Park and ride: Characteristics and demand forecasting
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An important note for the reader

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Executive summary

This report was developed by Booz Allen Hamilton as part of the Land Transport New Zealand Research Programme 2004–2005, primarily to examine the modelling of park and ride (P&R) public transport usage in a New Zealand context. The report provides an overview of the concept of P&R, as well as local and international evidence on the usage and support of P&R schemes. International modelling methodologies are summarised and approaches are then applied to a New Zealand situation.

Key characteristics

P&R attempts to combine the benefits of both car and public transport (PT) use into an efficient and effective system by providing car parking facilities well outside the central area of the city and linking the facilities to the central city by public transport services. Rail station car parks are a 'classic' example of P&R and have been used for many years in both Auckland and Wellington and in many other cities internationally. More recently, there has been a surge of interest in and development of bus-based P&R schemes, particularly in Auckland with the success of the Northern Busway.

The main objective of P&R policies is to transfer parking demand from the central business district (CBD) to suburban/urban fringe locations to achieve the following benefits:

- reducing traffic and congestion levels on urban radial routes and in the CBD itself
- correspondingly reducing the need/pressure for increased road capacity and reducing emission levels, energy use and other environmental impacts
- reducing the amount of parking required in the CBD (where land is scarce and expensive and large car parks may be out of scale with the CBD townscape) and replacing it with parking in other locations (where land is cheaper and more readily available).

P&R may also help to increase the level of service and cost-effectiveness of PT provision, by concentrating PT demand on the major line haul routes (between the P&R site and the CBD) and reducing the need for PT services in low-density suburban areas, which are difficult to serve cost effectively.

The evidence indicates that the most essential and almost universally applicable criterion for the success of P&R schemes is a shortage of reasonably priced central area parking. Where this criterion does not apply, then P&R is only likely to succeed if there is an exceptionally high level and quality of PT service linking the parking site with the CBD.

Other key features required for the success of P&R schemes are:

- appropriate car park sites, in terms of location and facilities/design
- separate PT corridor/lane and/or PT priority measures

- appropriate information and marketing of the scheme
- adequate personal and car security at the P&R site.

In essence, the basic requirement for success is that access to the CBD via P&R needs to be competitive with the use of the car for the whole trip in terms of perceived generalised costs (quality, reliability, comfort, travel time, out-of-pocket costs etc).

In the United Kingdom, rail-based P&R is very well established and plays a major role for movements to inner London, while bus-based P&R has been developed mainly over the last 20 years in a number of cities, and there has been a resurgence of interest in such policies over the last few years. In the United States, P&R plays a major role in association with a number of rail and bus-based line haul services. In Australia, rail-based P&R plays a major role in the larger eastern states cities; while bus-based P&R plays a major role with the Adelaide O-Bahn.

P&R is presently operational (in a formal way) in two New Zealand cities, Auckland and Wellington. P&R is being further pursued in these regions through inclusion in regional transport strategies and other localised studies.

There is general support for P&R in Auckland, particularly as a result of the recently developed Bus Rapid Transport (BRT) system, where P&R sites have been consistently over-utilised. P&R studies are currently taking place in the Rodney District to examine potential station parking sites around Orewa. Also, the regional public transport model includes specialised modelling of access to public transport via P&R sites.

Wellington already has a developed P&R system for the rail network, and the Greater Wellington Regional Council (GWRC) sees improvements and increases in capacity over the short to medium term. In particular, there are plans to improve lighting and security at existing sites, as well as the introduction of new sites to coincide with new rail stations on the western line. Other opportunities are being explored to expand existing P&R facilities in line with increasing demand, including the potential for integrating parking capacity around stations with other activities such as Johnsonville station which is adjacent to the Johnsonville Mall.

Christchurch currently has no formal P&R system. However, there is interest from city and regional councillors, with P&R being seen as a relatively simple measure to help address congestion. Some bus-based P&R ideas are currently being envisaged, with stations positioned on northern, south-eastern and south-western corridors, as well as in a central city location.

Modelling review

A literature review of P&R modelling methodologies has highlighted two primary methods which are currently being used to estimate future P&R usage; namely regional models and site-specific models. Each approach has strengths and weaknesses, and relies on common sense by the planner and a certain amount of local knowledge. A general theme is that as computing power and software has improved, so has the complexity of the demand forecasting models.

Regional-modelling approaches include P&R as a distinct mode within a multi-modal model. They use existing car and PT costs within a multi-modal context, provide a higher level of standardisation between site estimates and have the ability to include site-choice modelling. They do, however, require a higher degree of modelling sophistication and the success of their implementation is only as good as the regional model in which they sit.

Regional models concentrate on the relative costs of P&R against other modes and use these costs to develop mode split functions that can be applied to the catchment population of a site. Regional techniques are responsive to changes in measurable cost attributes of transport (such as frequency, travel time and fares), but do not usually include some of the more local (and perceived) factors such as safety and the local accessibility of site. Regional approaches can also be used to determine abstraction from other modes (such as car or PT all the way) as well as competition between sites (when catchments overlap) through a site-choice logit model.

Parameters for mode-split models rely on stated or revealed preference data. Revealed preference data is the easiest source of model parameters, but requires P&R to be an existing and statistically significant mode. Stated preference data for P&R is difficult to collect as P&R is normally a small proportion of the total PT market but provides an additional source of people’s attitudes to P&R as a mode from both users and non-users. However, stated preference scenarios generally need to include extreme changes in costs to encourage mode switching behaviour and even then a significant proportion of respondents will not change. As such P&R stated preference surveys can be an expensive exercise and the results of limited value. This was demonstrated by a stated preference survey conducted as part of the modelling project which was designed to provide data that could be compared with revealed preference analyses for the Wellington region. It became apparent after the survey pilot that conducting a statistically reliable survey would be extremely expensive and the survey was terminated at the pilot stage.

Site-specific models relate the usage at a P&R site to a number of variables associated with the location, catchment size and characteristics, transport costs from the site and facilities. These models can be developed using more localised data and do not require detailed transport modelling. However, data requirements may cause difficulty (as existing sites are desirable to calibrate a model), site-choice modelling is usually not included and the method does not explicitly forecast PT demand. The models differ from regional approaches in that they ignore other modes and are based purely on characteristics relating to the site (through the use of linear regression equations). These can give better estimates for individual sites as the calibration (to existing usage) can be more exact and more of the local site facility attributes can be included. However, because other modes are ignored, there is no indication of abstraction from say car or PT only users. It is difficult to estimate the impact of other sites in close proximity and, as many variables are often highly correlated, a robust model may not include transport-related variables such as travel time or fares.

Model development

Both regional and site-specific models were developed for the Wellington Region.

The **regional model** took the defined catchments, revealed preference demand data from surveys conducted in 2001/02, and transport costs from the Wellington Transport Strategy Model (WTSM), and estimated a mode-split model that could be applied within a regional modelling context. There were inconsistencies in the revealed preference data from differences in definitions between surveys. Further, the Wellington model did not have P&R explicitly represented within the network skims, and as such P&R costs were a combination of car access cost to and PT cost from a station zone (rather than the station), and the zone sizes could be considered large for P&R modelling purposes, with a significant proportion of car access trips within the same zone as the station.

In spite of these shortcomings, a nested-logit model with car access and non-car access to PT at the lower level and car all the way vs PT at the upper level was estimated successfully. This nested-logit formulation was then applied within an Emme/2 procedure, which also included capacity constraints at station car parks. A number of scenarios were run to test the model behaviour against industry-standard elasticities. The model performed adequately, both in terms of car and PT elasticities. Other tests were undertaken relating to site capacity increases, with results also looking sensible.

The **site-specific model** was developed by regressing usage data against demographic, service and facility-related variables to derive a model for car access to rail stations. There were high levels of co-linearity between distance/time/fare variables, but adequate relationships were still obtained. The final model included catchment population, number of express services, fare, safety, P&R information and a line-specific indicator. In addition, a variable was included which looked at competing population (where catchments overlapped).

Sensitivity tests for the site approach were undertaken which looked at the impact of changes to an existing station and the inclusion of a new station. The results of these two tests were reasonable. A test relating to an increase in PT fares was undertaken; the model proved to be too sensitive to fares, at least partly because of the exclusion of PT captive trips. Further tests were undertaken looking at future year population impacts.

Summary

This report reviewed and applied methodologies for modelling car access/P&R demand. These approaches should not be seen as substitutes and should be used in conjunction with one another to give a wider range of information for decision makers. These methodologies were applied to the Wellington Region but similar models could be developed for other regions for which adequate input data is available.

Abstract

This report examines the characteristics of park and ride (P&R) useage and suggests demand modelling methodologies based on these characteristics for changes in demand at existing sites, and estimation of demand at new sites. It reviews New Zealand and international evidence on the nature of P&R usage and the factors that influence it. The report then examines potential P&R modelling methodologies and identifies the most appropriate within a New Zealand context. Emphasis is given to the development of P&R catchments and resulting regional and site-specific modelling approaches. Finally methodologies are applied to a New Zealand situation and conclusions drawn.

Part 1: Key characteristics of park and ride (P&R)

1. Introduction

This report was developed by Booz Allen Hamilton as part of the Land Transport New Zealand (Land Transport NZ) Research Programme 2004–2005, primarily to examine the characteristics and modelling of park and ride (P&R) public transport demand with specific reference to New Zealand.

1.1 Scope and structure of paper

The report provides an overview of the main characteristics of P&R, as well as local and international evidence on the usage of P&R facilities. International demand modelling methodologies are reviewed and then applied to a New Zealand situation.

The report has three main parts:

- Part 1: Key characteristics of park and ride (P&R)
- Part 2: Review of international demand modelling practices
- Part 3: P&R model development for Wellington

Appendices provide detailed statistical data on P&R usage in New Zealand as well as documentation of a trial stated preference survey undertaken as part of the project.

2. Part 1 overview

2.1 What is P&R?

P&R essentially involves the provision of:

- car parking facilities well outside the central area of the city, and
- public transport services linking these car parks with the central city area.

P&R may be regarded as an extension of central area parking provision – with the parking facility being outside the central area rather than within it and linked to the central area with a good public transport service.

P&R attempts to combine the benefits of both car use and PT use into an efficient and effective system:

> *The essence of P&R lies in overcoming the idea that the private car and the public transport system are in competition, and seeks to create an interface between the two* (Moran 1990).

Rail station car parks are the 'classic' example of P&R and have been used for many years in both Auckland and Wellington and in many other cities internationally. More recently, there has been a surge of interest in and development of bus-based P&R schemes, particularly in the United Kingdom.

For the purposes of this report, P&R is taken as also including 'kiss and ride' (K&R), ie trips in which the traveller is dropped off by car at the P&R site. However, while both P&R and K&R have the common effect of reducing linehaul trips by car, P&R has far greater significance for physical planning as it requires specific infrastructure (eg station car parks) as volumes increase.

While the main focus of the project is on 'formal' P&R/K&R, the existence of a significant amount of 'informal' P&R/K&R also needs to be recognised (eg people driving their car and parking near a convenient bus stop, before continuing their trip by bus).

2.2 Scope of section

This section summarises evidence from New Zealand and from four overseas countries:

- United Kingdom: Rail-based P&R is very well established and plays a major role in travel to inner London. Bus-based P&R has been developed mainly over the last 20 years in a number of medium-sized cities and there has been a resurgence of interest in such policies over the last few years.
- United States and Canada: P&R plays a major role feeding a number of rail and bus-based line haul services.
- Australia: Rail-based P&R plays a major role in the larger eastern states cities; while bus-based P&R plays a major role with the Adelaide O-Bahn.

P&R also plays a significant role in urban transport in a number of other countries, in Europe and elsewhere, but this experience appears to be less well documented (certainly in the English language sources).

3. Objectives, policy context and success factors

3.1 General policy objectives and target markets

The main objective of P&R policies is to transfer parking demand from the central business district (CBD) to suburban/urban fringe locations, with a view to achieving the following benefits:

- reducing traffic levels and congestion levels on urban radial routes and in the CBD itself
- correspondingly reducing the need/pressure for increased road capacity as well as reducing emission levels, energy use and other environmental impacts
- reducing the amount of parking required in the CBD (where land is scarce and expensive and large car parks may be out of scale with the CBD townscape) and replacing it with parking in other locations (where land is cheaper and more readily available).

P&R may also help to increase the level of service and cost-effectiveness of public transport (PT) provision, by concentrating PT demand on the major line haul routes (between the P&R site and CBD) and reducing the need for PT services in low-density suburban areas, which are difficult to serve cost-effectively.

P&R schemes are almost always designed to serve trips to areas of concentrated demand, because:

- parking is likely to be scarce/expensive in such areas
- concentrated passenger flows are necessary to provide effective and economic PT services.

Most schemes are oriented to serving town centres. However, some schemes are designed to serve other locations, such as airports, sport stadiums and amusement parks.

Schemes oriented to town centre movements may be targeted at various segments. While most schemes internationally are targeted principally at commuters (typified by rail station car parks), other schemes are targeted principally at off-peak CBD travellers, particularly shoppers. Many of the United Kingdom bus-based schemes started off (and in some cases continue) to serve shoppers in the pre-Christmas period, when there was insufficient CBD parking to meet the seasonal demand.

There are good arguments in favour of targeting each of these markets and no single 'right' answer for all situations:

> *What is not yet clear is whether an authority should try to encourage P&R use by commuters to free up central parking for shoppers – who might make more productive use of the space – or if shoppers who represent a greater number of journeys per parking space should be the principal market for P&R in order to reduce overall traffic levels* (Huntley 1993).

3.2 New Zealand policies and experience

In New Zealand, P&R is primarily targeted at and used by commuters working in the CBD. This primarily reflects the relative price and availability of parking in the CBD and suburban areas (plus the fact that public transport is most competitive in time and cost with private car use for such trips). Few shoppers use P&R, reflecting the large proportion of shopping undertaken outside CBD areas and the relatively low price of parking (relative to other trip cost components) for shorter-duration trips: indeed, some councils encourage car-based shoppers through free/cheap parking facilities.

Section 591 (1) of the Local Government Act states that:

> *The Council may provide parking places and buildings and stations, and for that purpose may –*
>
> *(a) Take, purchase, or otherwise acquire any land or buildings or erect any buildings in or near to the district; …*

(d) Authorise the use as a parking place or transport station of any part of a road.

In this section 'parking place' means a place (including a building) where vehicles, or any class of vehicles, may wait. Thus, local authorities are enabled to construct parking places adjacent to public transport services – P&R sites.

Funding for P&R sites in Wellington and Auckland is presently provided by a combination of regional council rates and Land Transport NZ funding. Discussions with Land Transport NZ found the following approach to the funding of projects:

- if the project is within the road reserve it is treated as a roading project
- if it is outside the road reserve it is treated as an alternative to roading (ATR) project.

However, public car parks within the road reserve and associated with public transport services are also evaluated using the ATR evaluation procedures, on the basis that there may be some benefits arising from people switching from cars to public transport.

ATR capital projects have a cap of $400,000. Where P&R projects will cost more than this amount, the Land Transport NZ share of the project cost can be funded on an outputs basis as a service. The Auckland Regional Council has taken this approach for some projects with capital costs over the cap. In these cases the operator can lease the car park and Land Transport NZ will fund on the basis of an 'optimum charge' for the car park.

P&R is presently operational (in a formal way) in two New Zealand cities, Auckland and Wellington. P&R is being further pursued in these regions through inclusion in regional transport strategies and other localised studies.

Woods (2006) interviewed transport strategy practitioners in Auckland, Wellington and Christchurch in 2005–2006 to explore current plans/policies and issues relating to P&R. He found general support and enthusiasm for P&R. He also highlighted a desire by practitioners to better understand the size and nature of the P&R market, particularly with regards to origins of users and previous modes used.

The following regional councils have developed P&R policies, which are contained in their respective regional land transport strategies (RLTS), regional passenger transport plans (RPTP), and travel demand management (TDM) strategies (Appendix A). All of these strategies have the support of territorial authorities (TAs) and transport operators. Findings from these interviews and a summary of policies relating to P&R in New Zealand are discussed below.

3.2.1 Auckland

There is general support for P&R in Auckland, particularly as a result of the recently developed Bus Rapid Transport (BRT) system, where P&R sites have been continuously over-utilised. P&R studies are currently taking place in the Rodney District to examine potential parking station sites around Orewa. The regional public transport model also includes sophisticated modelling of access to public transport via P&R sites. This model was used to give indicative site usage numbers for the BRT system during project feasibility studies.

The Auckland Regional Council (ARC) in conjunction with other stakeholders developed a regional transport strategy (2005), a regional passenger transport plan (2003), and a travel demand management strategy (2000). In general, Auckland authorities are encouraging the further development of P&R facilities in the region with particular reference to accessibility to PT services and the use of more sustainable transport modes.

The key issue for ARC planners is to gain a better understanding of the nature of P&R usage including catchment areas and previous modes used.

3.2.2 Wellington

Wellington already has a developed P&R system for the rail network and the Greater Wellington Regional Council (GWRC) sees improvements and increases in capacity over the short to medium term. In particular, there are plans to improve lighting and security at existing sites, as well as the introduction of new sites to coincide with new rail stations on the western line. Other opportunities are being explored to expand existing P&R facilities in line with increasing demand, including the potential for integrating parking capacity around stations with other activities, such as at Johnsonville station which is adjacent to the Johnsonville Mall. The regional transport model includes a representation of car access to public transport, but it is not as sophisticated as that employed in the Auckland Passenger Transport (APT) model.

The GWRC in conjunction with other stakeholders developed a draft regional land transport strategy (2006), a regional passenger transport plan (2006) and a travel demand management strategy (2005).

One of the issues facing the GWRC is the development of P&R monitoring regimes to aid in evaluating against particularly strategic objectives.

3.2.3 Christchurch

Christchurch currently has no formal P&R system. However, there is political interest from city and regional councillors, with P&R being seen as a relatively simple measure to help address congestion. Woods (2006) outlines some of the bus-based P&R ideas that are currently being envisaged, with stations positioned on northern, south-eastern and south-western corridors, as well as a central city location.

Some of the issues that face Christchurch in terms of successful implementation of P&R include Christchurch’s strong car culture, issues of rural rate-payer funding (particularly when P&R is seen as solving city problems) and concerns about the competitive nature of P&R with the wider public transport system.

4. P&R usage

4.1 Usage indicators

Market share for P&R can be considered in two ways:

A. Proportion of PT passengers using P&R

This can be measured as either the proportion of passengers boarding at each stop who have used P&R or by P&R as a proportion of all PT mode passengers on the service or corridor. Little data is generally kept in regard to PT boardings by individual stop and this can also be a misleading indicator given that P&R users can often access several stops with similar cost and time. The most useful indicator is thus P&R as a proportion of all PT mode users.

B. P&R usage as a proportion of commuter trips

In many cities, P&R facilities are almost exclusively used by commuters travelling to the CBD. A relevant indicator in such cases is, therefore, P&R usage as a proportion of commuter trips to the CBD.

4.2 P&R usage as a proportion of public transport trips

Table C1 in Appendix C summarises access mode shares for public transport travel in major radial corridors in Australasian cities.

The following general conclusions may be drawn:

- P&R and K&R proportions are greater at peak than off-peak periods.
- For **rail** services, the P&R peak proportion is typically around 15% of users, with a further 15% by K&R (Adelaide, Sydney and Melbourne).
- In the case of Perth's Northern Suburbs Railway, which runs through a relatively low density area with limited walk-in catchments, the P&R proportion is significantly higher (28% peak/off-peak combined), with the walk proportion very much lower than for other rail systems.
- For typical **on-street (all stops) bus services**, P&R proportions are much lower than for rail. Typical peak figures (for Adelaide, Brisbane and Perth) are for the P&R proportion being 1–5%, with K&R accounting for approximately a further 5%.
- For **express/busway bus services**, proportions are more comparable with those for rail-based services. The Adelaide O-Bahn (peak) has about 12.5% P&R plus 11.5% K&R. In Sydney, the Warringah Peninsula express bus services to the CBD (which use an extensive length of transit lane) achieve about 14% car access (P&R/K&R together), while for longer distance passengers the car access proportion increases to 32% (all periods).

In other countries: **London** data (for Network South East (NSE) rail services) indicates that approximately 21% of NSE passengers to central London use station car parks (ie P&R). A 1993 survey (Parkhurst 1995) of weekday users of bus-based P&R in Oxford and York found the main access modes were:

- car driver (75% Oxford, 58% York)
- car passenger (16% Oxford, 15% York)
- walk (5% Oxford, 19% York)
- K&R (2% Oxford, 4% York).

United States data averaged from multiple metropolitan areas gives the following:

- car driver – alone 73%
- car – shared ride 11%
- K&R 11%
- walk 4%
- bus 1%.

Various United States studies into access modes of express bus users (often travelling on reserved freeway lanes) found that:

- for routes with the highest level of P&R facilities, between 60% and 95% of bus users gained access by car: the car driver share was between 45% and 69%
- for routes with a 'moderate' level of P&R facilities, between 30% and 60% of bus users gained access by car
- for routes with a 'limited' level of P&R facilities, between 4% and 40% of bus users gained access by car (Barton-Aschman Associates et al. 1981).

4.3 P&R usage as a proportion of commuter trips

P&R data for United Kingdom cities with bus-based P&R schemes indicates typical usage data in the range of 5–30 return trips/day per 1000 population (or 10–60 one-way trips/day). With typical total trip rates of three one-way trips per person per day, this indicates that P&R accounts for up to 2% of all trips.

P&R would of course account for a considerably higher proportion of CBD trips, typically up to 10%. Taking a typical P&R proportion of 15% and a public transport mode share for CBD travel of say 50% (typical of Melbourne), P&R typically accounts for 7.5% of all CBD trips, with K&R perhaps accounting for a similar proportion.

4.4 New Zealand facilities and usage

4.4.1 Auckland

Several P&R facilities are provided in Auckland for rail, ferry and bus services:

- four bus P&R sites on the North Shore, four in West Auckland and one in East Auckland (Pakuranga), typically between 10 and 40 spaces
- two BRT P&R sites on the Northern Busway with a combined capacity of around 700 spaces (typically fully utilised)
- four rail P&R sites in West Auckland and six in South Auckland, with a significant range in capacity between 15 and 200
- four ferry P&R sites on the North Shore, one on the Whangaparoa Peninsula, one at Half Moon Bay, and one on Waiheke Island, ranging in size from 30 to more than 150.

Table C2 in Appendix C lists the Auckland P&R sites with their capacity and utilisation in 1999, the most recent comprehensive information available on P&R usage. Since this table was collated, the Northern Busway has opened including two stations with P&R facilities. These stations (Albany and Constellation Drive) collectively have around 700 spaces dedicated to P&R, with usage consistently exceeding demand since opening in November 2005 (Woods 2006) and with overflow onto local streets. On the rail network, additional formal P&R sites are now located on the western line at Sunnyvale and on the southern line at Glen Innes, Panmure and Manurewa.

In 1999, there was high utilisation of rail and ferry P&R sites but much lower utilisation of bus P&R – although the level of signage and overall marketing at these much smaller sites would have contributed to the relative under-utilisation. Overall, utilisation in 1999 was around 70%.

P&R is seen as an important complement to Auckland's development of a quality rapid public transport network. Current plans include the development of bus P&R in the north and west of the region. In particular, there are plans for express bus P&R facilities located at Westgate and Hobsonville Village. Rodney District is currently undertaking a study to examine potential P&R sites in areas such as Silverdale North, driven primarily by the success of the Northern Busway and the potential for latent demand for P&R services. These sites could be developed in conjunction with an extension of the Northern Busway northwards. An informal ferry P&R site currently exists at Clearwater Cove in Waitakere City and there are plans to formalise this site as part of a marina development. P&R has also been successfully used in Auckland in conjunction with bus services to special events.

Surveys undertaken in 1997 and 2003 of access modes in the am peak (see Table C5 in Appendix C) show that:

- P&R accounted for 9% of rail access/egress movements in 2003 compared with 5% in the 1997 survey
- K&R accounted for a further 11% of rail access/egress movements in 2003 (12% in 1997)

- P&R accounted for 10% of ferry access/egress movements in 1997 (no comparable survey was undertaken in 2003)
- P&R access to bus services was negligible (0.7% in 1997).

As these figures cover both access and egress, the P&R proportion would be substantially higher, approaching twice these figures at the suburban (production) end of the trip and close to zero at the city (attraction) end. This is confimed by 1996 journey-to-work data, which gave market shares for car access to public transport (ie P&R and K&R combined) of 3.3% for bus, 44% for rail and 33% for ferry.

4.4.2 Wellington

P&R facilities are currently provided predominantly for rail services, with one ferry P&R site and only a single bus P&R site. Table C3 in Appendix C lists the existing Wellington rail P&R sites with their capacity and utilisation based on surveys undertaken in 2002–2004. Nearly all the Wellington sites have high utilisation rates. Overall, around 4000 spaces are provided through rail P&R sites, with an average utilisation of approximately 85%. Demand has continually exceeded supply at many stations. Waterloo and Paraparaumu in particular have seen new spaces being filled almost immediately upon construction. There are also large amounts of P&R demand overfill onto the local streets around stations as informal P&R.

The GWRC has a P&R development programme which it is implementing as funding becomes available. This primarily involves extensions and enhancements to existing P&R facilities. Several new rail stations are presently being evaluated and if proceeded with, these stations will have P&R car parks. Other P&R opportunities being explored include the potential sharing of parking capacity with private developers (such as Johnsonville Mall).

Survey data (given in detail in Tables C4 and C6 in Appendix C) shows around 20% of am peak rail passengers use P&R. This increases to 35% for all rail commuters to the CBD, which represents 9% of all CBD commuters from zones in the rail catchment area.

4.4.3 Christchurch

Although Christchurch currently has no formal P&R systems in place, informal P&R users are parking their cars at key locations on the transport network. These include:

- Diamond Harbour ferry, with locals driving to the south side of Lyttelton Harbour and catching a ferry and then bus to the city centre
- Church Corner, with people driving from outer townships and catching buses to the city centre
- south end of Papanui Road
- Tai Tapu Drive.

While P&R is mentioned as a concept in regional strategies, there is no mention of the development of specific formal P&R sites.

5. Alternative modes and influencing factors

5.1 Alternative means of travel

A **United Kingdom survey** of bus-based P&R users in the historic towns of Oxford and York found that:

- prior to the P&R introduction, 60%/51% of York/Oxford weekday users said they would have travelled to the city as car drivers, 6%/4% as car passengers, 26%/36% by public transport (all the way) and 7%/9% would have travelled by other means
- when asked about their alternative travel behaviour if P&R were to become unavailable, 55% of the York weekday respondents said they would travel to the city by car, 24% by bus, 11% would travel elsewhere or not that day, while 10% gave other responses. The Oxford responses were very similar
- alternative travel behaviour differed dramatically according to trip purpose. People travelling on work/education trips were much more likely to travel by public transport or cycle, while those on shopping trips were very likely to travel elsewhere or not make the trip (Parkhurst 1995).

A **United Kingdom** survey of bus-based P&R in four towns indicated that between 59% and 78% of P&R users would have driven into town if the facility had not been available. Of those who would not have driven (19%–40% of the total), the largest proportion (11%–25% of the total) would have made the same trip by bus; the second largest would have not travelled at all (4%–9% of the total); while 2%–8% would have visited another location (Pickett and Gray 1994).

An important issue in interpreting these surveys is whether the experience of using P&R makes people more favourably disposed than previously towards use of 'conventional' PT services. Table 1.1 summarises the results of United Kingdom surveys of bus-based P&R sites which compare the prior use of PT with stated alternative use of PT if the P&R option were not available. While the evidence is rather mixed, on balance use of P&R appears to make users more favourably inclined to PT (Parkhurst 2001).

Table 1.1 Change in perceived attractiveness of PT services following experience of P&R

City	Number of sites surveyed and opening date(s)	Previously used PT %	PT as stated alternative %
York	1 (1990)	19	35
York	1 (1990)	26/13	24/9
York	3 (1990–1995)	15	26
Oxford	4 (1973–1985)	36/35	31/20
Chester	1 (1992)	13	14
Brighton	1 (1991)	18	41
Cambridge	4 (1993–1997)	10	24
Coventry	1 (1991)	17	21
Norwich	3 (1991–1997)	24	29
Plymouth	2 (1992–1993)	14	32
Reading	1 (1997)	28	31
Shrewsbury	3 (1992–1995)	15	18

Source: Parkhurst 2001.

Notes: Where two numbers are given, these relate to two different surveys.

A major **United States review** study of P&R sites served by express bus services found that:

- 40%–60% of P&R/transit users previously commuted as car drivers
- a further 8%-15% were previously car passengers
- 25%–45% were former transit trips, where 15%–20% of users would have walked directly to the transit service in the absence of P&R facilities (Barton-Aschman Associates et al. 1981).

(Feeder bus services are often of a low level in the United States.)

A **Californian** study found that 27% of P%R users previously drove their vehicle alone to their destination (California Department of Transportation 1988).

More recent United States data from surveys in multiple metropolitan areas found that prior modes of P&R facility users were, on average: drive alone 49%, carpool/vanpool 23%, transit (bus/rail) 10%, did not make trips 15%.

The **Vancouver** survey (quoted earlier) found that 38% of P&R users were former car drivers, while 21% were former bus travellers (all the way) (Barton-Aschman Associates et al. 1981).

In **Adelaide**, the provision of P&R spaces associated with the O-Bahn is said to be a major contributing factor in encouraging former car drivers to use the O-Bahn for the greater part of their journeys to the CBD (Wayte 1991). However, detailed statistics appear to indicate that the P&R mode share by 'new' users is similar to that by 'existing' bus users.

In **Wellington**, a series of research studies into the characteristics and attitudes of P&R users (described in Appendix D) have found:

- nearly all rail P&R users are commuters travelling to Wellington CBD
- most rail P&R users make use of the P&R car park 3–5 days a week
- the level of rail service at a station affects the number of P&R users at that station
- only a very small proportion (1–3%) of motor vehicle users would be likely to switch to P&R if additional P&R car parks were available, or improvements were made to the car parks
- some informal bus P&R is currently occurring in Wellington City (a 1995 survey found 7% of bus users were P&R)
- 34% of bus users who had a car at home took the bus because of no parking at their destination.
- 43% of motor vehicle users in the 1995 survey parked in employer-provided parking; and 64% of these users indicated they would switch to bus if a car park was not available
- 8% of current P&R users would drive all the way to their destination if their current P&R car park was not available (rather than park on the street or park at another station).

In **Auckland** a survey was conducted around five months after the opening of the Northern Busway at the two principal stations (Albany and Constellation). P&R users of the busway comprised around 57% of people surveyed at Albany (52% drove alone, 5% drove with a passenger) and 35% of people surveyed at Constellation (33% drove alone, 2% drove with a passenger). The P&R catchment of Albany (further away from the CBD) was much larger than for Constellation, with 16% of P&R users travelling from as far north as the Hibiscus Coast and Kauakapaka (Tables D1 and D2 in Appendix D). A similar pattern is seen at Constellation station, demonstrating that people will drive significant distances to access PT services when quality services are provided. There is also evidence of some passengers driving against the direction of travel over shorter distances to access the site.

5.2 Service characteristics

5.2.1 Travel time, frequency and service hours

Travel time is one of the most important considerations when choosing whether to use a P&R facility. Facility access time, transit service headways and in-vehicle travel times are the three main components of P&R travel time. Figures 1.1 and 1.2 below show the results from 37 bus and 139 rail P&R sites in USA (Turnbull 2004). These relate site utilisation (average number of users per space) to PT headways and service hours.

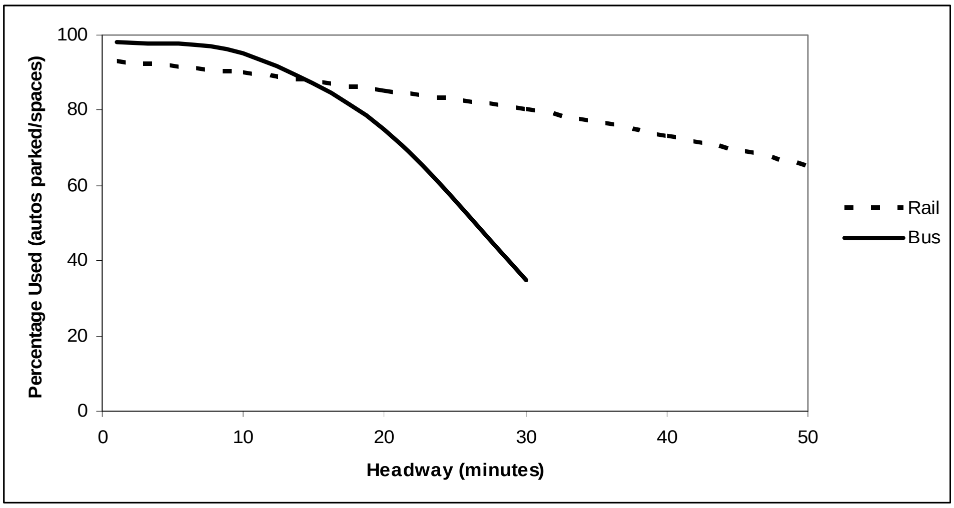

Figure 1.1 Effect of transit frequency on P&R utilisation.

As headways increase (the time between services), the demand for P&R decreases, although more markedly for bus than for rail. For significant bus P&R usage, headways of 15 minutes or better are required.

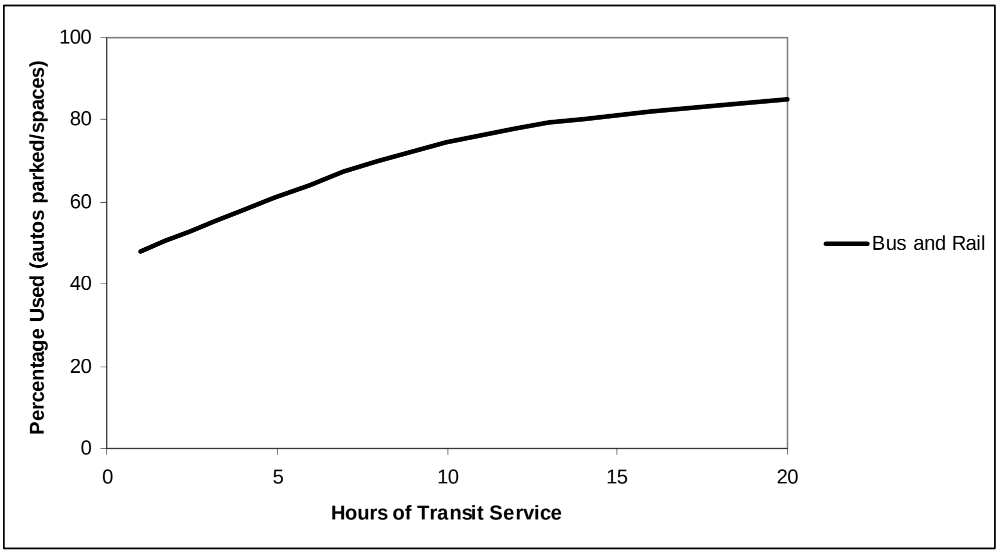

Figure 1.2 Effect of transit service hours on P&R utilisation.

The relationship between usage and hours of transit service operation shows that operating peak-only services (less than five hours) yields limited P&R usage (less than 60%), but offering people the flexibility of mid-day and evening services can increase usage to up to 80%.

Table 1.2 shows that the relativities of car and transit travel times are an important determinant for P&R usage, with a transit time 20 minutes worse only yielding a utilisation of 40–60%, whereas a transit time approximately 20 minutes better yields almost a full site.

Table 1.2 971 Boston modal travel times and station lot occupancy.

	From north	From west	From south
Car travel time (mins)	30	20	45
Transit travel time (mins)	20	40	22
Percent occupancy of transit parking sites	70–80%	40–60%	90–100%

The availability of parking spaces (both at the P&R site as well as in the CBD) will significantly affect the demand for P&R at a site. Sites where there is no on-street overflow will be constrained as to how many can park. CBD parking restraints will encourage car drivers to seek alternative forms of transport (such as P&R). Morrall and Bolger (1996) used data from eight Canadian cities to estimate the am peak CBD transit percentage as being:

$$AMPeakCBDPercentTransit = 68.2 - 81.0 \times \left(\frac{CBDspaces}{CBDemployment} \right) + 138.1 \times \left(\frac{P\,\&\,Rspaces}{CBDemployment} \right)$$

with an R^2 of 0.83. However, this equation took no account of relative costs and times of auto versus transit modes.

5.2.2 Mode specific penalties

Turnbull (1995) also examines mode change penalties, which explain non-modal cost and time factors (such as frequency, travel time and fare). These penalties might relate to car availability (for example using a car for P&R means that other household members cannot use the car), or might be a function of the model data and as such are difficult to interpret or to compare and apply across different models and geographic aspects. This is demonstrated in two examples of auto-transit mode change penalties for Atlanta and New Orleans (see Table 1.3).

Table 1.3 Auto-transit mode change penalties by trip purpose and income level (equivalent walk minutes).

	Atlanta mode choice model			New Orleans mode choice model		
Income level	**Home-based work**	**Home-based other**	**Non-home based**	**Home-based work**	**Home-based other**	**Non-home based**
Lowest	145	353	34	9	95	90
Low-medium	41	105	34	17	60	90
High-medium	13	61	34	22	39	19
Highest	-1	19	34	13	23	13

While the values differ significantly between the two models, it is clear that the penalty is positive; it generally reduces as income increases (presumably due to more cars being available or to trips being more concentrated in the CBD); and is higher for non-work trips. A research model for New York−New Jersey also derived an average transfer penalty of six equivalent walk minutes.

5.3 Site catchments

The catchment is the area around a P&R site that includes potential P&R users and is a key factor in estimating P&R usage. There have been a number of studies undertaken in North America looking at the shape and size of the catchment area; these are summarised by Turnbull et al. (2004).

Studies undertaken in Seattle and Texas tend to show similar behaviour, with P&R users generally coming from an 'upstream' location lying broadly on an axis towards the CBD (see Figure 1.3).

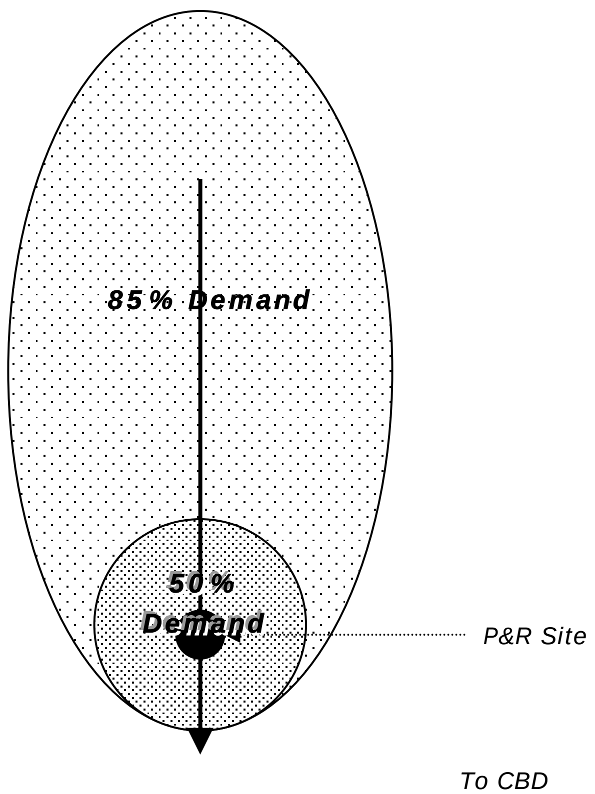

Figure 1.3 Park and ride catchment definition.

The Seattle study estimated catchment parabolas of around 2–2.5 miles towards the CBD and extending back around 10 miles upstream (so approximately 12 miles in total). Around 85% of site demand was located within this area. 50% of the demand was situated within a circle of radius 2.5 miles centred on the site and in general this circle has been more widely used as the catchment definition due to ease of definition and smaller data requirements. The Texas study found the same parabolic shape, but with different dimensions (0.5–1.5 miles downstream and 5–7 miles upstream), reflecting the different P&R site spacing, extent of the transport network and congestion within the region.

Other studies show little variation between cities: 53% of usage for Maryland came from within five miles (81% within 10 miles), 60% for Sacramento within five miles (82% within 10 miles) and 56% for Tri-Rail Florida within five miles (86% within 10 miles).

5.4 Reasons for use and non-use

5.4.1 United Kingdom market research

A 1993 survey of weekday users of bus-based P&R in the medium-sized cities of Oxford and York found that the reasons given in both cities for use of P&R were, in descending order of importance:

- cheaper than parking in CBD (42% Oxford, 31% York)
- CBD parking shortage/difficulty (22%, 27%)
- easier access to ultimate destination (13%, 19%)
- reduced stress on person and vehicle (10%, 13%).

Thus it is evident that the 'stick' of parking restraint is a dominant factor influencing use of P&R (Parkhurst 1995).

Speyer et al. (1996) discuss a 1995 Swansea self-completion survey at two P&R sites and two city-centre car parks. Response rates for P&R users were higher (59%) than for car parkers (30%) (possibly because the P&R users had more time to complete the survey while waiting for or travelling on their service), with an overall rate of 43%. Distance to travel to the site played a significant role on whether to P&R or not, with 63% of users travelling less than five miles. Conversely drivers travelling from a distance of greater than 10 miles chose to use the city-centre car parks. Tentative linkages between price and P&R demand were also found, with 37% of users choosing P&R due to city centre car parks being too expensive. Concern about road congestion and environmental issues were also examined and 66 per cent of P&R users stated this as their prime reason for using P&R. In summary, the survey found that:

- P&R attracted predominately older male users
- price was important
- younger drivers were fairly inelastic in travel patterns and behaviour, and road congestion and environmental problems alone would not attract this group into the P&R market
- every effort should be made to give the transfer mode (bus, rail) a speed advantage over the private car in urban areas.

A United Kingdom report into the effectiveness of bus P&R (Picket and Gray 1994) commented on a 1978 survey of Oxford P&R users, which found that the reasons given for using the scheme were:

- speed
- no parking problems
- no congestion

- no parking costs
- direct to centre.

This report also cited a 1987 survey as to reasons given by motorists for choosing **not** to P&R:

- inconvenient in time terms
- expensive
- driver 'car loving'
- awkward when carrying a load
- need to have car available for work
- not aware of service
- access to free or private parking
- location of town-centre bus stop inconvenient
- problems of children on bus.

5.4.2 North American market research

Several North American studies investigated the reasons for use of P&R facilities. Barton-Aschman Associates et al. (1981) concluded that the relative costs of car-all-the-way versus P&R were important. The point at which P&R suffered compared with car was when the transit time was approximately 10 minutes longer. At 25 minutes longer, P&R usage would be minimal. A significant factor in low P&R usage was when bus transit headways exceeded 15 minutes (resulting in an average access plus waiting time of 10 minutes or more).

Stevens and Homburger (1985) examined the use of P&R sites by bus commuters and concluded that passengers were concerned about safety at P&R sites and placed a high value on shelters. Passengers wanted improved bus services including longer hours of service and adequate capacity. Typical P&R users had the following characteristics:

- began their trip at home
- drove to a P&R lot and parked there
- boarded an express transit line bound for the largest CBD in the region
- walked less than 800 metres to work from the place where they left the bus
- the pattern reversed for the PM commute
- made the same trip, using the P&R lot, at least four times per week.

A 1981 United States survey (Barton-Aschman Associates et al 1981) found the following reasons for use, in descending order of importance:

- traffic congestion
- parking costs at destination
- trip costs
- parking shortage at destination
- trip length
- companionship.

In May 1989 a survey of P&R site users in the Sacramento region was conducted, as a first step to improve site location and size techniques (Al-Kazily 1991). Sites that were highly used were on clearly definable commuting corridors and had relatively high population densities for the service area of the site. Sites that performed less well lacked these characteristics and were relatively poorly located. Drive distances to the sites were asked as part of the survey, with 60% of respondents living within five miles and 71% within 7.5 miles – although there were large variations between sites. Most of the highly used sites drew between 60–75% of their users from within five miles.

A Vancouver survey of P&R users found the following reasons for changing to P&R by **former car drivers**, in descending order of importance:

- parking costs
- driving strain
- traffic congestion
- trip time
- more frequent buses
- less walking.

A survey of car commuters in a corridor not served by P&R indicated that a shift to P&R would require frequent bus services and minor travel time savings (Barton-Aschman Associates et al 1981).

Turnbull (1995) identified location factors (other than distance to the site) that could be influential in site usage:

- distance to destination – sites located very close to primary destinations experienced different responses to sites that were further away, with people less likely to switch to PT (with an interchange) for shorter distances
- heavy congestion – sites located in corridors with high levels of congestion (level of service (LOS) E or higher) typically had stronger demand
- high visibility – sites should be highly visible from approach roads, as this built awareness and also gave a better perception of security

- easy access – sites adjacent to main arterials generally experienced higher demand, particularly when users did not need to backtrack
- site spacing – sites close to each other generally behaved as being combined rather than separate facilities, and so a level of competition was developed which was likely to reduce the effectiveness of each individual site
- surrounding density – higher densities provided more population within given catchments and so was a larger market to tap.

Spillar (1997) included a much larger and encompassing list of contributing factors that might affect P&R demand (see Table 1.4).

Table 1.4 Contributing factors to park and ride demand.

Site attribute	Relational characteristic
1. Number of am peak-period express bus trips to CBD.	As the number of am express trips to the primary CBD increases, so does demand. Some sources have recommended a minimum of four express buses per peak hour at park-and-ride lots, to be effective.
2. Number of am peak-period express bus trips to major employment centres *other* than the CBD.	See relational characteristic 1.
3. Ratio of out-of-pocket car costs to transit costs.	As car costs increase relative to transit costs, transit demand tends to increase.
4. Distance between P&R site and primary business centre or CBD (measured as either the straight-line or road distance).	Within the Seattle Metro region, it has been observed that, as the distance between the P&R site and CBD increases, demand also tends to increase. However, there is likely a limiting factor with respect to this relationship.
5. Proximity to regional freeway system.	Sites immediately adjacent to a regional freeway have been found to demonstrate higher park-and-ride demand.
6. Availability of midday access between primary business centre (CBD) and the site.	Availability of midday access from the CBD to the P&R site increases potential demand.
7. Total population within the 50 percent service area of site.	Population within a 4 km radius of a site has been found to supply approximately 50 percent of the total demand for the site—the denser the population within the 4 km radius, the larger the potential P&R market.
8. Location within the region (for Puget Sound, the South Corridor demonstrated higher average demands)	Lots located within productive transit corridors will tend to generate higher P&R demand.
9. Percent multifamily within the service area of the P&R site.	The higher the multifamily concentration within the service area of the P&R site, the higher the potential market.
10. Percent of lower middle and lower income households within the service area of the P&R site.	Lower income populations tend to rely more frequently on transit: however, with P&R sites this relationship between income and transit usage may not be as strong as expected.
11. The average best scheduled transit time between the P&R site and primary CBD.	Shorter schedule times with respect to increasing distances increase P&R demand and provide a measure of service speed.

Site attribute	Relational characteristic
12. Travel time to secondary major destination.	See relational characteristic 11
13. Peak traffic on adjacent roadway facility.	Increasing traffic volumes on adjacent roadways may increase parking demand because such volumes may indicate higher downstream traffic congestion and potentially greater numbers of prospective P&R users.
14. Peak traffic on adjacent prime facility.	See relational characteristic 13.
15. Number of home-based work trips between market area and specific destinations (eg the CBD).	Increased trips between two locations increase the potential share of the modal split for P&R.
16. Employment or similar surrogate demand measure at activity centre destination.	The larger the employment level at the primary business centre served by the site, the higher the potential demand. Likewise if multiple centres are aligned downstream of the site, P&R demand will generally be increased.
17. Relative measure of roadway congestion between subject lot and destination.	Increasing congestion between the site and primary destination encourages P&R demand because of the potential increased competitiveness of transit with the car. To achieve a transit advantage requires preferential treatment of transit (eg an HOV lane), otherwise no advantage will be realised.
18. Age of park-and-ride service/lot.	New sites require time to develop their demand characteristics. Older sites may demonstrate a reduction in demand if not adequately maintained and remodelled periodically.
19. Availability of priority treatments.	HOV lanes or transit-only policies increase the general competitiveness of transit with respect to the private car.
20. Surrounding density.	Increased surrounding densities represent increased populations, and hence a larger potential usage.
21. Perceived safety characteristics of site.	To the user, perception is reality when it comes to personal safety. Sites perceived to be more dangerous than others will generally experience lower demand.
22. Site paving.	Paved sites are generally preferred to unpaved or gravel sites when an alternative is presented to the potential user.
23. Site lighting.	Well-lit sites promote the perception of a safe environment (see relational characteristic 21).
24. Provision of passenger shelter.	Shelter and other amenities generally add to the perception of safety and permanence of the site. This, in turn, will have a positive effect on demand.
25. Provision of passenger amenities.	See relational characteristic 24.
26. Transit information.	See relational characteristic 24.
27. Parking costs at primary destination.	Increased parking costs at the destination end of the commuting trip will increase car costs relative to transit, making transit more competitive in terms of cost.
28. Park-and-ride site access attributes.	Sites that are difficult to access, even though they may be highly visible, may demonstrate reduced demand characteristics.

5.4.3 New Zealand market research

In a 1994 study of P&R in the Hutt Valley for the WRC, Travers Morgan (1994) identified a similar set of factors:

- Demand for P&R facilities is related to the availability and price of car parking at both the destination and the P&R facility, as well as the cost of the train fare.
- The LOS on the PT mode must be competitive with the car in terms of critical LOS features, particularly trip frequency.
- The level of road congestion and the effect on journey time have an effect on the attractiveness of the P&R package.

In addition, evidence in Wellington over the last few years points to the importance of car park security for potential users.

6. Overall transport system impacts

6.1 Effects on public transport use

There is no doubt that P&R policies result in increases in the total numbers of trips (boardings) made on public transport in almost all circumstances. This is evident from the previous section, which indicates that a significant proportion of P&R users were previously car users.

London data (for Network South East (NSE) rail services) indicates that each person using P&R facilities generates, on average, 0.16 new daily return rail trips.

Similar United States (Connecticut) studies indicate approximately 0.2 new transit riders (daily return trips) per additional parking space provided in capacity-constrained situations.

However, one of the effects of P&R is typically to replace some longer public transport trips (with walk access or feeder buses) by shorter public transport trips (with car access). Thus it is possible that the total passenger kms travelled on public transport might reduce. This is more likely to be the case where P&R sites are provided relatively close to the CBD or other final destination: the PT passenger kms lost by passengers that now drive part of the way could exceed the passenger kms gain associated with intercepted car users.

Analysis for bus-based P&R schemes in eight United Kingdom cities showed that PT passenger kms increased significantly as a result of the scheme in seven out of the eight cases. However, in all these cases additional bus service were introduced to serve the P&R sites and there were reductions in use of the ‘conventional’ bus services (Parkhurst 2001).

6.2 Effects on road traffic levels

6.2.1 'Intercept rates'

One measure of the effect of P&R schemes on road traffic is the 'intercept rate', which is the proportion of all car travellers on the relevant radial route or corridor passing the P&R site that transfer to P&R. Typical intercept rates in UK cities which are oriented to bus P&R are in the range 10–20%:

> *P&R could attract up to 20% of traffic past the site which is travelling into a town centre* (Davidson 1992).
>
> *(In Oxford) 17% of car-based journeys from outside the urban area now transfer to P&R, but this contribution is helping to absorb growth, rather than displacing existing demand (*Huntley 1993).

In York, the P+R scheme intercepts 12% of car trips on the adjacent radial route.

However, while Oxford has probably the most utilised bus-based P&R scheme in the United Kingdom, the car park sites are near the outer edge of the city area. Thus the proportion of overall CBD-oriented traffic affected is very much less than the 17% figure. In addition, in the absence of P&R, not all the intercepted trips would necessarily have gone by car all the way to the CBD.

6.2.2 P&R use by former car drivers

The United States and Canadian data quoted above indicates that broadly half (38%–60%) of P&R users were former car drivers.

For United Kingdom bus-based schemes, the Oxford/York figures noted earlier were that 51%/60% of week-day P&R users would previously have driven by car to the city.

United Kingdom rail data tend to indicate smaller proportions of users transferring from car driver. The London NSE assessment is as follows:

- approximately 20% of NSE passengers to Central London use P&R
- for each person using the P&R facilities, there are 0.16 new return rail trips
- assuming NSE accounts for 70% of travel to Central London in the relevant corridors and each new return rail trip results in 0.7 fewer car trips, then closure of P&R facilities would result in 2.2% of the total travel market in the corridors transferring from train to car drivers.

This extreme scenario would have perceptible effects on the total travel market to/from Central London, but its effect on overall road traffic levels in the area concerned would be barely noticeable.

6.2.3 Generated road traffic

In some circumstances P&R schemes may generate additional road traffic:

- Some motorists may travel a greater distance to reach a P&R site rather than driving directly into the town centre (although this does not necessarily mean extra congestion and pollution, given that a short journey in a congested network may have a greater adverse impact).
- P&R may encourage motorists to make additional journeys.
- Cars left at a P&R site that were previously driven into the town centre may be replaced by other vehicles in the town centre.
- Some people who previously travelled all the way by bus now switch to driving to the P&R site, then continuing by bus.
- Any additional bus services will contribute to overall road traffic.

A United Kingdom survey of P&R users in four towns found that 75% of users travelled from/through the sector of town in which the P&R site was located; and most likely did not travel further than if they drove into the town centre (Picket and Gray 1994). The remainder would probably travel further 'but part of the extra mileage covered would be along less congested roads'. In addition, as noted earlier, a significant proportion of P&R users indicated they visited the town more often since the introduction of the P&R schemes, or would not have made the journey at all if the P&R scheme had not been not available (Parkhurst 1994).

6.2.4 Overall effects on traffic levels and congestion

Picket and Grey's report (1994) reviewed the relevant literature on bus P&R and found that 'none of the papers/articles reviewed demonstrated conclusively that P&R reduced urban traffic congestion'. This does not necessarily mean that P&R has not affected traffic volumes and congestion, but that any effects are relatively small and difficult to measure.

Analysis of survey data for bus-based P&R in eight United Kingdom towns/cities estimated the average reduction in car kms/day per car parked at the P&R site and also the corresponding additional bus passenger car unit (PCU) kms for the P&R bus services. It was found that (Parkhurst 1996, quoted in Balcombe et al 2004):

- the car kms saved were in the range of 1.5–8.5 kms/car parked per weekday
- the additional bus kms were in the range 1.3–3.7 PCU kms/car parked (counting 1 bus km = 3 PCU kms).
- overall there were net reductions in PCU kms in five of the centres, but net increases in the other three centres.

United States studies developed a relationship between vehicle kilometres travelled (VKT) savings per P&R parking space and the distance between the P&R site and the primary destination. Savings varied from 18 car kms/day for a site-destination distance of 16 kms up to 46 car kms/day for a distance of 64 kms. No account was taken of any increases in public transport services.

As noted above, P&R appears to have had some success in 'intercepting' road traffic (eg Oxford) and in attracting some former car users to public transport. However, analyses in Oxford and Canterbury have failed to detect any absolute reduction in traffic levels as a result of P&R, most likely because any road space freed up is filled by previously suppressed demand. In Oxford, there has been very little traffic increase during the last 20 years, over a period of considerable national traffic growth. It appears that the combination of P&R, other traffic measures (eg parking fees, increased enforcement) and lack of road capacity have contributed to this result. Parkhurst suggests that, in both Oxford and York, P&R has not directly reduced congestion, but that 'congested equilibrium' has been maintained.

These conclusions on the effects of P&R on road traffic levels are consistent with the finding of other commentators:

> *With only a few exceptions, (existing P&R services) have not been shown to have a significant effect on volumes of traffic in the wider urban are.* (Armstone 1992, referring to United Kingdom experience).

> *In Milwaukee, 6 shopping centre P&R lots removed 400 peak cars from radial routes, but these represented under 1% of car trips to the CBD*. (Barton-Aschman Associates et al. 1981).

6.2.5 Environmental and energy impacts

The effects of P&R policies on the environment (noise, emissions etc) and on energy use are directly related to their effects on total car travel (as discussed above).

However, any benefits in terms of energy usage and emissions are likely to be proportionally smaller than the reductions in car traffic levels. One effect of P&R will be to change longer car trips (to the destination) to shorter trips (to the P&R site). The emission reductions will be much less than pro rata to the distance saved, as emissions are much greater in the warming-up stage. Similarly, any switch from PT travel all the way to travel by car to P&R site followed by use of PT will cause significant extra emissions.

Another potential 'environmental issue' is the impact of the P&R site facility on the local ground level environment. In Cambridge, the new P&R scheme was seen by some as environmentally unacceptable as it was proposed to locate sites in green belt areas. Consideration of this issue deflected debate away from the overall benefits of the P&R scheme.

7. Key success factors

Although there have been many studies of individual schemes, international experience to date has not resulted in any simple set of universal rules for when P&R will or will not be successful and effective:

> *The wide variety of situations in which P&R has proved to be successful however argues against the existence of any such criteria of universal applicability.* (Armstone 1992).

> *There don't appear to be any….simple rules which would show whether or not P&R would be successful*. (Buchanan 1992).

However, some guidance can be given on the situations which generally favour P&R and the desirable characteristics of P&R schemes.

P&R is most usefully regarded as a component of CBD traffic and parking restraint policies and is most appropriate in situations where there is:

- a shortage of CBD parking spaces, whether as a result of geographic limitations or for transport policy reasons
- limited traffic capacity on radial routes into the CBD
- good quality public transport services into the CBD.

In the United Kingdom, rail-based P&R is most prominent in London, which has both parking and road capacity constraints. Bus-based P&R has been the most developed and had the greatest success in historic medium-sized cities (eg Bath, Cambridge, Chester, Chichester, Exeter, Oxford and York). These cities are all characterised by:

- very compact central areas, with high land values and a shortage of space for parking
- traffic problems due to the limited road space within the CBD and on radial routes
- a heavy emphasis on maintaining the fabric and integrity of the historic central areas.

There seems to be general agreement that CBD parking shortages are essential to the success of P&R:

> *The one rule which the (UK) Department of Transport seem prepared to concede is that … there needs to be a shortage of central area parking.* (Buchanan 1992).

> *Central area parking capacity is therefore a crucial factor in where P&R is likely to be seen most favourably … English historic towns, … where additional town centre parking is either difficult to provide or seen as environmentally unwelcome typify the circumstances in which P&R prospers*. (Huntley 1993).

Thus the 'stick' of traffic restraint appears essential to the success of P&R schemes. The evidence is also that this needs to be accompanied by the 'carrot' of a good quality PT service linking the P&R sites with the CBD:

> *The experience of P&R schemes is very mixed and in general car drivers seem to be willing to transfer to transit in mid-journey only if there is a considerable advantage in doing so: P&R in connection with the successful freeway bus lanes in North America or with the faster rail mode in to large cities, or for shopping at peak times*

> *(e.g. Christmas) when city centre parking is difficult, seem to offer the most successful examples.* (TRRL 1980).

It is important that P&R schemes are market oriented. Generally their potential users will have the option of making their complete trip by car, and hence for a scheme to be successful it must offer a level of service comparable with that for making the full trip by car, eg:

> *P&R passengers … are a different type of passenger to our normal bus user. They are car oriented and expect a standard of service that is normally higher. They want reliability, cleanliness and a good driver attitude.* (Miller 1991).

United States research which has investigated the sensitivity of P&R usage to various features and trip characteristics notes that:

> *The successful bus service/P&R facilities are in cities with downtown parking charges over $2/day, are served with buses running at least every 15 minutes, and are less than a 30 minute bus ride from the CBD.*

> *If extra time by P&R is less than 10 minutes, daily out-of-pocket savings of at least $0.30 are sufficient to attract P&R usage. If extra time is more than 10 minutes, P&R usage drops substantially, and is minimal if extra time is over 25 minutes.*

Successful schemes require PT headways no greater than every 10–15 minutes: for greater headways, usage falls rapidly (Barton-Aschman Associates et al. 1981).

The same report comments that rail P&R schemes are generally better patronised than bus P&R schemes:

- rail travel times are more reliable and more competitive with the car
- more intensive developments around rail stations restrict parking availability
- rail travel is more highly visible.

However, where bus P&R schemes are linked to high-occupancy vehicle (HOV) lanes and other priority measures, the performance of P&R is much closer to that of rail-based schemes. This is highlighted by the very strong P&R performance of the Adelaide O-Bahn.

P&R can also have a particular role in low density, high car ownership suburban areas, where it is not cost-effective to provide attractive levels of PT service through these areas, but where travellers may be attracted to a good quality of PT line haul service if they can get convenient access to this. This is the case in many United States situations, in the outer parts of the London conurbation and the Perth northern rail corridor.

In summary, the evidence indicates that the most essential and almost universally applicable criterion for the success of P&R schemes is a shortage of reasonably priced central area parking.

If this criterion does not apply, then P&R is only likely to succeed if there is an exceptionally high level and quality of PT service linking the parking site with the CBD.

Other key features required for the success of P&R schemes are:

- well designed car park sites, in terms of location and facilities/design
- separate PT corridor/lane and/or PT priority measures
- good information and marketing of the scheme
- adequate personal and car security at the P&R site.

In essence, the basic requirement for success is that access to the CBD via P&R needs to be competitive with the use of the car for the whole trip – in terms of perceived generalised costs (quality, reliability, comfort, travel time, out-of-pocket costs etc).

Part 2: Review of international modelling practices

1. Part 2 overview

This section discusses research undertaken, mostly through published material via the internet, on general demand forecasting approaches to P&R. There has been renewed interest in estimating demand for P&R, driven primarily by making better use of under-utilised public transport corridors, through encouraging use from over-utilised road networks. The literature review highlights two primary methods which are currently being used to estimate future P&R usage, namely regional models and site-specific models. Each approach has strengths and weaknesses, and requires common sense by the planner and a certain amount of local knowledge. A general theme is that as computing power and software has improved, so has the complexity of the demand forecasting models.

2. P&R modelling overview

2.1 Background

Interest in P&R as a mode expanded rapidly during the oil crisis of the 1970s. In the United States, both state and regional transit agencies examined ways to make car-pooling and public transport usage more accessible and convenient for suburban and rural residents working in centralised cities and major employment areas. Initial approaches to P&R site development were largely based on knowledge of the area and the constraints of land available for development rather than the potential usage of a site. The major driver behind P&R as a concept was that escalating oil prices would force drivers to seek more economically efficient forms of transport, such as mass transit.

P&R modelling interest peaked in the 1970s and early 1980s to coincide with the move to mass transit systems. A number of transportation agencies conducted extensive studies to examine P&R demand, particularly in Texas, Seattle, Houston and Portland. Since the mid-1980s, there has been little in the way of technique development. This has been due mainly to the stabilising of oil prices and the implementation of many P&R strategies. However, given recent increases in oil prices, P&R will again be a significant topic. Also, many agencies have adopted an incremental approach where test sites are developed and services and capacities enhanced where needed. Most agencies choosing this method still rely on practical knowledge of the proposed service area and are faced with the availability of multiple alternative sites.

In the United Kingdom, P&R began mainly in historic towns and cities as they suffered from traffic congestion earlier than other ‘planned’ cities. Primarily this was due to their spatial design, radial road network and limited scope for major traffic management and investment. In the early 1970s P&R strategies were introduced in Oxford and Nottingham and by 1996 P&R was a part of the transport strategy in 85% of local authorities, with 72% either expecting to expand or introduce new schemes. However, little was known about the criteria for a successful site.

2.2 Forecasting approaches

The potential approaches to forecasting P&R demand in any given situation depend on the particular aspects that are under consideration, such as whether it is a general strategy for an urban area, a plan for a specific corridor or an extension of existing sites.

Spillar (1997) identifies three broad types of forecasting approaches:

- post-modelling techniques
- direct regional forecasting techniques
- site-level forecasting (based on site and service characteristics).

Post-modelling frameworks are the simplest approach and may give reasonable and approximate figures. They are used in conjunction with either a multi-modal transport model or observed travel mode split data. The process requires the definition of catchment areas to a P&R site. Mode shares from the model or observed data are obtained to give the number of car vs PT travellers and then adjustment factors are applied to PT users to represent the proportion of passengers likely to use car access. These adjustment factors may be based on international experience or observed data where available. While this approach is easy to implement, it ignores implicit changes in transport supply (such as fare or journey time changes) and does not address the issue of station/site choice. Post-modelling frameworks are easy to implement and not particularly data intensive but require base forecasts, either from a multi-modal model or from observed data. Further, these techniques are relatively subjective, with much of the modal distribution effect left to the experience of the team – results can therefore differ widely when different approaches are used. These techniques cannot be used to examine station/site choice aspects and are largely being superseded by the two approaches discussed below.

Regional-modelling approaches include P&R as a distinct mode within a multi-modal model. Multi-modal models normally include a mode-split function, which gives the proportion of trips between an origin and destination by main mode. Functions are normally represented by a 'logit' equation, which relates the proportion of trips by each mode to mode-specific costs and parameters. These approaches allow P&R demand to respond not only to changes in its costs, but also to those of other modes; they also give the ability to include site-choice models and greater standardisation between site usage estimates. However, they require a higher degree of modelling sophistication and a significant level of commitment, often needing changes in the network and model structure of existing regional models. Further, their success is only as good as the regional model itself, particularly the mode-split structures and the quality of the base data, and they are generally unable to reflect local factors affecting individual site usage.

Site-specific approaches relate the usage at a P&R site to variables describing the location, catchment size and characteristics, transport costs from the site and facilities, which are assumed to define the attractiveness of car access to the station/site.

Regression equations are developed using data from existing sites, which may or may not include information from transport models. As these approaches can be based on localised data, they may give a better estimate of new site usage. However, although they do not require detailed transport modelling or explicit forecasting of PT demand, data requirements are significant with around 15 sites required to be able to deduce reasonably robust statistical equations. Finally, site-choice modelling can be difficult where site catchments overlap. It also requires careful examination of variables for suitability and to eliminate collinearity (particularly between distance, time and cost), which may then limit their future application.

Each of these approaches requires, to a greater or lesser extent, input from the analyst, whether in the form of direct estimates of demand or as parameter values used in particular methodologies. Davidson (1992) lists (in order of complexity) three main methods to obtain such inputs:

- market research
- ad-hoc forecasting
- stated/revealed preference analysis.

Market research in the early days significantly overestimated demand, particularly for new modes. Respondents were generally presented with a new mode and asked if they would use it and many said they would. Forecasts developed from these methods were seldom achieved, as what people said seldom carried through to their actual decisions. Davidson portrays market research as a useful tool for determining people's perceptions of problems and issues, which can then be applied when schemes are marketed back to the public. However, these approaches are not particularly useful for P&R demand forecasting.

Ad-hoc forecasting involves the use of model parameters from other studies to determine coarse estimates of ridership and revenue and is particularly useful at an early stage of a study. Many of these models involve the use of multinomial logit models (binomial models are a special case involving only two modes), where the model output is the probability of using the mode, based on a series of modal costs and associated parameters. However, while these model forms can generally be applied universally, the parameters cannot as many are a function of the local situation.

Stated/revealed preference methods extend the ad-hoc model to use locally developed parameters. Where P&R sites currently exist, revealed preference (RP) data (based on what people actually choose to do) can be used to determine model parameters, although this approach may not be applicable for new sites whose characteristics are vastly different from the existing ones. Stated preference (SP) data can be used when the alternative does not exist, or to test people's response under hypothetical scenarios. Respondents are asked which choice they would make given a series of alternatives with differing costs. This approach is really a more sophisticated form of market research and has the same disadvantage in that a respondent's choice may not be the same as what they do in practice. To minimise this, Davidson recommends using both RP and SP as complementary data sets.

3. P&R model development

3.1 Post-modelling techniques

The City of Calgary Transportation Department undertook a study for the planning and operation of future P&R sites (Kok et al. 1994). This study examined the parking and traffic generation characteristics of the existing sites, of which at the time of the study included 11. For demand forecasting purposes, the study involved the following five steps:

1. Define the catchment area for each station.
2. Determine the primary market – in this case it was downtown employees residing in the catchment.
3. Determine the primary demand – based on observed and expected modal split for P&R for home-based work trips destined to the CBD (in this case between 40–45%).
4. Estimate the proportion of primary demand attracted to P&R.
5. Estimate demand for short-term parking – taken as a proportion of long-term demand.

Using site usage as the dependent variable, trip rates were estimated by time period (am peak, pm peak, 24-hour), based on the site capacity, CBD workers in the catchment and driving distance from the CBD. For the am and pm peak hours, usage rates ranged between 62 and 68% based on site capacity, 7–8% of CBD workers in the catchment on average used P&R, and 50–55 extra P&R users were seen for each kilometre from the CBD (although the fit against observed data was poor for this variable). This approach was based on sites which were typically operating at 90–100% capacity; however, this is flawed in that the usage is constrained by the available capacity rather than the intrinsic demand, and as such is not useful as determining the potential usage of P&R sites.

Turnbull (1995) lists six steps to designing a P&R facility, including examining the need, defining the study area, estimating demand, determining size, evaluating and selecting site and designing the facility. In terms of estimating demand, a number of techniques are put forward, including using a proportion applied to a catchment population and a mode split approach (which extends the market area analysis by including mode share assumptions). Turnbull also outlines the Institute of Transportation Engineers (ITE) model, which is a function of peak-period traffic on adjacent facilities such as parallel roads. The model has two diversion factors – one for the total peak demand on adjacent facilities and the other for demand associated with the primary facility:

$$Demand = a(Peak) + b(Main)$$

where:

peak = total peak-period traffic on adjacent facilities

main = peak-period traffic on the primary facility

a, b = diversion factors for total traffic and prime facility traffic respectively (a = 1%, b = 3% recommended)

3.2 Regional modelling

P&R demand has been included in a number of regional models but most have used comparatively unsophisticated structures which are relatively insensitive to changes in network characteristics. The most comprehensive approaches have been developed within the Emme/2 modelling framework. This is a transport modelling package developed by INRO and is used extensively in New Zealand by local authorities, including the Wellington Transport Strategy Model (WTSM), the Auckland Regional Transport (ART) and Auckland Public Transport (APT) models.

Spiess (1996) wrote a paper outlining a procedure for modelling P&R within Emme/2. The procedure involves the use of mixed-mode logit models, but can be extended to include an intermediate station choice logit model. His procedure included the allowance of parking capacities at the sites through the use of shadow prices (reflecting the cost associated with the 'last' parking space in the site). A site that does not reach capacity has a shadow cost of zero. Practically, this process in Emme/2 needs to split a P&R trip into two legs, namely the access mode by car and the main mode by public transport. This can be achieved through the use of the matrix convolution function within Emme/2, which can give the split of access and main mode costs, as well as the number of people using a particular site and Spiess shows that a stable solution is achieved. Using an iterative approach, an additional car parking charge (shadow price) can be added where P&R exceeds capacity, which is a function of the demand at the site. This will redistribute P&R users to other sites where feasible and in combination with a full mode split model would allocate users to other feasible and competing modes. Spiess has developed an Emme/2 macro (parkride.mac) to undertake the P&R modelling, although this would need to be adjusted for specific models and situations.

Xie and Wies (2001) also outline an Emme/2 approach for estimating the combined cost of a P&R trip using matrix convolutions. Where this piece of work differs from Spiess is that it focuses on determining a cost associated with parking at a site, with the purpose of representing more accurate car-transit costs for mode split. As such, the authors claim this approach to be more appropriate to a regional model methodology.

Table 2.1 Parking cost index by area type.

Area type description	Area type label	Indexed parking cost
Inside CBD	1	100
Remainder of CBD	2	70
Remainder of Chicago	3	25
Inner suburbs	4	15
Remaining Chicago urban area	5	10
Indiana urbanised area	6	10
Other Illinois urbanised area	7	6
Inside other Indiana urbanised area	8	6
Remainder of NE of Illinois urban area	9	4
Rural	10	4
External area	11	0

The following equation was estimated through trial and error so that calculated values were reasonable and in scale with other cost and time components.

$$GenParkCost = IndexedParkingCost + 0.7 \times parkingfee - 0.3 \times Ln\ (parkingcapacity)^{1.2}$$

However, this model specification is of limited value due to site demand not being constrained, and the model parameters being estimated by trial and error and without the use of observed data.

The Emme/2 matrix convolutions approach has also been used within the Greater Vancouver Transportation Model (Hull 1998). Procedures for modelling P&R are based on the following assumptions:

- Transit riders to destinations with abundant free parking will not use P&R.
- Trip makers will not use P&R if the transit generalised cost from their origin zone to their destination is lower than the P&R cost via a parking lot.
- Where P&R is a reasonable option, the decision on transit access mode can be modelled using a logit function based on the comparison of generalised costs by each access mode.
- P&R generalised costs include appropriate parking charges and uncertainty of finding a park when demand exceeds capacity.
- Trip makers will be reluctant to use P&R unless travel time saved justifies the use of car – this includes the use of a modal penalty to avoid over prediction of short auto trips (four minutes for rail and six minutes for bus served).
- The primary mode of P&R users is transit, so that the auto leg trip will generally be shorter than the transit leg – to match the observed distribution it has been necessary to weight the auto leg of trip (by 1.25 for rail served and 1.35 for bus served).

- Where P&R is a reasonable option, the effective transit cost considered in making decisions about trip distribution and mode split will be lower than for people with no P&R option.

The methodology calculates the combined auto and transit costs via a P&R site and includes the addition of a modal bias and a shadow price for when demand exceeds capacity. Demand is distributed between a series of feasible P&R sites through the use of a multinomial logit model, with the resulting car access and transit egress matrices added onto the car and transit total trip matrices for assignment. The site-choice multinomial model is iterative due to the capacity and shadow costs. It was found that applying this P&R methodology improved the fit of modelled versus observed transit flows where P&R was prevalent.

3.2.1 Auckland Passenger Transport Model (APT)

The APT was developed in 2000–2001 by Booz Allen Hamilton for the ARC. The council already had a multi-modal 4-stage model (ART), but the representation of public transport was considered inadequate for looking at proposed PT schemes.

The APT includes car access to rail and ferry and car access to bus sites has now also been added (although this is not modelled in the base network). P&R is modelled by defining a catchment for each P&R site on an ART origin-site destination basis (through the use of an indicator matrix). Sites are represented as a zone in the APT. A car access cost to the site (zone) is determined from each APT zone in the defined catchment. The car access cost from the origin to the site is added to the PT cost from the site to the ultimate destination, to give a total P&R cost between origin-destination pairs.

The catchment areas were determined as follows. From the 1997 rail and the 2000 ferry surveys, car access to rail and ferry was examined by ART zone to determine suitable links between APT zones and the different P&R (rail and ferry) sites. APT zones that were very close (within walking distance) to the site were excluded from the definition.

The cost of P&R access to PT is determined by estimating vehicle access costs to key P&R sites using a car, and then determining the public transport cost from these sites to the ultimate destination. This can be done in Emme/2 using matrix convolutions, where the cost of a P&R trip (PRCost) from zone i to j by P&R site k, is:

$$PRCost_{i,j} = \min_k \{AutoCost_{i,k} + PTCost_{k,j}\}$$

Vehicle access costs are determined using the following equation:

$$AutoCost_{i,k} = AutoTime_{i,k} + (1.5 \times AutoDist_{i,k}) + Transfer$$

where:

$AutoCost_{i,k}$ = car access cost (mins) from zone i to k

$AutoTime_{i,k}$ = car access time on network (mins)

$AutoDist_{i,k}$ = car access distance (km) multiplied by 1.5 (15 cents/km)

Transfer = transfer penalty (mins) assumed 10 minutes.

The car access time on the network is determined by adding an auto mode to the APT roads, and assigning using the ART-based speeds to give the auto time. A speed of 30 km/hr is used for centroid connector speeds. The auto distance also results from this assignment. A factor of 15 cents per km was based on the *Project evaluation manual* (PEM) value of 20 cents per km, which was factored down by an average car occupancy of 1.3.

The public transport (rail or ferry) leg of the trip from the P&R site to the ultimate destination comes from the skimming process. Costs are estimated for the am peak and interpeak separately. It was found through the calibration process that too many people were using P&R for very short journeys, which was not seen in the observed matrix. To overcome this, a restriction was placed on P&R trips whereby the distance from the initial origin to ultimate destination had to be greater than 10 km.

P&R (including K&R) was explicitly included within the model, including access to both rail and ferry services (and future bus sites). Rather than modelling P&R through an assignment approach (as used in WTSM), car access to PT services was included within the mode-split hierarchy.

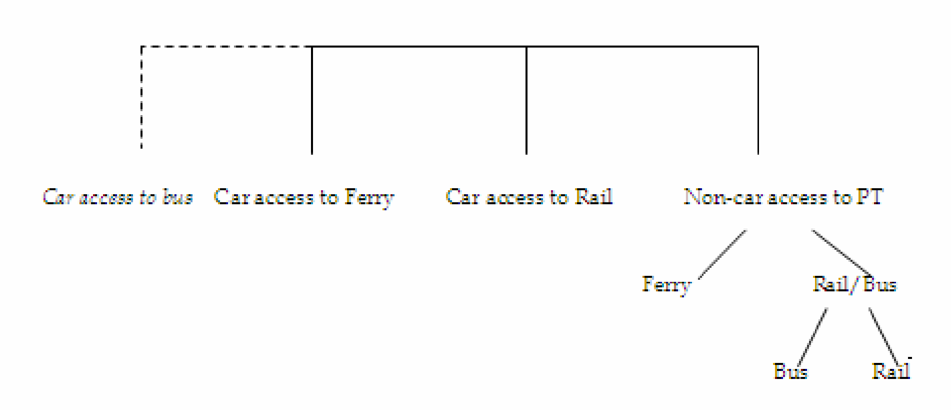

Figure 2.1 Sub-mode split structure

Table 2.2 APT sub-mode split parameter estimates.

	AM Rail	IP Rail	AM Ferry	IP Ferry	AM Rail P&R	IP Rail P&R	AM Ferry P&R	IP Ferry P&R
Lambda λ	-0.065	-0.049	-0.055	-0.048	-0.038	-0.0319	-0.040	-0.037
SE	0.00144	0.00120	0.00295	0.00205	0.00182	0.00276	0.00239	0.0041
SE′	0.00242	0.00188	0.00505	0.00376	0.00254	0.00415	0.00494	0.0083
Constant (Bus=0) β	-0.1716	-0.1838	1.364	1.306	-1.485	-2.521	-0.873	-0.54
SE	0.0255	0.0253	0.105	0.0969	0.0530	0.101	0.050	0.168
SE′	0.0429	0.0396	0.1797	0.1778	0.0740	0.1520	0.1033	0.341
MSC (mins)	2.64	3.75	-24.8	-27.2	39.4	79.0	22.0	14.5
R^2	.34	.25	.55	.60	.20	.22	.15	.24
Unweighted obs	4585	5081	506	708	2530	2296	1328	783
Weighted obs	12979	12471	1482	2383	4933	5197	5663	3224

Notes:

SE is the standard error

SE′ is an adjustment to the standard error due to the weighting of data. The adjustment is SE*sqrt (average expansion factor)

R^2 is the correlation with respect to constants (directly from Alogit statistical package)

Values of lambda for both the am peak and interpeak are consistent with the structure outlined in Figure 2.1, with the largest magnitude lambda for rail at the bottom of the tree and the P&R lambdas at the top. Resulting lambdas for P&R were consistently around -0.040 except for the interpeak rail P&R, and θ (the sensitivity of P&R to PT changes) ranges from 0.58 for am peak P&R to 0.77 for interpeak (IP) ferry. For the P&R modes, an average lambda was asserted and the constant modified until the total number of trips matched the observed.

The results imply large penalties or mode-specific constants (MSCs) for the P&R modes (from $1.40 for IP ferry to $7.90 for IP rail) and reflect the significant proportion of people that are in practice captive to non-car access to PT.

3.2.2 Wellington Transport Strategy Model (WTSM)

The Wellington Transport Strategy Model (WTSM) is the multi-modal model of the Wellington Region. The current version was developed by consultants Sinclair Knight Merz and Beca between 2001 and 2003 and delivered to the Greater Wellington Regional Council (GWRC) in late 2003. Since then it has been a source of transport data and the main tool for forecasting the impacts of alterations to transport networks, public transport services and land-use plans. It has been used in this capacity in all strategic and policy studies initiated by the GWRC over the last 18 months including the CBD Corridor Study, the re-evaluation of Transmission Gully Motorway, the Wellington Rail Review and the Wellington Transport Project.

P&R is included within the model through a series of network connector links (called P-connectors) from zones directly to stations. These P-connectors have a faster speed on them than normal centroid or walk speeds. This speed is not fixed and is related to the length of the connector, reflecting the further people travel the faster their average speed will be. As a result, P&R is represented only in the assignment and not as an individual mode in any mode choice model.

While this approach is adequate at successfully replicating existing behaviour (through the calibration of link lengths and speeds), it is not as useful for looking at P&R policies such as the development of new sites, increases in capacities, or site choice. Further, the behaviour in future years is unclear as the P-connector will abstract more demand to P&R (in a more congested network) without an increase in P&R capacity.

The suggested way for modelling increases in capacity is to shorten the P-connector link lengths. However due to the nature of the network, it is impossible to restrict other local trips from using the same links and so the additional demand generated by an 'improvement' in capacity will not necessarily be P&R demand (and may not even use the rail network). Further, users of the P-connectors (who would be using the road network) are not assigned on the road network and so do not impact on local congestion. Also the scale of magnitude change is subjective and not related to anything tangible (such as actual capacity assumptions).

3.3 Site-specific modelling

Spillar (1997) discusses a site-level P&R demand model estimated for the Seattle metropolitan region. The model included demand and site characteristic data for 31 active express-bus served sites. Five model equations were developed based on eight site-level variables:

- service area population
- ratio of auto costs to transit costs
- distance from P&R facility to major employment centre
- number of express buses during the am peak
- best (not average) time between the P&R facility and the CBD of the metropolitan area
- proximity to the regional freeway system
- presence of nearby P&R facilities
- availability of midday services.

Adjusted R^2 ranged from 0.40 (for an equation that included ratio of costs, number of peak buses and proximity to freeway) to 0.68 (which included: proximity to freeway –

FREE; existence of midday services – MIDD; distance to CBD – DIST; number of adjacent lots – LOTS; and market area population – TOTPOP) for the following equation:

$$Demand = \left(-49.85 + 36.71 \times FREE + 51.24 \times MID + 3.35 \times DIST + 10.07 \times LOTS\right) \times \frac{TOTPOP}{10000}$$

Spillar discusses transferability of model to other areas and concludes that the form of the model could be used (as a similar combination of variables is likely to apply in many contexts), but that coefficients need to be manually calibrated or estimated and for statistical robustness at least 30 sites are required. He highlights the problem of manual calibration through the applicability of the model equations to Denver using calibration factors, with little success.

Stevens and Homburger (1985) found that 55% of P&R users drove less than 3 km, 81% less than 8 km and 96% within 16 km. At the egress end 63% walked less than 160 m and 84% within 320 m (all within 800 m). A statistical relationship between site usage, number of spaces and the market (population within the area served by the site) was estimated for Marin County with an adjusted R^2 of 0.804,

$$Usage = -39.453 + 0.059 \times \left(Market\right) + 0.349 \times \left(Spaces\right)$$

and implies that an increase in market population of 1000 will generate an extra 59 P&R users, and an increase in spaces of 100 will generate an extra 35 P&R users at the site. It was noted (and unexpected) that none of the service level variables examined were significant. It was also concluded that sites should be located at least 16 km from the job locations where parking charges were substantial and that commuters were unlikely to switch to a bus route for relatively short journeys. Sites were also best located so that CBD-bound commuters could be intercepted – such as near entrances to freeways.

In 1995, an empirical model for forecasting P&R patronage for extensions to the Perth metro was developed (ARUP 1998). The objective of the model development was to have a better understanding of Perth commuters' preferences for P&R. Also, there was a need for more accurate estimates of the land required to accommodate sites as usable land was rapidly diminishing. Modelling was based on multiple linear regression (MLR) relationships using existing site usage. Independent variables included station catchment population and density, distance/car time/rail time to the CBD, distance from suburb to P&R station, congestion to adjacent station and levels of service of feeder buses.

It was recognised in this study that the estimation of station catchment was the most problematic element, as it was somewhat subjective – catchments were defined as rectangles (8 km long by 10 km wide), with the width reducing as the station approached the CBD.

Catchment population was found to be the only independent variable which was both statistically significant and not counter intuitive; it also explained around 75% of the variation in P&R usage. As some of the extra variation could be explained by facilities at each site, a dummy variable was added to differentiate sites of differing quality (eg size, visibility, access, convenience and walking distance to trains). This was found to improve the explanation of the model to around 95%; however, there were still significant outliers. The final equation was:

$$Patonage = 273 + 0.0127 \times (estimatedpopulationcatchment) - 173 \times (stationdummy)$$

indicating that a high quality P&R station (dummy=0) would have a base usage of 273 plus 1.27% of the catchment population. However, an equation such as this does not provide a useful indication of where to locate the site (unless to maximise population catchment), or what happens when catchments overlap. Also, improvements to rail services will have no impact on patronage unless the 'facility' (station dummy) is deemed to improve.

3.4 Stated/revealed preference studies

These studies are the most structured method of obtaining model parameters for use in the development of mode-share models and as such have specific applications to developing regional modelling approaches. Stated preference (SP) data can be used when P&R does not currently exist, or to test people's response under hypothetical scenarios. Respondents are asked which choice they would make given a series of alternatives with differing costs. This approach has the disadvantage that their choice may not be the same as what they might do in practice. Where existing P&R sites and usage occurs, revealed preference (RP) data (based on what people actually choose to do) can be used to determine model parameters. This approach can only be used where the alternative currently exists and may not be applicable to new sites where characteristics may be vastly different.

Hole (2004) discusses the merits of SP and RP, with emphasis on the sources of errors for each. Under an SP approach where respondents are asked a series of 'what if' scenarios, sources of error include model specification errors (wrong functional forms or variables) and taste differences between respondents. Respondents also have a tendency to behave differently in surveys than in practice. This may be due to learning effects (where answers given later in the survey may be based on answers given previously), fatigue effects (where options are not evaluated fully near the end of surveys), policy bias, or justification bias (where a person using a current option is more likely to justify their current choice).

RP analysis is based on observed behaviour and so errors relating to choice are excluded. However an additional measurement error is included, due to costs of choices being estimated (for a particular behaviour) rather than asserted as in an SP survey.

Because the sources of error are different between SP and RP, the two approaches typically give different results. Hole (2004) recommends two common methods for comparing SP and RP parameters. The first is to rescale the parameters in an SP survey based on a known RP value (such as the value of time for a segment). The second is to estimate parameters based on a combination of SP and RP data, although it is unlikely that consistent data of both types would be available for a study. Davidson (1992) also recommends using both RP and SP as complementary data sets.

3.4.1 Stated preference studies

The Transport Department of the Polytechnic University of Madrid and the Madrid Public Transport Authority carried out research intended to analyse present and potential P&R demand in the Madrid metropolitan area (Monzon et al. 1998). The research included an SP experiment. A computer-assisted telephone interview (CATI) was initially conducted with more than 6000 households in order to get a sample of 300 people (5% response rate) who, to qualify for inclusion, needed to:

- travel to the Madrid city centre
- use a private car
- travel three or more times a week
- be willing to participate in the SP experiment
- be able to provide base trip data such as origin, destination, and cost components.

A face-to-face interview was then conducted at each selected respondent's residence. The interview included three different questionnaires, including the SP experiment, household socio-economic data and attitudes towards P&R, pricing policies and public transport.

For the SP experiment three modal alternatives (private car, public transport and P&R) and two attributes (trip time and trip cost) were included. Ten different scenarios (based on varying the attributes around their base choice values) were given so that each option was relevant to the individual. The respondent was asked to rank each mode.

The survey found that 62% of respondents had never used P&R facilities. For people who had used P&R, security, the number of car spaces and car access were the most important aspects to be improved. It was also found that 39.6% of car drivers to the city centre had a parking lot provided by their employer.

Conclusions from the SP survey identified the difficulty in generating competitive scenarios between public transport and private car. Large changes in base trip values were required, reducing the credibility of the survey to the respondents. More than 30% of respondents did not change their current choice (private car) in any of the 10 scenarios presented. Further, constants associated with public transport were consistently negative (when segmented by distance, purpose and income level) and in every case lower than the P&R constant. This represents more of a reluctance to use P&R than public transport (all things being equal), which the study explains as fear of lack of security, or reluctance to transfer between modes.

In 2004, the University of St Andrews (Scotland) undertook a study looking at forecasting the demand for an employee P&R service (Hole 2004). The objective of the study was to reduce the number of employees commuting alone by car to work by encouraging the use of more environmentally friendly modes such as public transport, cycling and walking. One of the measures identified as achieving this objective was employer-driven, through the introduction of a P&R service via a large off-site parking space with a shuttle-bus serving the workplace.

Because the P&R service was a new mode of access and there was no existing data, stated rather than revealed preference estimation was the only option. All staff were asked whether they would choose to travel to work as usual or use P&R if such a service was provided by the University. There were three choices – 'Park-on-site', 'P&R', 'Don't know'). P&R door-to-door travel time and costs were varied over three different levels relative to the individual's current commute. Of the 1661 questionnaires distributed, 642 were returned (38.7% response rate), with respondents categorised as academics (or non-academics), and by income (low and high) based on their occupation.

A number of different forecasting approaches were examined; all were based on a binary logit model where people chose between two modes (in this case car and P&R), but differed in that parameters were corrected for respondent biases. The study identified that stated and revealed preference models may not give the same parameter values, primarily due to different sources of error.

It was found (assuming the same travel costs for both car and P&R) that estimates for the P&R mode share ranged from 18.5% (without scaling) to 12.1% (when rescaled). An alternative approach to the rescaling problem was suggested by Fowkes and Preston and involved the averaging of the probabilistic (18.5% mode share) and deterministic (0.4% mode share) parameters, which resulted in an estimate of 9.5%.

Ghali et al. (2000) report the results of travel behaviour research including road user charging, PT fares/integrated ticketing, parking charges, P&R initiatives and HOV lanes. Work was carried out at eight European cities (Athens, Como, Madrid, Leeds, York, Helsinki, Göteborg and Graz), although the project was only half completed at the time the paper was written.

As part of the project, a common SP survey was undertaken, concentrating on present car users and their willingness to change to PT or P&R if the price of using a car was substantially increased. The target sample size in each city was 300 interviews (split as home-based work, shopping and other trips). Respondents were recruited at parking and office buildings and basic information about their journeys collected to tailor the SP survey to their current journey. In the SP questionnaire all the attributes had three levels; for all travel times and costs for PT and P&R the levels were 80%, 100% and 120% of the base value, and for car costs the levels were 100%, 150% and 200%. Ten questions were then asked (including a reference question using existing status).

Unfortunately the paper only provides limited results and conclusions and little is applicable to P&R. Modelling for York however included P&R as a mode, and a bus priority measure (resulting in an 18% reduction in bus travel times) increased P&R usage by around 3%.

3.4.2 Revealed preference studies

In 1996, London Transport (LT) commissioned consultants Oscar Faber to assess the potential to develop car parks in the outer fare zones of London where land costs are relatively low and generated fare revenues are potentially high. Central to developing station car parks was the notion of 'gateway' stations, which would be highly accessible from the major road routes and incorporate a number of facilities that would be potentially attractive to existing car users. The demand model developed was a simple logit model where a diversion curve was used to estimate the proportion of trips switching from one mode to another based on the differences in the mode's generalised cost – in this case from car all the way to P&R. Models for two time periods were estimated: am peak (7 am to 10 am) and interpeak (10 am to 4 pm).

The P&R mode generalised cost of travel included:

- access time to the station
- cost of parking at the station
- walking from the car park to the platform
- cost of the ticket
- waiting for the service
- ride time on the service
- walking to final destination.

The car mode included:

- time spent driving the car
- time spent looking for a parking space
- cost of parking
- walk to final destination.

Vehicle operating costs were also included for the time spent in the car under both modes. The study does not mention how the parameters were obtained or how successful the methodology was for representing existing and future behaviour. However, potential demand for P&R was then converted into space required through an assumption of 25 m^2 per car parking space.

A University of Melbourne study (Joyce 1978) examining 'The choice of access mode to a suburban rail interchange' looked at developing access mode models to rail services through the use of binary mode (walk, bus, P&R and K&R) choice models. For Box Hill station, a zonal (aggregated) analysis was undertaken to derive relationships to give the proportion of passengers using each access mode based on distance, the level of bus service in the zone (comparison of walk vs total bus time), and car availability (proportion of zero, one and multi-car households). Equations for walk and bus gave the best validity (relating to distance, bus service and zero car households), with P&R and K&R models (relating to all variables) yielding poor results, with no significant parameters. The conclusion from the Box Hill study was that the relationships developed were of limited use for estimating car access proportions.

A survey was then conducted to look at developing models based on disaggregated information from individuals. Using discriminant analysis it was found that including household variables such as numbers of people in the household, number of household cars, where adults exceeded cars, and time and cost achieved the highest significance. However, the study concluded that small sample sizes in each binary pair contributed to poor levels of significance and that at best the survey indicated segmentation within population groups and classes only, rather than valuations of relative access modes.

Leicestershire County Council commissioned work (undertaken by the Transport Research Laboratory) in 1997 to model P&R and road pricing with MVMODL (a TRIPS-based software package) as part of the Leicester Environmental Road Tolling Scheme (LERTS) (Tolofari 1997). LERTS comprised three elements – namely bus priority measures, a P&R facility and a road pricing experiment. The modelling tools included the county council's link-based morning peak Greater Leicester Transport Model highway and public transport model. P&R was represented through the generation of highway and PT costs and the use of a two-stage method within MVMODL. The first stage involved an incremental choice model, which gave the change in demand between car and PT users due to cost changes between the base and option networks. The car category was then segmented further through the use of an absolute model into car all the way and P&R trips due to the introduction of the new mode (P&R).

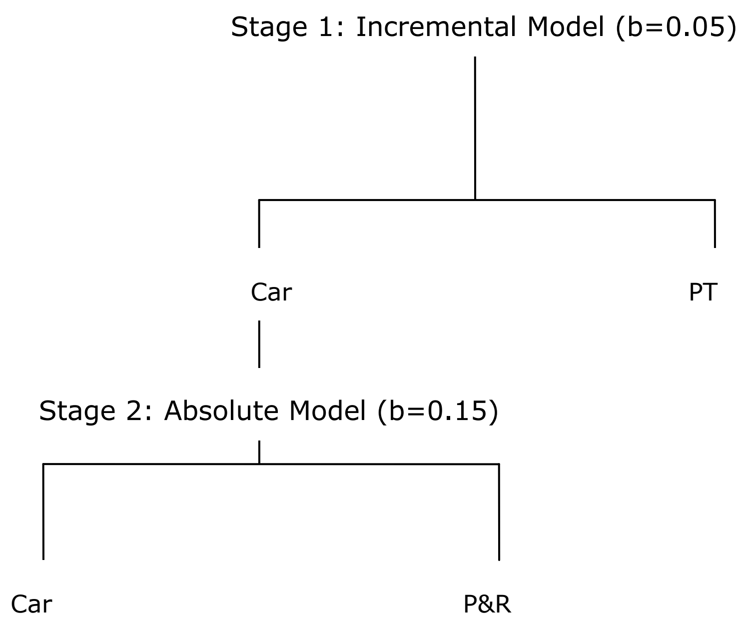

Figure 2.2 Mode choice model structure for LERTS.

To obtain a converged solution, the entire process was run through three loops. P&R bus usage assumed the same cost components as normal bus, but an additional interchange penalty of 10 minutes.

Lythgoe and Wardman (2004) examined a methodology for modelling passenger demand for parkway rail stations; at the time of writing there were around 15 such stations in

Great Britain. The purpose of the research was to develop a framework (focusing solely on inter-urban – longer than 80 km journeys) for modelling demand at parkway stations, which have a level of competition (with each other). It was concluded that the inclusion of a competition parameter improved the explanatory power of existing elasticity forecasting techniques and resulted in a more plausible generalised cost elasticity.

Lythgoe and Wardman list four desirable features that the parkway model should include:

- station choice, as parkway stations are likely to have overlapping catchments, where improvements at one site may abstract from others
- generation of new rail trips
- a procedure that is not too data intensive
- demand parameters that are suitable to parkway attracted travellers.

The model took the form of a hierarchical logit model, which included generalised cost calculations for an origin zone to an intermediate (parkway) station, and then from the station to the destination. Separate cost estimates were determined where an origin zone was served by more than one parkway station (a station choice model). A function of distance was also included in the model. The final parameters obtained were:

Table 2.3 Logit model parameters for a parkway station

Parameter	Estimate	T-Value
λ - spread	-8.429	-49.82
θ - generation	0.498	37.07
ζ - distance constant	-26.699	-18.45
η - distance factor	-0.009	-16.72
Adjusted R^2	0.5318	

As Lythgoe and Wardman (2004) discuss in the text, $\lambda\theta$ is the elasticity of rail demand given a change in generalised cost and in this case is -4.2. Analysis of non-London inter-urban flows gives a GC elasticity of -1.71 and a separate access time elasticity of -0.61, or a combined impact of -2.32. The higher elasticity for parkway users may be explained by the largely car-based market having distinctly different preferences for a stronger rail service and an aversion to access time – given they have a car available for use. The elasticity of -4.2 is converted to its constituent components by their proportion of total generalised costs: GJT=-2.27, fare=-1.1, access time=-0.66, access cost=-0.17. Elasticity to journey time (GJT) of -2.27 is significantly higher than the widely held average of -0.9, indicating that it is the strong competition between rail service quality and car that is the main contributor. The two terms ζ and η indicate that non-rail utility decreases with distance, but is a relatively small effect.

4. Summary

This section has outlined the approaches adopted for modelling P&R demand. Techniques have become more complex as computing power has increased, with P&R multi-modal routines now being included in large regional models. Interest in P&R (and subsequent demand estimation) is likely to increase as car operating costs (through fuel increases) rise.

International modelling practices of P&R revolve around two main techniques; namely direct regional and site-specific approaches. Direct regional approaches use the relative costs of P&R against other modes to develop mode split functions that can be applied to the catchment population of a site. They are responsive to changes in the measurable cost attributes of transport (such as frequency, travel time and fares), but do not usually include some of the more local (and perceived) measures such as safety and local accessibility of site. Regional approaches can also be used to determine abstraction from other modes (such as car or PT all the way) as well as competition between sites (when catchments overlap) through a site-choice logit model.

Parameters for mode-split models rely on stated or revealed preference data. Stated preference data for P&R is generally difficult to collect due to P&R being a small proportion of the total PT market. SP scenarios also generally need to include extreme changes in costs to encourage mode switching behaviour and even then a significant proportion of respondents will not change. As such, P&R SP surveys can be an expensive exercise and the results of limited value. RP data is the easiest source of model parameters but requires P&R to be an existing and statistically significant mode.

Site-specific models differ from regional models in that they ignore other modes and are based purely on characteristics relating to the site (through the use of linear regression equations). These can give better estimates for individual sites as the calibration (to existing usage) can be more exact and more of the local site facility attributes can be included. However because other modes are ignored, there is no indication of abstraction from other modes and it is difficult to estimate the impact on nearby sites. As many attributes are often highly correlated, a robust model may not include transport-related variables such as travel time or fares.

Both techniques require the definition of a catchment – the area around a P&R site where potential users are located (See Part 1, Section 5.3). Catchment shapes and sizes have been researched particularly in North America, with the shape being fairly constant between studies: the 50-percentile demand can be approximated by a circle and the 85 percentile by a parabolic curve aligned towards the main direction of travel. The dimensions of the circle and parabola are context specific and relate to local conditions such as levels of congestion, and site closeness. Generally it has been found that catchment definitions, site-specific and regional models can be universally applied, but that parameter values vary significantly from application to application.

In conclusion, both techniques have their own strengths and weaknesses and are sensitive to differing transport attributes. The development of two models, namely a site specific and a regional model (using circular catchments) is therefore probably the best combination for modelling P&R demand for a transport network.

Part 3: Analysis and model development for Wellington

1. Part 3 overview

The section outlines the development and testing of two park and ride (P&R) forecasting models for Wellington, for which current P&R usage is significant, data is readily available, and a suitable regional transport model exists. The models developed here could be applied (albeit with different parameters) to other locations.

The section examines two different approaches (regional and site-specific) to modelling car access/P&R demand to rail stations. Both approaches require the definition of car access catchments to each site. While this is easy to do when observed data exists, defining a catchment for a new station is more difficult. Station catchments also depend on the level of service offered. It was found that for Wellington stations, catchment size could be related to the number of express and total services serving the station, the time and distance to the central business district (CBD), whether the parking site was lit and whether it was at the end of a line.

2. Modelling frameworks adopted

Part 2 of this report 'Review of international modelling practices', outlined three main approaches undertaken when estimating P&R usage; namely 'post-modelling', 'regional', and 'site-specific' frameworks. While each approach has its own level of sophistication and its own advantages and disadvantages, they are essentially complementary and provide a sense-check of each other.

While post-modelling is the simplest approach, it ignores changes in level-of-service (such as fare, frequency or journey time changes) and does not address the issue of station/site choice. It has, therefore, not been considered further. Instead, a regional model and a site-specific model have been developed and a series of scenario tests undertaken.

A stated preference (SP) survey was also conducted as part of the modelling project to provide parameters for comparison with those derived from revealed preference (RP) analyses for the Wellington region. However, it became apparent after the survey pilot that conducting a large and statistically meaningful SP survey would be very expensive, and the survey was terminated at the pilot stage without parameter estimations. A detailed description of the pilot SP survey is given in Appendix E.

An important first stage in modelling P&R demand is to define the catchment for each potential P&R site. This is described in the next section, following which separate regional and site-specific models are developed.

3. Development of a P&R site catchment model

3.1 Overview

A critical element of P&R usage estimation is the definition of a P&R site's catchment area. This area represents the potential market of population/travellers that would feasibly use the site. These catchments are primarily used for the site-specific approach where inputs into the model relating to population characteristics are required, although catchments can also be defined within a regional model approach. The definition is particularly important in estimating demand at new sites, where there is no relevant observed data to define the potential market. Catchment areas may also change as characteristics of the site change (for example a catchment increasing as express services begin to serve a station).

This part of the report outlines the current characteristics of car access catchments to Wellington rail stations and derives models that can be used to define area sizes given changes in site characteristics. These are also applicable to new site market definition (similar models for other regions could be developed but with regional-specific parameters).

3.2 Observed access characteristics

A 2002 rail survey undertaken by the Greater Wellington Regional Council (GWRC) was the primary data source used to define catchments. Distance as recorded in the survey is straight-line distance rather than road-based. As such, all distances recorded here are straight-line[1]. Based on the 2002 rail survey, approximately 50% of car access to all rail stations in the Wellington Region is within 1.85 km, 75% within 3.5 km and 90% within 6.5 km. The maximum distance passengers are prepared to travel by car to access rail is 32 km and the minimum is around 250 m (this also includes car drop-off). Car passenger distance ranges are 1.6 km for 50%, 3.1 km for 75% and 5.9 km for 90% of demand.

[1] GWRC suggests a factor of 1.36 on average to convert to road-distance, although this will differ widely between zones as well as by distance; sample calculations give a factor of 1.68 for 1 km reducing to 1.18 for 50 km.

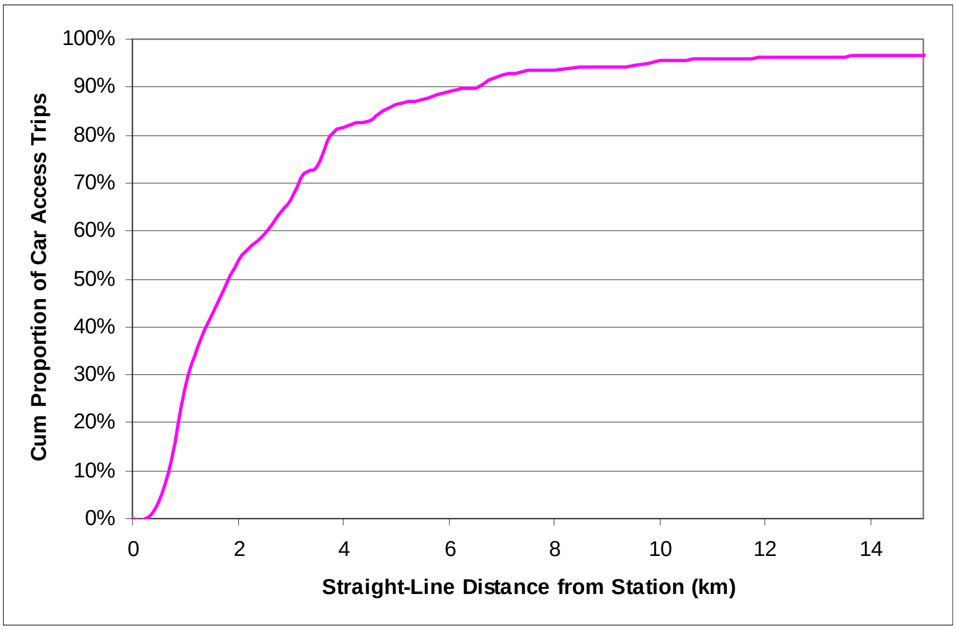

Figure 3.1 Car access cumulative trips by straight-line access distance (all stations).

At the station level, there is a wide variation in the size of the 50% catchment (the distance within which 50% of car access occurs), ranging from 330 m for Crofton Downs, to 3.2 km for Porirua. Other stations with larger catchment areas include Waterloo (2.6 km), Upper Hutt (2.7 km) and Paraparaumu (2.9 km). We would expect there to be a larger spread of catchment radius as the proportion of total demand included increases, due primarily to geographic constraints. The table below shows this, with 50% catchments ranging from a few hundred metres to around 3 km and the 90% catchments from around 1 to 9 km. All stations on the Johnsonville line have relatively modest catchment sizes, due primarily to terrain constraints and the resulting relatively high-density corridor.

Table 3.1 P&R observed catchment distance at 50%, 75% and 90% levels.

Site	50% Catchment distance	75% Catchment distance	90% Catchment distance	Ratio 75%:50%	Ratio 90%:75 %
Hutt line					
Petone	2.09	4.66	9.16	2.23	1.97
Woburn	1.18	3.64	6.46	3.08	1.77
Waterloo	2.63	5.08	7.69	1.93	1.51
Taita	2.17	2.70	3.04	1.24	1.13
Silverstream	1.01	1.69	3.52	1.67	2.08
Trentham	1.07	1.49	1.67	1.39	1.12
Wallaceville	1.22	1.53	1.58	1.25	1.03
Upper Hutt	2.75	3.29	5.25	1.20	1.60

Site	50% Catchment distance	75% Catchment distance	90% Catchment distance	Ratio 75%:50%	Ratio 90%:75 %
Melling	1.78	3.69	4.50	2.07	1.22
Johnsonville line					
Crofton Downs	0.33	1.54	3.46	4.67	2.25
Ngaio	0.53	0.73	1.35	1.38	1.85
Simlar Crescent	0.69	1.29	2.39	1.87	1.85
Khandallah	0.45	0.58	1.03	1.29	1.78
Raroa	1.29	1.32	2.22	1.02	1.68
Johnsonville	1.07	1.84	2.30	1.72	1.25
Western line					
Takapu Road	1.10	3.40	7.94	3.09	2.34
Redwood	0.86	1.27	1.73	1.48	1.36
Tawa	1.01	1.44	3.60	1.43	2.50
Porirua	3.23	3.92	5.20	1.21	1.33
Paremata	2.04	3.01	3.03	1.48	1.01
Mana	0.94	2.31	4.15	2.46	1.80
Plimmerton	1.31	1.59	4.70	1.21	2.96
Pukerua Bay	0.37	0.37	0.37	1.00	1.00
Paekakariki	1.17	5.64	8.28	4.82	1.47
Paraparaumu	2.93	5.14	7.59	1.75	1.48
AVERAGE (weighted by trips)	**2.08**	**3.79**	**5.78**	**1.82**	**1.53**

International research has shown that the incremental benefit of using a 75% over a 50% catchment area is low and that statistically robust models could be developed with 50% catchment areas. In the case of Wellington, increasing the catchment demand size from 50% to 75% (by 50%) requires an increase in radius of 82% (3.79/2.08-1), or an increase in area for data collection of 232% (assuming circle). Subsequently designing a catchment for 90% demand (increase of 20% over 75% demand) requires an area increase of 133% over the 75% case. Data outliers caused by survey error are also removed by using the closest 50% demand.

International studies have also shown that the 50% catchment could be defined as a circle centred on the P&R site, whereas percentiles larger than this were better modelled as a parabola (with the site at a focus and long axis towards the CBD).

Applying this to the Wellington Transport Strategy Model (WTSM), Figures 3.2 and 3.3 show the size of the 50% catchment areas, and the WTSM zones included. Individual colouring relates to the station within the catchment. Hatched colouring shows zones where station catchments overlap (and so relate to more than one station). The size of the red circle is the radius from Table 3.1 above at the 50% level.

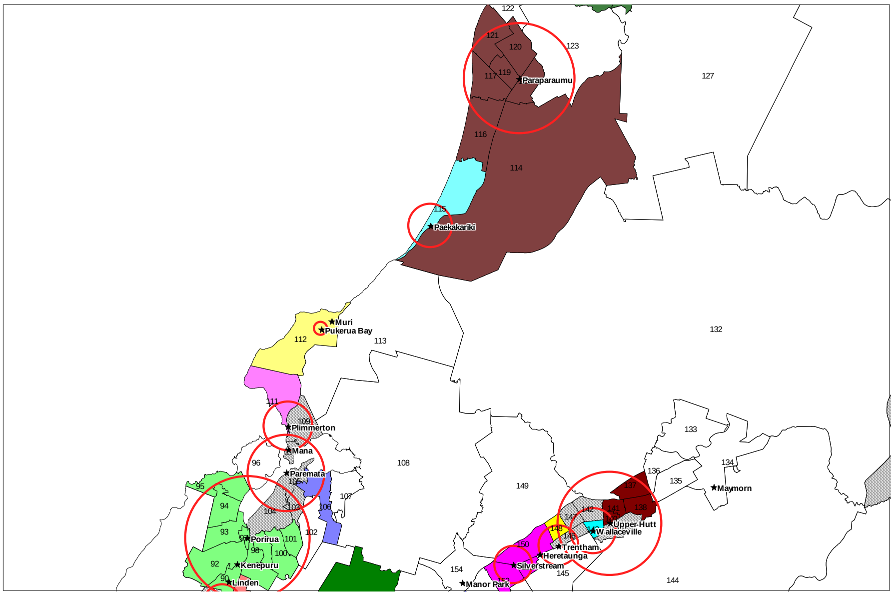

Figure 3.2 50% catchment areas for P&R stations (north).

The northern part of the network contains zones which are large and have little population. North of Plimmerton, station catchments are clearly definable on the western line, with no catchment overlaps. The zone around Pukerua Bay is significantly larger than the catchment, so we may expect an over-estimation of demand for this station (this becomes evident when applying the regional approach model). Through Mana Esplanade, the stations of Plimmerton, Mana, Paremata and Porirua overlap significantly, which may result in the distribution of car access trips between stations to be inaccurate.

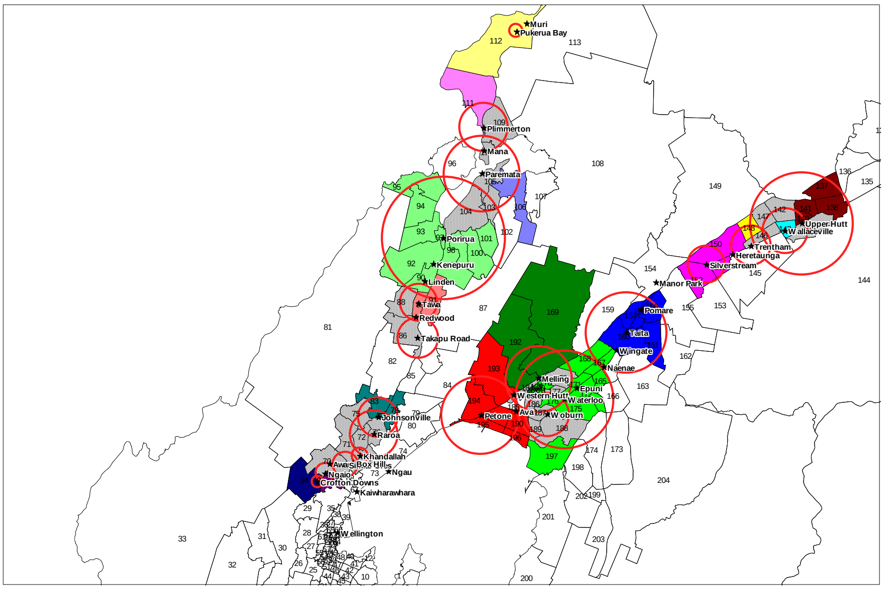

Figure 3.3 50% catchment areas for P&R stations (south).

For the Hutt Valley and Johnsonville, there are larger areas of catchment overlap, particularly in Lower Hutt where Woburn and Melling station catchments compete with Waterloo. Similarly in Upper Hutt, Wallaceville and Trentham are both in close proximity to Upper Hutt station. Almost all the zones within the Johnsonville line catchment overlap in some way.

Looking at other modes of access, as distance from the station increases the proportion of people accessing via car increases, until at 10 km virtually all access is car-based. The point at which people show indifference between walking and car access is around 800 m (where the shares are equal). Bus access to rail plays a minor role, with virtually no bus access within 1 km of the station and a fairly constant representation until around 8 km. Between 2 km and 8 km, bus and walk have similar mode shares (with the longer-distance walk trips including cycling). For better bus-served stations such as Porirua and Waterloo, the average bus modeshare between 2 and 10 km is 21% and 11% respectively.

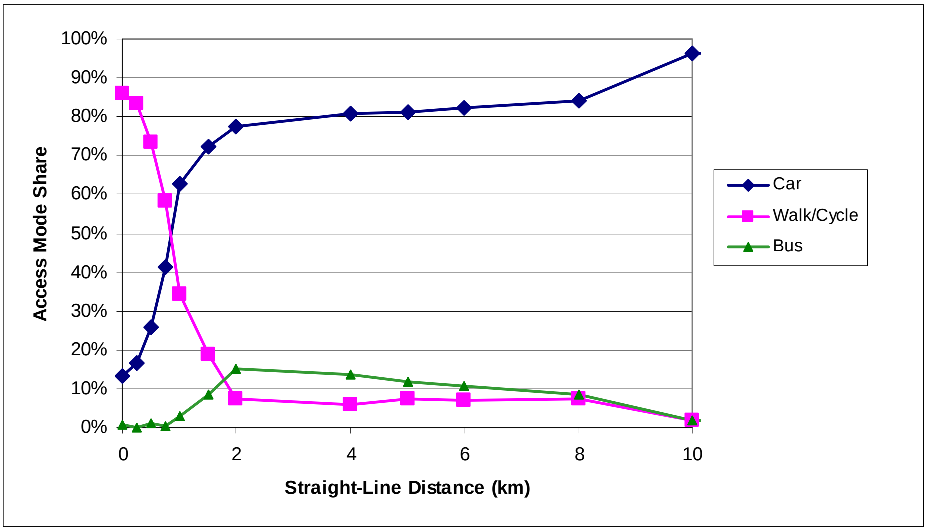

Figure 3.4 Access mode share by distance (all stations).

3.3 Catchment model estimation

The catchment model relates the 50 percentile demand radius from station to a number of attributes. A wide range of variables have been included in the regression, consistent with those used in Part 3, Section 5.2.2 for the site-specific model estimation. These have been categorised as 'transport related' and 'facility related' on the premise that the size of the catchment associated with a station is related to the level of service and facilities at that station. An initial hypothesis of expected impact on catchment size has also been made. The list of attributes included here is not exhaustive and relates to the information available at the time of this study.

Table 3.2 P&R catchment size variables included in regression.

Variable	Description	Source	Expected impact
Transport related			
AMSERVCBD	Number of peak express rail services to CBD	Timetables	**Positive**
AMSERVTOT	Total number of peak rail services to CBD	Timetables	**Positive**
BESTTIME	Best rail time to the CBD (mins)	Timetables	**Negative**
RATCARPT	Ratio of PT:Car generalised costs from station to CBD	Wellington Regional Model	**Negative**
DIST	Distance (km)	Wellington Regional Model	**Positive**
FARE	Adult fare to CBD ($)	Fare schedule	**Negative**
CLOSESTA	Time to next station in CBD direction (mins)	Timetables	**Positive**
ENDLINE	Station at the end of a line (0,1)	Timetables	**Positive**
Facility related			
SAFETY	Car park is patrolled (0,1)	GWRC P&R site inventory	**Positive**
PAVING	Car park is sealed (0,1)	GWRC P&R site inventory	**Positive**
LIGHTING	Car park is lit (0,1)	GWRC P&R site inventory	**Positive**
TRANSINFO	Car park is advertised for P&R (1,0)	GWRC P&R site inventory	**Positive**
PROXSH	Proximity to state highway (km)	Maps	**Negative**

The statistical estimation package LIMDEP was used to perform a multi-variate regression. The process undertaken was to include as many variables as possible in the starting model and then eliminate the least significant or wrong signed variables until the maximum adjusted R^2 was found.

'External' stations (Waikanae, Featherston, Woodside, Carterton, Solway and Masterton) have been excluded from the analysis as the catchment sizes from the survey and input variables are significantly coarser than the suburban rail network.

The estimated models adjusted R^2 began at 0.81 and finished at 0.83; not a significant improvement in predictive power, but a much simpler model. The process is described below:

- start with all variables (0.813)
- remove CLOSESTA as least significant and wrong sign (0.828)
- remove RATCARPT as least significant (0.840)

- remove TRANSINFO as least significant (0.849)
- remove PAVING as wrong sign (0.823)
- remove FARE as least significant (0.828)
- remove SAFETY as least significant (0.832)
- final adjusted R^2=0.832.

Table 3.3 Regression equation parameters for P&R catchment distance (excl externals).

Variable	Coefficient	P-value	Adjusted P-value*	Comment
AMSERVCB	0.137	0.005	0.097	Every additional CBD express service to serve station adds 137 m to the catchment radius
AMSERVTO	0.108	0.000	0.018	Every additional CBD service to serve station adds 108 m to the catchment radius
BESTTIME	-0.070	0.003	0.074	For every additional minute the best time to the CBD is reduced, 70 m is added to the catchment radius
DIST	0.057	0.017	0.168	For every km the station is from the CBD, an additional 57 m is added to the catchment radius
PROXSH	-0.167	0.115	0.378	For every km the station is closer to a state highway, the radius reduces by 167 m
LIGHTING	0.807	0.001	0.056	A station site that is lit adds 807 m to the catchment, although this is likely to be a proxy for other security attributes
ENDLINE	0.924	0.000	0.024	A station at the end of the line has a larger catchment radius of 924 m compared with a non-end of line station.

* The adjusted P-value rescales the standard error to take account of using aggregated data

Table 3.3 above gives the final model formulation and resulting conclusions. The adjusted P-value takes into account the use of expanded data.

Table 3.4 below gives a comparison of observed versus modelled 50% catchment sizes. Stations where car access demand is at its highest are represented accurately, including Petone, Waterloo, Upper Hutt and Paraparaumu. The largest differences are at the less significant stations such as Wallaceville and Raroa, although Porirua and Plimmerton do not provide a good fit. The underestimation of catchment size at Porirua is likely to result from an under-representation of its importance in terms of express services (where it is the last station before the CBD).

Table 3.4 P&R observed versus modelled 50% catchment size.

Site	2002 rail am peak 50% catchment distance	Estimated model distance	Difference
Hutt line			
Petone	2.09	2.07	-0.02
Woburn	1.18	1.12	-0.06
Waterloo	2.63	2.83	0.20
Taita	2.17	2.37	0.20
Silverstream	1.01	0.96	-0.05
Trentham	1.07	0.90	-0.17
Wallaceville	1.22	0.82	-0.40
Upper Hutt	2.75	2.66	-0.09
Melling	1.78	1.64	-0.14
Johnsonville line			
Crofton Downs	0.33	0.23	-0.10
Ngaio	0.53	0.83	-0.30
Simlar Crescent	0.69	0.70	0.01
Khandallah	0.45	0.63	0.18
Raroa	1.29	0.75	-0.54
Johnsonville	1.07	1.35	0.28
Western line			
Takapu Road	1.10	1.12	0.02
Redwood	0.86	1.09	0.23
Tawa	1.01	1.08	0.07
Porirua	3.23	2.42	-0.81
Paremata	2.04	1.93	-0.11
Mana	0.94	1.05	0.11
Plimmerton	1.31	1.95	0.64
Pukerua Bay	0.37	0.65	0.28
Paekakariki	1.17	1.31	0.14
Paraparaumu	2.93	2.88	-0.05

4. Regional modelling approach

4.1 Overview

The regional modelling approach includes P&R as a distinct mode within a multi-modal model, through the use of a mode-split (logit) function. This allows changes in other modal costs to be included and site-choice to be developed. However, the success of such an approach is dictated by the quality of the survey/observed data and the accuracy of the regional model.

4.2 Data

The regional modelling approach requires an extensive amount of data relating to observed travel demand behaviour (revealed preference data) and corresponding travel costs. Observed travel patterns are determined usually through the use of travel surveys: for the Wellington region, the available surveys included a Household Interview Survey (HIS) conducted in 2001, a rail survey conducted in 2002 and various P&R site surveys. Travel cost components are usually obtained from a multi-modal model (in this case WTSM), but can be determined through the use of public transport timetables and road-based distances and parking costs; however, this is significantly more time-consuming. GWRC supplied the raw survey output as well as car and PT generalised cost skims from the regional model.

4.2.1 Travel demand data

The first task involved the creation of the observed travel demand data. Low sample rates for rail users in the 2001 HIS meant that a subsequent 2002 rail survey was undertaken. For this project, all rail main-mode data was deleted from the HIS dataset, with the rail survey data replacing it (as was done in the WTSM redevelopment). The P&R survey data was not used as it had not been expanded and the rail survey captured all the required characteristics.

Segmentation of the datasets was required, based on:

- **Main mode of travel**, where three main modes of travel were included. 'Car all the way' includes both car driver or passenger and does not include a PT leg. 'PT' all the way includes all PT (rail and bus grouped) main-mode trips that do not have a car access component either as driver or passenger (so for rail will include bus feeder and walk access trips). P&R includes all rail trips where the station has been accessed via a car either by a driver or passenger. Slow mode (walk or cycle all the way) has been excluded from the analysis.
- **Car availability**. There are significant issues when trying to split out (PT) captive, competition and choice (which are distinguished in WTSM). Firstly, the two surveys did not ask consistent questions on car availability. The rail survey asked whether there was a car available (as driver, as passenger, or not at all) whereas the only definition that can

be gained from the HIS is based on household car ownership and relativities to the number of car-driving occupants. Also the rail survey has a number of passengers who said they did not have a car available either as driver or passenger, but still accessed the rail station via car driver or passenger. However these inconsistencies aside, competition and choice have been separated. For rail trips, 'captive' defines users who did not have a car available (as driver or passenger), 'competition' defines users who had a car available as passenger and 'choice' defines users who had a car available as driver. For all other trips, captive defines zero car owning households, competition is where number of household adults exceeds number of cars and choice is where adults are equal to or less than cars. PT captive trips have been excluded as they do not have cars available.

- **Time period**. The analysis only considers am peak trips, as this is the time period where P&R is significant. The general definition for the morning peak in Wellington is 7–9 am. HIS uses the mid-point of the journey, whereas the only time-based information in the rail survey is the rail boarding time (which is not likely to be the mid-point). To overcome this, a rail survey boarding time of 6.30–8.30 am was used as this was the two-hour period which maximised the expanded rail demand. There is, however, an inconsistency in the am peak definition between the two data sources.
- **Trip purpose**. Both surveys asked consistent trip purpose questions. The dominant segment for P&R usage was for home-based work (HBW) trips and so only these have been included in the analysis.
- **Trip destination**. The rail survey suggests that a majority of P&R trips are to the CBD – initial model estimation involving all trip data proved unsuccessful and so only CBD destination trips have been included
- **Trip origin**. Only trip origins involving rail and P&R via rail have been included in the analysis. The Wairarapa has been excluded due to inadequacies in its inclusion in the regional model (large zone sizes) and sparseness of observed data.

Table 3.5 below shows the incremental effect on car access trips of excluding each segment. The largest impact is when captive trips are excluded – these are people who said they did not have a car available as driver or passenger and yet still accessed the station via car (presumably the car was not available for the complete trip to work). Removing non-CBD destined trips eliminates 800 from the analysis and including only rail corridor zones eliminates a further 200.

Table 3.5 Car access trips by exclusion

Exclusion	Car access trips	Change on base
2002 rail survey am peak	5,175	-
+ Exclude PT captives	4,261	-914 (-18%)
+ Exclude non-CBD destination	3,459	-1,716 (-33%)
+ Exclude origins outside scope	3,260	-1,915 (-37%)
+ Exclude non-HBW purposes	3,116	-2,059 (-40%)

The market has, therefore, been defined as car all the way (as driver or passenger), PT all the way, or P&R HBW trips in the morning peak to the Wellington CBD where a car was available for the journey with base P&R trips of 3,116. Correction factors have been used for site usage to account for excluded car access trips.

4.2.2 Cost skim data

Cost skims from the WTSM were used in the development of a regional-based model. WTSM is a multi-modal strategic transport model, which has highway and PT-based generalised cost matrices as an output. At the time of this study, only total costs were available to the modelling team and so time and cost components could not be separated. There are some issues with the cost skims that need to be recognised.

First, the PT cost skim includes an access cost to PT; however, the access cost is a weighted average of walk and car access to PT. In other words, when connectors are longer, the incremental time on the link is reduced. Having car access represented on connector links is potentially a problem, although we would expect access within the same zone as the station to be mostly walk, and so this will have little bearing on the combined car and PT cost that would be required for the P&R mode.

Second, while there are cost skims for car and PT, there are no cost skims for P&R. P&R costs can be thought of as the combination of car and PT costs. Splitting a P&R trip into two legs, namely the car and then the PT (and assuming no car at the egress end), the total cost is the car cost from the trip origin to the rail station of choice, plus the PT cost from the station to the final destination. A rational traveller would choose the intermediate rail site so that the combined cost would be minimised. In other words:

$$PRCost_{i,j} = MIN_k \left\lfloor CarCost_{i,k} + PTCost_{k,j} \right\rfloor$$

where:

PRCosti,j = P&R cost between origin i and destination j

CarCosti,k = Car cost between origin i and intermediate site k

PTCostk,j = PT cost between intermediate site k and destination j.

Emme/2 has a ‘matrix convolution’ function which can be used to undertake complex matrix calculations such as this. For this project, a dummy Emme/2 network was built containing the zone numbers from the WTSM model. The car and PT generalised cost matrices were then input into the network and combined minimised P&R costs between each zone pair was developed. If this process was being undertaken within the regional model then a better approach would be to code P&R sites with their own individual zones, so that more accurate costs to and from the intermediate (P&R) sites could be calculated and represented. This approach is being done outside the model, but using the same techniques and as such an approximation has been made whereby the site-related costs are assumed to be the same as the zone it lies within.

Finally, the zone size within WTSM could be considered too coarse for a P&R model. Many P&R trips originate from the same zone as the station and an intrazonal access cost between the two must be asserted. Some zones also contain more than one station making it difficult to separate the two nodes. Finally, large zone sizes result in reduced variation in costs making robust models difficult to estimate.

4.3 Model estimation

Mode-split models are usually of a multinomial or nested logit form, where the cost of each mode between a zone pair is the input and the proportion of trips by each mode is the output. A multinomial logit model assumes that all modes compete directly with each other (each mode is highly substitutable with the other modes) and as such all lie on the same level within the decision tree. In other words, a reduction in car costs will abstract a similar proportion of demand from all other modes. A nested logit on the other hand assumes that different mode groups have differing levels of competition, with sensitivity reducing as a traveller moves up the decision tree. In this project we have initially hypothesised that we would expect PT and P&R to be directly competitive (due to the PT component in both and the fact that car availability has been segmented by captive/competition/choice), with car being less sensitive to changes in either. So the structure would look like:

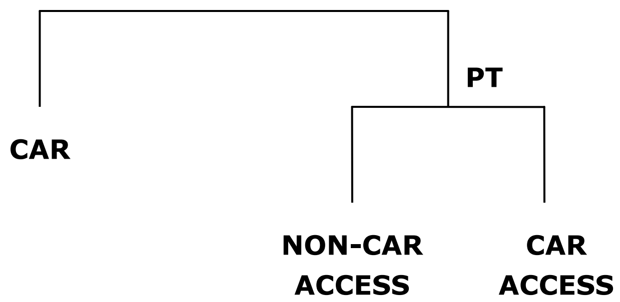

Figure 3.5 Hypothesised mode split structure.

One approach to testing whether the above structure is sensible is to look at the parameters from the estimation (lambda and mode-specific constants (MSCs)). The lambda represents the sensitivity of choice to the cost difference between modes – there is a different value for lambda at each level with the relative sensitivity of each level represented by theta (the ratio of the upper level to the lower level lambda). Lambda should decrease as we move up the tree (so theta should be less than '1'), indicating a reduction in sensitivity. So in the above structure a change in car access PT costs will have the largest impact on non-car access PT costs and a smaller impact on car all the way. If it is found that the value of lambda at each level is similar then this indicates all modes have a similar level of competitiveness and so a multinomial structure (all modes at the same level) is more appropriate.

MSCs are balancing factors that match the total number of trips by each mode observed. Whereas the lambda looks at the cost difference between modes, the MSC only relates to an individual mode and represents a fixed cost that is not included in the cost skims. This fixed cost may be a perceived cost that travellers face, but is not captured in the cost skims (such as comfort, reliability etc.). It may also represent inaccuracies or biases within the model that has supplied the skims. For this reason, MSCs are often difficult to interpret.

4.3.1 Parking capacity restrictions

Initial estimated models tended to overestimate P&R demand at smaller stations, which have limited car park spaces and overflow capacity (on-street parking). Station-specific time-based penalties can be used to restrict P&R usage when demand exceeds capacity. Calibrating such penalties is difficult (particularly where catchments overlap). The approach undertaken was to estimate the full model, look at where demand exceeded capacity, manually adjust penalties and re-estimate the model. This was repeated until a converged solution was reached.

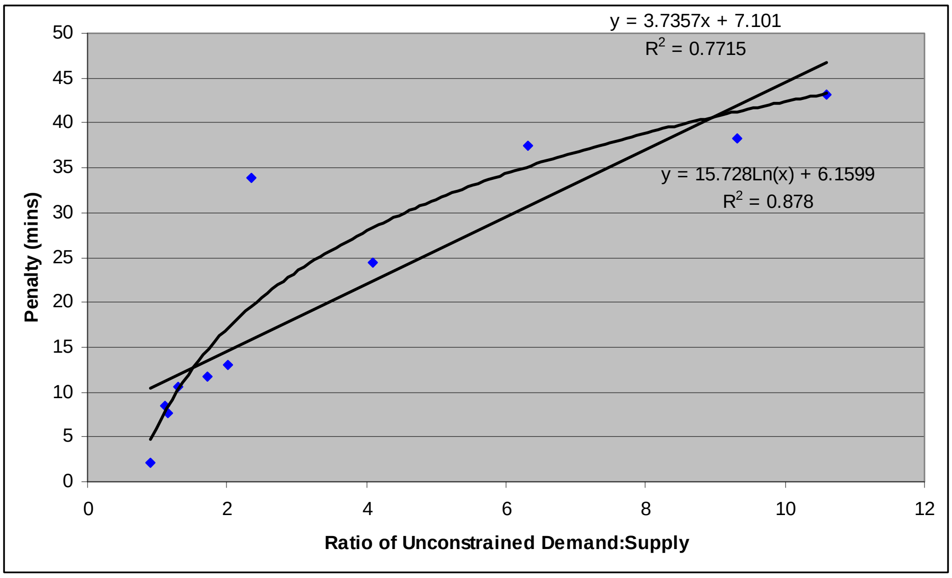

Figure 3.6 Station site penalty versus unconstrained utilisation.

Figure 3.6 shows the site-specific penalties given the initial utilisation (unconstrained demand divided by spaces). Linear and logarithmic lines of best fit have been determined; the linear best fit indicates a fixed 7.1 minute penalty and 3.7 minutes for every multiple by which the site capacity is exceeded; the log curve has a better fit and gives a fixed penalty of 6.2 minutes and a log coefficient of 15.7 minutes. There is one significant outlier which gives a penalty of around 35 minutes for an unconstrained utilisation of around 2. This observation corresponds to Pukerua Bay/Muri stations, which are located in an area of the model where the road and zone system is particularly coarse.

Implementing the penalties within the methodology is done through an iterative process. Initial station demands are determined via the model and, where demand exceeds supply, the ratio of demand to supply is added as a penalty. The process is repeated until demand at all stations is less than supply. For example, say a station initially has an unconstrained demand/supply ratio of 3, then in the first iteration a 3-minute penalty is given to the station. The second iteration may result in a demand/supply ratio of say 1.5 and so this is added to the 3 to give a total penalty of 4.5 minutes. This is repeated until the utilisation is less than 1.

A shortcoming of this approach is that the utilisation may fall below '1' with a penalty rather than being exactly 1. The process was modified so that there was a reduction in the penalty when the utilisation was less than 1 (for stations that had a penalty), although this proved to make little difference to the answer and caused problems with convergence. However, further improvements to this approach could be made.

4.3.2 Model calibration

A number of models were estimated and tested. Initially the CBD-only models overestimated shorter-distance P&R trips, and under-represented longer-distance and so distance as a scaling factor was also examined. Including distance involved dividing the modal costs by a function of distance – the square-root of distance gave the best fit.

Eight estimated models are outlined in Table 3.6 based on scaling costs by the square-root of distance. These models differ as to whether competition and choice are segmented, whether a nested or multinomial structure is assumed, or whether unweighted data (by trips) is used. None of the models estimated gave particularly good R^2 values (goodness of fit), but lambda signs and relativities (between lower and upper values) look broadly sensible apart from the nested unweighted which suggested a more sensitive upper level. The theta (level of competitiveness between car and PT modes) indicates that PT is more of a substitute for car under a choice scenario than competition.

Table 3.6 Logit model equation parameters (√dist).

	Multinomial model				**Nested model**			
Parameter	**Competition**	**Choice**	**Combined**	**Combined (unweighted)**	**Competition**	**Choice**	**Combined**	**Combined (unweighted)**
Lower lambda	-0.24	-0.16	-0.18	-0.14	-0.30	-0.20	-0.23	-0.14
PT constant	0.72	-0.49	-0.25	-0.46	0.63	-0.38	-0.19	-0.44
Upper lambda	NA	NA	NA	NA	-0.19	-0.16	-0.17	-0.18
Car constant	-0.09	-1.38	-1.01	-3.33	-0.11	-1.37	-0.95	-3.57
Theta	NA	NA	NA	NA	0.63	0.81	0.74	1.29

Figure 3.7 shows the corresponding 95% error bounds for the lambda values. The bounds are a statistical measure of where the true value of the lambda is likely to lie between based on the observed data. Note that the bounds have been adjusted for the use of expanded data, which underestimates the size of the standard errors.

Starting from the left, the competition lower and upper (levels) appear to be statistically different from each other and so for competition the nested model appears to be appropriate. For choice, there is overlap between the lower and upper lambda bounds, however, the mean of the upper is outside the upper bound of the lower. Combining competition and choice gives lambdas for the lower and upper levels that are statistically different, which further supports the nested model. For the multinomial models, competition and choice are statistically different, and as expected, the combined model is between the two. The unweighted lambda is higher than the weighted.

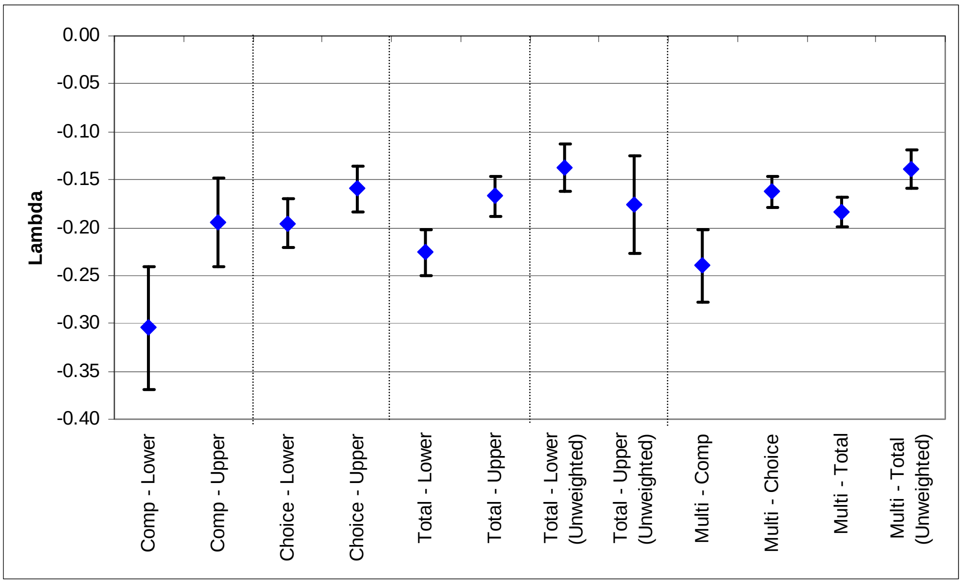

Figure 3.7 Calibrated lambdas and 95% error-bounds.

4.3.3 Model application

Based on the calibrated models, it was decided to take the nested logit formulation forward, with separate models for competition and choice, and scaling the modal costs by the square-root of distance. An iterative procedure was developed in Emme/2 whereby modal proportions by model zone were calculated by competition/choice, modelled site usage was determined, and site-specific penalties were calculated where demand exceeded supply. This was repeated until a convergence criteria was reached. The sum of squares of the difference between subsequent site usages was calculated and convergence was reached when this value was less than 1.

Figures 3.8 to 3.10 give comparisons of observed and modelled trips by mode, with each point representing a model sector (grouping of zones into board geographic areas).

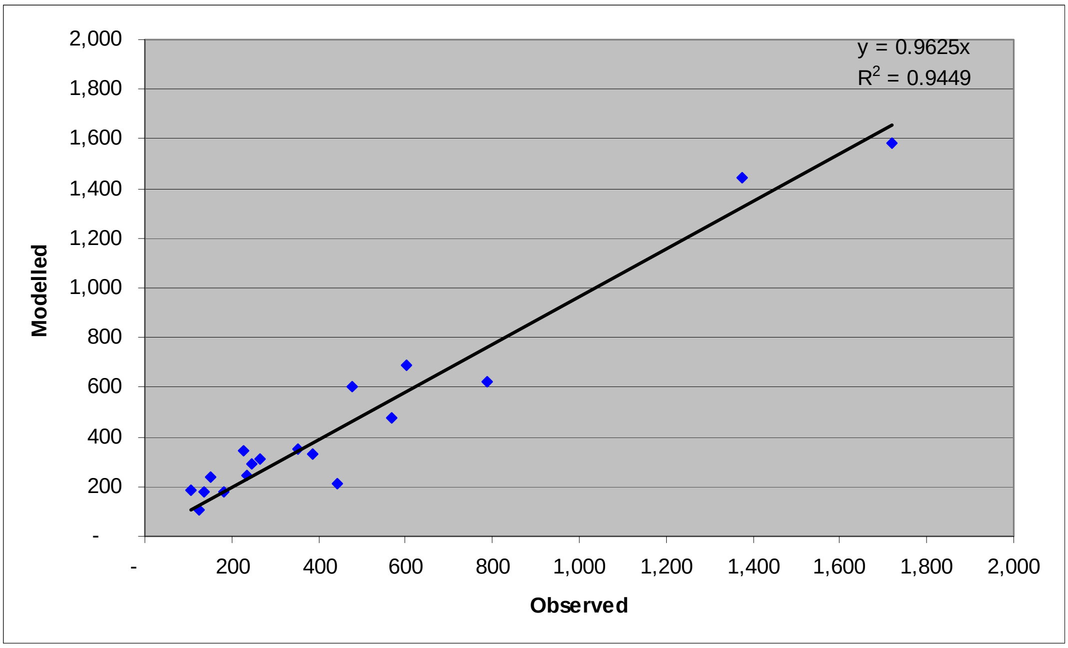

Figure 3.8 Modelled versus observed car trips by model sector.

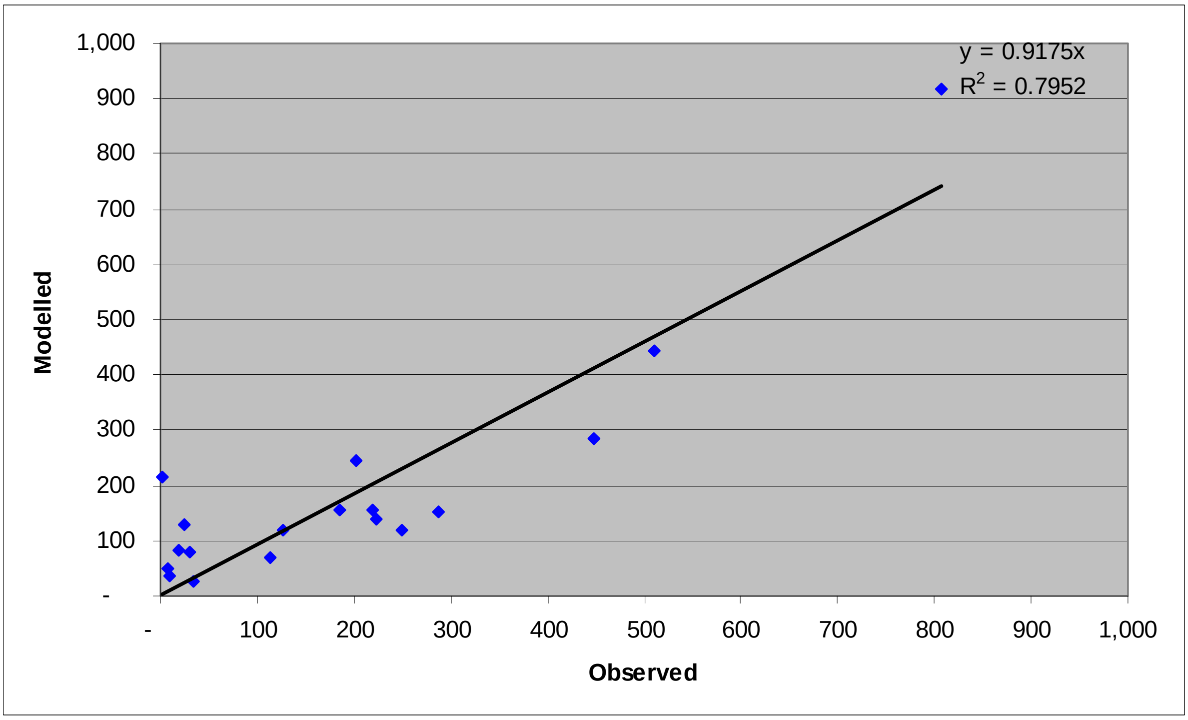

Figure 3.9 Modelled versus observed PT trips by model sector.

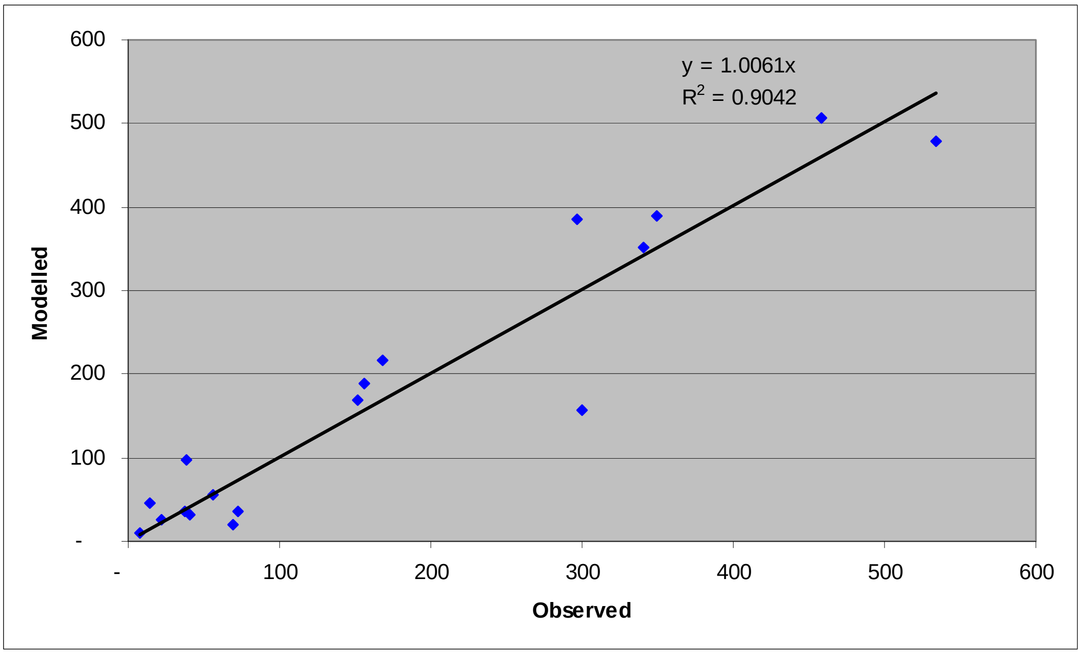

Figure 3.10 Modelled versus observed P&R trips by model sector.

Generally the comparison is favourable for all modes, with the gradient of the line of best fit close to 1. There are some large outliers for smaller PT movements, although these are due to an overestimation of car rather than P&R trips.

4.4 Scenario testing

A number of scenarios have been tested with the regional model approach. As the regional model only uses outputs from WTSM, and so does not have the full model behind it, only broad scenarios can be tested as there is no network/assignment module to interact with. Further, if implemented fully there would be interaction between changes in mode (car, PT, P&R) and costs. For example, an increase in parking spaces at a particular station may encourage more cars driving to the station, and increase congestion around the station as a result. Feedback from changes on modal share to costs is not included in these tests, but could be implemented when applied within a full regional model.

The scenarios that have been run include:

- global increase in car generalised cost of 25%. This will have a negative impact both on car all the way and well as car access to rail (P&R) demand
- global increase in PT generalised cost of 25%. This will have a negative impact both on PT and well as car access to rail (P&R) demand
- number of station car parks increase by 25% – would expect this to abstract demand from both car and PT
- Paraparaumu station impact – last year 160 extra spaces were added at Paraparaumu station and since then these car parks have been filled. This test updates car and PT costs

as well as base level demand growth assumptions to determine usage under an increased capacity scenario.

4.4.1 Global scenarios

Table 3.7 below shows the impact of each scenario on trips by segment and mode. Scenarios have been run under two parking supply assumptions; the status quo and an increase of 25% in all car park capacities at stations. Note that if this was applied in a full regional multi-modal model then changes in other network changes such as vehicle kms, walk versus bus access trips, and revenue could be determined.

Increasing car generalised costs by 25% reduces total car trips by 10% without site capacity increases, and by 12% with the capacity increases. Conversely, PT usage increases by 21% and 16% and P&R by 5% and 14% (total PT by 13% and 15%). With no capacity improvements, a high proportion of trips switch from car to PT rather than P&R. This is partly due to car cost increases affecting P&R access trips, but also because there is not the required capacity at stations to take on extra P&R demand. When capacity is increased by 25%, the split of switch traffic between PT and P&R is closer. P&R abstracts some increased demand from PT (as shown by the reduced increase on PT from 21% to 16%), but total rail usage increases (PT/P&R increases from 13% to 15%). The implied own elasticity for car generalised cost with respect to car demand is between -0.41 and -0.49, with PT cross-elasticities ranging from 0.49 to 0.61, and P&R ranging from 0.14 to 0.41. PEM suggests a car journey time elasticity in the peak of -0.2, but a higher value for CBD destined trips of -0.25. This only includes sensitivity to journey time, and does not include monetary cost components such as parking charges and fuel/operating costs which may double the elasticity – so the range of car elasticity from the regional approach looks broadly consistent with PEM recommended values. Car captive trips were found to comprise only around 1.4% of total car HBW trips and so no correction was required.

Increasing PT generalised costs by 25% increases car trips by 20% with no site capacity increase and 19% when number of car parks is increased by 25%. PT only trips fall by 36% and 38% and P&R by 14% and 9% (PT/P&R reduces by 26% and 24%). An increase in PT generalised cost has its largest impact on PT only trips, and a smaller impact on P&R due partly to the car access leg remaining unchanged as well as there being a latent P&R site demand which will access the stations as other demand is reduced. PT/P&R demand included in these numbers do not include PT captive trips, which will remain broadly unchanged as PT costs increase. PT captive trips form approximately 22.5% of PT demand to the CBD in the am peak, and so elasticities needed to be factored down by 29% (the uplift in trips). PT generalised cost elasticities (including PT all the way and P&R) range from -0.75 to -0.79. Splitting the segments, PT elasticities range between -1.01 and -1.11, while P&R range between -0.26 and -0.61, indicating a larger impact on non-car access to rail. Car cross elasticities range between 0.76 and 0.89. PT elasticities of around -1.0 are normally used.

Increasing car parking capacity by 25% but no other cost changes takes slightly more demand from PT than from car in percentage terms (this is reversed for absolute differences). Roughly, a 25% increase in capacity equates to approximately 800 new spaces region-wide. However this only generates an additional 245 P&R users (of which 100 were previously rail only users and 145 car only).

Table 3.7 Change in trips by segment and mode for scenarios.

Segment	Mode	Observed	Modelled base	No capacity change		Capacity +25%		
				Car GC +25%	PT GC +25%	No cost change	Car GC +25%	PT GC +25%
Competition	Car	4244	4247	3883	4852	4207	3836	4830
	PT	1137	1136	1469	612	1111	1431	602
	P&R	358	356	387	276	421	471	306
Choice	Car	4145	4138	3634	5230	4033	3523	5146
	PT	2361	2361	2748	1617	2286	2641	1581
	P&R	2755	2763	2880	2415	2943	3097	2535
Total	Car	8389	8385	7517	10082	8240	7359	9976
	PT	3498	3497	4217	2229	3397	4072	2183
	P&R	3113	3119	3267	2691	3364	3568	2841
Total change on base	Car			-10%	20%	-2%	-12%	19%
	PT			21%	-36%	-3%	16%	-38%
	P&R			5%	-14%	8%	14%	-9%
	PT/P&R			13%	-26%	2%	15%	-24%
Implied elasticity	Car			-0.41			-0.49	
	PT/P&R*				-0.79			-0.75

Table 3.8 Own and cross elasticites.

	With respect to	
Mode	Car GC	PTGC
Car	-0.41 to -0.49	0.76 to 0.89
PT*	0.49 to 0.61	-1.01 to -1.11
P&R*	0.14 to 0.41	-0.26 to -0.61
Overall PT*	0.41 to 0.48	-0.75 to -0.79

* Note that PT/P&R elasticity includes a correction for PT captive trips of 29%

4.4.2 Paraparaumu station

In 2004, additional car parking capacity was added at Paraparaumu and has subsequently been filled by users. A scenario looking at improvements at Paraparaumu station has been developed to see whether the model would predict a similar increase in usage. The regional model is based on 2001/02 data, and so to be consistent with current day usage, changes in population, car and PT costs, as well as the increase in capacity was developed.

Assumptions:

- Paraparaumu station number of car parks increase from 300 to 460.
- Total trips from Kapiti zones increase by 10% (based on population projection numbers for Kapiti TLA).
- PT generalised costs decrease by 10% due to an increase from three to five trains in the morning peak.
- Car generalised costs increase by 25% due to fuel increase of approximately 25%, car time increase of 10%, and CBD parking charge increase of 50%.

In the base (no changes assumed) the total number of P&R users at Paraparaumu station is the same as the capacity at 300, with a corresponding site penalty (due to more demand than supply) of 8.5 minutes. Under the option (changes as above) the number of P&R users increases to 420 (+120 on the base) and no site penalty (as demand is less than the increased capacity of 460 spaces). This scenario suggests a lower increase in demand than what has been seen in practice. This may be partly due to changes in other factors outside the generalised cost such as improvements in frequency outside the peak period (particularly in the evenings), which would affect P&R users more than bus access (where buses do not meet these later trains).

5. Site-specific modelling approach

5.1 Overview

The site-specific methodology relies on collected information about an existing or proposed site, as well as the surrounding area. These models are often based on the theory that a site's attributes relating to location and service characteristics largely define the attractiveness of the site for potential users. Site-specific demand is heavily influenced by a number of characteristics that cannot be represented accurately within a regional model, such the site location, the facility's characteristics, the availability of competing sites, and perceived convenience. To develop design-level forecasts for P&R sites, these specific characteristics need to be considered, and as such go beyond a regional approach.

Site-specific forecasting tools generally include the definition of a given catchment (see Section 3) for a number of individual P&R sites. Explanatory equations are developed through the use of multiple-regression techniques based on observed usage. These equations can then be used to test the impact of new sites, or changes in usage based on service or facility characteristics. The equations developed are only applicable to the area in which they are being applied (in this case the Wellington region); however, the structure of the equations (variables included) may be appropriately transferred to other contexts.

The next section outlines the context within which a site-specific model has been developed and the dataset definitions.

5.2 Context and dataset

P&R as defined for the site-specific model includes K&R (so all car access) to rail as a main mode. P&R to bus was excluded as this is a tiny proportion of the total P&R usage in Wellington. Wellington's 'formal' P&R sites are consistently fully utilised, but most stations have on-street parking within relatively close proximity to allow this to be a feasible 'over-flow' location for car access to rail stations. Rather than using actual site counts (which are restricted by site size in Wellington) the 2002 rail survey has been used, where P&R is defined as any trip that has used car to access the station either as a driver or a passenger[2]. In summary, the observed usage is based on rail travellers who used car to access the station in the morning peak as either car driver or car passenger. For formal P&R sites the usage is listed in Table 3.9. These numbers differ from the numbers used in the regional approach due to differing assumptions on which trips to include in the analysis (HBW trips, CBD only etc.).

Table 3.9 P&R observed usage.

Site	2002 Rail am peak survey car access
Hutt line	
Petone	320
Woburn	148
Waterloo	716
Taita	225
Silverstream	123
Trentham	107
Wallaceville	35
Upper Hutt	199
Melling	168
Johnsonville line	
Crofton Downs	106
Ngaio	47
Simla Crescent	0
Khandallah	24
Raroa	9
Johnsonville	137
Western line	

[2] While the household survey could also have been used, it did not record the station boarded and did not focus on rail travel.

Site	2002 Rail am peak survey car access
Takapu Road	89
Redwood	85
Tawa	101
Porirua	789
Paremata	294
Mana	67
Plimmerton	259
Pukerua Bay	3
Paekakariki	71
Paraparaumu	498
External	
Waikanae	41
Featherston	72
Woodside	30
Carterton	41
Solway	11
Masterton	46
TOTAL	**4861**

Waterloo and Porirua are the largest car access stations with over 700 users, followed by Paraparaumu with close to 500. On the Hutt line, Petone/Taita/Upper Hutt are all significant, and on the Western line, Paremata/Plimmerton. Car access to Johnsonville station is low by regional standards. Stations external to the metro network have modest levels of car access.

5.2.1 Definition of catchments

The definition of the service area (catchment) for a P&R site is an important component of any site specific approach. For the existing Wellington sites, the 50% catchment has also been used. These catchments were derived by sorting the observed car access data by station and then by origin zone (WTSM), and subsequent distance to station. Zones were included where the cumulative total of demand was within 50% of the total. Some zones were included for more than one station; this indicated areas where catchments overlapped and where sites were in potential competition. Further zones were also added as part of the catchment analysis undertaken in Part 3, with final catchments corresponding to the maps shown in Figures 3.2 and 3.3. Table 3.10 gives the WTSM zones included in each stations catchment and indicates which zones (in bold italics) and stations are in competition.

Table 3.10 Station P&R catchments (50%) by WTSM zone.

Site	Catchment zones	Competition stations
Hutt line		
Petone	191, 195, 194, 196, 193, 190	None
Woburn	*187*, *188*, *186*, *189*	Waterloo
Waterloo	175, *177*, 176, 178, *170*, 182, 171, 172, *186*, *187*, 181, *188*, 179, *189*, 183, 165, 167, *184*, 197, 168	Woburn, Melling
Taita	160, 157, 161, 156, 158	None
Silverstream	152, 151, 150	None
Trentham	*146*, 148	Wallaceville
Wallaceville	*139*, *146*, *142*, *147*, 143	Wallaceville, Upper Hutt
Upper Hutt	140, *139*, 141, *142*, 138, *147*, 137	Wallaceville
Melling	192, *177*, *170*, *184*, 169	Waterloo
Johnsonville line		
Crofton Downs	34	None
Ngaio	69, *70*	Simla Crescent
Simla Crescent	*71*, *70*	Ngaio, Khandallah
Khandallah	*71*, 72	Simla Crescent, Raroa
Raroa	*76*, *75*,*72*	Johnsonville
Johnsonville	77, 83, *76*, *75*, 78	Raroa
Western line		
Takapu Road	*86*	Redwood
Redwood	*88*, *86*	Takapu Road, Tawa
Tawa	89, *88*, 91	Redwood
Porirua	99, 97, 98, 93, 94, 100, 101, 95, *103*, *104*, *105*, 92, 90	Paremata
Paremata	*110*, *105*, *104*, *103*, 106	Porirua, Mana
Mana	*110*, *109*	Mana, Plimmerton
Plimmerton	*109*, 111, *110*	Mana, Plimmerton
Pukerua Bay	112	None
Paekakariki	115	None
Paraparaumu	119, 118, 120, 114, 117, 116, 121	None
External		
Waikanae	126, 125	None
Featherston	207, *218*	Woodside
Woodside	*218*, 208	Featherston
Carterton	209	None
Solway	*211*, 212	Masterton
Masterton	210, *211*	Solway

Catchments need to be designed for new stations or sites. Also, the size of the catchment may change when other transport costs change. For example, Waterloo has a much larger catchment area than Woburn, partly due to the large number of express services at Waterloo. If these services also stopped at Woburn then we may expect catchment sizes to change.

5.2.2 Regression variables included

Attributes have been included in the regression analysis to cover a wide range of possible responses. These have been categorised as 'transport related', 'facility related', and 'land-use related'. Transport-related variables included the characteristics of the public transport that serves an individual site, as well as other competing modes. Facility-related variables examine the impact of signage, safety, paving, shelter and the like at the site. Land-use variables rely on the definition of a site's catchment and uses corresponding population and employment data. Note that the list of variables included in Table 3.11 is not exhaustive and represents the data that was easily available for this study. Also note that site size is not included in the analysis (this was a short-coming of early site-specific model developments). There are two reasons for this. Firstly in the context of Wellington, most of the sites are fully utilised and so the size of the lot adds little to the analysis particularly when K&R and on-street parking is included. Secondly, including the size of the site means the tool is useless as a site planning tool, as it would be an input as well as an output of the process.

Table 3.11 P&R site – specific variables included in regression.

Variable	Description	Source	Expected impact
Transport related			
AMSERVCBD	Number of peak express rail services to CBD	Timetables	Positive – P&R usage should be higher where express trains stop – Suggestions are 4 express services per peak hour to be effective
AMSERVTOT	Total number of peak rail services to CBD	Timetables	Positive – P&R usage should be higher where there is more frequency and hence more options for travellers
BESTTIME	Best rail time to the CBD (mins)	Timetables	Negative – Usage should be higher where travel times are shorter (express vs. non-express) – May be highly correlated with distance and/or fare
RATCARPT	Ratio of PT:Car generalised costs from station to CBD	Wellington Regional Model	Negative – As the PT cost becomes comparatively more favourable (ratio reduces) usage should go up - May be highly correlated with distance and/or fare – Also because from station does not relate to ultimate origin of trip
DIST	Distance (km)	Wellington Regional Model	Negative – As distance increases, people are likely to prefer travelling by car all the way rather than using PT possibly due to congested bottlenecks comprising smaller proportion of car

Variable	Description	Source	Expected impact
			generalised costs
MIDDACC	Existence of midday rail services (0,1)	Timetables	Positive – Passengers having the option to return home throughout the day are more likely to use PT – For Wellington there are very few stations that do not have services throughout the day, so this variable is not likely to be significant
FARE	Adult fare to CBD ($)	Fare schedule	Negative – The lower the fare the higher the PT usage – Fare may influence which stations people choose to drive to, as they may drive not to the nearest but to the next over a fare boundary
CLOSESTA	Time to next station in CBD direction (mins)	Timetables	Positive – The further apart a station is to the next one, the less competitive that next station will be
ENDLINE	Station at the end of a line (0,1)	Timetables	Positive – A station at the end of a line is likely to have a larger catchment
Facility related			
SAFETY	Car park is patrolled (0,1)	GWRC P&R site inventory	Positive – Regular patrolling of sites likely to encourage P&R usage
PAVING	Car park is sealed (0,1)	GWRC P&R site inventory	Positive – Cars don’t get dirty or stone chips
LIGHTING	Car park is lit (0,1)	GWRC P&R site inventory	Positive – Lighting another safety issue
TRANSINFO	Car park is advertised for P&R (1,0)	GWRC P&R Site Inventory	Positive – Advertising of a station as having P&R facilities should have a positive impact
PROXSH	Proximity to State Highway (km)	Maps	Positive – A station that is accessible to major roads is likely to encourage car access
Land-use related			
TOTPOP	Total population within 50% catchment area	Statistics New Zealand 2001	Positive – The more people that are accessible to a station the higher number who may use it
COMPOP	Competing population within 50% catchment area	Statistics New Zealand 2001	Negative – Where there is overlap of station catchments, these will have a negative impact of usage
ADEMP	Total adult employed population within 50% catchment area	Statistics New Zealand 2001	Positive – Workers are the majority of P&R users, and more workers accessible to P&R the higher the use – This is likely to be highly correlated with population
COMEMP	Competing adult employed population within 50% catchment	Statistics New Zealand 2001	Negative – see COMPOP

Variable	Description	Source	Expected impact
	area		
DENSITY	Average density of 50% catchment area	Calculated	Neutral – No clear view on what effect density has on P&R usage
Constants			
ONE	Constant		Neutral – Balancing factor to match total P&R usage
LOCJOHN	Location attribute if station on Johnsonville line (0,1)	Timetables	Neutral – Line specific factors which represent differences in corridors relative to each other – Will include such things as propensity to use rail, and capture other corridor-specific variables not included
LOCHUTT	Location attribute if station on Hutt line (0,1)	Timetables	
LOCWEST	Location attribute if station on Western line (0,1)	Timetables	

5.3 Model estimation

The statistical estimation package LIMDEP was used to perform the multi-variate regression. The process undertaken was to include as many variables as possible in the starting model; the least significant or wrong signed variables were then eliminated until the maximum adjusted R^2 was found.

DIST, FARE, and BESTTIME were highly correlated, meaning the final model could not include all three variables (as the parameter values would be too high). Initially all three were included, with the two with the lowest significance subsequently dropped. It was subsequently found that the fare would be included. The resulting model is not sensitive to changes in rail time but converting time changes using appropriate values-of-time and inputting as a fare change is a feasible way of representing this. This approach could also be adopted for other variables not included in the final model formulation.

Two sets of models have been estimated; with and without 'external' stations. These are Waikanae, Featherston, Woodside, Carterton, Solway and Masterton which lie outside the suburban rail network of Wellington. The zone structure of the Wellington Regional Model is significantly coarser in these areas which makes the definition of catchment areas particularly difficult.

Excluding the externals, variables LOCWEST (colinearity with other locational variables) and MIDDACC (all suburban stations have all-day access) also had to be excluded. The estimated models adjusted R^2 began at 0.93 (which is an extremely good fit to begin with), and finished at 0.96. The process is described below:

- Start with all variables except LOCWEST and MIDDACC (0.930)
- Remove LIGHTING as least significant (0.944)
- Remove AMSERVTO as least significant (0.953)

- Remove PROXSH as least significant and wrong sign (0.960)
- Remove RATCARPT as least significant (0.965)
- Remove CLOSESTA as least significant and wrong sign (0.969)
- Remove ENDLINE as least significant (0.971)
- Remove ADEMP and COMEMP as wrong sign and least significant (0.966)
- Remove PAVING as least significant and wrong sign (0.969)
- Remove BESTTIME as highly correlated with DIST and FARE (0.965)
- Remove DIST as highly correlated with FARE (0.959)
- Remove DENSITY as least significant (0.962)
- Final adjusted $R^2=0.962$

When the externals were included, the final model resulted in the same variables plus LOCWEST (as the colinearity was removed) with resulting adjusted R^2 of 0.94.

Table 3.12 lists the final variables of the regression model, as well as parameter values and significance levels (the closer the P-Value is to zero the more significant). The dependent variable is total car access usage at a station. Because the observed data is based on expanded travel data, the P-Values (level of significance) need to be adjusted by the square-root of the average expansion factor (in this case 1.8). An implied elasticity has been determined based on the average values for each variable. A comment on the significance of each coefficient is included in the final column. Note that the model implicitly allows for abstraction of demand between stations through the population competition variable. If a new site is developed, or services are improved at an existing station, there is likely to be a change in the catchment size. A station that may not have been competing may now be in competition and so demand at both stations will change.

Table 3.12 Regression equation parameters for P&R usage (excl externals).

Variable	Coefficient	P-Value	Adjusted P-Value	Implied Elasticity	Comment
ONE	81.427	0.211	0.487		Unexplained car access to any rail station on the Western line will be 81 passengers
AMSERVCB	23.659	0.001	0.033	0.42	Every additional CBD express service to serve station adds 24 P&R passengers
LOCHUTT	-64.768	0.011	0.136	-0.13	Relative to the Western line, the Hutt line has a significantly lower propensity to use P&R
LOCJOHN	-38.019	0.447	0.675	-0.05	Relative to the Western line, the Johnsonville line has a lower propensity to use P&R

Variable	Coefficient	P-Value	Adjusted P-Value	Implied Elasticity	Comment
SAFETY	64.059	0.073	0.310	0.14	A station that is patrolled adds 64 P&R passengers
TRANSINF	29.447	0.188	0.463	0.11	A station that is advertised as having P&R facilities adds 29 P&R passengers
TOTPOP	0.025	0.000	0.000	1.21	2.5% of people within a stations catchment use P&R – all else being equal
COMPOP	-0.017	0.000	0.009	-0.37	1.7% of people within a competing catchment are lost to the station due to competition – sensible and should be lower than TOTPOP given split between more than one station
FARE	-33.134	0.007	0.107	-0.78	An additional $1 in adult fare will reduce P&R usage by 33 passengers

Observed versus modelled usage (as shown in Table 3.13) shows that for the most-part the model is a reasonable representation of the observed, with the larger stations (Petone, Waterloo, Porirua, Paremata and Paraparaumu) looking favourable. Some smaller stations (such as Simlar Crescent, Raroa and Carterton) have negative values, which are a function of the regression equations and should normally be set to zero.

Table 3.13 P&R observed versus modelled usage.

Site	2002 Rail am peak survey car access	Estimated usage via model	Difference
Hutt line			
Petone	320	323	3
Woburn	148	79	-69
Waterloo	716	714	-2
Taita	225	271	47
Silverstream	123	106	-17
Trentham	107	68	-39
Wallaceville	35	81	46
Upper Hutt	199	239	40
Melling	168	160	-8
Johnsonville line			
Crofton Downs	106	111	5
Ngaio	47	48	1
Simla Crescent	0	5	5

Site	2002 Rail am peak survey car access	Estimated usage via model	Difference
Khandallah	24	12	-12
Raroa	9	-7	-16
Johnsonville	137	153	17
Western line			
Takapu Road	89	86	-3
Redwood	85	111	25
Tawa	101	109	8
Porirua	789	808	19
Paremata	294	288	-6
Mana	67	83	16
Plimmerton	259	192	-67
Pukerua Bay	3	43	40
Paekakariki	71	104	33
Paraparaumu	498	434	-65
External *			
Waikanae	41	108	68
Featherston	72	31	-41
Woodside	30	24	-6
Carterton	41	-13	-54
Solway	11	75	64
Masterton	46	16	-31
TOTAL	**4861**	**4861**	**0**

* Note external estimates using 'including external' model

5.4 Scenario testing

A number of scenario tests have been developed to test the impact of the P&R site-specific model, some of which are site-specific, and some which are region-wide:

Site specific:

- Addition of express services serving Tawa station
- New site location at Glenside station

Region-wide:

- 10% increase in fares

- Estimated usage in 2006 and 2016 (assuming no changes in transport supply or catchments – only population based).

5.4.1 Tawa express services

This scenario assumes that three express services will stop at Tawa station (where currently no express services stop). These three services are additional to the non-express, and so there is a 50% increase in train frequency at the station.

Tawa's base 50% catchment size (using the catchment formulation as outlined in Section 4) is 1.08 km and includes model zones 88, 89 and 91. An additional three (express) services increases the catchment size to 1.63 km which further includes zone 90 (see Table 3.14).

Table 3.14 Revised catchment size calculation for Tawa station

Variable	Coefficient	Base value	Scenario value	Comment
AMSERVCB	0.137	0	3	Assumes 3 trains in peak period are express
AMSERVTO	0.108	6	9	3 additional trains serving station
BESTTIME	-0.070	18	16	Because of express trains, best time to CBD now reduced (assumes 1 minute per station excluded=2)
DIST	0.057	16.46	16.46	No change
PROXSH	-0.167	0.2812	0.2812	No change
LIGHTING	0.807	1	1	No change
ENDLINE	0.924	0	0	No change
	Catchment size	**1.08 km**	**1.96 km**	Tawa station catchment radius increases by 880 m
	Model zones	**89, 88, 91**	**89, 88, 91, 90**	Catchment extended to include zone 90, which does not overlap with any other station catchment

Table 3.15 below shows the impact of the extra three express services. The total population within the catchment has the largest impact on car access (an additional 95 users), and with the inclusion of three express services (additional 70 users) results in a total car access increase of 164. The revised catchment does not overlap with any other station, and so demand at other stations will remain unaffected.

Table 3.15 Car access station usage estimation for Tawa station

Variable	Coefficient	Base value	Scenario value	Comment
ONE	81.427	1	1	No change
AMSERVCB	23.659	0	3	3 express services now serving station
LOCHUTT	-64.768	0	0	No change
LOCJOHN	-38.019	0	0	No change
SAFETY	64.059	1	1	No change
TRANSINF	29.447	0	0	No change
TOTPOP	0.025	5,351	9,143	Increase due to the inclusion of zone 90 in catchment
COMPOP	-0.017	3,123	3,123	No change as the extra zone does not compete
FARE	-33.134	3.5	3.5	No change
	Estimated usage	**109**	**273**	Car access usage to Tawa station estimated to increase by 164 passengers

5.4.2 New station at Glenside

A new station at Glenside (Churton Park) has been mooted for the past 10 years. This scenario looks at what a station at Glenside would be likely to draw in terms of car access demand. It has been assumed that five services stop at the station in the am peak (none of them express), time to Wellington station is 12 minutes, distance is approximately 12 km, the station would be located 500 m from State Highway 1, and it would be fully lit. Based on these assumptions Glenside station would have a 50% catchment size of 1.1 km (including model zones 82 and 85).

Table 3.16 Catchment size calculation for Glenside station.

Variable	Coefficient	Value	Comment
AMSERVCB	0.137	0	Assumes no express services from Glenside to Wellington CBD (sensible as last station before Wellington CBD)
AMSERVTO	0.108	5	Assumes same as Takapu Road (next station up the line)
BESTTIME	-0.070	12	Assumes 12 minutes (speed of 60 km/h as consistent with Takapu Road)
DIST	0.057	12	Approximately 12 km to CBD
PROXSH	-0.167	0.5	Station location 500 metres from SH1
LIGHTING	0.807	1	Assumes site is fully lit
ENDLINE	0.924	0	Station is not located at the end of a line
	Catchment size	1.10 km	Includes zones 82 and 85 from the

Variable	Coefficient	Value	Comment
			regional model – there is no overlap with other station catchments
	Model zones	**82, 85**	

Using the same assumptions for the car access demand estimation indicates that usage at a Glenside station is estimated at 180 car access passengers. This estimate compares favourably with work undertaken by Booz Allen Hamilton (1999), which estimated am peak car access trips to the station to be around 120. The defined catchment does not overlap with any other station, and so demand at other stations will remain unaffected.

Table 3.17 Car access station usage estimation for Glenside station

Variable	Coefficient	Value	Comment
ONE	81.427	1	Constant
AMSERVCB	23.659	0	No express services
LOCHUTT	-64.768	0	Not located on Hutt line
LOCJOHN	-38.019	0	Not located on Johnsonville line
SAFETY	64.059	1	Assumes that the site will be patrolled
TRANSINF	29.447	1	Assumes the site will be signposted
TOTPOP	0.025	4,429	Total population in catchment (zones 82 and 85)
COMPOP	-0.017	0	No competing population (no catchment overlap)
FARE	-33.134	3.5	Assumes fare of $3.50 – same as Takapu Road
	Estimated usage	**180**	Estimated car access to station is 180 passengers

5.4.3 Regional tests – fare change

A global 10% increase in rail fares reduces car access demand by around 11% (excluding negative stations). This is an implied fare own-elasticity of -1.0, a little higher than conventional values, but reflects the market segment and nature of choices for passengers. We may expect passengers who do have access to a car to be more sensitive to fares than people who are captive to public transport. Captives to PT comprise approximately 23% of am peak journeys to the CBD, so including captives would reduce this elasticity by around 30% to -0.7.

Table 3.18 P&R regional fare test impacts.

Site	Estimated usage via model	10% global fare increase
Hutt line		
Petone	323	311
Woburn	79	67
Waterloo	714	703
Taita	271	258
Silverstream	106	89

Site	Estimated usage via model	10% global fare increase
Trentham	68	51
Wallaceville	81	62
Upper Hutt	239	219
Melling	160	148
Johnsonville line		
Crofton Downs	111	101
Ngaio	48	38
Simla Crescent	5	-5
Khandallah	12	2
Raroa	-7	-17
Johnsonville	153	144
Western line		
Takapu Road	86	75
Redwood	111	99
Tawa	109	97
Porirua	808	795
Paremata	288	271
Mana	83	66
Plimmerton	192	176
Pukerua Bay	43	23
Paekakariki	104	81
Paraparaumu	434	407
External *		
Waikanae	108	77
Featherston	31	-1
Woodside	24	-7
Carterton	-13	-51
Solway	75	34
Masterton	16	-25
TOTAL (excluding negatives)	**4882**	**4393 (-10%)**

* Note external estimates using 'including external' model

5.4.4 Regional tests – future years

Car access to stations for future years 2006 and 2016 has also been tested. Future car access scenarios assume no changes in transport supply or infrastructure (in the model there is no change in fares, express services, or site facilities), and are based purely on forecast population changes within the catchments (as well as competition). Table 3.19 below gives overall territorial local authority (TLA) population growth projections for the Wellington region (medium), indicating modest growth on average, significant growth for the Kapiti Coast and Wellington City, and little growth or decline elsewhere. Zone-specific projections have been supplied and used within the scenario testing.

Table 3.19 Projected regional population growth by TLA.

TLA	2001–2006 Medium pop. growth	2001–2016 Medium pop. growth
Kapiti Coast	10.3%	16.7%
Porirua	3.2%	3.6%
Upper Hutt	-1.3%	-3.4%
Hutt	0.2%	0.0%
Wellington City	5.4%	8.2%
Masterton	-0.9%	-2.2%
Carterton	-0.3%	-1.1%
South Wairarapa	-0.7%	-2.2%
AVERAGE	**3.3%**	**4.8%**

The two population-based scenarios examining a 2006 and 2016 future shows little change in car usage compared with the base (+2% and +3% respectively overall), although station-specific changes are more variable. Paraparaumu sees an increase of around 90 car access passengers, with Waikanae being the other large gainer. Most stations on the Hutt line see slight decreases, which is consistent with the rather pessimistic view of population growth in both Upper and Lower Hutt. The Johnsonville and Western lines see small increases in demand.

Table 3.20 P&R regional future year test impacts.

Site	Estimated usage via model	2006 estimated usage	2016 estimated usage
Hutt line			
Petone	323	323	316
Woburn	79	79	78
Waterloo	714	712	706
Taita	271	274	273
Silverstream	106	105	97
Trentham	68	68	65
Wallaceville	81	79	76
Upper Hutt	239	236	228
Melling	160	160	155
Johnsonville line			
Crofton Downs	111	116	120
Ngaio	48	49	51

Site	Estimated usage via model	2006 estimated usage	2016 estimated usage
Simla Crescent	5	7	9
Khandallah	12	13	16
Raroa	-7	-6	-4
Johnsonville	153	161	168
Western line			
Takapu Road	86	88	89
Redwood	111	112	114
Tawa	109	111	113
Porirua	808	822	822
Paremata	288	291	292
Mana	83	85	85
Plimmerton	192	198	199
Pukerua Bay	43	43	42
Paekakariki	104	107	112
Paraparaumu	434	468	522
External*			
Waikanae	108	126	143
Featherston	31	33	29
Woodside	24	26	25
Carterton	-13	-11	-15
Solway	75	75	70
Masterton	16	18	18
TOTAL (excluding negatives)	**4882**	**4984 (2%)**	**5034 (3%)**

* Note external estimates using 'including external' model

6. Summary

The **regional approach** took the defined catchments, revealed preference demand data from surveys conducted in 2001/02 and transport costs from the WTSM, and estimated a mode-split model that could be applied within a regional modelling context. There were inconsistencies in the revealed preference data relating to differences in definitions between surveys (particularly am peak-time period and competition vs choice). Further, the Wellington model did not have P&R represented within the network skims and so P&R costs were a combination of car access cost to and PT cost from station zone (rather than the station). Also zone sizes could be considered large for P&R modelling purposes, with a significant proportion of car access trips within the same zone as the station.

In spite of these shortcomings, a nested-logit model with car access and non-car access to PT at the lower level and car all the way vs PT at the upper level was estimated successfully. This nested-logit formulation was then applied within an Emme/2 procedure, which also included capacity constraints at station car parks. A number of scenarios were run to test the model behaviour against industry-standard elasticities. The model was found to be performing adequately, both in terms of car and PT elasticities. Other tests were undertaken relating to site capacity increases, with results also looking sensible.

A **site-specific approach** was then developed. The advantage of such an approach over the regional approach is that it is simpler to apply and less data intensive. Site usage was regressed against demographic, service and facility-related variables to determine a multivariate model for car access to rail stations. There were high levels of co-linearity between distance/time/fare variables, but adequate relationships were still obtained. The final model included catchment population, number of express services, fare, safety, P&R information and a line-specific indicator. In addition, a variable was included which looked at competing population (where catchments overlap). It was found that all things being equal the population coefficient implied 2.5% of catchment population used car access to the station and that where station catchments overlapped -1.7% of overlapping population would be lost.

Sensitivity tests for the site-approach were undertaken, first looking at the impact of changes to an existing station and then the inclusion of a new station. The results of these two tests looked reasonable. A test relating to an increase in PT fares was undertaken; the model proved to be too sensitive to fares but this was partly due to the exclusion of PT captive trips. Further tests were undertaken looking at future year population impacts.

The two approaches should not be seen as substitutes and should be used in conjunction with one another to give a wider range of information for decision makers. While these methodologies have been designed for the Wellington Region, similar models could be developed for other regions. However, the quality and completeness of the input data will always ultimately dictate how successful these models will be.

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APPENDIX B P&R policies in New Zealand urban transport strategies

Auckland

Auckland Regional Land Transport Strategy (ARC 2005)

The Auckland Regional Land Transport Strategy (RLTS) 'details the way forward for the region's transport system for the next 10 years'. P&R is mentioned in Chapter 7 – 'Achieving the Objectives: RLTS Policies' of the latest RLTS update in 2005. With particular reference to P&R, the RLTS strives to:

- support the efficient use of land for P&R facilities (S1.7.14)
- develop a regional parking strategy 'including a regional policy position for the provision of P&R facilities'– (S3.4.6)
- develop a regional passenger plan to provide standards and guidelines for P&R (S4.1.1)
- ensure that charges for ancillary services (such as P&R) are set to level as to encourage patronage and development initiatives (S4.1.8).

Auckland Regional Passenger Transport Plan (ARC 2003)

The Regional Passenger Transport Plan describes how the strategies related to passenger transport services contained in the RLTS will be implemented.

- It appears to have no general policy statements re P&R.
- **North Shore Busway** (Chapter 6.1). Notes P&R facilities to be provided at Albany station (facilities for approximately 370 vehicles) and Constellation station (facilities for approximately 200 vehicles) – stations have since opened (November 2005) and have been full with excess informal parking on surrounding streets.
- **Rail system** (p 84). Notes the importance of P&R access to the rail system. Classifies stations into two groups according to P&R potential: Major (over 100 spaces, access by major arterial, and catchment of 2–5km or more in outlying areas), local (less than 100 spaces, and catchment of 2 km). Mentions the extension of services south to Drury and the identification of an associated P&R site.
- **Ferry services** (p 95). Notes that P&R provision is essential to attract ferry patronage. States that 'Wherever practicable, any new ferry terminal facilities shall be provided with an adjacent dedicated park-and-ride area within easy walking access to the wharf'. Mentions new P&R site at Hobsonville Wharf.
- There appears to be no mention of P&R policies for the remainder (non-busway) parts of the bus system.

Travel Demand Management Strategy (ARC 2000)

- P&R facilities identified as a TDM transport supply measure (Table 2)
- Shuttle buses from P&R sites put forward as an alternative mode TDM measure (Table 3).

Wellington

Regional Land Transport Strategy (GWRC 2007)

The vision as stated in the executive summary is 'to deliver an integrated land transport system that supports the region's people and prosperity in a way that is economically, environmentally and socially sustainable'. Support for P&R is seen as one way of attaining this vision through:

- support for ongoing development of new and existing P&R facilities (p 57), which in turn will support the RLTS objectives of assisting economic and regional development, improving access/mobility/reliability, and ensuring environmental sustainability
- efficient integration of modes is seen as an important objective for the RLTS, including safe and easy access between stations and P&R facilities
- short to medium term projects (2007–2016) include new and upgraded stations along the Western rail corridor with associated P&R facilities. Continued improvement of P&R facilities on the Hutt/Melling lines is also signalled.

There is no explicit mention of bus or ferry P&R.

Draft Regional Transport Passenger Plan (GWRC 2006)

- To pursue opportunities to secure ownership of long-term lease of current P&R sites to aid in future increases in capacity and improved facilities (p 17)
- Creation of seamless bus-train transfers to reduce the need for major P&R capacity expansion (p 18)
- Recognises the quality and usage of P&R facilities has grown significantly over the last five years, and partnerships between the regional council and existing property owners are key to ensuring future improvement (p 19)
- Reiterates short to medium term projects in the RLTS.

Travel Demand Management Strategy (GWRC 2005)

- Provides no mention of P&R as a TDM measure.

Christchurch

Canterbury Regional Land Transport Strategy 2005–2015 (Environment Canterbury 2005)

- Integrating 'the passenger transport network with other modes though the provision of appropriate facilities such as P&R' (1.3.7)
- Planning for the future needs to the rail network, and protecting land close to stations for such uses as P&R (1.5.2)
- Plan for interchange points - including P&R (4.2.2)
- No mention of specific P&R schemes.

Canterbury Regional Passenger Transport Plan (Environment Canterbury 2006)

Policy 1.4 states 'regional connections shall be provided only where there is strong community support', and may include demand response services such as P&R

Policy 5.8 states 'Environment Canterbury shall work with and encourage road controlling authorities to support public transport' through supportive land-use planning providing for facilities such as P&R areas that are comfortable, safe, and well lit

No mention of specific P&R schemes.

APPENDIX C Detailed usage of P&R facilities

Table C1 Public transport access mode shares – Australasian major city corridors % of total inbound public transport users by access mode.

Mode/Corridor	Source	AM peak %					Off peak %					Total %				
		P+R	K+R	Walk	PT	Other	P+R	K+R	Walk	PT	Other	P+R	K+R	Walk	PT	Other
Adelaide																
Rail – Northern	(1)	14.2	21.1	36.9	25.9	1.8	5.0	7.5	63.5	21.7	2.4					
Rail – Southern	(1)	17.0	11.1	56.0	14.6	1.3	5.1	4.2	80.4	9.1	1.2					
Busway (O-Bahn)	(2)	12.6	11.5	69.2	6.1	0.5	7.6	5.2	76.9	9.9	0.3					
Bus – Northern	(1)	0.7	5.6	82.9	10.1	0.7	0.7	1.2	86.0	10.9	0.6					
Bus – S. Eastern	(1)	2.4	7.3	67.2	22.6	0.4	2.4	2.4	83.6	11.2	0.5					
Brisbane																
Bus total – Northern	(3)	3.4(5)	5.6(5)	81.5	9.1	0.5	2.5(5)	3.1(5)	71.7	22.0	0.6					
Bus express – Northern	(3)	4.9(5)	8.8 (5)	78.8	7.5	-	2.2(5)	5.4(5)	76.2	15.4	0.7					
Bus stopping – Northern	(3)	2.9(5)	4.6(5)	82.3	9.6	0.6	2.6(5)	2.5(5)	70.6	23.6	0.6					
Perth																
Rail – Total	(12)	43														

Mode/Corridor	Source	AM peak %					Off peak %					Total %				
		P+R	**K+R**	**Walk**	**PT**	**Other**	**P+R**	**K+R**	**Walk**	**PT**	**Other**	**P+R**	**K+R**	**Walk**	**PT**	**Other**
Rail – Northern suburbs	(4)											28.2[(5)]	14.1[(5)]	16.3	38.6	2.9
Bus – Total	(12)	5.0														
Bus – Northern suburbs	(6)											4.6	6.3			
Sydney																
Bus Express –Warringah ave	(7)											13.8		82.5	3.3	0.4
Bus Express –Warringah max	(7)											32.0				
Rail – Liverpool station	(8)											15.5	15.7			
Melbourne																
Rail – Overall	(9)											20.4[(5]	7.6[(5)]	47.0	14.0	11.0
Wellington																
Rail – Hutt Valley	(10)	19.7														
– Paraparaumu	(10)	18.9														
– Johnsonville	(10)	12.0														

Mode/Corridor	Source	AM peak %					Off peak %					Total %				
		P+R	K+R	Walk	PT	Other	P+R	K+R	Walk	PT	Other	P+R	K+R	Walk	PT	Other
– Wairarapa	(10)	61.8														
Bus – WLG City overall	(11)	7.0														
Auckland																
Rail – Overall	(10)	8.5														

Notes/Sources:

(1) APTRANS Survey Report, Travers Morgan, March 1992.
(2) North East (Busway) Market Analysis Report, State Transport Authority, February 1994.
(3) Brisbane Northern Corridor Line Haul Study, Travers Morgan.
(4) NSR Questionnaire Survey (August 1993), as analysed by Webster Research (1993) and Transperth (1993).
(5) P&R figure is 'car driver'; K&R figure is 'car passenger'.
(6) Pre-NSR survey.
(7) Manly–Warringah Corridor Bus Study, Travers Morgan, 1990. Maximum figure relates to longest distance trips (from Narrabeen and further north).
(8) SRA Study.
(9) Advice ex DoI Victoria.
(10) Refer WP B2 for details.
(11) Estimated from household survey – refer WP B2. Most of this is 'informal' P&R.
(12) BAH estimates – relate to CBD-bound trips only.

In this table:

- all figures relate to **inbound** travel only
- figures relate to am peak (typically 7–9 am) and interpeak (weekdays) separately where available, otherwise to weekday totals
- P&R has been distinguished from K&R where possible. In some cases, the only separation available was car as driver (taken to represent P&R) and car as passenger (taken to represent K&R).

Table C2 Auckland P&R sites and usage (April 1999).

Facility	No. of car parks	Usage	Utilisation (%)
Bus			
Mays Rd Trial[3]	400	21	5
Silverdale	19	10	53
Dairyflat	10	7	70
Northcross	20	19	95
Waimauku	35	6	17
Kumeu	22	10	45
SH 16&18	14	6	43
Whenuapai (now closed)	8	7	88
Pakuranga	30	N/A	N/A
Total bus[1]	**158**	**65**	**41**
Rail			
Homai[2]	100 +	27	N/A
Papatoetoe	60	30	50
Papakura[2]	200 +	200 +	N/A
Glen Eden	60	40	67
Ranui	10	4	40
Waitakere	15	12	80
Swanson	25	13	52
Total rail	**470+**	**326+**	**69**
Ferry			
Bayswater	100	87	87
Birkenhead	120	114	95
Devonport	200 +	200 +	N/A
Northcote Point	30	17	57
Half Moon Bay	120	70	58
Gulf Harbour	100 +	25	N/A
Total ferry	**670+**	**513+**	**77**
Auckland total[1]	**1298+**	**904+**	**70**

Notes
1. Mays Rd Trial excluded.
2. Both rail and bus.
3. Mays Rd Trial 1997 numbers.

Table C3 Wellington rail P&R sites and usage.

Site	Spaces	Demand			Utilisation[1]		
		2002	2003	2004	2002	2003	2004
Johnsonville line							
Crofton Downs	44	45	39	44	100%	89%	100%
Ngaio	50	29	42	41	58%	83%	82%
Simla Crescent	6	6	6	5	100%	92%	83%
Khandallah	7	6	7	7	86%	100%	100%
Raroa	8	12	10	8	100%	100%	100%
Johnsonville							
– station	49	53	48	49	100%	97%	100%
– Moorefield Road	36	-	36	36	-	100%	100%
Western line							
Takapu Rd	84	68	72	69	81%	86%	82%
Redwood							
– Taylor Park	90	89	75	73	99%	84%	81%
– North	40	18	16	38	45%	41%	95%
Melville St Tawa	32	28	25	30	88%	79%	94%
Duncan St Tawa	38	-	15	15	-	39%	38%
Porirua station	265	263	260	300	99%	98%	100%
Paremata							
– station (west)	246	116	156	131	47%	63%	53%
– East	52	13	33	22	25%	63%	42%
Mana	20	18	18	20	90%	90%	100%
Plimmerton	35	36	18	-	100%	51%	-
Pukerua Bay	25	4	8	15	16%	30%	60%
Muri – Muri Rd	3	-	2	-	-	67%	-
Paekakariki	82	50	52	58	61%	63%	71%
Paraparaumu							
– Epiha St	293	290	293	318	99%	100%	100%
– Epiha St sth extension	160 (Sep 04)	29	54	155	-	-	97%
Waikanae	54	23	47	-	43%	87%	-
Otaki station	40	-	20	-	-	50%	-
Melling line							
Melling station	150	97	-	126	64%	-	84%

Site	Spaces	Demand			Utilisation[1]		
		2002	2003	2004	2002	2003	2004
north	75	16	-	13	21%	-	17%
Wairarapa line							
Featherston	129	81	-	-	62%	-	-
Woodside	45	30	42	-	67%	93%	-
Carterton	44	34	52	-	76%	100%	-
Solway	20	10	27	-	50%	100%	-
Masterton	73	43	46	-	58%	63%	-
Upper Hutt line							
Upper Hutt							
– main park	118	116	118	-	98%	100%	-
– rear of library	47	28	64	-	60%	100%	-
Wallaceville	103	38	35	-	36%	33%	-
Trentham							
– sealed area	68	66	67	-	97%	99%	-
– north unsealed	15	6	9	-	40%	60%	-
Silverstream							
– Fergusson Dr park	34	31	34	-	90%	100%	-
– Gard St	60	40	57	-	67%	94%	-
– Kiln St		15	25	-			-
Manor Park							
– Anabela Grove		6	-	-	-	-	-
– Golf Rd	10	2	-	-	20%	-	-
Taita							
– East side car park	65	63	52	60	97%	80%	92%
– High Street east	77	47	60	71	60%	78%	92%
– High Street west	6	6	3	4	92%	50%	67%
Naenae – Oxford Tce	26	11	9	5	42%	35%	19%
Epuni – Oxford Tce	31	20	-	22	65%	-	71%
Waterloo Interchange							
– northwest	152	153	-	152	100%	-	100%
– Oxford Tce by Canopy	9	9	-	9	100%	-	100%
– NE plus platform	203	187	-	200	92%	-	99%
– Cam Tce bus stop	27	27	-	27	100%	-	100%
– platform south end	21	21	-	21	100%	-	100%

Site	Spaces	Demand			Utilisation[1]		
		2002	2003	2004	2002	2003	2004
– south east	130	129	-	130	99%	-	100%
– ambulance station	61	63	-	63	100%	-	100%
Woburn							
– Cambridge Tce	120	93	118	110	78%	98%	92%
– Oxford Tce	40	28	20	19	70%	50%	48%
Petone							
– main station park	194	172	201	189	89%	100%	97%
– Korokoro London Rd	30	-	29	35	-	97%	100%
Total Wellington	**3942**			**3329[2]**			**84%**

Notes: 1. Utilisation constrained to 100%

2. Demand for sites not surveyed in 2004 assumed to be the same as in 2003 for total demand purposes

Table C4 P&R usage as proportion of am peak passengers.

PT service	Am peak pass	P&R users[2]	% P&R
Wellington rail:[1]			
Hutt Valley line	5900	1160	19.7
Paraparaumu line	4600	870	18.9
Johnsonville line	1080	130	12.0
Wairarapa	340	210	61.8
Total rail	**11,920**	**2370**	**19.9**
Auckland:[3]			
Bus	35,000	250	0.007
Rail	3200	160	5.0
Ferry	2500	270	10.8

Notes: 1. Wellington rail patronage based on 1996 Census Day count by WRC (total boardings 0630-0900).

2. P&R users based on 1.2 persons per parked vehicle for Wellington and 1.3 persons per vehicle for Auckland – derived from analysis of several WRC and ARC surveys.

3. Auckland rail passengers derived from ARC 1997 rail survey matrices; Auckland bus and ferry passengers indicative estimate provided by ARC.

Table C5 provides more recent data for Auckland Rail P&R market share, from the 2003 Rail Origin–Destination Survey. It shows that:

- overall, P&R accounted for 9% of access/egress movements, compared with 5% in the 1997 survey

- K&R accounted for a further 11% of access/egress movements (12% in 1997)
- as expected that the P&R proportion is substantially higher (approaching twice) these figures at the suburban (production) end of the trip, close to zero at the city (attraction) end.

The survey report (Section 6.2) comments further on these results, as follows:

> *P&R remains a relatively small proportion of the access modes, but on the basis of these responses appears to make up a greater proportion in 2003 (9% who responded that they drove to/from the station) than in 1997 (5%). It is not clear from the responses, however, whether the 9% represent a true figure for P&R. It is possible that some of those who responded that they drove to the station did not leave the vehicle at the station, or there was someone else with them to take the vehicle away. Because the questionnaire only returned responses from a sample of the total users, the exact number of the passengers who drove to or from the stations is not known.*
>
> *From the questionnaire responses a proportionate distribution at each station can be established as a gauge to the potential P&R activity. On this basis, Pukekohe stands out with 55% of the respondents who stated they either got on or off at Pukekohe also stating that they drove to/from the station. The next highest response rate was for Papakura, with 29%. Other stations indicated from the responses as having significant P&R were Manurewa, Papatoetoe and Homai in the south and Glen Eden, New Lynn, Swanson and Waitakere in the west. Stations along the waterfront recorded relatively high "driver" usage as a proportion of the returned samples, but the overall numbers are small reflecting the low use of these stations.*

Table C5 Auckland rail access/egress modes.

Access/egress mode	2003 Survey		1997 Survey % Total
	Number[(1)]	% Total	
Car driver	430	9%	5%
Car passenger	537	11%	12%
Walk	3273	65%	68%
Bus	524	10%	9%
Another train	117	2%	2%
Bicycle	65	1%	3%
Taxi	17	0%	
Other	19	0%	
Not stated	48	1%	
Total	**5030**	**100%**	**100%**

Source: ARC 'Rail Origin Destination Survey, May 2003'. Sept 2003, Table 6.2.1.

Note 1. These figures relate to sum of access and egress modes for passengers completing survey forms (about 12,000 passengers in total were carried per weekday in May 2003).

P&R usage as a proportion of commuter trips

P&R facilities are almost exclusively used in Auckland and Wellington by commuters travelling to the central business district (CBD). A relevant indicator is, therefore, P&R usage as a proportion of commuter trips to the CBD. The data presently available for Auckland and Wellington in 1996 and is summarised in Table C6.

These results indicate the substantial role of P&R in terms of CBD commuter travel. In Wellington, P&R is used by 35% of all rail commuters to the CBD; which represents 9% of all CBD commuters from zones in the rail catchment area. In Auckland P&R is a substantial portion of the rail and ferry CBD commuter market, but is much less important for bus CBD commuter trips (it has been assumed that all P&R passengers are CBD commuters – surveys of P&R users in Wellington have found this to be the case).

Table C6 P&R usage as a proportion of CBD commuter trips.

PT service	% JTW to CBD
Wellington rail	
Hutt Valley line	34.3
Paraparaumu line	34.1
Johnsonville line	19.7
Wairarapa	100.0
Total	**34.9**
Auckland	
Bus	3.3
Rail	44.1
Ferry	32.7

Source: 1996 JTW survey

APPENDIX D New Zealand market research related to P&R

Wellington

Rather limited research into the characteristics and attitudes of P&R users in New Zealand has been undertaken and most of this relates to Wellington. Travers Morgan carried out (for WRC) two surveys of Hutt Valley rail P&R in 1994 and a survey of Wellington City commuters in 1995. WRC has undertaken a more recent (2002) survey. The main findings of these surveys relevant to this project are summarised below.

Hutt Valley P&R Survey (Travers Morgan NZ Ltd 1994)

In a 1994 study of P&R in the Hutt Valley for the WRC, Travers Morgan identified a similar set of factors which impact on the demand for P&R facilities.

- Demand for P&R facilities is related to the availability and price of car parking at the destination. Where parking is limited and expensive, demand for P&R facilities will be higher. However, this will also depend on the availability and price of parking at the P&R facility. In both Wellington and Auckland, P&R parking is free. In the Wellington CBD the price of parking has been increasing over the last 10 years, particularly in regard to 'fringe parking' (Wellington City Council introduced a coupon parking scheme in these areas in 1993). P&R usage has increased in Wellington over this period.

- To attract people making car-based trips to use P&R facilities, the level of service (LOS) on the PT mode must be competitive with the car in terms of critical LOS features. One important LOS feature is trip frequency. The effect of trip frequency on P&R usage has been demonstrated in Wellington with the refocusing of Lower Hutt bus and train services on the Waterloo interchange in 1989. Prior to this all the Wainuiomata bus services had met the train at Woburn and all trains stopped there. With the advent of the Waterloo interchange the Wainuiomata bus services were re-routed to Waterloo, and train services were introduced from Upper Hutt which were express from Waterloo (ie did not stop at Woburn). The service frequency at Waterloo, therefore, became nearly double that of Woburn and the majority of the Woburn P&R users moved to Waterloo.

- The relative cost of the P&R/PT package against the cost of car travel and parking at the destination affects the attractiveness of P&R to people making car-based trips. In both Auckland and Wellington P&R users do not have to pay for parking and are only charged the normal train fare. This should give P&R some cost advantage over private car travel to the CBD (however, many workers have free or subsidised parking at/near their workplace). Rail fare stages will also influence the relative usage of different P&R sites on a rail line. This has been evident with the change in rail fares on the Hutt Valley line at different times.

- The level of road congestion and the effect on journey time has an effect on the attractiveness of the P&R package. This has been evident at Paraparaumu where P&R

usage has been increasing significantly over the last few years. Road congestion between Paraparaumu and Wellington has gradually worsened, with roading developments planned to alleviate it. As more P&R spaces are provided they are filled immediately, indicating a latent demand which has not yet been satisfied (this increasing demand may also reflect the increases in the commuter population living in the Kapiti area).

- Although not highlighted by Travers Morgan, evidence in Wellington over the last few years points to the importance of car park security for potential users. For example, usage at the Porirua facility had been running at around 100 vehicles for several years. Security was not particularly good. Following several car break-ins the Police mounted a surveillance program and apprehended the people responsible. Public perception of security at Porirua has improved and usage has increased significantly.

Waterloo P&R Survey (1994)

A survey of users of the Waterloo Station car parks was carried out with the objectives of gathering information about the characteristics of P&R users and determining the likely response of Waterloo P&R users to different options for Waterloo P&R.

In terms of P&R user characteristics, nearly all users were travelling to work, made use of the car parks three or more times a week and were predominantly in the 25 to 59 age group. Convenience, quicker journey time and environmental reasons were the main reasons for using the train.

Users were asked to indicate their likely action under four different options. The response can be summarised as follows:

- **Option 1 – $2/day parking charge at Waterloo**. This option was strongly opposed, with only 16% of respondents indicating they would continue to park at Waterloo. Most people indicated they would either park at another station (31%), walk/cycle to the train (18%), or travel to Wellington by car (15%).

- **Option 2 – Extra 200 m walk to platform**. This option would discourage a significant number of present users from parking at Waterloo (69% would continue at Waterloo). Most of those switching from Waterloo would park at another station.

- **Option 3 – Improved bus service**. A significant number of present users (14%) indicated they would switch to the bus as their access mode to the train under this option.

- **Option 4 – Express trains also stop at Woburn/Naenae**. A large number of present users indicated they would switch to park at another station under this option. The majority would be likely to use Woburn rather than Naenae.

Waterloo Telephone Survey (1994)

A random telephone survey of people travelling from the 'wider Waterloo area' to the Wellington central city area was carried out to assist in evaluating P&R alternatives for Waterloo and to provide data for analysis of other Hutt Valley corridor P&R issues.

Respondents were asked to indicate what they would have done for their trip to Wellington under several different scenarios. The main conclusions were:

- New P&R users at Waterloo attracted by the availability of extra car parks would primarily be current train users. Around half of those parking at stations other than Waterloo would switch to Waterloo if parking was assured and around 15% of train users with a car available (half of all train passengers) would also become P&R users at Waterloo.
- The parking charge option would have the greatest effect in causing present P&R users to transfer from Waterloo, with the majority parking at other stations. Both the improved bus service options and express trains stopping at Woburn/Naenae would result in up to 15% of present users switching from P&R at Waterloo.
- Very few motor vehicle users (less than 1%) would switch to using the train if extra parks were available at Waterloo or improvements were made to all station car parks.

These results are consistent with the understanding that most motor vehicle users do not use the train for convenience-related reasons and significant improvements to the total PT system are required to attract these people. Providing a P&R facility, even one of a high quality, will on its own attract few motor vehicle users out of their cars on to PT.

Another aspect of this survey involved asking existing train users to rank different car park features in terms of importance. Good security and good lighting received the highest rankings, followed by a short walk to the platform.

Waterloo 'After' Survey (2000)

Following the extension of the Waterloo P&R facility, users of the new facility were surveyed as to their previous travel behaviour. The findings were:

- 10% previously drove all the way into Wellington CBD
- 75% previously parked their car elsewhere in the vicinity of Waterloo
- the remainder either parked at another station or accessed the station by non-car mode.

Wellington City Bus P&R Survey (Travers Morgan NZ Ltd 1995)

In 1995, Travers Morgan carried out a random survey of people travelling from three selected areas to work in the Wellington central city area before 9 am weekdays. Respondents were asked a number of questions regarding their attitude towards P&R facilities associated with bus services. They were also asked to indicate the likelihood of using a specific P&R car park in their area. The response was gathered for both motor vehicle users and bus users who normally have a car available for their trip to work. The results are summarised below.

Existing bus users

- Nearly all bus users walk to the bus stop, with only a very small number taking their car to the bus stop and parking at the stop (6.7%).

- The majority of bus users surveyed had a motor vehicle available for their most recent trip to work (65% of bus users) and nearly all of these had it available to them as a driver (90% of this group).
- The most common reasons for those people who had a motor vehicle available and chose to travel by bus were no parking at their destination (34% of this group) and convenience (33%).
- Only a very small number of those with a vehicle available indicated they would be 'almost certain' to use the proposed P&R facility in their area (3.7%), with the great majority (84%) stating they would be 'not likely' to use it.

Non-bus users (ie all respondents who did not travel by bus on their most recent trip).

- Over half (55%) of the respondents who made their most recent trip to work by motor vehicle indicated they did not use the bus at all for their travel to work. However, 9% used the bus at least once a week and a further 10% used the bus at least once a month.
- The main reason for not using the bus was convenience which related primarily to the need for the car during the day, the greater flexibility of the car, and the relative ease of travel (eg don't have to walk to bus, better in bad weather, less waiting time). The next highest reason was travel time, which related to the shorter journey time of car versus bus.
- A significant proportion (43%) of motor vehicle users parked in employer-provided parking. This group would be very unlikely to switch to bus unless there was a change in their personal circumstances. Such a change would be if the car park was not available. In this case 64% of motor vehicle users indicated they would switch to bus for their trip to work.
- Non-bus users were asked to indicate how likely it would be that they would use the bus under six different bus service scenarios:
  - existing fares halved
  - more frequent bus service (every five minutes)
  - bus stop very close to your house
  - bus stop very close to your work
  - express services to city centre
  - P&R facility available (no other change)
  - P&R facility available, bus frequency every five minutes, express service available.
- The most attractive single improvement for non-bus users appeared to be instituting express services. This reflected the importance of journey time for commuters. Simply providing a P&R facility on its own was the least attractive improvement.

- Motor vehicle users were asked how likely they would be to use a specific proposed new P&R facility. Only 2.7% indicated they would be almost certain to use the proposed new car park. The majority (66%) stated that they would not be likely to use it at all.

Birdwood Street Bus P&R Survey (1999)

A survey of users of the Birdwood Street (Karori) car park was undertaken by Booz Allen for the WCC in May 1999. 31 cars used the car park: 16 survey forms were handed out and 13 returned (post-paid).

Relevant results include the following:

- **Reasons for use of bus**. Most common reasons for use of the bus rather than driving all the way were: cheaper (33%), lack of parking at destination (31%).
- **Reasons for use of facility**. Main reasons given for use of the P&R facility rather than parking elsewhere on the Karori bus route were the greater service frequency, and the lack of car parks elsewhere. 12 of the 13 respondents had available a closer bus service to their home; but preferred to catch the bus from the P&R facility because of higher frequency, faster trip, more convenient times etc.
- **Reasons for driving to site**. People drove to the P&R site (rather than walk or be dropped off) because it was too far or too long to walk and no one was available to drop them off.
- **Prior travel mode**. Prior to the opening of the facility, about 30% of respondents drove all the way and 30% walked to their nearest bus stop. For the 17 respondents, eight made additional bus trips, with five making shorter bus trips; while five long (to CBD) car trips were replaced by 13 short (local) car trips.
- **Alternative travel mode**. If the P&R facility were no longer available, 19% said they would drive all the way, 31% would walk to their nearest bus stop and 50% would drive to another location and take the bus.
- **Desired facility improvements**. The main suggested improvements to the P&R facility were increased capacity and additional lighting.

WRC P&R Survey (2002)

A survey of P&R users was carried out by the WRC one morning in April 2002, covering 1362 P&R users and all rail P&R car parks throughout the region. Of the respondents, 95.4% were travelling from home to work, 1.3% going to education and 0.8% to recreation. Thus, nearly all current P&R users are commuters.

Also, 97.4% of respondents were travelling to Wellington station, with 77.5% using the P&R car park five times a week and 14.1% three or four times a week. The P&R users came from high car-owning households with 51.8% having two cars in their household and 15.6% with three or more cars.

Respondents were also asked what they would do if the P&R car park they were using on that day was not available to them. Of those who replied, 62.1% indicated they would park on the street nearby, 11.4% would park at another rail station and 8% would drive all the way to their destination (18.5% did not answer this question).

Summary of Wellington market research studies

The main findings from the P&R studies summarised above were:

- nearly all rail P&R users are commuters travelling to Wellington CBD
- most rail P&R users make use of the P&R car park 3–5 days a week.
- the level of rail service at a station affects the number of P&R users at that station
- only a very small proportion of motor vehicle users would be likely to switch to P&R if additional P&R car parks were available, or improvements were made to the car parks (less than 1% of motor vehicle users in the 1994 Waterloo telephone survey and 2.7% of motor vehicle users in the 1995 Bus P&R survey
- some informal bus P&R is currently occurring in Wellington City (1995 survey found 6.7% of bus users were P&R; this proportion may have increased with the advent of coupon parking)
- 34% of bus users who had a car at home took the bus because of no parking at their destination
- 43% of motor vehicle users in the 1995 survey parked in employer-provided parking and 64% of these users indicated they would switch to bus if a car park was not available
- the WRC 2002 P&R survey found that 8% of current P&R users would drive all the way to their destination if their current P&R car park was not available (rather than park on the street or park at another station).

Auckland

The 'Northern Busway Station Survey – Albany and Constellation Express Services' was conducted by the ARTA in April 2006, around five months after the opening of the Northern Busway. The survey collected information on the catchment of the busway stations, the CBD catchment area, the modal shift before and after the opening of the busway and modes of access.

In terms of P&R users of the busway, it was found they comprised around 57% of people surveyed at Albany station (52% drove alone, 5% drove with a passenger) and 35% of people surveyed at Constellation station (33% drove alone, 2% drove with a passenger). The catchment for P&R users of Albany station (further away from the CBD) was much larger than Constellation, with 16% of P&R users travelling from as far north as the Hibiscus Coast and Kauakapaka. A similar pattern is seen at Constellation station, reinforcing the fact that people are prepared to drive a significant distance to access PT services when quality services are provided. There is also evidence of some passengers driving against the direction of travel over shorter distances to access the site.

Table D1 Proportion of P&R users by distance (Albany).

Distance	Area	Proportion of P&R users
Less	Albany area	28%
	Torbay/Waiake	40%
	Dairy Flat	7%
	Paremoremo	10%
	Orewa/Hibiscus Coast	10%
More	Takekeroa/Kaukapaka	6%

Table D2 Proportion of P&R users by distance (Constellation).

Distance	Area	Proportion of P&R users
Less	Sunnynook/Unsworth	28%
	Murrays/Mairangi Bay	22%
	Greenhithe/Bayview	20%
	Albany	17%
More	Torbay/Waiake	13%

APPENDIX E Trial stated preference survey of P&R usage

Survey methodology

The survey used software developed in Excel to examine peoples' choices between their current mode of travel and next best alternative (NBA) given a series of costs (time and monetary), with the purpose of developing values of time for the cost components. The modes considered for the study were 'car all the way' (car), 'car then train' (P&R) and 'walk/bus then train' (PT). Bus all the way users were excluded due to the lack of bus P&R sites in Wellington. Component cost values were gathered on users' current and NBA mode of transport. These costs were then varied using a 9 or 16 showcard orthogonal design (depending on the mode combination chosen), with the respondent choosing between their current and NBA. The first showcard represented their current and NBA situations as given.

Recruiting the interviewing was conducted by the TNS research company. Recruitment was done via random telephone calls in areas of Wellington broadly served by the rail network, with a series of filtering questions defining the market as people:

- leaving home between 7 am and 9 am
- travelling to the Wellington CBD
- living within areas that were rail accessible
- whose current mode or NBA was P&R
- who were not car or PT captive
- who paid for either their car fuel or parking costs (excluded where they paid for neither, as unlikely to change).

Other demographic information was gathered of respondents to allow for rescaling of survey results, although this was optional. Respondents were given the option of having the survey conducted in their own home or at a central CBD location. An incentive in terms of a prize draw was also offered.

Pilot survey recruitment

A pilot survey was conducted of 53 completed interviews. It became apparent through the recruitment process that response rates were going to be extremely low. This was partly due to some recruitment occurring during school holidays when families were more likely to be away from their homes – this contributed to a large proportion of 'no answer calls'. Finding households that had a member who travelled to the Wellington CBD in the morning peak was also a difficult task. The following table gives response rates of around

2% for total calls (2,603 calls were required for 53 completed interviews) and 7% for calls that were usable (not business, engaged or no answer). For respondents who qualified for the survey only seven refused to do the survey which indicated that offering the respondent the option of interviews at home or in the CBD, and the use of the prize draw were sufficient levels of incentive. There were also 10 'no-shows' to the survey.

Table E1 Recruitment statistics.

Total calls made	**2603**
Business numbers	186
Engaged	373
No answer	1107
Call back again	180
Refused to talk	183
No qualifier for am peak CBD	567
Qualifier but refused	7
No shows	10
Completed interviews	53
Interviews/call	2%
Interviews/usable call	7%
Interviews/qualifier	88%

The low response rate was due primarily to the number of unusable calls (which was due to the random sampling of households), as well as the clearly defined market being a small proportion of the population. It is clear from this that a more efficient sampling process is required when targeting the potential market.

Pilot survey results

One of the purposes of a pilot survey is to provide input into refining the market segment recruited and showcards presented so that the number of non-traders (which do not contribute to parameter estimates) are minimised. While significant pre-pilot testing was undertaken, the number of non-traders was still high, but in line with many other SP surveys of this nature.

Of the 53 completed surveys, almost half of the respondents did not trade in the SP. The following table gives a breakdown of non-traders by mode combination, and some observations.

Table E2 SP survey qualitative analysis.

Current mode	NBA mode	Number	No. traders[1]	Comment
Drive all the way	P&R	21	8	3 people traded on the first set, indicating that their current choice may not be their most efficient, that there were other influences not included, or that the interviewer did not explain the process sufficiently 8 people didn't trade at all. 4 of these had free parking. Of the other 4, 2 of them had unrealistic responses (ie walk from train = 150 mins or car IVT = 2 mins). Of the remaining 2 that did not trade but did pay for parking, all had car IVTs > 40 mins Of the 8 that traded a bit, 1 had unrealistic data. Of the remaining 7, only 2 had a car IVT >= 40 mins. Interestingly, of the 8 that traded away from drive all the way, 4 had free parking
Bus and ride	P&R	1	0	Only 1 person who chose their NBA on first set of cards.
Walk and ride	P&R	11	8	1 person's data had errors 8 people did not trade at all – proves that this was not the best test. 4 of these people walked less than 10 mins to the station. But of these 8 people, only 1 person walked less than 10 minutes from the train station to the destination, most were 20–30 mins. Indicates that walk & ride does not really compete with P&R Of the 2 that traded, they chose to drive and walk to the same station. Car IVT was approx half the walk to train stations time.
P&R	Drive all the way	14	3	5 of 14 people selected NBA on 1st set. Of those 5, 3 of them selected NBA for all 16 cards. 2 did not trade at all. They both had 5 min drives to the station, 17 min train IVTs. They were a min of 30 min Car IVT from city. One had a walk from train of 25 mins but still wouldn't trade. Of the 3 that traded only a little, 2 caught the train from the same station and said that to drive all the way would take considerably longer (one of them had a car+train IVT of 22 mins and a drive all the way IVT of 45). The other person had a very long trip, including a 75 min walk from the train to destination, but still wouldn't trade much. The 3 that traded well had train IVTs between 14 and 18 minutes. 1 person's data had errors.
P&R	Bus and ride	3	2	2 didn't trade at all. The one person that did trade had good data

Current mode	NBA mode	Number	No. traders[1]	Comment
P&R	Walk and ride	3	0	All 3 traded well. All had similar journeys: 5 min drive to station or 15–20 minute walk. 40–50 minutes train IVT. 2 of the respondents walked in excess of 50 mins from the train station.
	TOTAL	**53**	**22**	

Note 1: One or fewer trades

While we cannot deduce parameters from the pilot survey, we can conclude the following:

- Random phone recruitment when trying to recruit from a small proportion is not cost effective; a more efficient recruitment process would involve recruiting at rail stations and parking buildings, but these introduce their own biases.
- Offering flexibility of where the survey is conducted (home or CBD location) and including a prize draw gives low refusal rates.
- The mode that has the highest level of competition with P&R is car all the way.
- While walk access to rail and P&R are feasible alternatives for some people, they are unlikely to change.
- The quality of the input data and interviewer instructions are paramount to the success of an SP survey, particularly when recruitment is so costly.
- Free CBD parking charges (employer-paid parking costs) do not seem to be a significant reason for car all the way users not trading.

Pilot study recommendations

A number of changes to the SP survey software were recommended as a result of the pilot; these changes would improve the quality of the data as well as reduce the number of non-traders:

- Fix egress time for rail trips so that the NBA egress time is the same as the current egress time.
- Check so that 'car all the way' IVT times cannot be less than 10 minutes.
- Increase the extremity of the SP tolerances to encourage more traders
- Make it clear that the egress time is either walk or bus or whatever – doesn't matter what mode they use – it's based on their current journey.
- Include a warning box for indicating when the current mode is not chosen on the first showcard.

The biggest problem, however, was to do with the recruitment and finding suitable candidates. The response rate was far too low and the cost/interview too high. There were a number of options suggested:

(i) Continue as is, but reduce the sample size substantially (to maybe 150)

- Problems with small sample sizes
- Analysis of segments would be crude and have large confidence intervals
- Expensive per interview costs

(ii) Continue as is with a much smaller sample (say an additional 50–100) and recall non-traders to determine why they did not trade

- Even though we can’t use them in the SP, we might be able to get some useful qualitative information from non-traders
- Problems with small sample sizes
- Analysis of segments would be crude and have large confidence intervals
- Expensive per interview costs

(iii) Recruit on street/station and then survey as is

- This would get around the problem of very low response rate as could recruit at station platforms (for current rail users) and parking buildings or possibly on-street parking for car users
- Reduces the randomness of the survey and introduces biases that can’t be corrected for
- Car users may only be captured from paid parking – would need to ask recruiting questions to make sure people had a choice of rail so that their NBA would be P&R – also need to think about am peak and the time they make their journey
- Rail users – would also need to ask recruiting questions to make sure they currently use P&R or their NBA is P&R – also if they had a car available – we may also pick up some usual car vs P&R users who may have used rail on that day
- This would reduce the cost per interview.

(iv) Bail out

It was decided that option 3 (recruitment at stations and parking buildings) would be the recommended way forward with the survey. However, due to the expensive pilot and the fact that the sampling process of the pilot and continuation would not be consistent (and biases different), it was decided (after consultation with the client) that option 4 (bail out) was the best way forward (recognising that the pilot would not produce parameter estimates).

Abbreviations and acronyms

APT	Auckland passenger transport
ARC	Auckland Regional Council
ATR	Alternative to roading
BRT	Bus Rapid Transport system (Auckland)
CBD	Central business district
GWRC	Greater Wellington Regional Council (also referred to as WRC)
HBW	Home-based-work
HIS	Household Interview Survey
HOV	High-occupancy vehicle
IP	Interpeak
JTW	Journey to work
K&R	Kiss and ride
LERTS	Leicestershire Environmental Road Tolling Scheme
LOS	Level of service
LT	London Transport
MLR	Multiple linear regression
MSC	Mode-specific constant
NBA	Next best alternative
NSE	Network South East rail system (London)
P&R	Park and ride
PCU	Passenger car unit
PEM	*Project evaluation manual* (Land Transport New Zealand 2005)
PT	Public transport
RLTS	Regional land transport strategy
RP	Revealed preference
RPTP	Regional passenger transport plans
SP	Stated preference
TA	Territorial authority
TDM	Travel demand management
TLA	Territorial local authority
VKT	Vehicle kilometres travelled
WRC	Wellington Regional Council (also referred to as GWRC – see above)
WTSM	Wellington Transport Strategy Model