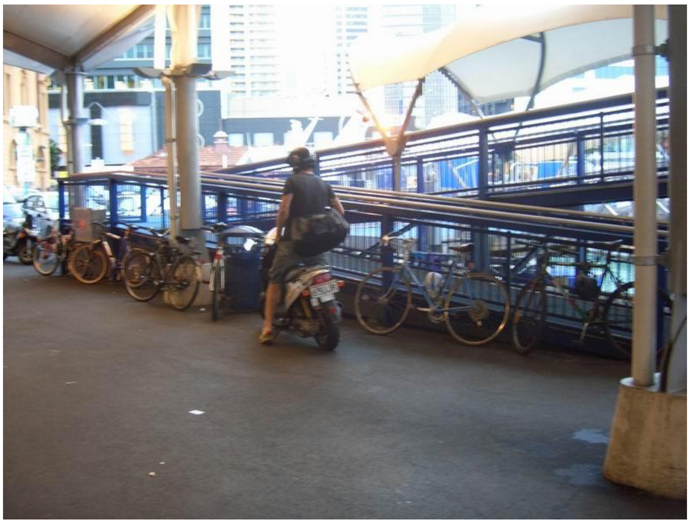
	Number of passengers arriving	Number of passengers departing
7am–9am	1854	309
Cycles counted	69	10
% passengers with cycles	3.7%	3.2%

This figure of 3% to 4% for BoB is likely to reflect the absence of bicycle storage options at the departure points for ferries heading towards the downtown terminal. Figure 3.2 shows some of the impact of this ad hoc cycle storage by the terminal. The bicycle parking shown in the photo has since been banned.

It is important to note that the analysis in this research assumes that BaR parking could occur at either end of the public transport trip. If secure bicycle storage is provided at the end of the public transport trip, then the forecast of BoB demand will need to include the demand for BaR at each origin point – in this case all the wharves with services terminating at the downtown terminal.

Based on the information available, the BoB demand as mode share for trains will also be used for ferry services.

Figure 3.2 Ad-hoc cycle parking previously occurring at Auckland's central ferry terminal



3.3 Greater Wellington region

Data from the 2006 Census reveals that the mode share for public transport in the Wellington region was significantly higher than the national average. The 2006 mode share for public bus was 11.3% while the mode share for train was 7.4%.

There are approximately 480 buses (including 60 electric-powered trolley buses) in service in the Wellington region. The TMIF reports the total patronage for the 2005/06 year on the bus network in the region was 23.5 million. The total patronage for the train network was 11.3 million while for the Eastbourne ferry it was 155,000.

The patronage assumed for this modelling is from the 2008/09 patronage figures in the TMIF. These are 23.1 million bus trips, and 11.9 million rail and ferry trips per year.

There are over 800,000 rail trips in a typical month in Wellington region. Peak-period trains arrive and depart from the Wellington station every two to three minutes with over 10,000 passengers arriving at the station on a typical weekday morning between 7am and 9am.

As of 1 July 2008 the Greater Wellington's Transport and Access Committee removed the fee requirement to bring a bicycle on board. The bike on train is a first-come-first-served process subject to availability of space. Bicycles are also allowed free of charge on the region's ferry system. Anecdotally, the use of BoB is severely restricted during peak services which would make the data inconclusive when comparing with potential BoB demand.

No bicycles are allowed on buses in the Metlink transport network.

Greater Wellington Regional Council has installed bicycle lockers in several railway stations and they are available on a long-term leased basis.

3.4 Christchurch region

The 2006 Census indicated that the mode share for public bus was 5.0%. Figures provided by Environment Canterbury suggest the Christchurch Metro network's total public bus boarding in 2005 was in the region of 15.2 million trips, more than 50% higher than in 2001. Figures from the 2008/2009 season show that ridership continued to grow to 17.7 million trips.

Larger percentages of Canterbury residents cycle or walk to work, at 6.4% and 5.6% respectively, than in any other region in New Zealand.

The Canterbury region's Metro transit service began a BoB trial in November of 2007. The trial met expectations and has been continued on specific bus routes. There is no data available on rates of BoB or BaR from the trial and the current number of BoB trips will not necessarily reflect longer-term demand. It is likely that the trial will be incorporated into the operating agreements for local public transport operations as part of contract revisions.[6]

3.5 Hamilton region

The 2006 Census indicated that the mode share for public bus was 2.0%, with 3.1% bicycling and 6.2% walking. Environment Waikato runs the regional public transport system with urban routes such as the popular Orbiter and rural routes serving communities within the larger Waikato region. A new integrated ticketing system BUSIT is expected to increase use of the bus system over the next few years.

The TMIF and Environment Waikato's 2008/2009 annual report indicate that the Hamilton City bus service carried around 4.3 million patrons.

3.6 Tauranga region

The 2006 Census indicated that the mode share for public bus was 1.0%, with 2.6% bicycling and 4.3% walking.

The Environment Bay of Plenty Regional Council runs the regional public transport system, BayBus, serving the urban areas of Tauranga and Rotorua as well as the smaller communities of Te Puke, Katikati, and Whakatane and Opotiki. The urban Tauranga region has focused on improving urban arterials to facilitate quality bus service and interchanges in the CBD and in the urban fringe.

Based on information in the 2008/2009 annual report, the Bay of Plenty bus service carried approximately 1.3 million trips.

3.7 Dunedin region

The 2006 Census indicated that the mode share for public bus was 3.7%, with 2.0% bicycling and 11.7% walking. The Dunedin city provides a dense urban core with populated hillsides with a general close proximity to the CBD that encourages walking. TMIF data shows 2.0 million bus patronage in 2008/09.

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[6] ECan Bike Trial. January 2009 article in www.stuff.co.nz For Christchurch Metro information on bike racks see: www.metroinfo.org.nz/bikeRacks_Main.html

The Otago Regional Council runs the regional public transport system, GoBus. The system implemented an integrated electronic ticketing system, GoCard, in 2007 that is expected to increase use of the public bus system.

3.8 Summary of patronage data

Table 3.4 shows the annual patronage assumed for the modelling of cycle-PT.

Table 3.4 Public transport trips per annum

Centre	Public bus	Ferry	Train	Total
Auckland	46.3 million	4.2 million	7.2 million	57.7 million
Wellington	23.1 million	11.9 million		35.0 million
Christchurch	17.7 million			17.7 million
Tauranga	1.3 million			1.3 million
Dunedin	2.0 million			2.0 million
Hamilton	4.3 million			4.3 million

4 Forecasting demand for cycle-PT (bike and ride, bike on board)

4.1 Development of the forecast models

The provision of cycle-PT expands the number of options cyclists have to use their bicycles more frequently. The demand forecasts for cycle-PT will capture all users, from commuters to those recreational riders using the bus to and from riding routes. BoB can provide a critical service on transportation links unfriendly for cyclists, such as tunnels and bridges, or serve riders late at night or during poor weather.

A ratio to total patronage used by Puget Sound Regional Council (2002) for considering the provision of secure storage lockers has been used as part of the input into this research. No models were discovered that forecast demand for cycle-PT or the split between BaR and BoB. Therefore the research described in this report was required to develop the forecast demand models.

Assumptions around demand forecasting include:

- Cycle-PT will be added to all public transport services, as isolating one route or particular hours of the day will not produce the same level of demand as a complete regional system.
- There will be different levels of demand in different contexts as maximising cycle-PT demand requires a high-quality public transport system combined with cycling infrastructure to give cyclists safe and efficient access to the public transportation network.

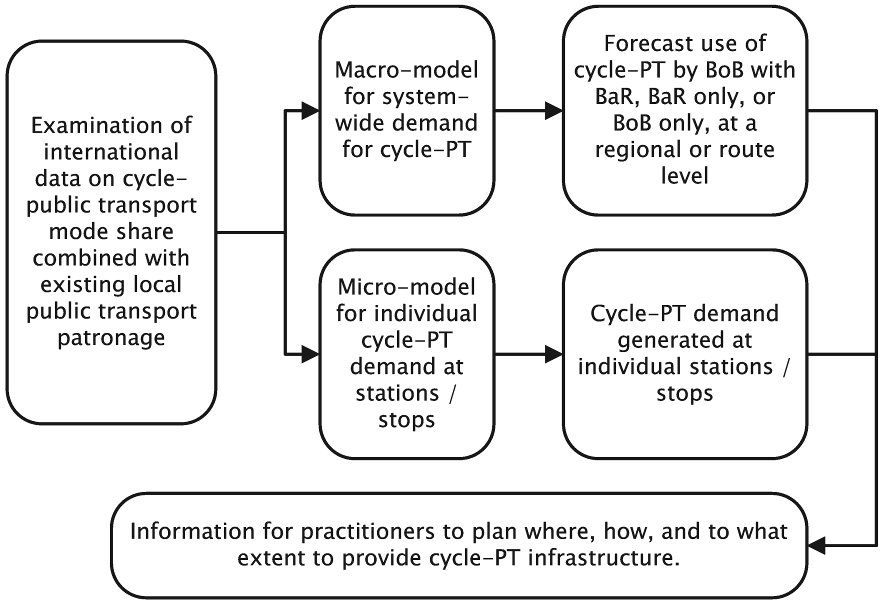
This section of the report outlines the framework developed to estimate the demand by users willing and able to combine a cycling and public transport trip.

Two equations are used in tandem to develop demand forecasts for a cycle-PT implementation plan for a public transport system:

- **Macro-model equation:** assesses the entire system at a macro level by general demand equations for the number of cycle-PT users and lockers per system.
- **Micro-model equation:** a simplified equation that provides cycle-PT user and locker demand estimates for individual routes, stops and stations.

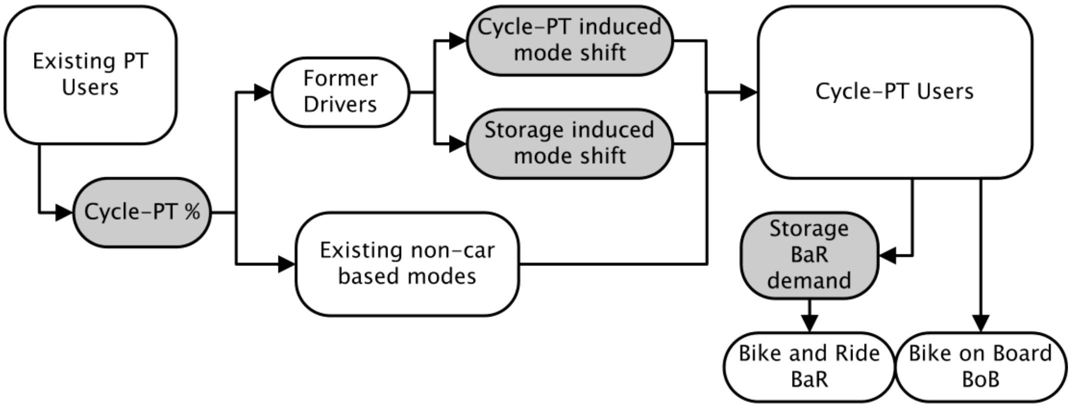
The model framework developed to estimate the demand for cycle-PT is shown in schematic form in figure 4.1.

Figure 4.1 Process for developing the cycle-PT forecasting models and their application



The model process is shown in figure 4.2 with the model variables shaded.

Figure 4.2 The cycle-PT model



The decision tree to estimate cycle-PT demand starts with combining observed data on cycling and public transport mode share with observed international data estimates on the likely range of public transport users who will utilise the on-board bike racks or secure lockers.

The macro-model provides system-wide or entire-route forecasts of the number of BoB and BaR users[7] and the amount of secure bicycle storage to provide for BaR patrons. The model uses international benchmarks of observed BoB cycle-PT as a percentage of total public transport patronage, and assumes that this includes those who without BoB would either drive or be passengers in cars, or alternatively use non-car-driver modes (public transport, cycling, walking). This means that the potential audience interested in cycle-PT is already part of the transport system.

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[7] A cycle-PT user is defined as a person who makes two one-way cycle-PT trips per day.

The model then assumes that the introduction of secure storage would induce further demand for cycle-PT BaR from predominantly previously car-based trips, and there would also be some minimal mode shift from current cycling or non-BoB public transport trips.

The total cycle-PT patronage with BaR is then in excess of the originally observed cycle-PT uptake rates where only BoB was provided. This total cycle-PT can be disaggregated into BoB and BaR components.

'Existing public transport users' is modelled from total patronage figures. This value has been documented in chapter 3 for each region and mode in the study.

To determine peak and off-peak public transport patronage, the typical urban peaks occur from 7am–9am and from 4pm–6pm on the average weekday. Bus patronage data suggests that approximately 46% of the weekday daily trips occur during these peak periods[8]. Additional data on public transport usage indicates that approximately 88% of total patronage occurs on weekdays. The data included in the study uses this to break the annual patronage data down into weekday and weekend trips, then the weekday trips into peak and off-peak trips.

4.2 Model equations

The model layout can be translated into simplified formulae that account for the factors that approximate the cycle-PT demand based on the existing level of public transport patronage.

The factors and variables are described in section 4.3.

Note that in the following formulae that StorInducedPT_i is equal to zero for scenarios where there is no BaR secure storage provided.

$$\mathit{CyclePT}_{ij} = \mathit{existing\ PT\ patronage}_{ij} \times \mathit{cycle\text{-}PT\ rate}_{ij} \times (1 + \mathit{StorInducedPT}_i) \qquad \text{(Equation 4.1)}$$

$$\mathit{CyclePT}_{ij} = \mathit{BaR}_{ij} + \mathit{BoB}_{ij} \qquad \text{(Equation 4.2)}$$

$$\mathit{BaR}_{ij} = \mathit{existing\ PT\ patronage}_{ij} \times \mathit{cycle\text{-}PT\ rate}_{ij} \times (\mathit{StorageBaRDemand}_i + \mathit{StorInducedPT}_i) \qquad \text{(Equation 4.3)}$$

$$\mathit{BoB}_{ij} = \mathit{CyclePT} - \mathit{BaR}_{ij} \qquad \text{(Equation 4.4)}$$

$$\mathit{BoB\ from\ private\ car}_{ij} = \mathit{BoBBaRModeShift} \times \mathit{BoB}_{ij} \qquad \text{(Equation 4.5)}$$

$$\mathit{BaR\ from\ private\ car}_{ij} = (\mathit{BoBBaRModeShift} \times \mathit{StorageBaRDemand} + \mathit{StorInducedPT}_i) \times (\mathit{existing\ PT\ patronage}_{ij} \times \mathit{cycle\text{-}PT\ rate}_{ij}) \qquad \text{(Equation 4.6)}$$

A worked example of these formulae is shown below for a public transport network currently without cycle-PT with an existing patronage of 10,000 trips per peak period each day where both BoB and BaR are planned. It is assumed that there will be a 1% cycle-PT rate with 4% induced public transport trips because of the provision of secure storage (StorInducedPT), with 16% of cycle-PT riders choosing secure storage (StorageBaRDemand). It also assumed that 50% of those who will use cycle-PT previously made their trips by car (BoBBaRModeShift).

The cycle-PT demand will be 10,000 x 0.01 x (1+0.04) = 104 users (equation 4.1).

The demand for BaR one-way trips will be 10,000 x 0.01 x (0.16 + 0.04) = 20 trips (equation 4.3).

These 20 trips will demand 20 lockers, plus a factor to meet peak/day-to-day fluctuations.

The number of BoB trips will be (10,000 x 0.01 x 1.04) - 20 = 84 trips (equation 4.4).

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[8] Bus data from Environment Bay of Plenty on ridership by time of day.

The number of BoB trips previously made driving a private car = 50% x 84 = 42 (equation 4.5).

The number of BaR trips previously made driving a private car = (50% x 0.16 + 0.04) x (10,000 x 0.01) = 12 (equation 4.6)

This worked example is a simplistic approach making use of specific assumed factors. An alternative Monte Carlo approach will take into account the variability inherent in each factor and this is described in the following sections.

4.3 Monte Carlo model simulation

A dominant issue in the research on cycle-PT is the lack of data on the contributing factors to cycle-PT demand. In order to make use of the limited number of data points and provide for sensitivity to the possible range of input variables, the calculations for demand are based on an estimate of the mean and standard deviation and distribution pattern for each variable.

The Monte Carlo simulation provides a statistical confidence test to evaluate the distribution of the variables in an equation. As each of the four variables described below has a distribution, the simulation runs the equations in section 4.2 for 10,000 iterations. Each iteration is unique and the value of each variable is based on the probability described by the distribution. The cumulative average, median and 95% percentile range is the outcome of these 10,000 tests.

For example, the cycle-PT has a log-normal distribution with a likely value of 1.2, a 5% probability of being less than 0.5% and a 95% probability of being less than 2.7%. The 10,000 iterations of the cycle-PT equations reflect the range of these variables combined.

This model has been implemented in Microsoft Excel where four variables are used for three public transport modes (bus, rail and ferry) with the three cycle-PT scenarios. The four variables are bolded earlier in figure 4.2 and further described in table 4.1. They are then described in turn after the table.

Table 4.1 System-wide model variables

Variable	Description
Mode	Select mode: bus, rail or ferry
Scenario	Select provision: BoB only, BaR only, or BoB and BaR
1) Cycle-PT rate	Range of usage rates (mode and facility dependent)
2) StorInducedPT	Increase in the demand for cycle-PT due to the presence of bicycle storage
3) BoBBaRModeShift	Percentage of the demand for cycle-PT from those currently not using public transport
4) StorageBaRDemand	The demand for storage units expressed as a percentage of total cycle-PT users

4.3.1 Mode

Three modes of public transit are included in the macro system-wide model for cycle-PT estimation: bus, rail, ferry (BRT[9] is considered as having the same characteristics as rail).

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[9] Bus rapid transit is a facility such as Auckland's Northern Busway where buses have exclusive priority and run as an express service with limited stops.

4.3.2 Scenario

1. **BoB only**: no secure storage provision at the stations or at the termination of the public transport trip.
2. **BaR only**: storage only at stations/stops. No provision of BoB public transport services.
3. **BoB and BaR**: storage is provided at stops/stations combined with the option to take BoB public transport services.

4.3.3 Variable 1: cycle-PT rate

This is based on the national and international literature review and two benchmark analyses (refer section 2.4). The variable provides an observed ratio of cycle-PT users to total public transport patronage. This figure typically does not include any BaR users.

Based on analysis of the range of US data, appropriate observed rates of cycle-PT as a proportion of total patronage for public transport systems with similar patronage to New Zealand's were calculated. These are shown in table 4.2, which is based on the observed rates shown in table 2.4.

Table 4.2 Forecast range of cycle-PT users by public transport mode for systems similar to New Zealand's

PT mode	Low	Average	Maximum
Bus	0.5%	1.2%	5%
Rail and ferry	1.5%	3%	6%

The range and distribution of cycle-PT demand shows the degree of variation that exists within the observed North American data. The pattern, however, shows that most systems do obtain at least the low rate with the majority of the systems working around the average value. However, as the long tail in figures 4.3 and 4.4 shows, several bus systems have higher cycle-PT rates.

Figure 4.3 has the observed cycle-PT rate distribution for bus systems from North America data. This data represents systems relevant to New Zealand with monthly boardings less than 10 million (57 systems are in the database).

Figure 4.4 shows this for rail.

Figure 4.3 Cycle-PT rate distribution – buses

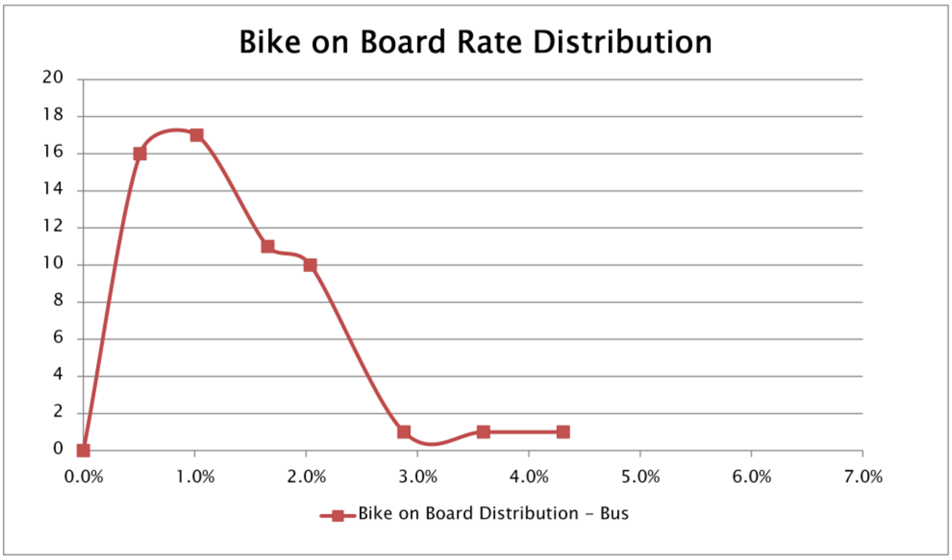
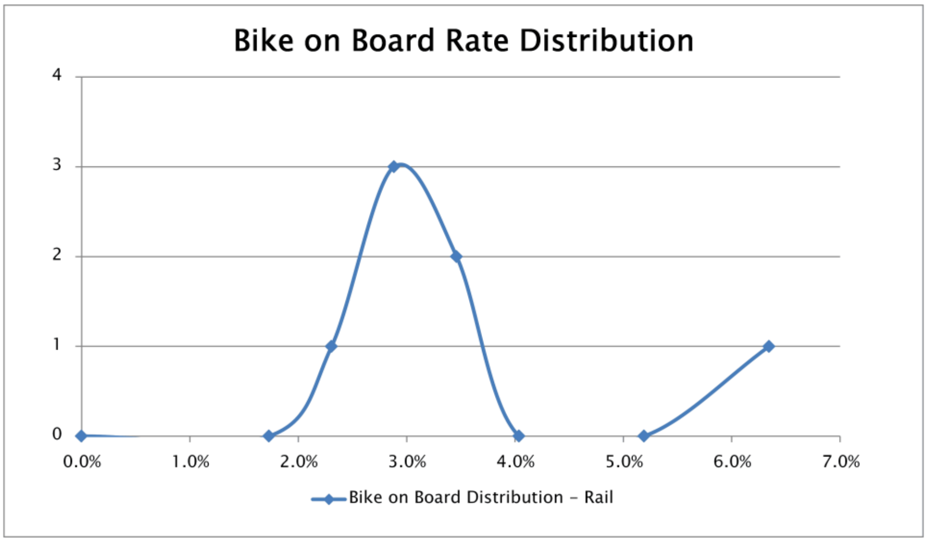


Figure 4.4 **Cycle-PT rate distribution – rail**



The observed cycle-PT rates were translated into a log-normal distribution and used throughout the analysis in the Monte-Carlo simulation.

4.3.4 Variable 2: StorInducedPT

This variable captures the effect of placing secure storage facilities in an area. The provision of secure storage alone will induce certain users to use the storage unit and then use public transport. These users are never observed as BoB in typical studies as they would have parked their bicycle before boarding. Users explained by this variable will increase net cycle-PT users (BoB + BaR) above the observed rates of variable 1: cycle-PT rate.

The value was derived as part of the initial research for the National Bicycling and Walking Study (FHWA 1994) conducted in the United States before a national effort to improve walking and cycling programmes. The likely value is about 4% with a range extending from a low of 1% to a high of 12%. The range of this variable is taken into account by a log-normal distribution (similar shape of curve to that shown in figure 4.3).

4.3.5 Variable 3: BoBBaRModeShift

A significant source for many of the quotes on BoB usage is a report published by the Center for Transit Research at the University of South Florida. The report (Hagelin 2005) states that approximately 25% of riders started using public transport because of BoB programmes. The author states that this number may be artificially low because even sporadic public transport users were defined as previous public transport users, where mode choice surveys often designate the most frequently used mode as the primary mode.

A study by the Denver Regional Transportation District in 1999 found that of the 2300 daily users of bus mounted bicycle racks, 50% of riders surveyed said they were new riders to public transport and 27% said they would be sitting in a single occupancy vehicle if they did not have the option to put their bike on the bus (Robinson 2003).

Pinellas Suncoast Transit Agency indicated in a 1999 survey of their BoB riders that 70% were single occupant drivers or carpool riders before using the BoB programme (Hagelin 2005).

A 1992 study in Vancouver, Canada, found that 30% of those using bike lockers at a commuter rail station had not, prior to the installation of the lockers, used public transport to commute (Victoria Transport Policy Institute 2010). The converse is that 70% of BaR users were also previously public transport users.

There is difficulty in comparing data and differing or unclear definitions of a ‘previous public transport user’. For this reason there is a large range in the variable with the likely value being 50% of cycle-PT users are new to public transport, with a range from a low of 25% to a high of 70%. A normal distribution was used in modelling the variable.

This variable captures the effect of induced public transport riders switching from other modes due to the presence of cycle-PT BoB and BaR options. Without any better data, it is assumed these new riders to public transport were previously driving a single-occupancy private car.

4.3.6 Variable 4: StorageBaRDemand

The model BaR forecasts the percentage of cycle-PT patrons using secure storage in their cycle-PT trip. This includes riders who may use storage at the front end of the public transport trip and those who may prefer to store their bicycle at end of their trip.

BaR demand is forecast as a percentage of total cycle-PT users. As cycle-PT is forecast as a degree of overall public transport patronage, the degree that BaR is available is unlikely to affect the overall cycle-PT demand. Therefore, as the attractiveness of storage increases, a reduction in BoB may be observed. The BoB predicted within this study represents trips that do not use secure storage provided at stations.

There was little information available on the demand for storage based on patronage figures.

The research used for this variable was the likely demand for secure locker storage developed by the Puget Sound Regional Council (2002). The 16% demand estimated by the council was reached with an understanding that in some areas demand for storage would exceed this value and in other areas it would be lower. Therefore the expected value of BaR has been assumed as 16% of total cycle-PT users which does not include the additional induced users shifting to cycle-PT described by variable 2: StorInducedPT.

The value is described by variable 4: StorageBaRDemand and is the recommended method for New Zealand practitioners. By applying a distribution to the demand for locker space, with the ranges corresponding to the type of adjacent land use and bicycle facilities in the vicinity, an estimate for locker demand can be produced.

The rate of BaR attractiveness is expected to vary by location within the overall system. It is up to the local practitioners to determine the BaR rate most applicable to the site.

Table 4.3 BaR demand contextual scenario

Contextual scenario	BaR attractiveness	Factor
Sites with lower densities, little multi-modal, and weak cycling infrastructure or little cycling demand	Low	8%
Average density, average multi-modal integration and infrastructure.	Average	16%
Areas that may have higher densities, strong multi-modal system interaction, and larger numbers of cyclists.	High	24%

4.4 Secure bicycle storage supply versus forecast demand

While the model forecasts the demand for BaR, the decision on how many secure lockers to provide needs to take account of seasonal and day-to-day fluctuations, as well as the effects of charging and operation.

In terms of operation, secure bicycle storage is usually rented to an individual for a particular period. Due to the long-term nature of the rentals, seasonal trends do not play a significant role in locker deployment.

Case study

The Bay Area Rapid Transit District (BART) in San Francisco, California tries to supply 10% more secure lockers than current demand to account for future growth. They also indicate that the existing supply has traditionally been about 75% occupied at any one time. BART suggests that Class 2 bicycle parking (traditional U-locks) is more susceptible to seasonal fluctuations in demand.

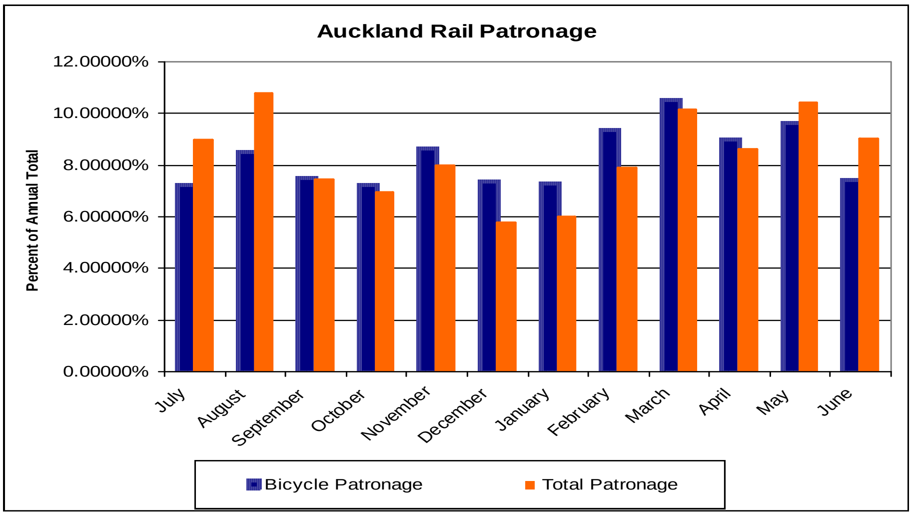
To get the maximum use of secure storage lockers under such an operational scheme, some lockers will remain empty on any given day. For this reason, the deployment of lockers needs to be greater than the forecast demand of the average daily number of cycle-PT users.

4.4.1 Seasonal variation

Figure 4.5 shows the average seasonal variation in total patronage and bicycle patronage. The chart indicates that most cycling occurs during the warm summer months of February and March, with the smallest amount of cycling occurring in the winter months of June and July. Total rail patronage shows similar trends, but with a significant drop in December and January due to summer holidays.

An effort to provide adequate long-term storage to meet seasonal demand for public transport in Auckland indicates that individual station storage supply assessments should occur at the end of summer, around March. This would provide a slightly higher than average estimate of patronage.

Figure 4.5 Auckland rail season variations (2004–2006 average)



4.4.2 Day-to-day fluctuations

The model provides an estimate of average cycle-PT users throughout the year; however, these users of cycle-PT may not travel every day.

Approximately 26% of BOB users, especially those who commute to work by BOB, indicated that the bus arriving at their stops with the rack full was a problem.

While only 8% indicated that bicycle parking racks were available at the bus stops they use, 22% reported that they would lock up their bicycle at the stop if parking racks were available, and the bus arrived with full racks. Additionally, 43% stated they would park their bicycles at a bus stop if they could not afford to wait for the next bus to arrive. The longer the headway, or time between buses, the more important access to bicycle parking becomes (Hagelin 2005).

This fluctuation is not of concern when estimating cycle-PT BoB users but it becomes important when estimating the amount of secure cycle locker space to supply.

Many locker systems are provided to users on a term basis, longer than day to day. Therefore, one locker will be used (locked) by one person even though that person may not commute by cycle every day. Cycling may be subject to a wider range of day-to-day fluctuation. Weather, daily demands for errands, and a wide array of other factors contribute to the daily decision to cycle or not. In order to provide for the day-to-day variation of cycle commuting it becomes necessary to supply a larger number of lockers in the system than those required on any given day (ie more lockers than the average daily number of cycle-PT users).

North American commuter data indicates that the typical male cyclist makes 6.7 one-way trips per week by cycle (out of a total of 10 one-way trips) while the typical female makes 5.8 one-way trips per week by cycle. This suggests that on any given day 67% of the male cycle commuters will be commuting by bicycle (or in our case using cycle-PT).

The ratio of peak to average use (10 trips to 6.7 trips = 1.49) provides an estimate of how many additional secure lockers should be provided within the system to accommodate the total peak demand for cycle-PT storage (BaR). Accommodating for the peak demand would probably be less cost efficient.

Given the range of usage, from zero to 10 trips within a week with the likely use about 6.7 trips, it would be appropriate to provide a supply of lockers that would meet at least the likely (average) use with a small excess to accommodate spikes in usage. By multiplying the demand by a factor of 1.3, the locker supply should meet approximately 96% of total demand and account for day-to-day variation.[10]

Storage locker technology and innovative locker programmes can reduce the needed supply and still account for spikes in demand. For example, the BART transit system in Oakland California has successfully used secure lockers at their train stations for a number of years. In order to improve efficiency in their locker programme (maximise time used) they have instituted a smart lock system with swipe cards. The cards only give access to the user whose bicycle is in the locker. This eliminates the need to reserve a locker for someone. The programme does provide a higher degree of utilisation, although there are still issues with overall supply versus demand.

4.4.3 Time-of-day variation

The demand for public transport varies throughout a typical day similar to that of other transport infrastructure. Most public transport experiences typical am and pm peak periods with a sustained inter-peak demand.

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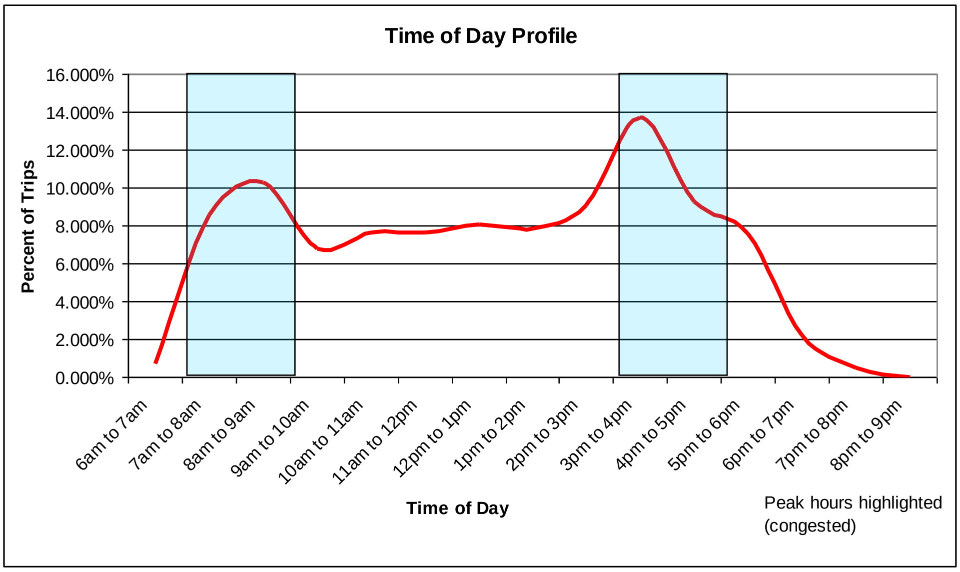
[10] Likely value of 6.7 with a standard deviation of 0.68, normally distributed.

Figure 4.6 indicates that approximately 46% of daily weekday trips occur during the congested peak periods. As 88% of annual trips occur on weekdays then approximately 40.3% of all trips occur in the congested weekday periods.

Figure 4.6 Time-of-day public transport profile



Source: Tauranga Bayhopper service from Environment Bay of Plenty

Secure locker demand therefore should take into account the peak-hour demands since users will require a locker in the am peak and retain it until the pm peak. For inter-peak use it is likely that the locker will not remain in use as long and will have a higher turnover. Sophisticated locker management systems that allow more than one user per locker would have to take these variations into account.

4.4.4 Sensitivity to pricing and promotion

All major transit services reviewed that offer BoB do not charge additional fares for cycle-PT beyond the standard user fare. Typically fare increases reduce patronage and if costs associated with implementing a BoB programme were to be passed onto the end user this would impact on cycle-PT patronage.

International research on price elasticities for public transport suggests that a 10% increase in fees would result in a decrease in ridership by 4%. A US study (Pham and Linsalata 1991)[11] published by the American Public Transit Association documents a range of elasticities based on hours of analysis:

Table 4.4 Bus price elasticities

Bus type	Bus price elasticities
Average for all hours	-0.36 to -0.43
Peak hour	-0.18 to -0.27
Off-peak	-0.39 to -0.46
Off-peak average	-0.42
Peak-hour average	-0.23

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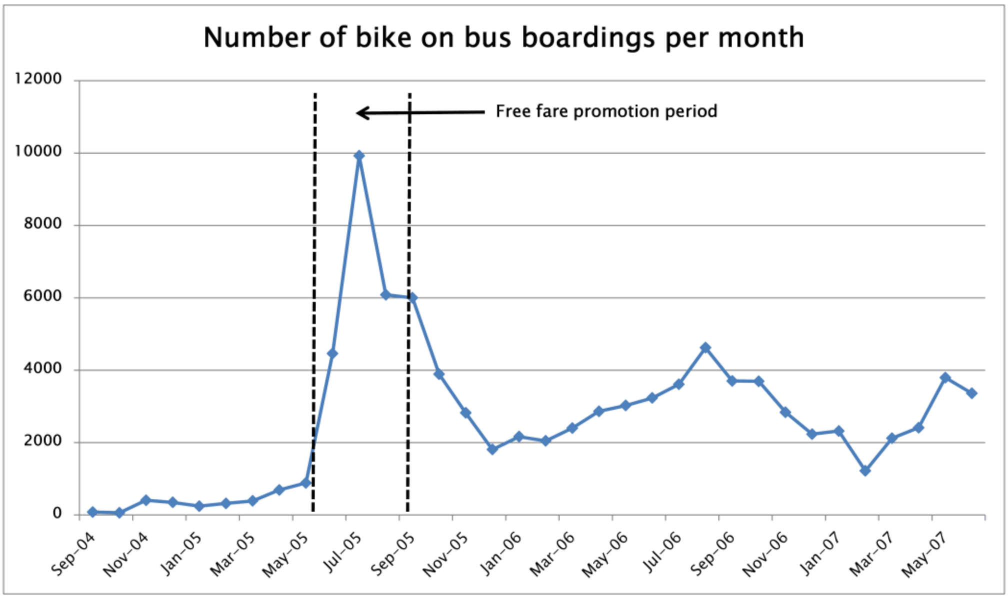
[11] Work done by the Victoria Transport Policy Institute has arrived at similar price elasticities.

The Bicycle Coalition of Greater Philadelphia[12] conducted research into the benefits of a bike-on-bus programme established by the Central Ohio Transit Authority. A free bus fare promotion was introduced for those using the bike racks between Memorial Day and Labor Day in 2005 (from 30 May 2005 to 5 September 2005.

As can be seen from figure 4.7 the effect of the promotion shows a significant short-term increase in BoB patronage. This dropped during the winter months after the promotion. Although the following summer did not match the patronage of the promotional months, a comparison of before and after patronage suggests the promotion was successful in increasing patronage in the long term. The study shows that the pricing, levels of promotion and familiarity with using the racks can alter long-term cycle-PT demand.

New Zealand practitioners should consider carefully the fares for cycle-PT in the context of their region and farebox policy when implementing a system. The literature research suggests that typically no additional fare should be recovered from the BoB user because of the effect on cycle-PT patronage.

Figure 4.7 Bike on bus patronage trend for the period of September 2004 – June 2007 on Central Ohio Transit Authority



4.5 Macro-model cycle-PT forecasts

Figure 4.8 shows a flow chart for the macro-model with the variable distributions used in the Monte Carlo simulation. A Monte Carlo simulation[13] was developed to create a range of potential values and a 95th percentile confidence interval for the cycle-PT demands. The distributions of the four variables were based on the values obtained from the international literature review.

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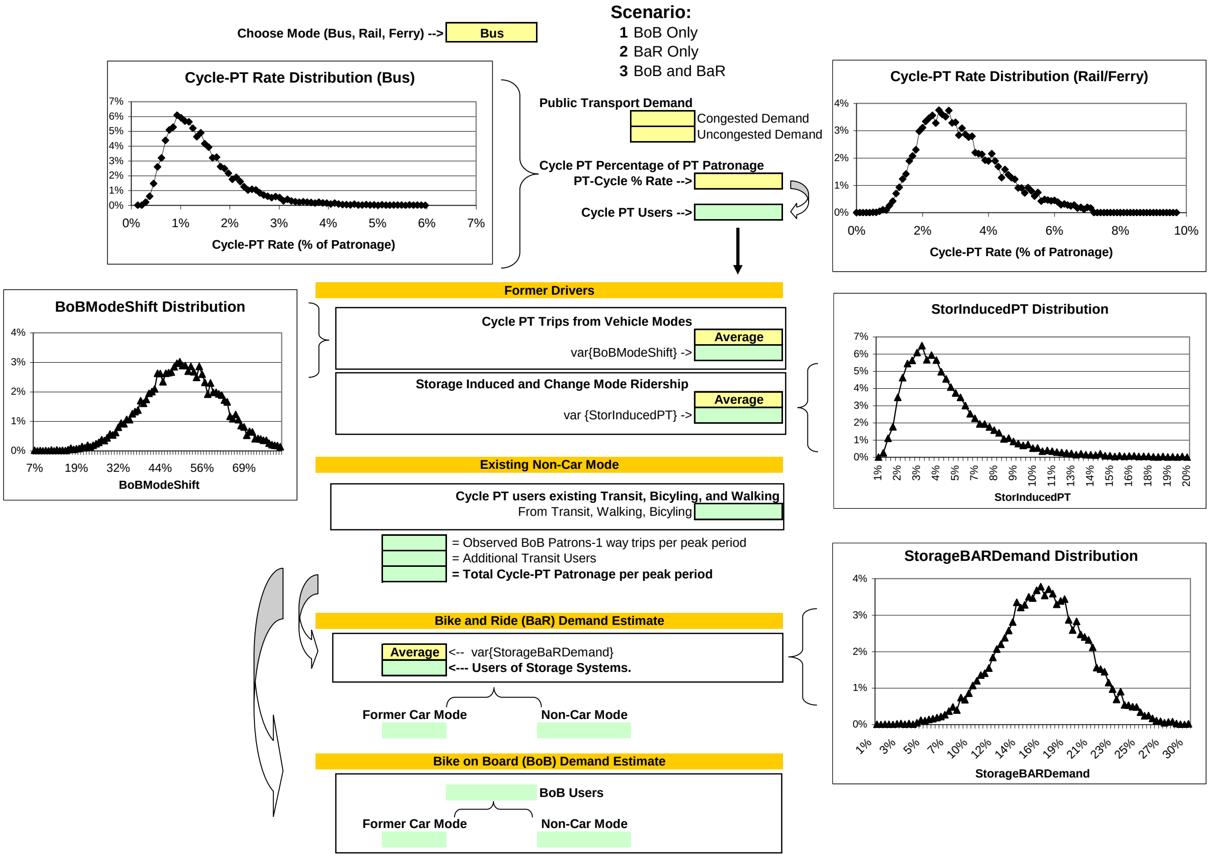
[12] Data provided from John Boyle, Advocacy Director *john@bikemap.com* via email on 29 June 2007.

[13] Monte Carlo simulation based on 10,000 iterations of the ranges of variables described above. Cycle-PT and StorInducedPT based on log-normal distributions, BoBModeShift, and StorageBaRDemand based on normal distributions.

Figure 4.8 Cycle-PT model and setup



The flow chart demonstrates the steps used in the assessment of BoB and BaR and the estimation of users shifting from car modes to cycle-PT. The process provides the distribution pattern of the four variables involved in the demand assessment of cycle-PT. The variables are all multiplied by the existing overall PT patronage to obtain estimates of cycle-PT, BoB and BaR users, and users shifting from private cars.

The Monte Carlo simulation carried through the analysis equation for cycle-PT but accounted for the unique distribution of the variables included in the analysis. In this manner the study attempted to reflect the range and likely values of cycle-PT based on the varying contexts of New Zealand cities.

The example calculations that follow illustrate how the model can be used to forecast the effect of providing scenario 1: BoB; scenario 2: BaR; or scenario 3: both.

The examples show, based on the data available, that 95% confidence would produce 40–55% higher demand than the average demand predicted. This factor is similar in scale to that discussed in section 4.4 where average demand is factored to provide forecasts for the number of secure lockers that should be supplied to meet the varying day-to-day demand, but it is a different and separate phenomenon.

4.5.1 Scenario 1 – bike on board only

Scenario 1 (BoB only) assumes that only the BoB programme is implemented and no secure locker programme is available. Total cycle-PT numbers are based on the observed cycle-PT rates shown in table 4.2. The results of the Monte Carlo simulation are shown in table 4.5.

Table 4.5 Worked example for BoB only scenario (bus only) daily users

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Auckland							
Bus	Peak	BoB	452	**511**	276	200	1040
	Off-peak	BoB	534	**605**	326	230	1220
	Weekend	BoB	292	**331**	178	130	670
Wellington							
Bus	Peak	BoB	225	**255**	138	100	520
	Off-peak	BoB	267	**302**	163	120	610
	Weekend	BoB	146	**165**	89	60	330
Christchurch							
Bus	Peak	BoB	173	**195**	105	70	400
	Off-peak	BoB	204	**231**	125	90	470
	Weekend	BoB	112	**126**	68	50	260
Hamilton							
Bus	Peak	BoB	20	**24**	14	10	50
	Off-peak	BoB	50	**56**	30	20	110
	Weekend	BoB	27	**31**	17	10	60
Tauranga							
Bus	Peak	BoB	13	**14**	8	10	30
	Off-peak	BoB	15	**17**	9	10	30
	Weekend	BoB	8	**9**	5	0	20
Dunedin							
Bus	Peak	BoB	19	**22**	12	10	40
	Off-peak	BoB	23	**26**	14	10	50
	Weekend	BoB	13	**14**	8	10	30

4.5.2 Scenario 2 – bike and ride only

Scenario 2 (BaR only) assumes that only the BaR programme is implemented and there is no BoB option. Lockers would be available for secure bicycle storage. It is assumed that these demands would be realised in additional public transport trips, so long as lockers are provided at the front end of trip.

Table 4.6 shows the results of the Monte Carlo simulation for BaR for all public transport modes with the sub-totals identifying the forecast users of secure bicycle storage.

Table 4.6 Worked example for BaR only scenario (bus, rail and ferry) daily users

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Auckland							
Bus	Peak	BaR	91	**106**	65	40	230
	Off-peak	BaR	108	**125**	76	40	270
	Weekend	BaR	59	**69**	42	20	150
Rail/ferry	Peak	BaR	112	**125**	63	50	250
	Off-peak	BaR	133	**148**	75	60	290
	Weekend	BaR	36	**41**	20	20	80
	Sub-total	BaR	539	**614**			
Wellington							
Bus	Peak	BaR	46	**53**	32	20	110
	Off-peak	BaR	54	**63**	38	20	130
	Weekend	BaR	29	**34**	21	10	70
Rail/ferry	Peak	BaR	117	**131**	66	50	260
	Off-peak	BaR	139	**155**	78	60	300
	Weekend	BaR	38	**42**	21	20	80
	Sub-total	BaR	423	**478**			
Christchurch							
Bus	Peak	BaR	35	**41**	25	10	90
	Off-peak	BaR	41	**48**	29	20	100
	Weekend	BaR	23	**26**	16	10	60
	Sub-total	BaR	99	**115**			
Hamilton							
Bus	Peak	BaR	8	**10**	6	0	20
	Off-peak	BaR	10	**12**	7	0	30
	Weekend	BaR	5	**6**	4	0	10
	Sub-total	BaR	23	**28**			
Tauranga							
Bus	Peak	BaR	3	**3**	2	0	10
	Off-peak	BaR	3	**3**	2	0	10
	Weekend	BaR	2	**2**	1	0	0
	Sub-total	BaR	8	**8**			
Dunedin							
Bus	Peak	BaR	4	**5**	3	0	10
	Off-peak	BaR	4	**5**	3	0	10
	Weekend	BaR	3	**3**	2	0	10
	Sub-total	BaR	11	**13**			

4.5.3 Scenario 3 –bike on board and bike and ride

Scenario 3 (BoB and BaR) is the worked example evaluated further in this report and corresponds with the example shown in figure 4.8. The scenario includes both BoB and BaR programmes.

Table 4.7 Cycle-PT projection ranges (bus only) daily users

Location and mode	**Time period**	**Type**	**Users per day**			**95th percentile**	
			Median	**Mean**	**Standard deviation**	**Low**	**High**
Auckland							
Bus	Peak	BoB	379	**429**	233	160	880
		BaR	91	**106**	65	40	230
	Off-peak	BoB	449	**508**	275	190	1040
		BaR	108	**125**	76	40	270
	Weekend	BoB	245	**278**	151	110	570
		BaR	59	**69**	42	20	150
Wellington							
Bus	Peak	BoB	189	**214**	116	80	440
		BaR	46	**53**	32	20	110
	Off-peak	BoB	224	**253**	137	100	520
		BaR	54	**63**	38	20	130
	Weekend	BoB	122	**139**	75	50	280
		BaR	29	**34**	21	10	70
Christchurch							
Bus	Peak	BoB	145	**164**	89	60	340
		BaR	35	**41**	25	10	90
	Off-peak	BoB	171	**194**	105	70	400
		BaR	41	**48**	29	20	100
	Weekend	BoB	94	**106**	58	40	220
		BaR	23	**26**	16	10	60
Hamilton							
Bus	Peak	BoB	35	**40**	22	20	80
		BaR	8	**10**	6	0	20
	Off-peak	BoB	42	**47**	26	20	100
		BaR	10	**12**	7	0	30
	Weekend	BoB	23	**26**	14	10	50
		BaR	5	**6**	4	0	10
Tauranga							
Bus	Peak	BoB	11	**12**	7	0	20
		BaR	3	**3**	2	0	10
	Off-peak	BoB	12	**14**	8	10	30
		BaR	3	**4**	2	0	10
	Weekend	BoB	7	**8**	4	0	20
		BaR	2	**1**	1	0	0

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Dunedin							
Bus	Peak	BoB	16	**19**	10	10	40
		BaR	4	**5**	3	0	10
	Off-peak	BoB	19	**22**	12	10	40
		BaR	5	**5**	3	0	10
	Weekend	BoB	11	**12**	6	0	20
		BaR	2	**3**	2	0	10

4.6 Micro-model forecasts: cycle-PT demand at individual stops/stations

This section addresses management of the cycle-PT programme for individual routes or stations within the public transport system. The macro-model includes assessment of the entire system which may provide a more accurate assessment overall. However, the placement of individual lockers and deciding which routes are to receive prioritisation for racks comes down to a route-by-route analysis.

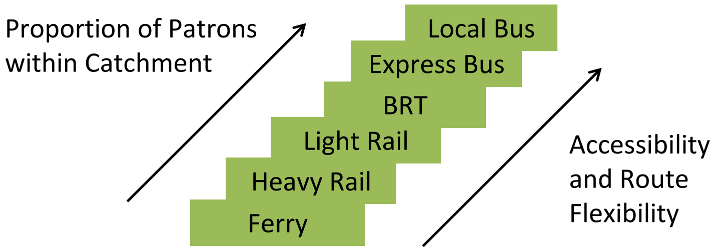
The demand for cycle-PT at a micro level comes from those who:

- are outside the walking catchment but are included in the **increase in catchment size** category as they can ride a bicycle to a public transport service (BaR or BoB)
- are currently **within the walking catchment** but their destination is outside walking distance from the end of the public transport journey (BoB).
- **already cycle the full journey**, but want to take public transport with their bicycle (BoB).

The sum of these three demands will equate to the BoB plus BaR patronage.

The research methodology assumes that the cycle-PT% rates are indicative of catchment effects for different types of public transport services (eg local bus, rail) and therefore the micro-model could make use of existing data for public transport patronage boarding or alighting at a particular stop. The catchment effects relate to the general attractiveness and user benefits associated with specific modes. This concept is shown in figure 4.9.

Figure 4.9 Concept of modal attractiveness



The micro-model assumes that each mode has its own level of use that incorporates both the expansion of the catchment and attraction to cycle-PT. At one end of the spectrum, for typical local bus public transport it is unlikely that park and rides are the primary demand locations (more often demand is based along arterials). Then for each decrease in accessibility, an increasing amount of public transport users arrive from outside the 800m walking radius (thereby increasing the attractiveness of cycling over walking).

Figure 4.9 highlights the need to understand the ‘observed’ cycle-PT rate to use at each localised public transport station. Because each mode has different characteristics of catchment and attraction to public transport it is important to use the appropriate cycle-PT rate for a local bus and a 3% cycle-PT rate for ferry and rail stations.

The micro-model assists practitioners to determine localised cycle-PT secure storage demands by applying a simplified approach relative to the macro (system-wide) model.

$$\textit{CyclePT for route or station} = \textit{existing PT patronage} \times \textit{cycle-PT rate} \qquad \text{(Equation 4.7)}$$

Table 4.8 shows how the variation in cycle-PT rate (using the Monte-Carlo simulation) for each mode varies by the size and mode of the existing public transport patronage. This table can be used to estimate cycle-PT demand for a route or a station.

The use of the Monte Carlo simulation increases the complexity of the calculation. However, it provides a better representation of the potential ranges of uptake and confidence intervals. The likely and median values represent the log-normal distribution of the cycle-PT variable rate.

The table provides an indication of the size of the system that would be necessary based on the general public transport patronage at a station or route. The use of the Monte Carlo simulation provides confidence that the likely rates could be used with an indication of the potential demand ranges.

It is acknowledged that this table in isolation would not be sufficient for a system to be designed at the micro-level and would need to be supplemented by materials developed at the practitioner level.

Table 4.8 Example forecast demand ranges for cycle-PT for typical routes

	Boardings per am peak period	**Users per am peak period**			**95th percentile**	
		Median	**Mean**	**Standard deviation**	**Low**	**High**
Local bus						
Cycle-PT in am peak = existing public transport patrons x cycle-PT rate for local bus (~1.2%)						
Cycle-PT (BoB & BaR)	100	1.2	**1.5**	0.8	0.5	3.0
BaR	100	0.2	**0.3**	0.2	0.1	0.6
Cycle-PT (BoB & BaR)	500	6.3	**7.2**	4.0	2.7	14.9
BaR	500	1.2	**1.4**	0.9	0.5	3.1
BRT, rail, ferry						
Cycle-PT in am peak = existing PT patrons x cycle-PT rate for BRT, rail, ferry (~3%)						
Cycle-PT (BoB & BaR)	100	3.1	**3.5**	1.5	1.6	6.3
BaR	100	0.6	**0.7**	0.3	0.3	1.3
Cycle-PT (BoB & BaR)	500	15.7	**17.2**	7.6	7.9	31.5
BaR	500	3.1	**3.4**	1.7	1.4	6.7
Cycle-PT (BoB & BaR)	1000	31.3	**34.3**	15.2	15.6	63
BaR	1000	6.1	**6.8**	3.4	2.7	13.4
Cycle-PT (BoB & BaR)	2000	62.6	**68.7**	30.5	31.3	125.9
BaR	2000	12.2	**13.6**	6.9	5.5	26.8

Accounting for secure storage locker space uses the estimated cycle-PT patrons for the route or station and finds the amount of storage necessary based on the StorageBaRDemand variable described in section 5.2.

The BaR numbers shown in table 4.8 should be multiplied by the peak demand factor of 1.3, derived in section 4.4.

Table 4.9 shows the supply and demand range of secure locker facilities for a variety of stations for different modes using the simplified micro-model forecasting equation (equation 4.7).

Table 4.9 Example secure locker demand for typical public transport routes

Mode (cycle-PT rate)	One-direction boardings	Cycle-PT users	Storage demand (BaR demand)			Storage locker supply (BaR supply)		
			Low (8%)	Average (16%)	High (24%)	Low (8%)	Average (16%)	High (24%)
Local bus (1.2%)	50	0.6	0	0	0	0	0	0
	100	1.2	0	0	0	0	0	0
	300	3.6	0	1	1	0	1	1
	500	6	0	1	1	1	1	2
Bus rapid transit (BRT) (3%)	500	15	1	2	4	2	3	5
	1000	30	2	5	7	3	6	9
	2000	60	5	10	14	6	13	19
Rail (3%)	1000	30	2	5	7	3	6	9
	2000	60	5	10	14	6	13	19
	4000	120	10	19	29	13	25	37
Ferry (3%)	1000	30	2	5	7	3	6	9
	3000	90	7	14	22	9	19	28
	5000	150	12	24	36	16	31	47

Practitioners need to use this model in association with the macro-model to avoid any double-counting of secure storage demand within the system. For example, if a walking public transport user is counted at more than one point (station/terminal/stop) on the route (eg both where they board and where they alight the service), then the micro-model will forecast cycle-PT BaR usage for that user at each point, double-counting storage demand.

Guidance to practitioners

Literature research from the USA indicated that 61% of BoB users cycled more than one mile to reach public transport but 80% travelled less than one mile after alighting (Hagelin 2005). This suggests that secure bicycle storage would be more effective at the start of the public transport trip.

5 Provision of cycle-PT facilities

5.1 Bike on board (BoB)

5.1.1 Buses

5.1.1.1 Bus capacity

Given that the predicted BoB ratio to total patronage is around 1% to 3% for a bus carrying 50 passengers, this would equate to one to two bicycles per bus.

In communities with successful BoB programmes, the most commonly cited challenge was the limitations on capacity. Several agencies in the USA reported having to turn away cyclists when racks were full.

The effect of a small variability in demand for BoB will inevitably lead to buses arriving with full racks, leading to the prospective BoB patron having to wait for the next service. Where the service is for example a 20-minute service with no guarantee of a spare rack on the next bus, this is a serious frustration.

Three-bike racks are available and King County Transit in Seattle, Washington, for example, now uses three-bike racks on several of their routes[14]. Initially operators reported problems with the final gross weight of the full racks. While technology has improved and three-bike racks are beginning to be adopted in greater numbers, three-rack systems pose additional operational issues with expanding the turning radii of the buses and have greater potential for interfering with headlight operation.

There are some transit agencies in the USA that allow BoB patrons to bring their bicycles on board when the racks are full based on bus operator discretion and availability of the wheelchair area. None of these agencies have modified the interior of their buses to accommodate BoB. None of the agencies reported any problems in regard to this policy (Hagelin 2005). Given potential frustration noted above on services with substantial time between buses, this strategy is recommended for consideration in the New Zealand context along with investing in local BaR at key boarding locations to mitigate on-board capacity constraints.

5.1.1.2 Bus cost

While the cost could be anywhere between NZ$1000 to $5000 per bike rack on bus, this sum is highly dependent on the number of racks installed. US sources quote the average cost per rack of purchasing and fitting racks in the order of US$500. Selecting NZ$2000 per bus for a fleet of 500 buses, a sum of NZ$1,000,000 would be a likely investment for a comprehensive BoB scheme.

> In all, transit agencies have invested very little into their BoB programmes compared with the returns they receive and the costs of other transit agency initiatives.
> (National Center for Transit Research 2005)

There is a cost in dealing with bicycles forgotten on or stolen from racks, but driver training is seen as a positive means of reducing the costs of this. It is expected that there will need to be on average a quarter of the effort of one of the organisation’s staff to administer the programme (Hagelin 2005).

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[14] http://seattlepi.nwsource.com/transportation/346273_metro07.html

5.1.1.3 Safety issues with bike on board buses

The integration of BoB with public transport has been met with support and has experienced only very few operational safety issues worldwide. Given the larger operating space for BoB on ferries and rail, operational problems have not been noted as areas of safety concern in the international literature.

It would appear that BoB on buses could have positive safety benefits through improving cycling safety without introducing any significant safety risks.

Operational safety issues have not caused problems in areas where BoB programmes were already implemented.

Brisbane has been trialling a BoB programme since 2002, and by 2006 had not had a single bike rack-related safety incident.[15]

Operational issues can arise that need to be dealt with on a case-by-case basis. One example is when buses need to stop further back than usual from an intersection to avoid an extended bike rack jutting out into the traffic flow. Another example is where racks fitted too high on buses mean that bicycles with child seats can reduce the driver's vision. The design of bus racks and mounting locations on the buses should ensure that no bicycle blocks the driver's vision.

The USA, known to be a litigious safety environment, has continued to expand BoB programmes over the last 10 years, which suggests there have not been significant financial issues such as law suits to serve as an impediment. For instance, in Santa Barbara there are 70 buses equipped with bike racks in a programme that has been operating since 1995. Bike racks have been involved in only three accidents in 11 years, and only in one of those was the rack itself deemed to be a contributing factor.[16]

Although there may be safety sensitivities regarding increasing cycle activity, a number of studies suggest increased cycle usage does not lead to a proportional increase in cycle accidents, as cycle investment and greater awareness of cyclists improved overall safety conditions. Our literature review identified a study suggesting this had occurred in North American cities (de Cerreño and Nguyen-Novotny 2006), as well as a study in which 10 European countries were compared and it was found that those with a higher rate of cycling had a lower number of fatal cycle accidents per 100 million kilometres of cycle activity (Wittink 2003).

The 'safety in numbers' phenomenon has been well documented by Peter Lyndon Jacobsen, a public health consultant in California, USA. He states that as the number of cyclists or pedestrians increases the fatality rates per capita begin to drop in a non-linear fashion (Vanderbilt 2008).

Based on the assumption that cyclists avoid intimidating parts of their route such as busy arterials, bridges and tunnels, a key perceived safety benefit for BoB will be removing cyclists from these segments of their journey. There may be an associated drop in safety for the remaining cyclists on arterial routes due to the potential loss of 'safety in numbers' but given the existing cycling volumes on arterials, this effect could be negligible.

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[15] Information supplied by Brisbane City Council, Australia

[16] Information supplied by Santa Barbara Metropolitan Transit District, USA.

5.1.2 Trains

5.1.2.1 Train capacity

Train carriages can be modified for the purposes of carrying more cycles, often at the expense of a small amount of passenger space. Other deterrents include configurations of train stations, train compartment setup, stairs, and uneven or large distances between platforms and train carriages.

Often limited space on the train carriage is the most substantial hurdle to bringing a cycle on-board trains during peak times. The space required for a 120-person capacity carriage-set would be for four bicycles, assuming a 3% cycle-PT rate.

With day-to-day and seasonal variation, it is recommended that five to six cycle spaces be provided per each 120 person carriage-set.

5.1.2.2 Train cost

The relative cost of fitting carriages to include bicycle racks is negligible. The issue requiring consideration by New Zealand practitioners is the effect of the loss of patronage space. Fit-outs are available whereby seats fold up to provide for bicycles. As an alternative to carriage fit-out, rail stations are considered as a key location for the provision of secure long-term bicycle storage.

It is common for transit agencies to prohibit bicycle access on train cars during peak travel times. This is done to reduce congestion on the train and friction in boarding and exiting the train. An independent analysis of 47 transit agencies found that some urban rail systems in the USA prohibit bicycles at all times (22). The same analysis showed a nearly even divide between agencies that restrict bicycle access during peak hours and those that allow bicycles at all times. There are no time restrictions on bicycle access for:

- 5 of 13 (38%) heavy rail systems
- 10 of 21 (48%) light rail systems
- 7 of 16 (44%) commuter rail systems.
  (Hagelin 2005)

5.1.3 Ferries

5.1.3.1 Ferry capacity

Like trains, ferries can also be modified for the purpose of carrying more cycles at the expense of a small amount of passenger space. Ferries often have spaces that may be undesirable for patrons that would provide suitable storage opportunities for cycles, such as under stairs or along exposed areas of the ferry.

The capacity of the ferry services is typically between 160–650 passengers depending on the size of the ferry. With a 3% cycle-PT rate, a range of 7–25 cycle spaces should be provided.

5.1.3.2 Ferry cost

The cost of implementing storage space and cycle parking on a ferry may be negligible. A standard cycle rack could be placed inside the ferry and underutilised space allocated as described above.

5.2 Bike and ride (BaR)

5.2.1 The provision of BaR

A BaR system provides public transport operators and patrons with the opportunity to store bicycles at one end of the trip.

Typically this secure storage occurs at the point of boarding the public transport service, where there is a sufficient number of patrons to warrant providing lockers or a secure area.

Alternatives include existing private enterprise services similar to Bike Central in downtown Auckland which cater to the cycling commuter. Facilities may provide amenities such as food, shower, locker, repair services, and secure indoor bicycle storage facilities for a fee. Current rates vary by commitment length, but one-year contracts are approximately $25 per week.

The provision of secure storage could be provided at either end of the public transport trip. The system-wide macro-model provides overall estimates for locker demand and supply based on average rates of demand. The practitioner should make use of the simplified micro-model to estimate individual station/terminal demand for lockers that takes into account local demographics, land use and connectivity to other transport modes. The recommended approach for practitioners is described in section 6.1.1.

As an example, table 4.6 suggests there will be demand from around 500 cyclists for secure storage in Auckland and Wellington and as outlined in section 4.4.2 forecast demand should be factored by 1.3 times (to 650) to develop the provision of secure storage. The Monte Carlo simulation results in table 4.6 also suggest doubling this amount of secure storage to cater for the likely 95th percentile of forecast demand.

The costs of BaR are covered in chapter 7.

5.2.2 Developing an implementation programme for BaR

This section explores the mechanics of implementing a complete cycle-PT system based on data from the local public transport service. The process is two tiered using the macro-model assumptions and then a detailed, station-by-station analysis of demand for cycle-PT BaR.

The macro system provides an overall range for the expected cycle-PT usage including BoB and BaR demand, as well as accounting for those users shifting from car modes. The simplified local model uses the overall cycle-PT rates and estimates demand for storage and BoB calculations.

The demand for cycle-PT should be evaluated route by route if not applied system wide at one time. Routes with the highest patronage should be implemented first.

Implementation process for cycle-PT BaR is described below:

- To work out how a number of lockers can be distributed across the system or route, use the micro-model with the patrons getting on or off at that point to examine:
  - a particular major station/stop/terminal
  - a group of isolated stops.
- To avoid double counting by the micro-model, only boarding patrons should be considered. But if secure storage is being provided at the end of the public transport trip (in which case there also needs to be BoB) then alighting passenger numbers can be used for that end of the trip. However as the micro-model calculates users (who make two trips per day) double counting will occur if more than one direction of public transport is used for the calculation.
- Tables 4.3 and 4.9 should be used to assess the level of cycle-PT and local BaR demand, taking seasonal demand into account.
- At locations where the required supply of BaR lockers is less than two, there will be extreme variability in locker requirements as day-to-day demand may rise to three or four, for example. Where there is only a small numerical requirement for BaR lockers at a location, then there are two possible courses of action:
  - a minimum of two lockers at any location

- group lockers at one location to cater to demand from a number of stops (with a minimum of two lockers at any point).

Aggregate the number of lockers to be provided based on the micro-model, to ensure that it is at least the number calculated by the macro-model (see table 4.7). If lockers are allocated using the micro-model, it is likely that the route/system-wide number will be higher than the macro-model, due to rounding up the number of lockers at each point.

Further consideration is required by practitioners of the practical implementation of BoB and BaR cycle-PT in their particular regions. Although the cycle-PT BoB is the most cost effective, the full benefits cannot be attained without implementation across the system and the addition of BaR secure storage at key locations.

To attain the best results for cycle-PT it is recommended that a system is implemented in discrete packages rather than in a progressive or a disconnected manner and that each package is accompanied by a substantial education and communication strategy.

6 Economic analysis using the EEM framework

This section of the report summarises the economic appraisal of cycle-PT projects under the existing *Economic evaluation manual* (EEM) framework. Each component of the benefit to be evaluated is further described in the following sections.

There are substantial benefits associated with the integration of cycling and public transport. Hagelin (2005) summarises the costs and benefits of cycle-PT and these have been modified for New Zealand in table 6.1. Economic benefits are quantified in chapter 7.

Table 6.1 Costs and benefits of cycle-PT

Cycle-PT investments or costs	Cycle-PT returns or benefits
Capital cost of fitting BoB to public transport vehicles	Increased patronage on public transport
Capital cost of BaR infrastructure	Increased public transport catchment coverage
Marketing costs of programmes	Providing link across non-cyclable bridges/tunnels
Maintenance costs of BoB and BaR	Health benefits to users
Administrative cost of day-to-day operations (staff, expenses)	Improved mobility options for non-drivers
Increased waiting time at stops due to cycle-PT users	Reduced congestion for non-users
Bikes stolen from racks, forgotten on racks	Reduced vehicle operating costs for users
Training/permitting users	Safety (increased cycling, avoiding arterials)
Insurance and liability	Reduced emissions (CO_2, CO, NO_x, SO_x, O_3 etc)
	Improved image of public transport
	Supporting transit-oriented-development/land-use with lower vehicle ownership.
	Lower investment/better return on car park and ride
	Parking cost savings (increased revenue from renting previously occupied spaces)
	Making cycling a more visible travel choice

The NZ Transport Agency (NZTA) publishes procedures for approved New Zealand organisations to evaluate the economic efficiency of transport projects and activities funded by the NZTA within the value-for-money framework of the NZTA's overall investment and revenue strategy.

These procedures, which are set out in the EEM, volumes 1 and 2 (NZTA 2010a, b) apply monetary values to the various components of the benefits likely from particular transport projects.

Volume 1 of the EEM contains the basic concepts of economic efficiency evaluation and specific evaluation procedures for road activities. Volume 2 includes procedures to be used for evaluating transport demand management proposals, travel behaviour change proposals, walking and cycling, transport services, private sector financing, toll road activities and parking measures.

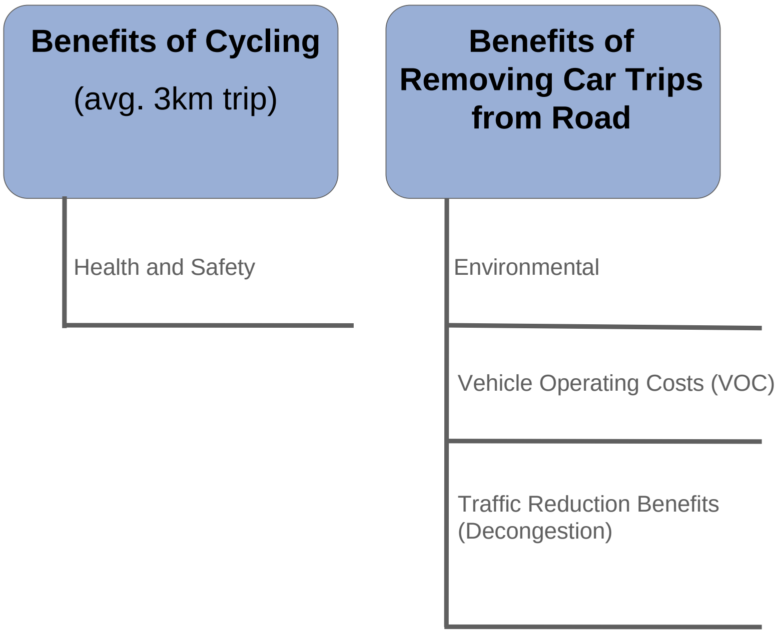
Simplified procedure 10 (SP10) contained in volume 2 of the EEM is a simplified method for appraising the costs and benefits of activities to improve an existing passenger transport service through the provision of capital infrastructure and/or service improvements. SP10 has been applied in this research for the economic evaluation of cycle-PT in New Zealand.

This simplified procedure assumes the following:

1. Service improvements primarily concern existing peak period services and as a result of improvements commuters change modes from private vehicles to bus or rail.
2. The primary benefits are: travel time savings (including congestion reduction), vehicle operating cost savings, accident cost savings, parking and environmental benefits (including CO_2 reduction), reliability benefits and vehicle and infrastructure benefits.
3. The activity will not generate road maintenance and renewal cost savings, as the majority of traffic removed from the road network will be light vehicles. There will also be no road capital cost savings.
4. Other benefits (positive or negative) are not significant. However, allowance can be made for other benefits in these procedures.
5. The activity will not generate a drop off in existing passengers (ie due to a fare rise).
6. Activities adopted will be established or constructed in the first year and will be operating by the end of year 1.
7. An 8% discount rate and 15-year analysis period are used.
8. A 12% service provider rate of return is used for analysis of the funding gap.
9. All costs are exclusive of goods and services tax (GST).

Figure 6.1 highlights the primary benefits used from volume 2 of the EEM for the economic evaluation of cycle-PT.

Figure 6.1 Outline of the primary benefits of cycle-PT



6.1 Health and safety benefits

Non-motorised travel involves physical exercise, which can provide substantial health benefits. Inadequate exercise and excessive body weight are increasing problems that result in a variety of medical problems, including cardiovascular diseases, bones and joint injuries, and diabetes (Victoria Transport Policy Institute 2010). The EEM states the following:

> *Regular physical activity is associated with an improvement in a wide range of health conditions, including heart disease, mental health and diabetes. The health benefits of walking and cycling have been researched, and this indicates significant benefits associated with these activities.*

Health and safety benefits will apply to new cyclists shifting from private automobiles to public transport as a result of the integration of cycling and public transport.

As SP10 only deals with benefits for the passenger transport portion of the cycle-PT trip, the health and safety benefits for increased cycling to and/or from passenger transport have been added to the SP10 procedure. The value for health and safety benefits from cycling are included in EEM2 in table 8.3 which states that:

> *...the currently accepted level of health plus safety benefit for a cyclist is $1.35 per cyclist per kilometre. This applies to both the new and existing cyclists* (NZTA 2010b)

There are economic health benefits to commuting by bicycle, and an average ride of 3km has been assumed in this research. This distance represents the typical commuter distance for a bicycle where the user would then board public transport or securely store their bicycle.

6.2 Cycle-PT demand mode shift

The source of cycle-PT patrons derives from a shift from private car modes, walking and existing cycling and public transport modes. Variables in the macro-model estimate the extent of the shift from car-based modes. The subsequent difference between total cycle-PT users and those shifting from car-based modes represents the number of users attributed to walking, cycling and public transport.

The number of cycle-PT patrons shifting from car-based modes is a significant factor in the economic analysis of cycle-PT using the EEM process. Table 6.2 contains the results of the macro-model forecasts of cycle-PT users who have changed from driving cars to using BoB (bus only) as well as those who changed to using both BoB and BaR (for bus only).

The data shown in table 6.2 is annualised and then used in rows c1 and c2 in the economic evaluation shown in section 7.9.

Table 6.2 Cycle-PT patrons from car mode (bus only) for BoB and BoB/BaR systems

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Auckland							
BoB	Peak	Car to bus	220	256	154	90	540
	Off-peak	Car to bus	261	303	182	100	640
	Weekend	Car to bus	142	165	100	60	350
BoB and BaR	Peak	Car to bus	241	280	170	100	590
	Off-peak	Car to bus	285	332	201	110	700
	Weekend	Car to bus	156	181	110	60	380

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Wellington							
BoB only	Peak	Car to bus	110	128	77	40	270
	Off-peak	Car to bus	130	151	91	50	320
	Weekend	Car to bus	71	83	50	30	170
BoB and BaR	Peak	Car to bus	120	140	85	50	300
	Off-peak	Car to bus	142	166	100	60	350
	Weekend	Car to bus	78	90	55	30	190
Christchurch							
BoB Only	Peak	Car to bus	84	98	59	30	210
	Off-peak	Car to bus	100	116	70	40	240
	Weekend	Car to bus	54	63	38	20	130
BoB and BaR	Peak	Car to bus	92	107	65	40	230
	Off-peak	Car to bus	109	127	77	40	270
	Weekend	Car to bus	60	69	42	20	150
Hamilton							
BoB only	Peak	Car to bus	20	24	14	10	50
	Off-peak	Car to bus	24	28	17	10	60
	Weekend	Car to bus	13	15	9	10	30
BoB and BaR	Peak	Car to bus	22	26	16	10	50
	Off-peak	Car to bus	27	31	19	10	60
	Weekend	Car to bus	14	17	10	10	40
Tauranga							
BoB only	Peak	Car to bus	6	7	4	0	20
	Off-peak	Car to bus	7	8	5	0	20
	Weekend	Car to bus	4	5	3	0	10
BoB and BaR	Peak	Car to bus	7	8	5	0	20
	Off-peak	Car to bus	8	9	6	0	20
	Weekend	Car to bus	4	5	3	0	10
Dunedin							
BoB Only	Peak	Car to bus	10	11	7	0	20
	Off-peak	Car to bus	11	13	8	0	30
	Weekend	Car to bus	6	7	4	0	20
BoB and BaR	Peak	Car to bus	10	12	7	0	30
	Off-peak	Car to bus	12	14	9	0	30
	Weekend	Car to bus	7	8	5	0	20

6.3 Private vehicle operating cost savings

Vehicle operating costs (VOCs) include the direct expenses of owning and using a vehicle. They comprise the costs of fuel, tyres, repairs and maintenance, oil and the mileage-based depreciation. Delay experienced by vehicles is outside the VOC cost considerations and must be accounted for separately.

The integration of cycling and public transport will result in some private vehicle operating cost savings. These savings will be a result of the shift from private vehicle travel to public transport due to the increase in the public transport catchment area.

Based on the EEM, the vehicle operating costs consist of the base running costs categorised by speed and gradient, road roughness, road surface texture, pavement elastic deflection, congestion, bottleneck delays and speed-change cycles. For simplicity, it is suggested that a base running cost of 24.6 cents/km (50km/h for a passenger car)[17] be used to evaluate the private vehicle operating cost savings for the mode shift from private vehicle travel to public transport.

The distance travelled using cycle-PT is based on the 2006 NZ Census data that states: ‘Most people in New Zealand do not travel very far to their workplace, with just under half (47 percent) travelling less than 5km and two-thirds (67 percent) travelling less than 10km’.

Table 6.3 is sourced from the 2006 Census and demonstrates the recent commuting distances and trends in New Zealand’s major cities.

Table 6.3 Employed population who travelled to work in major cities, by distance travelled

City	Year	Distance travelled to workplace (km)		
		Lower quartile	Median	Upper quartile
Four cities of Auckland	1996	2.6	6.0	11.3
	2006	2.7	6.0	11.6
Four cities of Wellington	1996	2.4	4.6	10.2
	2006	2.4	4.8	11.3
Christchurch city	1996	2.6	4.9	8.1
	2006	3.0	5.0	9.0

The average commute distance is already built into the SP10 for the main study centres. The SP10 has assumed that mode shift from private vehicle travel to public transport will not require additional public transport capacity to accommodate the new public transport users.

6.4 Benefit to remaining road users

Shifting trips from car-based modes to public transport allows the remaining users of the road to benefit from decreased congestion, air pollution and costs. The average benefit to remaining road users applies to the peak-hour traffic, and is $1.41/vehicle-km for Auckland, $1.08/vehicle-km for Wellington and $0.10/vehicle-km for Christchurch. See the EEM, volume 2 (NZTA 2010b, pp3–15).

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[17] See table A5.1: Passenger car VOC by speed and gradient (cents/km – July 2008), EEM, volume 1 (NZTA 2010a, pA5-10).

The congestion reduction benefits to other road users during peak periods are listed in table 6.4 below.

Table 6.4 Peak period average benefits to remaining road users (2008 $s)

	Auckland	Wellington	Christchurch	Other
Average benefits including travel time, VOC and CO_2 (/vehicle-km)	$1.41	$1.08	$0.10	$0.00

The EEM provides further guidance on the benefits noting that as decongestion initially occurs, additional traffic will be induced to travel because of the reduced delays. To account for the changing patterns and demand in traffic the actual accrued benefits to the remaining road users are approximately 50% of those shown in table 6.4.

The SP10 used in this study accounts for both peak and off-peak travel benefits.

6.5 Parking cost savings

Owners of parking spaces released through a change to cycle-PT would be able to generate additional revenues from re-selling those spaces. The EEM volume 2 provides an example:

> *...if a business has 100 parking spaces, and its commute trip reduction programme reduces demand to 60 parking spaces, it will have 40 parking spaces that are no longer needed. The business will need to sell, lease or rent these spaces, or convert the land to other uses, in order to benefit from this reduced demand. (*NZTA 2010b, p10-5)

A commuter who shifts from paying a typical parking fee at a park-and-ride lot to using cycle-PT will realise an actual cash saving on every trip. This, as noted above, accrues additional external benefits if the switch to cycle-PT removes the demand for a parking space.

Two types of user benefit from parking cost savings: users new to public transport who would have driven all the way into the CBD; and users currently parking a car at a park-and-ride facility to access public transport.

This study estimates the portion of cycle-PT users who will be shifting away from the use of a private car and who are new to public transport and will therefore no longer need a parking space within the CBD.

6.6 Environmental benefit

The mode shift from private vehicle use to cycle-PT would result in environmental benefits such as reduction in emissions (CO_2, CO, NO_x and other VOCs).

For example, emissions studies and research suggest CO_2 emissions for light vehicles to be between 140–160g/km. This equates to approximately 700–800kg of CO_2 saved in a year from a single vehicle travelling 10km to work (20km return trip) for 245 work days.

By switching to bicycle and the bus, small but not meaningless reductions in emissions occur. The FHWA (1994) National Bicycling and Walking Study reported that switching to bicycling had important air quality benefits because emissions from short one- or two-mile trips were nearly as great as typical 5- to 10-mile trips, and that approximately 90% of emissions occurred in the first mile after a cold start.

6.7 Potential additional benefits not included

6.7.1 Supporting land-use development

The Chicago Area Transportation Study found that half of all drivers using park and ride lived within two miles of the facility (Federal Highway Administration 1993). Providing cycle-PT integration and encouraging local park-and-ride users to cycle rather than drive could therefore be a means to freeing up valuable car parking spaces for the benefit of those travelling longer distances.

6.7.2 Improved public transport

Public transport can be strengthened by increasing its reliance and importance within the overall transportation network. Expanding the system to fully accommodate cycling makes every bus stop and rail and ferry station multi-modal transfer points. The EEM, volume 2 (NZTA 2010b) supports the integration of the two modes by the following:

> *Cycling and passenger transport are complementary modes. Cycling is ideal for relatively short (less than five km) trips with multiple stops on lower traffic roads, while passenger transport is most effective when travelling longer distances along busy corridors. Coordination can be enhanced by cycle racks and storage lockers near passenger transport stops, racks for carrying cycles on buses and pool vans, and cycle routes to passenger transport stops.*

The use of cycle-PT can also improve overall system reliability as users are able to shift from private car to public transport.

6.7.3 Improved accessibility for non-drivers to public transport

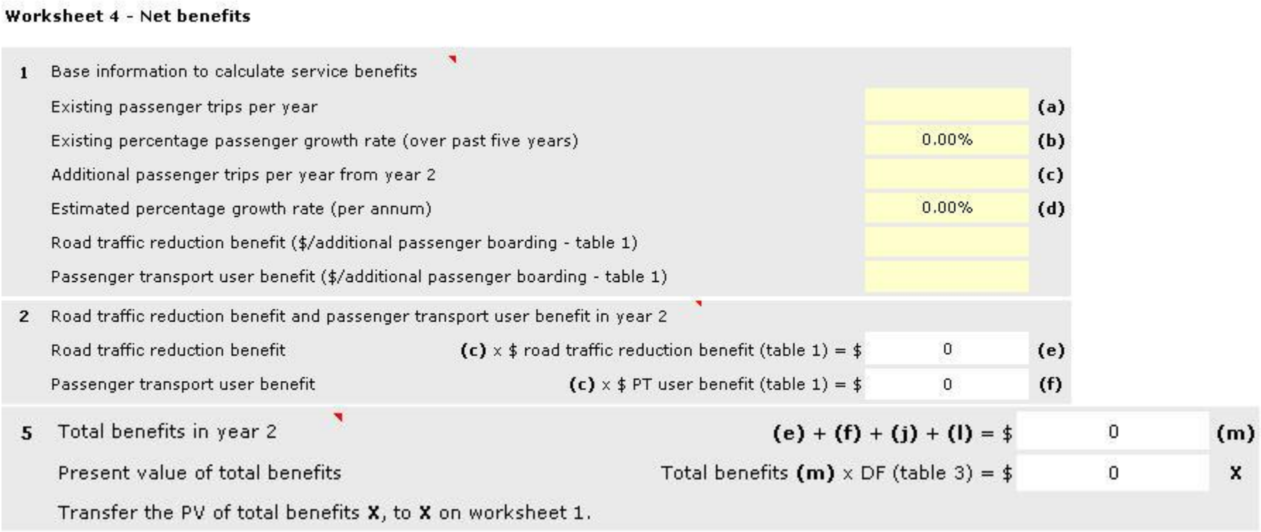
While public transport benefits those without access to a car or who cannot drive for any number of reasons, the integration of cycling with public transport would further increase the accessibility of public transport as a result of the increased catchment area associated with cycle-PT facilities.

6.8 Suggested method for economic appraisal

Economics benefits can be evaluated for the cycle-PT implementation using the template shown in figure 6.2, with the health benefits from new cycle trips as outlined in section 6.1 assessed separately and then added to the benefits in the template.

Cycle-PT users may shift from existing public transport, walking, or cycling modes but it is difficult to assess changes in benefits for cycle-PT users who switch from existing non-car mode and this is not included in the study. Therefore, the assessed benefits only accrue to former drivers who switch to cycle-PT and the level of benefits depends on their period of travel, peak or off-peak.

Figure 6.2 Simplified procedure 10 for economic evaluation of cycle-PT initiatives



Worksheet 4 - Net benefits

1 Base information to calculate service benefits

Existing passenger trips per year (a)

Existing percentage passenger growth rate (over past five years) 0.00% (b)

Additional passenger trips per year from year 2 (c)

Estimated percentage growth rate (per annum) 0.00% (d)

Road traffic reduction benefit ($/additional passenger boarding - table 1)

Passenger transport user benefit ($/additional passenger boarding - table 1)

2 Road traffic reduction benefit and passenger transport user benefit in year 2

Road traffic reduction benefit **(c)** x $ road traffic reduction benefit (table 1) = $ 0 **(e)**

Passenger transport user benefit **(c)** x $ PT user benefit (table 1) = $ 0 **(f)**

5 Total benefits in year 2 **(e) + (f) + (j) + (l)** = $ 0 **(m)**

Present value of total benefits Total benefits **(m)** x DF (table 3) = $ 0 **X**

Transfer the PV of total benefits **X**, to **X** on worksheet 1.

The SP10 for existing passenger transport services accounts for the primary benefits of:

- travel time savings (including congestion reduction), VOC savings and accident cost savings
- parking and environmental benefits (including CO_2 reduction).

Table 6.5 contains the details of economic benefits to road traffic and to cycle-PT users who have moved from driving a car to using cycle-PT. This table is referred to as 'table 1' in the EEM SP10 and in figure 6.2 above.

Table 6.5 Benefits from additional passenger boarding ($/passenger 2008)

Location	Mode	Average trip length (km)	Road traffic reduction benefits		Passenger transportation user benefits	
			Peak	Off-peak	Peak	Off-peak
Auckland	All	7.70	$12.61	$0.86	$8.59	$5.73
Auckland	Train	16.50	$17.27	$1.65	$13.18	$8.78
Auckland	Bus/ferry	6.60	$11.73	$0.76	$8.02	$5.35
Wellington	All	12.14	$13.25	$1.25	$10.90	$7.27
Wellington	Train	22.76	$17.70	$1.99	$16.44	$10.96
Wellington	Bus/ferry	6.97	$11.97	$0.89	$8.21	$5.48
Christchurch	All	8.05	$2.71	$1.24	$8.78	$5.85
Other	All	7.86	$2.06	$1.00	$8.68	$5.78

The costs (NPV) evaluation is undertaken with a 15-year economic evaluation period. The discounting factor will depend on the public transport growth. The discounting factor in the template above assumed implementation in year 1 and benefits accruing in years 2 to 15 (inclusive) with 0% base growth in public transport patronage.

Table 6.6 contains the economic discount factors applicable to different assumptions of patronage growth. This is referred to as 'table 3' in the EEM SP10 and in figure 6.2.

Table 6.6 Discount factors for different estimated patronage growth rates

Passenger growth rate	0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
Discount factor	7.93	8.20	8.47	8.74	9.01	9.28	9.55	9.81	10.08

The health benefits from the cycling portion of the cycle-PT trip are added, and the economic appraisal of cycle-PT using this modified SP10 is shown in section 7.8.

6.9 Costs

The cost of implementing a cycle-PT programme is primarily based on the size of the public transport system, the number of buses, and the number of locations requiring storage lockers. Additional variability can occur in staff time and promotion activities. Table 6.9 below identifies and describes typical costs associated with cycle-PT schemes.

Table 6.9 Typical costs associated with cycle-PT schemes

Cycle-PT investments or costs	Description
Capital cost of fitting BoB to public transport vehicles	Fleet wide average costs of racks can approach US$500 (Hagelin 2005). Assumed around NZ$2000 per rack[18].
Capital cost of BaR infrastructure	Installed bicycle locker costs are reported by the Pedestrian and Bicycle Information Centre as NZ$1000 per locker (Pedestrian and Bicycle Information Center). Costs range up to NZ$2500 per locker. A cost of NZ$5000 has been used in this study.
Marketing costs of programmes	Varied by agency, some just staff time and up to $50,000
Maintenance costs of BoB and BaR	Estimated to be 10% of rack cost
Administrative cost of day-to-day operations (staff, expenses)	Often ¼ to ½ full-time staff equivalent (Wittink 2003) (NZ$20,000 – $30,000).
Route delay and increased dwell time	Negligible
Bikes stolen from racks, forgotten on racks	Negligible
Training/permitting users	Staff time, typically two hours for all drivers
Insurance and liability	Liability lies with bike rack user. Most agencies insure the bicycle up to a certain amount.

6.9.1 Bike bus racks

The cost of installing and setting up a complete bus system provides an efficiency of scale that reduces the per rack cost. It is estimated that costs can come down with mass purchases and changes in technologies.

6.9.2 Staff costs and staff training

Staff time required to implement and manage the cycle-PT programme varies widely. Factors to consider include leasing and renting locker administrative costs, marketing responsibilities, maintenance records and general programme development.

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[18] ECan Bike Trial. www.stuff.co.nz, January 2009 article.

Training bus drivers is a critical step to cycle-PT success. Buses now have a wider turning radius that may require adjustments to driving patterns. Basic training includes understanding the rack system and how to react if any issues arise.

6.9.3 Other costs

Cost and staff time devoted to bicycles left on racks has had a negligible effect on general operations. The majority of agencies in the USA have developed a protocol for bicycle collection, storage and eventually the donation of the unclaimed bicycles.

Liability has not become an issue in the particularly litigious USA environment. Only one transit company of those surveyed said while their costs remained the same their insurance coverage included descriptions of the additional liability of carrying bicycles.

7 Cycle-PT economics for New Zealand

This section of the report covers the forecast demand for providing both BoB and secure storage BaR for a selection of cities in New Zealand, the costs of implementing cycle-PT schemes to meet that forecast demand, and the calculation of economic benefits from providing the cycle-PT schemes on bus networks including the benefit-to-cost ratios (BCRs).

Due to the uncertainty of costs for BoB rail and ferry services, the costs and hence the economics of those schemes are not assessed.

7.1 Cycle-PT scheme forecast demand

The cycle-PT model forecast that if cycle-PT was implemented in full across the selection of New Zealand regions listed in table 7.1, approximately 1.7 million cycle-PT trips would occur per annum. The stretch goal shown in the table represents the number of cycle-PT trips forecast to occur if the uptake rate is closer to the high end of the range of cycle-PT achieved in the more successful North American schemes.

Table 7.1 Forecast annual cycle-PT trips based on simplified calculation from annual patronage

Location	Mode	Current PT patronage (million per annum)	Forecast annual cycle-PT trips	
			Goal	Stretch goal
Auckland	Bus	46 million	550,000	1,380,000
Auckland	Train	7 million	210,000	420,000
Auckland	Ferry	4 million	120,000	240,000
Wellington	Bus	23 million	140,000	360,000
Wellington	Train and ferry	12 million	360,000	360,000
Tauranga	Bus	1 million	10,000	30,000
Rotorua	Bus	1 million	10,000	30,000
Dunedin	Bus	2 million	20,000	60,000
Christchurch	Bus	18 million	220,000	220,000
Hamilton	Bus	4 million	50,000	120,000
Total			**1,690,000**	**3,220,000**

Further information on the cycle-PT trips is contained in subsequent sections of this report based on the use of the Monte Carlo model. This shows higher forecast trips due to the log-normal distribution of some factors. Annual trips calculated from that approach are shown in section 8.2.

The time of day and the weekday or weekend timing of the cycle-PT trips makes a difference to the economic benefit of the trip.

Decongestion benefits only accrue for those cycle-PT trips made on weekdays at peak commute periods. It is estimated that 88% of total cycle-PT trips are made on weekdays, and of those approximately 42% are made during ‘congested’ periods. All other benefits accrue 365 days a year for all cycle-PT users.

7.1.1 Auckland cycle-PT forecast demand

7.1.1.1 Auckland bus services

Table 7.2 contains the results of the macro-model forecast for cycle-PT demand for the Auckland bus network. This shows that 390 secure storage lockers would be required to meet an average daily demand from 300 cycle-PT users (106 peak, 194 off-peak). In addition 1215 users are forecast to take their bikes on board the bus on an average day.

This is forecast to remove 793 cars per day from the region including 280 from the peak period.

The cost of providing the 378 storage lockers is approximately $1.95 million.

Table 7.2 Auckland cycle-PT bus user forecast

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Auckland							
Bus	Peak	BoB	379	429	233	160	880
		BaR	91	106	65	40	230
	Off-peak	BoB	449	508	275	190	1040
		BaR	108	125	76	40	270
	Weekend	BoB	245	278	151	110	570
		BaR	59	69	42	20	150
	Peak	Car to bus	241	280	170	100	590
	Off-peak	Car to bus	285	332	201	110	700
	Weekend	Car to bus	156	181	110	60	380

A BoB programme would provide an on opportunity for cyclists to overcome some of the geographic impediments to cycling, such as the Auckland Harbour Bridge and stretches of motorway that do not allow cycling. Auckland experiences the worst congestion within New Zealand but currently has low cycle mode share compared with other New Zealand cities.

7.1.1.2 Auckland rail and ferry services

Providing secure cycle parking would be a means of improving the train catchment area, and allowing for safe storage of cycles when either onboard bike carrying capacity has been exceeded or when peak hour demands prohibit cycles.

Ferry patronage in Auckland has seen an upward trend over the last couple of years. There are existing facilities to cater for the bike on ferry schemes (see section 3.2.3). It is estimated that over 3% of peak-period ferry passengers currently cycle to ferry stations. However, there is little scope for improving on-board storage space, which is currently close to capacity on some services. Throughout Auckland there is little in the way of secure cycle storage at ferry terminals and it has been noted that secure cycle lockers could be installed at ferry terminals to further enhance the integration of cycling and ferry.

Table 7.3 contains the results of the macro-model forecast for cycle-PT demand for the Auckland train and ferry network. This shows that 409 secure storage lockers would be required to meet an average daily demand from 314 cycle-PT users.

In addition 1268 users are forecast to take their bikes on board the services on an average day.

This is forecast to remove 829 cars per day from the region including 331 during the peak period.

The cost of providing the 409 secure storage lockers is approximately $2.05 million.

Table 7.3 Auckland rail and ferry cycle-PT user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Auckland							
Rail and ferry	Peak	BoB	464	**506**	217	240	910
		BaR	112	**125**	63	50	250
	Off-peak	BoB	549	**599**	256	280	1080
		BaR	133	**148**	75	60	290
	Weekend	BoB	150	**164**	70	80	290
		BaR	36	**41**	20	20	80
	Peak	Car to rail/ferry	296	**331**	166	130	640
	Off-peak	Car to rail/ferry	350	**391**	197	160	760
	Weekend	Car to rail/ferry	96	**107**	54	40	210

Ferry operators have pointed out that unlike park-and-ride and suburban public transport services, most car parking at ferry terminals requires a cost to the user, as demand for space around ferry terminals is at a premium. As cycle parks make up to eight times more efficient use of space than car parking, providing secure storage could improve the efficiency of the land utilised by ferry services and provide an increase in patronage with more people able to use ferry modes. It is noted that many rail park-and-ride lots are experiencing similar parking demands.

As noted in section 6.5, the ability for a car-driver to shift to public transport and free up a parking space provides secondary benefits for the cycle-PT integration that are not included in this analysis. However, those users already parking at a ferry or rail park and ride will experience a positive economic realised return (the price they would have paid for parking) if they shift from car parking to cycling to the station.

7.2 Wellington cycle-PT forecast demand

7.2.1 Wellington bus services

Table 7.4 contains the results of the macro-model forecast for cycle-PT demand for the Wellington bus network. This shows that 195 secure storage lockers would be required to meet an average daily demand from 150 cycle-PT users. In addition 606 users are forecast to take their bikes on board the bus on an average day.

This is forecast to remove 396 cars per day from the region including 140 from the peak period.

The initial cost of providing 195 storage lockers is approximately $0.98 million.

Table 7.4 Wellington cycle-PT bus user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	High	Low
Wellington							
Bus	Peak	BoB	189	214	116	80	440
		BaR	46	53	32	20	110
	Off-Peak	BoB	224	253	137	100	520
		BaR	54	63	38	20	130
	Weekend	BoB	122	139	75	50	280
		BaR	29	34	21	10	70
	Peak	Car to bus	120	140	85	50	300
	Off-peak	Car to bus	142	166	100	60	350
	Weekend	Car to bus	78	90	55	30	190

7.2.2 Wellington rail/ferry services

Wellington’s trains and the Eastbourne and Petone ferries allow bicycles to be carried for free. Bicycles are not permitted in the seating area of the trains and only permitted to be stored in the luggage compartment of all services.

It should be noted that the costs to install on-board racks in rail carriages and ferries are not included in this cost estimate. The initial estimate of locker utilisation combined with the ability to bring the cycle on trains and ferries provides a favourable return on investment.

A survey of Wellington train passengers conducted during December 2005 indicated that 24% would be quite likely or very likely to consider cycling to train stations if suitable facilities were available (Kirkman 2006).

Although the terrain around Wellington can be quite hilly, the CBD area is largely flat. A BoB system would provide people with the opportunity to make use of public transport for travelling to and from the city, but to cycle around the CBD, for instance, to work, education, shopping or entertainment.

Table 7.5 contains the results of the macro-model forecast for cycle-PT demand for the Wellington rail and ferry networks. This shows that 427 secure storage lockers would be required to meet an average daily demand from 328 cycle-PT users. In addition, 1324 users are forecast to take their bikes on board the trains and ferries on an average day.

This is forecast to remove 865 cars per day from the region including 345 from the peak period.

The initial cost of providing the 407 storage lockers is approximately $2.1 million.

Table 7.5 Wellington cycle-PT rail/ferry user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	High	Low
Wellington							
Rail and ferry	Peak	BoB	484	**528**	226	250	950
		BaR	117	**131**	66	50	260
	Off-peak	BoB	573	**625**	268	290	1130
		BaR	139	**155**	78	60	300
	Weekend	BoB	156	**171**	73	80	310
		BaR	38	**42**	21	20	80
	Peak	Car to rail/ferry	309	**345**	174	140	670
	Off-peak	Car to rail/ferry	366	**408**	205	170	790
	Weekend	Car to rail/ferry	100	**112**	56	50	220

7.3 Christchurch cycle-PT forecast demand

Table 7.6 contains the results of the macro-model forecast for cycle-PT demand for the Christchurch bus network. This shows that 150 secure storage lockers would be required to meet an average daily demand from 115 cycle-PT users. In addition 464 users are forecast to take their bikes on board the bus on an average day.

This is forecast to remove 303 cars per day from the region including 107 during the peak period.

The cost of providing the 150 storage lockers is approximately $0.75 million.

Table 7.6 Christchurch cycle-PT bus user estimates

Location and mode	Time period	Type period	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Christchurch							
Bus	Peak	BoB	145	**164**	89	60	340
		BaR	35	**41**	25	10	90
	Off-peak	BoB	171	**194**	105	70	400
		BaR	41	**48**	29	20	100
	Weekend	BoB	94	**106**	58	40	220
		BaR	23	**26**	16	10	60
	Peak	Car to bus	92	**107**	65	40	230
	Off-peak	Car to bus	109	**127**	77	40	270
	Weekend	Car to bus	60	**69**	42	20	150

While the forecasts shown in table 7.6 are based on typical cycle-PT rates, the existing cycle mode share of 6.1% (table 3.1) suggests that the cycle-PT uptake rate may be higher than the typical city. With an existing higher degree of cycling in the Christchurch area, the shift to cycle-PT may be more pronounced and experience larger utilisation and a higher degree of mode shift from other modes such as private car.

A BoB programme would complement Christchurch's existing cycle initiatives and provide cyclists and tour cyclists with a means of crossing the Lyttelton tunnel which currently has a prohibition against cycling.

7.4 Hamilton cycle-PT forecast demand

Table 7.7 contains the results of the macro-model forecast for cycle-PT demand for the Hamilton bus network. This shows that 37 secure storage lockers would be required to meet an average daily demand from 28 cycle-PT users. In addition 113 users are forecast to take their bikes on board the bus on an average day.

This is forecast to remove 74 cars per day from the region including 26 during the peak period. The cost of providing the 37 storage lockers is approximately $0.2 million.

Table 7.7 Hamilton cycle-PT bus user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Hamilton							
Bus	Peak	BoB	35	40	22	20	80
		BaR	8	10	6	0	20
	Off-peak	BoB	42	47	26	20	100
		BaR	10	12	7	0	30
	Weekend	BoB	23	26	14	10	50
		BaR	5	6	4	0	10
	Peak	Car to bus	22	26	16	10	50
	Off-peak	Car to bus	27	31	19	10	60
	Weekend	Car to bus	14	17	10	10	40

7.5 Tauranga cycle-PT forecast demand

Table 7.8 contains the results of the macro-model forecast for cycle-PT demand for the Tauranga bus network. This shows that 11 secure storage lockers would be required to meet an average daily demand from eight cycle-PT users. In addition 34 users are forecast to take their bikes on board the bus on an average day.

This would remove 22 cars per day from the region including eight during the peak period. The cost of providing the 11 storage lockers is approximately $0.06 million.

Tauranga could be well suited to a BoB programme as many urban and suburban areas are separated by long peninsulas and bridges. A BoB programme would provide an opportunity for cyclists to overcome this, and also provide people with a means of moving between Tauranga and Mt Maunganui without contributing to congestion or competing for the limited parking available.

Table 7.8 Tauranga cycle-PT bus user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Tauranga							
Bus	Peak	BoB	11	12	7	0	20
		BaR	3	3	2	0	10
	Off-peak	BoB	12	14	8	10	30
		BaR	3	4	2	0	10
	Weekend	BoB	7	8	4	0	20
		BaR	2	1	1	0	0
	Peak	Car to bus	7	8	5	0	20
	Off-peak	Car to bus	8	9	6	0	20
	Weekend	Car to bus	4	5	3	0	10

7.6 Dunedin cycle-PT forecast demand

Table 7.9 contains the results of the macro-model forecast for cycle-PT demand for the Dunedin bus network. This shows that 17 secure storage lockers would be required to meet an average daily demand from 13 cycle-PT users. In addition 53 users are forecast to take their bikes on board the bus on an average day.

This is forecast to remove 31 cars per day from the region including 11 during the peak period. The cost of providing the 17 storage lockers is approximately $0.09 million.

Table 7.9 Dunedin cycle-PT bus user estimates

Location and mode	Time period	Type	Users per day			95th percentile	
			Median	Mean	Standard deviation	Low	High
Dunedin							
	Peak	BoB	16	19	10	10	40
		BaR	4	5	3	0	10
	Off-peak	BoB	19	22	12	10	40
		BaR	5	5	3	0	10
	Weekend	BoB	11	12	6	0	20
		BaR	2	3	2	0	10
	Peak	Car to bus	10	12	7	0	30
	Off-peak	Car to bus	12	14	9	0	30
	Weekend	Car to bus	7	8	5	0	20

7.7 Cycle-PT scheme costs

7.7.1 Bus cycle-PT scheme costs

Estimated initial costs and the net present value of 15 years of annual upkeep of outfitting the bus systems for the study areas are shown below in tables 7.10 and 7.11. The following assumptions are included in the 15-year planning horizon:

- NZ$2000 price per bus rack, NZ$5000 per secure locker, purchased in year 1 with a 10-year lifespan, with full replacement cost occurring again in year 11.
- One full-time staff member required for the scheme in major centres, with a half-time employee required in smaller centres; wages growing at 2% per year.
- Two hours of training required per bus driver with 5% of staff turnover per year requiring new training.
- Annual maintenance of racks and lockers is set at 10% of the rack price per annum.
- The locker supply reflects the peak factor of 1.3 (as recommended in section 4.4.2).
- The NPV for the schemes is calculated using an 8% discount factor over a 15-year period.

Table 7.10 Bikes on board (bus): first year and 15-year net present value costs

Cycle-PT BoB	Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
Cost per rack	$2000	$2000	$2000	$2000	$2000	$2000
Number of buses[19]	950	500	300	60	20	40
Bus cost	$1,900,000	$1,000,000	$600,000	$120,000	$40,000	$80,000
Training for bus drivers	$74,000	$39,000	$23,000	$4700	$2000	$3000
Total initial cost	$1,974,000	$1,039,000	$623,000	$124,700	$42,000	$83,000
15-year net present value of costs	$4,422,000	$2,327,000	$1,396,000	$279,000	$93,000	$186,000

Table 7.11 Bike and ride (bus): first year and 15-year net present value costs

Cycle-PT BaR	Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
Locker cost	$5000	$5000	$5000	$5000	$5000	$5000
Locker demand	300	150	115	28	8	13
Locker supply (1.3 factor)	390	195	150	37	11	17
Storage locker cost	$1,950,000	$975,000	$750,000	$185,000	$55,000	$85,000
Administrative staff wage	$50,000	$50,000	$50,000	$25,000	$25,000	$25,000
Total initial cost	$2,000,000	$1,025,000	$800,000	$210,000	$80,000	$110,000
15-year net present value of costs	$4,971,000	$2,755,000	$2,244,000	$690,000	$395,000	$463,000

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[19] Fleet numbers are based on estimates from patronage data.

Table 7.12 shows the combined cost of an integrated BoB and BaR cycle-PT scheme for buses.

Table7.12 Costs for cycle-PT schemes (bus)

Cycle-PT scheme costs	Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
BoB initial cost	$1,974,000	$1,039,000	$623,000	$124,700	$42,000	$83,000
BaR initial cost	$1,950,000	$1,025,000	$800,000	$210,000	$80,000	$110,000
Total initial cost	$3,924,000	$2,064,000	$1,423,000	$334,700	$122,000	$193,000
15-year net present value	$8,346,000	$5,082,000	$3,640,000	$969,000	$488,000	$649,000

7.7.2 Rail/ferry cycle-PT scheme costs

Estimated present year costs and value of 15 years of the annual upkeep of outfitting the cycle-PT scheme for trains and ferries for the selected cities are shown below in table 7.13. The following assumptions are included in the 15-year planning horizon:

- NZ$5000 per secure locker, purchased in year 1 with a 10-year lifespan.
- One full-time staff for the scheme in major cities; wages grow at 2% per year.
- Annual maintenance of lockers set at 10% of locker price per annum; full replacement cost occurs again in year 11.
- The NPV for the schemes is calculated using an 8% discount factor over a 15-year period.
- The costs for implementing cycle-PT for the rail and ferry systems vary substantially between rail and ferry with some schemes requiring substantial retrofitting to accommodate cyclists while others might be able to put a rack in immediately. Practitioners need additional information before estimating the potential costs involved in retrofitting existing rail carriages and ferries to accommodate cycles and therefore no estimates of costs have been provided in this research.

Table 7.13 Bike and ride (train and ferry): first year and 15-year net present value costs

Cycle-PT: BaR	Auckland	Wellington
Locker cost	$5000	$5000
Locker demand	314	328
Locker supply (1.3 times demand)	409	427
Storage locker cost	$2,045,000	$2,135,000
Administrative staff wage	$50,000	$50,000
Total initial cost	$2,095,000	$2,185,000
15-year net present value of costs	$5,187,000	$4,878,000

7.7.3 Combined bus/rail/ferry cycle-PT scheme costs

Combining the costs from tables 7.12 and 7.13 provides a system-wide initial cost and NPV for the implementation of cycle-PT schemes in a selection of New Zealand cities. This combined cost is shown in table 7.14.

Table 7.14 Costs for regional cycle-PT schemes for a selection of New Zealand cities

Cycle-PT scheme costs	Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
BoB initial cost	$1,974,000*	$1,039,000*	$623,000	$124,700	$42,000	$83,000
BaR initial cost	$4,045,000	$3,210,000	$800,000	$210,000	$80,000	$110,000
Total initial cost	$6,019,000	$4,249,000	$1,423,000	$334,700	$122,000	$193,000
15-year net present value of costs	$13,533,000	$9,960,000	$3,640,000	$969,000	$488,000	$649,000

* Note: No cost estimated for BoB on rail or ferry services. Refer section 7.8.2.

7.8 Summary of economic analysis

The detailed assessments of the urban areas considered in this study are summarised in the following tables with BCRs shown for each region. Table 7.16 displays the economic assessment results for the implementation of the full cycle-PT programme which includes the BoB bus racks and the secure storage lockers. Table 7.17 displays the economic assessment results for the implementation of the BoB bus rack cycle-PT programme.

Table 7.15 describes the sources of each row in the economic evaluations shown.

Table 7.15 Source of information used in the economic evaluation

Row in economic evaluation (SP10)	Source	Table reference
a Existing patronage	This is based on the Ministry of Transport TMIF patronage for 2008/09 and growth from 2003/04.	Table 3.4
b Patronage growth		
c1 Additional patrons from cars (peak)	This is the daily number of cycle-PT users from cars (peak), doubled to make trips per day, and multiplied by 250 days per annum.	Table 7.2
c2 Additional patrons from cars (non-peak)	This is the daily number of cycle-PT users from cars off-peak and weekend, doubled to make trips, and multiplied by 250 days for weekday off-peak and 115 days per annum for weekend.	
d Estimated patronage growth	This is set to 0% to reflect that the cycle-PT supply (racks/lockers) is related to current patronage and the capacity for growth in cycle-PT may be limited. This will have a conservative effect on the economics.	Relates to use of table 7.6
e1 Road traffic reduction benefit (peak)	This is c1 multiplied by the road traffic reduction benefit value (peak) for the region.	Table 7.5
e2 Road traffic reduction benefit (non-peak)	This is c2 multiplied by the road traffic reduction benefit value (non-peak) for the region.	
f1 Passenger transport user benefit (peak)	This is c1 multiplied by the passenger transport user benefit (peak) for the region.	
f2 Passenger transport user benefit (peak)	This is c2 multiplied by the passenger transport user benefit (non-peak) for the region.	
m Total benefits in year 2	This is e1+e2+f1+f2. New cycle trip health benefits for an assumed 3km ride to the cycle-PT are added to this.	N/A
n PV of total benefits	This is total year 2 benefits multiplied by the discount factor of 7.93 for 0% patronage growth.	Table 6.6

The economic analysis that follows indicates that either cycle-PT option would produce favourable results and result in benefits exceeding costs. It is therefore likely that the economics of appropriate cycle-PT schemes will justify funding.

The BCRs reflect the result that would be achieved from a typical response to the implementation of cycle-PT with typical costs per rack and locker. In each case the implementation of a system and its operating context will differ and for any funding application the economics need to be calculated by practitioners for each particular scheme rather than relying solely on the economics shown.

Table 7.16 demonstrates that investment in cycle-PT programmes is likely to generate benefits in excess of $2 for every $1 invested. The greatest degree of benefits arises from the regions with decongestion benefits for every vehicle-km removed from the roadway system with Auckland, Wellington and Christchurch all realising benefits approximately three to four times costs.

Table 7.16 Benefit to cost ratio for bus cycle-PT scenario 3 (both BoB and BaR)

			Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
Existing passenger trips per year		a	46,300,000	23,100,000	17,700,000	4,300,000	13,000,000	2,000,000
Existing percentage passenger growth rate (over past 5 years)		b	1%	2%	4%	34%	18%	9%
Additional passenger trips per year 2 (peak from cars)		c1	140,000	70,000	53,500	13,000	4000	6000
Additional passenger trips per year 2 (non-peak from cars)		c2	207,630	103,700	79,370	19,410	5650	8840
Estimated percentage growth rate (per annum)		d	0%	0%	0%	0%	0%	0%
Road traffic reduction benefit (peak)		e1	$1,642,200	$837,900	$144,985	$26,780	$8240	$12,360
Road traffic reduction benefit (non-peak)		e2	$157,799	$92,293	$98,419	$19,410	$5650	$8840
Passenger transport user benefit (peak)		f1	$1,122,800	$574,700	$469,730	$112,840	$34,720	$52,080
Passenger transport user benefit (non-peak)		f2	$1,110,821	$568,276	$464,315	$112,190	$32,657	$51,095
Total benefits in year 2		m	$4,033,619	$2,073,169	$1,177,448	$271,220	$81,267	$124,375
Health and safety for new cycle trips								
(c1 + c2) x $1.35 $/km x 3 km = $			$1,407,902	$703,485	$538,124	$131,261	$39,083	$60,102
Total benefits			$5,441,521	$2,776,654	$1,715,572	$402,480	$120,350	$184,477
PV of total benefits		n	$43,151,260	$22,018,866	$13,604,484	$3,191,669	$954,372	$1,462,904
PV of total costs (15-year NPV)			$9,393,000	$5,082,000	$3,640,000	$969,000	$488,000	$648,975
BCR			4.6	4.3	3.7	3.3	2.0	2.3

Table 7.17 demonstrates that implementation of the cycle-PT BoB system alone could produce benefits in excess of five times costs. Removing the secure locker component reduces the overall cycle-PT demand slightly but reduces the cost of implementation significantly.

Table 7.17 Benefit to cost ratio for cycle-PT bike on board scenario 1 (BoB only)

			Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
Existing passenger trips per year		a	46,300,000	23,100,000	17,700,000	4,300,000	13,000,000	2,000,000
Existing percentage passenger growth rate (over past 5 years)		b	1%	2%	4%	34%	18%	9%
Additional passenger trips per year 2 (peak from cars)		c1	128,000	64,000	49,000	12,000	3500	5500
Additional passenger trips per year 2 (non-peak from cars)		c2	189,450	94,590	72,490	17,450	5150	8110
Estimated percentage growth rate (per annum)		d	0%	0%	0%	0%	0%	0%
Road traffic reduction benefit (peak)		e1	$1,501,440	$766,080	$132,790	$24,720	$7210	$11,330
Road traffic reduction benefit (non-peak)		e2	$143,982	$84,185	$89,888	$17,450	$5150	$8110
Passenger transport user benefit (peak)		f1	$1,026,560	$525,440	$430,220	$104,160	$30,380	$47,740
Passenger transport user benefit (non-peak)		f2	$1,013,558	$518,353	$424,067	$100,861	$29,767	$46,876
Total benefits in year 2		m	$3,685,540	$1,894,058	$1,076,964	$247,191	$72,507	$114,056
Health and safety for new cycle trips								
(c1 + c2) x $1.35 $/km x 3 km = $			$1,285,673	$642,290	$492,035	$119,273	$35,033	$55,121
Total benefits			$4,971,212	$2,536,348	$1,568,999	$366,464	$107,540	$169,176
PV of total benefits		n	$39,421,711	$20,113,238	$12,442,159	$2,906,056	$852,788	$1,341,568
PV of total costs (15 year NPV)			$4,422,000	$2,327,000	$1,396,000	$279,000	$93,000	$185,975
BCR			8.9	8.6	8.9	10.4	9.2	7.2

7.9 Increased fare revenue from cycle-PT

Providing BoB is forecast to increase public transport patronage by the figures shown as from ‘car to bus’ in table 6.2. There will therefore be a corresponding increase in fare revenue. The actual increase received by operators will depend on how the particular service contract with the operator treats fare revenue and the fare levels themselves.

The factors to consider differ between and within New Zealand regions and in many cases the data required is difficult to obtain because of commercial sensitivity of the information to operators.

The use of broad estimates suggests that in some cases the costs of BoB would be recovered by operators through extra fare revenue, with a positive economic NPV. The costs of the provision of BaR secure lockers are, however, unlikely to be recovered fully through increased fares from increased patronage.

Practitioners examining the implementation of cycle-PT in their regions should examine the potential return to operators and hence a corresponding potential split of funding between operators and local, regional and central government.

8 Research conclusions

8.1 Overview

Cycle-PT can provide additional transport modal choice and flexibility in the utilisation of existing public transport. Providing additional means and methods can realise an increase in public transport patronage and can encourage an increase in non-car travel. It also provides options for cyclists who at times may wish to use public transport for part of their journey.

The provision of bicycle racks on-board public transport or secure storage at stations can increase overall patronage and provide an overall benefit in the local region by reducing congestion, improving health of patrons and reducing the environmental impact of transport.

This research project is based on a literature review of cycle-PT experiences worldwide. North American data provides observed rates of cycle-PT utilisation and the ranges of variables to estimate the sources of cycle-PT demand. The research described in this report provides a unique overview of the variables to determine the demand for cycle-PT, including an estimate of the shift from private cars and the demand for secure lockers, as well as an assessment of economic benefits using the standard New Zealand project evaluation process found in the EEM, volume 2 (NZTA 2010b).

A key outcome of this research has been a forecasting model to be used as part of the cycle-PT demand estimation process. This model is based on the range within factors affecting demand analysed in a Monte Carlo simulation. The demand equation can provide New Zealand practitioners with a likely value and range of potential values for demand to be used in planning a cycle-PT scheme and also for providing inputs into economic assessments of funding applications for cycle-PT projects.

The economic benefits of cycle-PT as assessed for New Zealand regions using the procedures outlined in the EEM indicate a positive economic return for the introduction of a combined BoB and BaR system. The economic returns from a BoB system alone are higher than with a BaR component and overall are particularly high in the Auckland, Wellington and Canterbury regions.

8.2 Potential for cycle-PT in New Zealand

This research has developed a demand forecasting model for cycle-PT which is described by the factors shown in table 8.1. The values for these factors are derived from North American observed data on the use of cycle-PT. The equations for the models are in sections 4.2 and 4.6.

For BoB, the rates for cycle-PT as a percentage of total PT patronage vary depending on the mode. The rates for ferry and BRT modes are the same as for rail. These are shown in table 8.2. The rates reflect the average as well as the range of rates that are typically achieved in the longer term. Short-term rates would be sensitive to the level of promotion, education and percentage of the fleet/routes with fitted vehicles, as well as any additional fares required.

Table 8.1 System-wide model variables

Variable	Description
Mode	Bus, rail, or ferry
Scenario	BoB only, BaR only, or BoB & BaR
(1) Cycle-PT	Range of usage rates (mode and facility dependent)
(2) StorInducedPT	Demand for PT due to the presence of bicycle storage
(3) BoBModeShift	Demand for PT due to the ability for bikes on board
(4) StorageBaRDemand	Demand for storage units, expressed as a percentage of total cycle-PT users.

Table 8.2 Bike on board percentages relevant to New Zealand

Mode	Average BoB % of total PT patronage	Typical range of BoB %	Relevant cities
Bus	1.2%	0.5% -3%	All
Train, ferry	3%	1.5% -6%	Wellington, Auckland

When the simplified macro-model developed in this research is applied to six of New Zealand's urban areas, it forecasts around 1.7 million cycle-PT trips per annum across bus, rail and ferry.

The daily forecast weekday trips are shown in table 8.3 for three different scenarios: BoB only, BaR only, and a third scenario when both are provided.

Based on the North American data, each demand variable in the forecast model has a range associated with it. A Monte Carlo simulation is used to determine the range of forecast demand and this analysis shows that for a highly successful cycle-PT system the demand could double from that forecast but a poorly performing scheme could have roughly half the demand.

Table 8.3 also demonstrates the forecast numbers of private car drivers who will make use of cycle-PT therefore removing a car trip from the road. The effect of their contribution to slightly reduced road congestion is significant in the economic evaluation process.

Table 8.3 shows the lockers forecast for bus services. When combined with rail and ferry, the forecast model shows that for the major centres of Auckland and Wellington, there would be demand for potentially 800 lockers in Auckland and over 600 in Wellington. The location of the lockers is key for a successful BaR scheme and the macro and micro models developed in this research can be used to determine the most appropriate approach for the provision of cycle lockers for different modes and in different contexts.

Table 8.3 also shows the potential economics of implementing cycle-PT schemes on buses in the six regions shown. These economics are based on indicative costs and assume that the cycle-PT scheme is used at similar average rates to those observed in North America.

The economics assume a split between peak-time and off-peak time use of cycle-PT as an additional decongestion benefit applies to peak periods in major cities.

Table 8.3 Cycle-PT summary by option scenario (bus only)

		Auckland	Wellington	Christchurch	Hamilton	Tauranga	Dunedin
Scenario 1: BoB only (bus)							
	Annual cycle-PT trips	634,130	316,450	241,980	47,130	17,570	27,220
	Annual cycle-PT trips from cars	317,450	158,590	121,490	29,450	8650	13,610
	Secure locker supply	-	-	-	-	-	-
	Benefit to cost ratio	8.9	8.6	8.9	10.4	9.2	7.2
Scenario 2: BaR only (bus)							
	Annual cycle-PT trips	131,370	65,820	50,480	12,380	3460	5690
	Annual cycle-PT trips from cars	84,120	42,060	32,410	7420	2230	3460
	Secure locker supply	390	195	150	37	11	17
	Benefit to cost ratio	N/A					
Scenario 3: BoB and BaR (bus)							
	Annual cycle-PT trips	663,810	331,290	253,860	61,860	18,570	28,950
	Annual cycle-PT trips from cars	347,630	173,700	132,870	32,410	9650	14,840
	Secure locker supply	390	195	150	37	11	17
	Benefit to cost ratio	4.6	4.3	3.7	3.3	2.0	2.3

All BCRs across the six selected cities have shown that benefits exceed costs.

The BCRs are lower for the scenario when BaR is provided in addition to BoB. While this suggests that the better approach would be to provide BoB only, it is important that BaR is provided where there are large concentrations of public transport patrons to mitigate BoB capacity constraints and to attract commuters out of private cars to park-and-ride locations.

Given the range of factors that are included in the development of the forecast cycle-PT demand, and that the costs used in this evaluation are only indicative, practitioners will need to calculate funding BCRs for their respective projects.

Currently there is limited cycle-PT in New Zealand with BoB on buses only available in parts of Christchurch and on rail in Auckland and Wellington in a restricted manner. The forecast demand models indicate that there is sufficient demand for cycle-PT schemes to justify the funding for implementation of schemes in New Zealand cities.

9 Recommendations

The following are nine recommendations arising from the research project:

1. Current public transport services in major New Zealand centres should be reviewed to determine whether vehicles and contracts can be altered to allow bicycles onboard. Providing for BoB public transport services will give a good economic return sufficient to justify the investment.
2. Major public transport stations and terminals in New Zealand should be reviewed to determine whether the forecast demand for secure bicycle storage can be provided for. Secure bicycle storage at major stops, stations and terminals provides an additional means of increasing access to public transport services. Provision at key rail stations and ferry terminals will provide the best return on investment in lockers.
3. No additional fare should be charged for BoB passengers. The effect on farebox recovery needs to be clarified if operators have to supply and maintain BoB equipment and pay extra insurance costs.
4. Given the quantum of the benefits from cycle-PT especially during congested periods, and current observations which suggest that cycle-PT demand is not being met, a re-examination is required of options available where public transport operators decline to carry bicycles at peak times. This may include retrofitting of trains to provide flexible areas for passengers/cycles and/or providing more secure bicycle storage at boarding stations.
5. The research should be extended to examine the likely demand from cyclists who need to avoid non-cyclable routes such as harbour bridges and tunnels.
6. This research has necessarily been based on overseas data. As New Zealand trials occur and permanent implementations are carried out, data needs to be collected on long-term usage, as well as survey data on the previous travel patterns of cycle-PT users, and the attractiveness of secure storage options over BoB. Any operational issues that arise need to be similarly collected and stored.
7. The patronage results of New Zealand cycle-PT implementation can be tested against benchmarks identified in this research to determine how well the system is attracting patrons and whether additional marketing or other initiatives or changes could produce further patronage. Further data collected on the demographics of cycle-PT users in New Zealand would assist in the further development of cycle-PT schemes in New Zealand.
8. As marketing of the scheme and education of potential patrons has been found to be a critical factor in the growth of use of a cycle-PT scheme, a New Zealand approach to this needs to be developed.
9. A New Zealand practitioners' guide for forecasting demand and implementing cycle-PT in the New Zealand context is required. This will give the best leverage to the research outlined in this report and maximise the return on investment in cycle-PT.

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