"Ticket to ride": factors affecting park-and-ride travel in Perth, WA

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Abstract

In many cities park-and-ride (PnR) is gaining popularity for its ability to integrate car driving with public transport. PnR increases access for residents living at the city's edge and helps alleviate congestion. In terms of efficiency PnR reduces investment on frequent public transport services in low-density areas.

PnR is particularly relevant to a low-density city like Perth, Western Australia. In recent years PnR has been a key ingredient to generating a high volume public transport ridership on newly constructed lines. More than 15,000 PnR bays have been incorporated into transit-oriented developments (TOD) around the 20 stations. This in contrast to the 48 legacy stations which have in total 2,500 bays.

The paper aims to identify the effectiveness of the PnR direction taken by Perth city planners by first looking at the differences in facilities at the older and newer stations. A survey of passengers' stated importance of levels of service offered at rail stations is augmented by their ratings of the existing level of service. The attitudes and ratings of the PnR network are related to train patronage.

1. Introduction

Park-and-ride (PnR) provides residents of low-density suburbs or at the urban fringe with a fast and flexible access mode and reduces congestion on arterial roads (Holguin-Veras et al., 2012). For this reason, interest in the use of park-and-ride (PnR) has surged in recent years. The principle of the system is to enable commuters to make part of a journey (usually to a central location) by train, saving on higher parking costs in the central business district and avoiding congested roads. For residents of low-density suburbs, PnR provides a fast and flexible access mode (Holguin-Veras et al., 2012; Duncan and Christensen, 2013). The journey to and from the railway station is not constrained by the infrequent timetable of local buses.

Substantial corpus of research identifies two main categories of PnR users:
a) car drivers, who find it appealing by saving in cost and time (congestion, parking in the city) (Parkhurst, 2000; Hamid, 2009; Holguin-Veras et al., 2012); and b) public transport

users, who embrace it because they can avoid the low frequency services close to their homes (Karamychev and van Reeven, 2011; Duncan and Christensen, 2013).

PnR is also beneficial for communities as it takes advantage of the scale economy offered by public transport and reduces congestion on arterial roads (Karamycev and van Reeven, 2011). Hole (2004) found that effective PnR in the United Kingdom persuaded commuters to use more environmentally friendly public transport modes. This was later confirmed by Dijk and Montalvo (2011) in many other European cities, where PnR facilities discouraged car use. This promoted investment in PnR, although to different degrees. Their survey in 45 major European cities highlighted that adoption may be uneven, dependent on the policy-makers interpretation of PnR. According to the authors, the drivers for engaging in PnR development are not only its economic implications and the demand, but also the organisational learning capabilities, i.e., how the transport authorities are capable to organise PnR.
In New York, the Department of Transport places a high importance on PnR as is evidenced by its inspection, design and construction of PnR facilities (Holguin-Veras et al., 2012). Similarly, In Australia, PnR has become part of the urban landscape, especially in relation to TOD (Olaru et al., 2011). The relative low-density of the urban areas may explain the PnR's fast rise (Duncan and Christensen, 2013). In Kuala Lumpur, on the other hand, the PnR facilities are smaller and appear to have a lower utilisation (between 80 and 95%) (Hamid, 2009).

1.1 Local PnR Situation

In Australia, the State Government of Victoria committed $90 million to construct 5,000 new car parking spaces at metro railway to bring the total PnR supply to 31,500 (Hamer, 2009). This was in response to the high demand for PnR, exceeding the capacity by about 50% (overflow parking occurring on local streets). In Perth, there are more than 17,500 PnR bays at 55 (out of 70) railway stations, along five rail lines (Curtis, 2008; Martinovich, 2008). Their majority were built at the newly constructed stations along the North-South spine of the city. These corridors have stations spaced much further than the traditional lines and have as many as 1,000 parking bays. Yet, one in three of these new stations is positioned in fledgling TOD centres.

Currently, the limited parking spaces are occupied on a first-come basis, with a spillover from free parking to pay parking at the slight charge of $2 per day. In general, the parking areas are full by 7:30am and the cars occupy the bays until 4:30-5:00pm. Young relatively low-income workers arrive at busy stations early to secure free parking, which are usually full by about 7:00am. The paid parking section fills soon after and in many parts of the city cars are found parked on commercial or residential areas adjacent to the train stations. In order to meet rapidly growing public transport needs over the next 20 years, a fund of some $2.9 billion has been budgeted for infrastructure upgrades, of which $135 million will be used to improve transit interchanges such as PnR facilities (PTA, 2011). However, the high construction cost of each bay (about $20,000 AUD) means that the government needs to re-assess the location of new parking areas, the supply of services required, the latent commuter demand and parking charges.

Excluding the two central stations, this paper provides a detailed audit of PnR features at 68 railway stations in Perth. The dominant feature that separates the type of station is whether it is a PnR station or a traditional station. These results are used to provide context to an investigation into patrons' stated level of expectations or importance of features found a railway stations as well as their assessment of the network's current state.

The paper opens with a review of the literature on the factors affecting the use of PnR systems (Section 2). This is followed by a description of the data collection (PnR features and attitudes, evaluation from an intercept survey) and methodology (Section 3). Results

regarding associations between railway station facilities, level of ridership, as well as the attitudes and perceptions of travellers about PnR are presented in Section 4 and the paper concludes with comments on implications for research and practice.

2. Factors Affecting PnR Travel

2.1 Departure Time and Congestion

Despite increases in PnR provision, generally commuters need to arrive at the railway station early in the morning to secure a parking bay. Fifty-six precent of the commuters in the San Francisco Bay area depart between 4:00am and 6:00am every morning in order to find PnR spaces at stations on corridor I-80 (Shirgaokar and Deakin, 2005). In Perth many stations start to fill before 6:00am and have no more available parking bays by 7:30am (Martinovich, 2008). Studies of commuter choice within the context of PnR must then account for the link between departure time and the probability of finding parking.

Departure time is critical to the choice of travel mode and, in the case of PnR, of the station and access mode. PnR commuters face the daily challenge of locating a parking space, thus arriving early at the railway station increases the likelihood of securing a space. Peak hour congestion may increase car commuters' travel time by a factor of three. Commuters trade-off departure time against their expectation of the level of congestion on the roads (De Jong, et al., 2003; Bajwa et al., 2008). Regardless of the treatment of time - either as a continuous variable (Yang and Hai-Jun, 1997; Wang et al., 2004) or in discrete groups (Hess et al., 2007; Bajwa et al., 2008), "early" or "late" (Bhat and Steed, 2002; Hess et al., 2007), the choice of travel mode is modelled jointly with the choice of departure time by making some of the modal attribute levels functions of the chosen departure time.

2.2 Public Transport Services

Whilst for drivers, travel time and travel time variation are viewed as the major influencing factors in mode choice (Noland and Polak, 2002; Li et al., 2010), Shiftan et al. (2003) indicated that parking search time and parking walk time have significant negative relationships with the utility of car users. Commuters using public transport are assumed to be more concerned about waiting time, access time and egress time (Tsamboulas et al., 1992; O'Fallon et al., 2004; Debrezion et al., 2009). Bhatta and Larsen (2011) found that the inclusion of transfer time and number of transfers were important factors affecting mode choice. Clearly, with a shadow price of more than $20,000 on each parking space in Australia, their provision needs to be substantially supported, accounting for the whole suite of benefits (travellers drawn out of their cars reduce congestion on arterial roads only if the PnR alternative is convenient to them).

2.3 Access Modes

Access time and cost significantly affect the choice of travel mode and station (Tsamboulas et al., 1992; Hole, 2004; Polydoropoulou and Ben-Akiva, 2011). For walking, distance is important and significant in access mode choice; Debrezion (2009) found that commuters are reluctant to walk to the rail station if the distance is greater than 1.1 km. Parking cost has been consistently found significant, while parking search time, security and amenity of park-and-ride facilities have some weak influence on travellers (Hendricks and Outwater, 1998; Shiftan et al., 2003; Hensher and Rose, 2007; Polydoropoulou and Ben-Akiva, 2011). For bus, Hensher and Rose (2007) have shown that waiting time and bus fare are significant attributes.

2.4 Socio-Economic Characteristics

In regard to socioeconomic variables, commuters with higher income prefer to drive rather than use public transport (De Jong et al., 2003; Hensher and Rose, 2007; Hensher, 2008). Women are more likely to use the car as main transport mode, whereas men prefer public

transport (Bhatta and Larsen, 2011; Zaman and Habib, 2011). Hensher and Rose (2007) found that men prefer public transport for work but use the car for non-work trips. Middle-aged commuters are inclined to drive more, because of their family obligations, whereas financial and mobility restrictions cause the elderly and young to use more public transport or share driving (Bhatta and Larsen, 2011; Shiftan et al., 2003; Hensher and King, 2001; Cirillo and Axhausen, 2006). Employment status affects commuters' transport mode choices: part-time workers prefer cars due to their flexible working hours more than full-time employees (Zaman and Habib, 2011; O'Fallon et al., 2004). The number of cars per household is also a significant predictor of mode choice, with a positive effect on the choice of car and park-and-ride, but negative on the use of bus (Debrezion, 2009).

2.5 PnR and TOD

Literature focusing on PnR and TOD is ambivalent about the role of PnR in changing for the better the conditions of our evolving cities (Duncan and Christensen, 2013). Whereas numerous TOD proponents see PnR as a detractor from the smart, well-mixed development (Giuliano, 2004; Cervero, 2005; Kim et al., 2007; Curtis, 2008), others acknowledge that low densities make use of transit impossible if users cannot access the station by motorised travel modes (Meek, 2008; Martinovich, 2008) or that railway stations' potential for TOD may be limited even in the absence of parking (Duncan and Christensen, 2013).

The consequences of PnR can be both positive and negative and a full accounting of the impacts would need to regard both short- and long-term reactions, as well as a distribution of those effects over the population. PnR offer residents far away from railway stations a feasible option to combine car with public transport travel. The increased ridership is associated with less car travel, lower congestion, and increased revenues for public transport services, or reduced costs for local feeder bus services (Karamycev and van Reeven, 2011). However, PnR facilities use substantial space near stations where compact development could take place, they discourage walking, attract noise, traffic and may be visually unappealing.

Several studies question the role of PnR in reducing traffic arguing that PnR offers incentives both to car drivers to use public transport and to the public transport users to use car for a part of their journey (Karamychev and van Reeven, 2011). This reciprocity is considered particularly relevant in cities where the train trip is shorter than the access trip (Parkhurst, 2000). In the same line of thought, AASHTO (2004) criticised location of PnR facilities near places of destination and advocated for locations close to origin (Parkhurst and Richardson, 2002).

In Australia, PnR seems to be adopted as a pragmatic solution for the local conditions of low densities, and not as a feature of the "evil" transit-adjacent development. With or without parking, the stations may be integrated into mixed land-use precincts. Depending on the station's location, closer to the inner city or at the fringes, the PnR provision varies and consequently the train access modes. Stations close to the city attract more walking, cycling, whereas stations further away will rely heavily on PnR and KnR (Kim at al., 2007; Hamer, 2009). Regardless, by building mixed land use areas with good city-wide access, planners aim and expect to induce changes in the residents travel behaviour (Cervero, 2005; Duncan and Christensen, 2013).

3. Data Collection and Methodology

3.1. Surveys

This paper reports findings from two data collection stages: 1) an objective evaluation of PnR facilities (a detailed audit of park-and-ride features using 30 measures of services, facilities

and accessibility of the train stations) and; 2) a survey of preferences for PnR features and travel, conducted at a sample of seven train stations.

The comprehensive audit of PnR characteristics or measures was performed at all 70 railway stations in Perth. The radial network, including five corridors is presented in Figure 1.

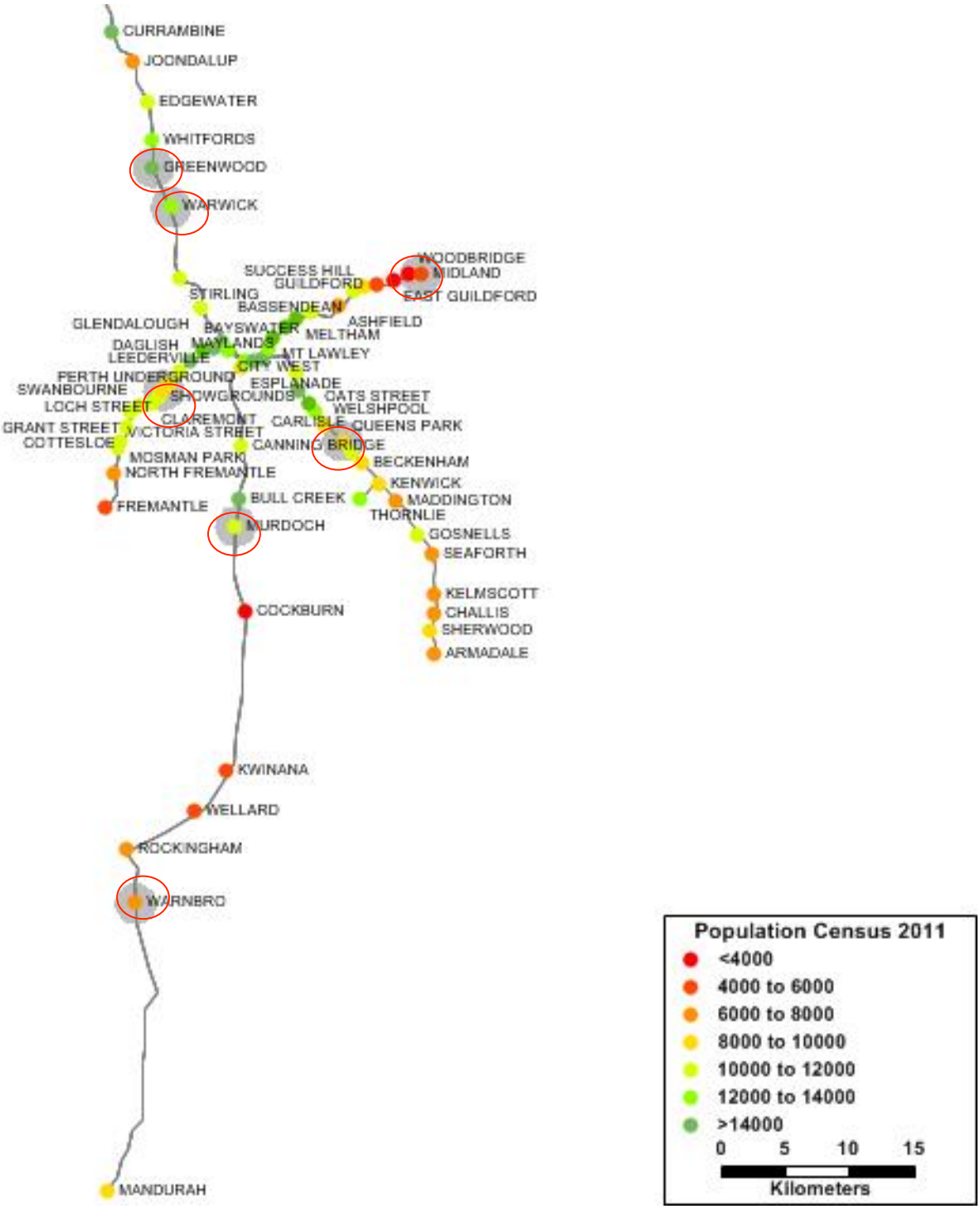

Figure 1: Railway network, stations sampled for the intercept survey, and the population within 1.6km radius from the station

The stations vary in age (from 6 to 132 years), style, and facilities. From Victorian buildings to modern designs, the stations cover a variety of layouts and functions (transit interchanges, transit oriented stations, insular stations in the middle of the freeway with pedestrian access

bridges). The East-West corridors (Fremantle and Midland) were built more than a century ago. The Northern corridor, Clarkson, has been operating from middle 80's and the Southern line, Mandurah, is the latest addition to the network (operating since 2007). The Clarkson-Mandurah corridor is primarily a PnR and bus interchange system. It has ample PnR supply, with several stations up to 1,000 bays. On the Fremantle line (West) PnR is almost inexistent (in average 30 bays/station), and on the Midland and Armadale corridors (East) is limited to 500 bays (in average only 120 bays).
Figure 1 also displays the population density around the train stations. They vary from less than 50 residents/ha to 175 residents/ha, at least an order of magnitude lower than average population densities for cities (http://www.newgeography.com/content/002808-world-urban-areas-population-and-density-a-2012-update).

The second data set was collected in July-August 2012 using an intercept survey at seven train stations across the five railway corridors, highlighted on Figure 1. The survey was conducted between 6-10:30am and 3-6pm, on the platforms, interviewing travellers before boarding their trains. The survey included questions related to the access mode to the train station, origin and destination of the trip, motivation for choosing that particular train station, as well as a number of attitudinal questions aimed at understanding what facilities and services are important for riders and how they view their quality at the selected train station. The sample of 945 respondents has the following general characteristics: 47% males and 53% females; 46% under 30 years of age, 39% between 31 and 55, and 15% above 56 years; and a roughly equal number of responses at each of the seven stations.

3.2. Data Analysis

To summarise the features and local accessibility measurements, as well as the traveller preferences for PnR characteristics, we performed factor analysis. The reasoning for this is that single measures are unlikely to cover the level of service provided by PnR stations; also many indicators go hand-in-hand (because of the design practices or agglomeration economies) or complement each other. By using factor analysis we created composites, likely to mirror the set of offerings for PnR and the public attitudes towards them.
Then, correlation analysis was applied to test the association between PnR and access features with railway patronage, followed by latent class analysis to identify homogeneous groups of travellers in their preferences for PnR. Detailed results are presented in Section 4.

4. Results and Discussion

4.1. Objective Measures (PnR Audit)

Confirmatory factor analysis identified four key differentiating factors of access and service across rail corridors. The uni-dimensional constructs include: *parking supply* (free and secure, locked and paid parking), *facilities* within the station perimeter (public utilities, bike lockers, disabilities access, retail and food, etc.), *land use mix* around the railway station, and *distance/time accessibility* by motorised and non-motorised modes.

Each summary/construct has a measure of reliability, so instead of the 30 individual local accessibility measures, we use a reduced number of four measures, based on their commonality. The factor analysis provides loadings, which reflect the strength of relationship between the construct and the individual measure and show how consistent the items are within a construct. Some items are strongly related to the construct, others are weak. Loadings show the relative importance/contribution of the items within the construct based on the objective transport planning practices applied in railway stations and precincts around them. In addition, these summaries are continuous variables, providing an advantage in modelling over binary or ordinal variables, which require special approaches.

Table 1 presents the structure of these constructs. Two of them have reliabilities above 0.65, and two above 0.55. We notice that 14 out of 19 items have loadings above 0.7, confirming the appropriateness of using construct measures to evaluate the facilities provided at the train stations and land use around them. In relative terms, provision of PnR bays (either free or paid) (1.000 and 0.862), presence of transit officers/personnel (0.991 and 0.899), basic facilities such as ATM and restrooms (0.861 and 0.894) seems to have higher contribution to the constructs than parking bays for individuals with disability, public telephones, bike or walking access (lower values for loadings). Although essential to many public transport users, these reduced loadings may be reflective of the limited availability of these services and relative lack of variability across the railway network in Perth. This represents a prime indication for planning practice of vital elements that have to be incorporated for increasing the overall access of railway stations in Perth.

Table 1: PnR facilities – factor loadings

Construct – GOF and variance explained	Items	Standardised factor loadings
Parking supply X^2 = 1.005 (2); p=0.605 RMSEA=0 CFI, TLI=1 SRMR=0.018 Var = 0.643	PnR bays (free of charge)	**1.000**
	PnR bays (locked - $2)	**0.862**
	Taxi bays	0.742
	Parking bays for people with disabilities	0.598
Station facilities X^2 = 349.049 (620); p=1.000 Var = 0.569	Railway station personnel	**0.991**
	Security personnel	**0.899**
	ATM/change money machines	**0.861**
	Restrooms	**0.894**
	Locked bike facilities	0.674
	Public phones	0.584
	Vending machines	0.779
	Convenience store	0.758
Land use around the railway station (100m radius) X^2 = 13.894 (2); p=0.001 Var = 0.629	Shops	**0.984**
	Restaurants	0.799
	Offices	0.738
Station accessibility X^2 = 36.502 (4); p=0.001 Var = 0.572	Access by car	**0.806**
	Access by public transport	**0.895**
	Bike access	0.683
	Walk access	0.481

The factor scores were then further applied to compare the five corridors. Notably, a cluster analysis on latent scores indicated that the station's characteristics are mostly dependent on which line the station is on. The highest scores for parking supply and station facilities were recorded for stations on the North-South lines, Clarkson and Mandurah (averages of 1.185 and 0.927 for parking and 0.784 and 1.140 for facilities), compared to negative values for the other three corridors. Whereas these differences were statistically significant at 0.01 level, the land use and the access to the station were not. Nevertheless, the highest scores for land use and access were obtained for stations on the Fremantle corridor (West). Table A1 shows the standardised latent construct values for faciltiies and local access by train station. Negative values indicate a lower level of combined facilities and access, whilst a positive value indicates that the station has a higher quality of services and a higher level of access.

The corridors with the largest supply of PnR have the highest ridership. Figure 2 displays the average patronage for a weekday in 2012 (daily boardings March 2012) along with the PnR supply. As indicated in Section 3, this appears to be a function of the period in which the

station was built. Car accessibility and the parking supply were most influential in determining the number of daily boardings. This is expected given the low densities in Perth, which means that "traditional" catchment areas of walking (1.6 km or a mile) need to be reconsidered in order to achieve the level of ridership required for train.

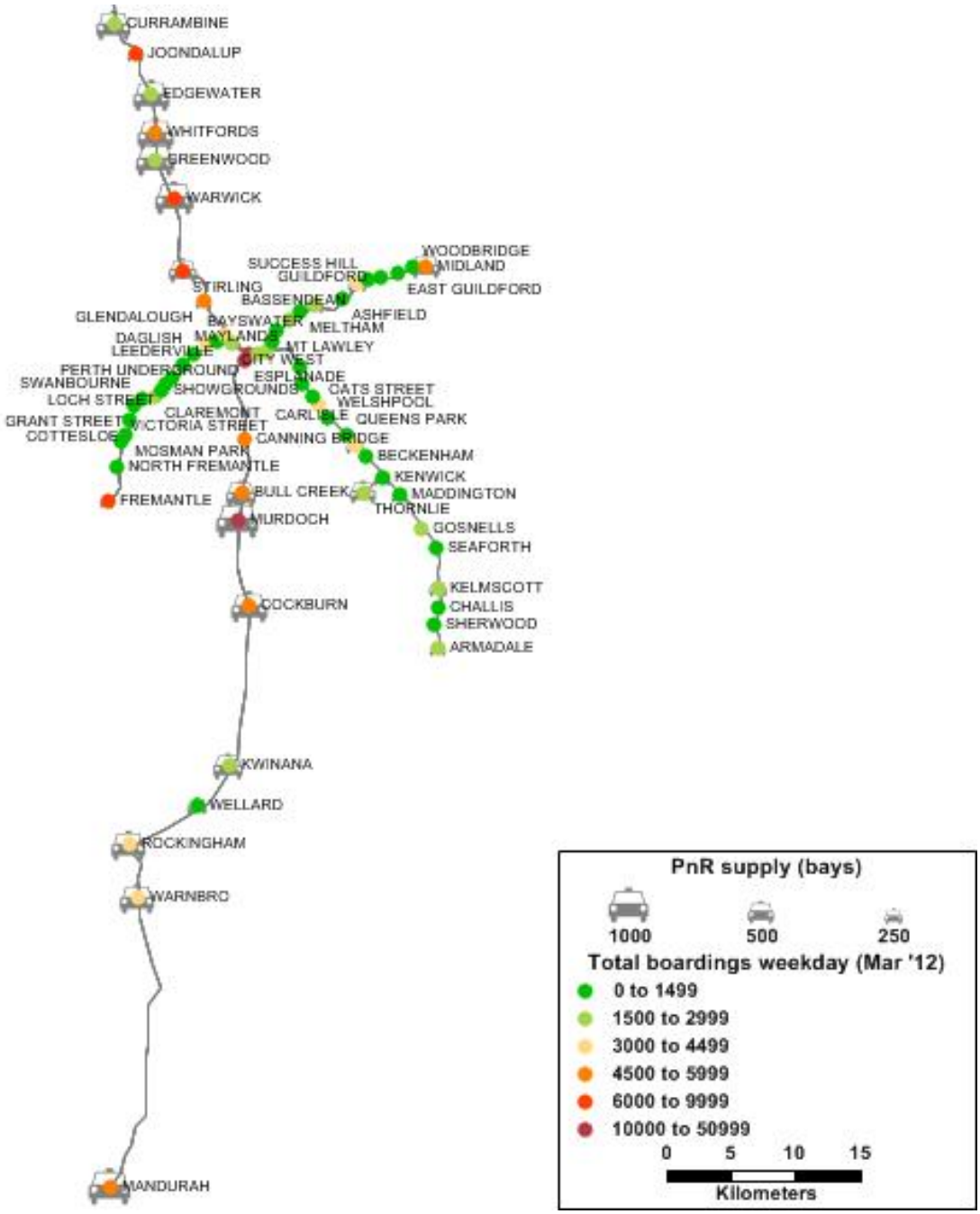

Figure 2: PnR supply and patronage (boardings) per railway station

Table 2 further explores the associations between transport services, supply of PnR, land use and stations' accessibility with the number of boardings and access mode. Although not as high as parking supply, accessibility measures (car, PT, walking and cycling) are associated with higher patronage.

The new stations (North-South spine, including Clarkson and Mandurah lines), situated in less diverse land-use mix locations, have the highest level of patronage, indicating that availability of parking is the driver of train ridership, more so than collocating activities and

public transport hubs found on the East-West corridors. The level of boardings on the Clarkson and Mandurah is 3-4 times higher than for the other three lines, and the stations are accessed by car and feeder buses, whereas on the East-West lines the access is mainly by walking and feeder buses.

Table 2: Correlations between factor scores and patronage levels

	1	2	3	4	5	6	7	8
1 Parking	1							
2 LU station	-0.265*	1						
3 Facilities within station	**0.715****	-0.134	1					
4 PnR unlocked	**0.927****	-0.288*	.0657**	1				
5 Locked/Pay PnR	**0.862****	**-0.397****	**0.646****	**0.783****	1			
6 Access to station	**0.510****	-0.091	0.379**	0.412**	0.413**	1		
7 Total boardings weekday	**0.490****	0.103	**0.706****	**0.479****	**0.483****	0.227	1	
8 %PT transfer	**0.608****	-0.164	**0.674****	**0.525****	**0.557****	**0.492****	**0.682****	1

Note: ** denote correlations significant at 0.001 level, * significant at 0.05 level.
In bold, correlations above 0.4 in absolute value.

The correlations also show that the mix of uses around station is significantly associated only with the number of secure parking bays, highlighting the competition for land between transit oriented developments at the intermodal point and the parking facilities.

4.2. Subjective Measures (Intercept Survey)

Tables 3 presents additional descriptive statistics from the second data collection, regarding travel purposes and access modes for train patrons. Across the sample, the dominant access modes are PnR and bus (in equal proportions), followed by walking and Kiss-and-Ride (KnR). Two thirds of the trips are for commuting or education and 9% for personal business.

Table 3: Access mode to the train station (N=945)

Access mode	Travel mode Survey day (%)	Regular travel mode (%)	Purpose of travel	(%)
Car (driver)/PnR	29.8	28.6	Work	52.8
Car (passenger)/ Kiss & Ride	19.7	13.1	Education	16.9
Bus	27.1	30.6	Personal business	8.7
Walk	18.9	19.2	Shopping	3.5
Bike	1.2	2.5	Discretionary (social)	0.9
Taxi	0.5	0.2	Accompany someone	2.3
Other	2.7	5.7	Other (attending/spectating events, etc.)	3.4
			Return home	11.0

When asked about their main motivation to choose PnR, the respondents indicated advantages such as: convenience (33%), low cost (26%), and speed (20%). Qualitative answers to an open-ended question showed that Perth travellers enjoy the presence of PnR at train stations as a possibility to have a wider choice set, not “forcing them out” of their cars. More than 60% of the respondents have also stated they would pay $3 or more to secure a parking bay at the train station. Importantly, if parking were not available at the

station, half of the PnR travellers would continue driving to the next station or to the destination and 37% would return home, changing their travel plans.
A second factor analysis confirmed three uni-dimensional constructs of facilities, this time based on their importance allocated by respondents: *parking and bike facilities* (free and secure, locked and paid parking, bike storage), *basic facilities* within the station perimeter (public utilities, disabilities access, information), *seating and retail/food* establishments. Similar structure was confirmed for the rating provided by respondents on the facilities available at the train station.

Table 4: Loadings factor analysis attitudes and subjective evaluations of train facilities

Importance facilities		Construct	Items	Rating facilities	
GOF and variance	Loadings			GOF and variance	Loadings
X^2 = 8.08 (9); p=0.526 Var = 0.547	**0.882**	Basic facilities	Lighting	X^2 = 15.507 (9); p=0.078 Var = 0.472	**0.896**
	0.832		Staff		**0.810**
	0.529		Information		0.668
	0.791		Emergency services		0.695
	0.869		Easy access to platforms		**0.859**
	0.909		Frequency services		**0.916**
X^2 = 0.000 (0) Var = 0.659	**0.790**	Parking and bike facilities	Free PnR	X^2 = 0.000 (0) Var = 0.679	**0.794**
	0.986		Locked PnR		**0.983**
	0.604		Locked bike storage		0.701
X^2 = 0.000 (0) Var = 0.603	**0.838**	Seating and retail/food establishments	Seating on the train	X^2 = 0.000 (0) Var = 0.516	**0.882**
	0.953		Seating on the platform		**0.921**
	0.590		Shops/food outlets		0.762

The structure of these constructs is different from that obtained using the objective measures. PnR and bike facilities are now combined together and LU was not significant for respondents, thus not included here. PnR provision seems to be crucial for PT travellers, as indicated by the higher factor loadings (0.790 and 0.986). The basic facilities factor was weighted more heavily by frequency (0.909), easy access (0.869), lighting (0.882), and presence of staff (0.832), than information and emergency services. The construct of seating and retail was (not surprisingly) dominated by the comfort on the platforms while waiting for the train (0.838).

4.3. Attitudes and Travel Behaviour

The latent scores from the confirmatory factor analysis were then used to identify groups of travellers homogeneous in their preferences for facilities at railway stations via latent class analysis (LCA). When comparing models with various numbers of classes, the 4-class model was chosen for its good fit (BIC), reduced error, and easier interpretability. Table A2 shows only modest improvements of the goodness-of-fit of the model with five classes, but substantial increase of the number of parameters.

The parameters of the 4-class LCA model are provided in Table 5. The significance level (<0.001) confirms that all six factor scores contribute in a significant way towards the ability to discriminate among the four clusters. Across the six variables, PnR facilities and bike facilities recorded the highest loadings, supporting the relevance of these features for Perth travellers.

The largest latent class is class 1, with the lowest stated importance for seating and shops and the lowest rating of these facilities. We called this class *"Average rider"*, as the rating for basic public transport facilities and PnR are common for Perth's train patrons. The second

largest class includes a quarter of the interviewees and they allocate high importance to all facilities, but appreciate they are lacking at many train stations (*"Important, but missing"*).

Table 5: Parameter estimates for Latent Class Analysis (LCA)

Factor score	Class 1 *"Average rider"*	Class 2 *"Want facilities, but unsatisfied with supply"*	Class 3 *"Expectations met"*	Class 4 *"Don't care/ unresponsive"*	Wald	p-value	R^2
	43.95%	25.98%	16.97%	13.09%			
Importance PnR and bike facilities	-0.104	**0.816**	0.795	-1.508	4,097.595	<0.001	**0.663**
Importance basic access (1st tier facilities)	-0.440	**0.622**	0.501	-0.684	382.611	<0.001	0.370
Importance seating and shops	-0.534	**0.438**	0.239	-0.144	159.511	<0.001	0.232
PnR and bike facilities	0.117	0.015	*1.097*	-1.229	2,523.826	<0.001	**0.470**
Basic access (1st tier facilities)	-0.314	0.104	*0.805*	-0.595	376.618	<0.001	0.284
Seating and shops	-0.406	-0.020	*0.410*	0.016	65.489	<0.001	0.111

The remaining two classes cover two very different segments: class 3 seems happy with the existing facilities (*"Expectations met"*), whereas class 4 regards lowest the importance of facilities and has the lowest evaluation of these services at the train stations (*"Don't care, unresponsive"*). The model also included three active nominal covariates: gender, group age, and the train station (Table 6).

Table 6: Covariates for LCA

Covariates	Class 1 *"Average rider"*	Class 2 *"Important, but missing"*	Class 3 *"Expectations met"*	Class 4 *"Don't care, reluctant"*	Wald	p-value
Gender						
Male	**0.196**	-0.359	-0.014	**0.177**	19.863	<0.001
Female	-0.196	**0.359**	0.014	-0.177		
Age group						
Young adult	0.097	**0.137**	0.008	-0.241	17.209	0.009
Middle aged	**0.153**	**0.267**	0.020	-0.440		
Senior	-0.250	-0.403	-0.028	**0.681**		
Train station						
Cannington	-0.457	-0.461	-0.501	**1.419**	77.180	<0.001
Claremont	0.088	-1.521	-0.360	**1.793**		
Greenwood	0.018	-0.646	-0.554	**1.181**		
Midland	**0.785**	**1.322**	1.338	-3.444		
Murdoch	0.156	0.907	**2.049**	-3.112		
Warnbro	-0.789	0.326	0.090	0.373		
Warwick	0.199	0.075	-2.063	**1.790**		

The results suggest that males are more likely to be in classes 1 and 4, young travellers are more likely in class 2, whereas senior people are likely to appear more frequently in class 4. There are also associations between the train stations and the classes. Class 2 is associated with travellers from the East-West corridors, class 4 with the North and West corridors, and 3 with the South line. This is consistent with anecdotal evidence, showing that the newest stations, South of the river, many built on greenfield, and further away from the city, cater better for the PnR demand. Finally, three bivariate residuals, between importance and ratings of the three categories of facilities (PnR and bikes, 1st tier access, and seating and shops) were included in the model (bivariate residuals above 4).

We present below the profile of the four latent classes in tabular format (Table 7).

Table 7: Means for class indicators

Variables	Class 1 *"Average rider"*	Class 2 *"Important, but missing"*	Class 3 *"Expectations met"*	Class 4 *"Don't care/ unresponsive"*
PnR and bike facilities	0.031	-0.070	**1.012**	-1.315
Importance PnR and bike facilities	-0.234	**0.687**	**0.666**	-1.637
Basic access (1st tier facilities)	-0.288	0.130	**0.831**	-0.569
Importance basic access (1st tier facilities)	-0.459	**0.603**	0.481	-0.703
Seating and shops	-0.282	0.104	**0.534**	0.140
Importance seating and shops	-0.484	**0.488**	0.289	-0.093
Trip distance (km)	17.4	**26.1**	22.4	15.1
PnR and KnR access (%)	45.7	49.3	**52.4**	47.1
Walk-on and cycling access (%)	22.9	21.1	10.5	19.4
Gender (%)				
Male	**58.3**	35.6	54.1	53.0
Female	41.7	**64.4**	45.9	47.0
Age group (%)				
Young adult	49.7	50.3	49.4	46.3
Middle aged	**42.3**	41.9	38.5	29.8
Senior	8.0	7.8	12.1	**23.9**
Train station (%)				
Cannington	16.4	13.9	12.9	**27.2**
Claremont	16.3	3.2	9.0	22.5
Greenwood	12.9	5.9	5.9	9.5
Midland	11.4	15.3	16.4	0
Murdoch	5.1	7.9	**26.2**	0
Warnbro	14.1	**34.8**	**27.5**	11.5
Warwick	**23.9**	19.0	2.1	**29.3**

The results confirm once again substantial heterogeneity of travellers in their allocated importance to facilities, and their evaluation and use of the train station services. The travellers from class 2, unsatisfied with the current supply, appear to travel the furthest,

whereas those from class 4, who rated facilities the lowest, also use them the least. Conversely, respondents from class 3, the most satisfied with the PnR, accessed the stations mostly by car.

The significant associations between train station/corridor and class illustrate that PnR facilities are vital for Perth travellers, although the supply is currently insufficient to meet the demand. On the North-South spine corridor (Clarkson and Mandurah), the PnR supply is substantially more generous than on the East-West corridors (Midland, Armadale, and Fremantle), nevertheless the development of new estates greatly increased the number of incoming residents, exceeding the expectations of public transport use.

5. Conclusions and Implications for Research/Policy

The combined evidence from the two surveys clearly indicates some mismatch between the currently available facilities and what the travellers appreciate as determinant for their travel arrangements. The provision of PnR facilities at stations is the most significant driver of rail patronage in a low-density city like Perth and has been identified as the "number one" facility used by train riders. Basic facilities at the stations are important, but with few exceptions (presence of security officers, restrooms, ATM machines), they seem to be satisfied in most of the stations. On the other hands, second tier facilities (commercial spaces, food establishments, etc.) or activity centres at rail stations appear less important for Perth travellers.

Because of the reduced population and employment densities, most train stations in Perth are accessed by car and to a lesser extent by feeder buses, walking, or cycling. Although there are attempts to change the access mode share for many stations, they have yet to yield the anticipated results. As a consequence, when the frequency of local transport services is reduced, when the access by active transport modes is poor, or when the PnR supply is insufficient, we notice a reduced "affective catchment" of the station, as illustrated by the low factor scores. Given that many stations in Perth have a trying time in integrating public transport services with mixed facilities around the station, this research opens the debate on what planners are aiming to achieve. High levels of patronage seem to be associated with high PnR supply, but increased parking bays around stations represent a deterrent in building active and vibrant centres. Pursuits of these goals appear to lead to very dissimilar station precinct designs.

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Appendix

Table A1: Standardised facilities and local access values by train station

Corridor cluster	Corridor	Station	Parking facilities	LU around station	Facilities at station
East	Armadale	Armadale	-0.140	1.416	1.259
East	Armadale	Beckenham	-0.335	-1.248	-0.901
East	Armadale	Belmont Park	-1.036	-1.248	-0.901
East	Armadale	Burswood	-1.034	0.326	-0.901
East	Armadale	Cannington	0.549	0.326	0.936
East	Armadale	Carlisle	-0.447	0.326	-0.901
East	Armadale	Challis	-0.450	-0.729	-0.901
East	Armadale	Claisebrook	-1.036	0.326	-0.247
East	Armadale	Gosnells	-0.220	0.361	0.936
East	Armadale	Kelmscott	-0.067	-0.729	0.175
East	Armadale	Kenwick	-0.103	0.361	-0.901
East	Armadale	Maddington	-0.120	-0.193	-0.901
East	Armadale	McIver	-1.036	-1.248	-0.578
East	Armadale	Oats Street	-0.380	-0.729	-0.571
East	Armadale	Perth	-0.439	0.897	1.614
East	Armadale	Queens Park	-0.368	0.897	-0.901
East	Armadale	Seaforth	-0.434	-0.729	-0.901
East	Armadale	Sherwood	-0.423	-0.729	-0.901
East	Armadale	Thornlie	0.443	-1.248	0.889
East	Armadale	Victoria Park	-0.352	-0.729	-0.188
East	Armadale	Welshpool	-0.387	-0.193	-0.901
West	Fremantle	City West	-1.036	-0.193	-0.901
West	Fremantle	Claremont	-0.425	0.897	-0.571
West	Fremantle	Cottesloe	0.149	1.416	-0.901
West	Fremantle	Daglish	-0.934	-0.730	-0.901
West	Fremantle	Fremantle	-0.124	0.361	1.614
West	Fremantle	Grant Street	-1.036	-0.729	-0.901
West	Fremantle	Karrakatta	-1.034	-0.729	-0.901
West	Fremantle	Loch Street	-0.482	-0.729	-0.901
West	Fremantle	Mosman Park	0.162	1.416	-0.901
West	Fremantle	North Fremantle	-0.333	-0.729	-0.901
West	Fremantle	Shenton Park	-0.488	-0.729	-0.901
West	Fremantle	Showgrounds	-1.036	-1.248	-0.901
West	Fremantle	Subiaco	-1.034	1.416	-0.571
West	Fremantle	Swanbourne	-1.036	1.416	-0.901
West	Fremantle	Victoria Street	-1.036	1.416	-0.901
West	Fremantle	West Leederville	-1.036	1.416	-0.901
North	Joondalup	Clarkson	2.127	1.416	1.251
North	Joondalup	Currambine	1.473	-0.729	0.590
North	Joondalup	Edgewater	1.276	-0.158	-0.201
North	Joondalup	Glendalough	0.537	-0.729	0.513
North	Joondalup	Greenwood	1.919	-1.248	0.167
North	Joondalup	Joondalup	0.492	1.416	1.614
North	Joondalup	Leederville	-0.439	1.416	0.154
North	Joondalup	Stirling	0.670	-1.248	1.614
North	Joondalup	Warwick	2.027	-1.248	1.251
North	Joondalup	Whitfords	1.775	-1.248	0.881
South	Mandurah	Bull Creek	1.279	-0.729	1.290
South	Mandurah	Canning Bridge	-0.439	1.416	-0.901

South	Mandurah	Cockburn Central	1.765	0.361	1.290
South	Mandurah	Esplanade	-1.036	0.897	0.900
South	Mandurah	Kwinana	1.266	-1.248	0.960
South	Mandurah	Mandurah	2.265	-1.248	1.614
South	Mandurah	Murdoch	2.278	-1.248	1.614
South	Mandurah	Perth Underground	-1.036	0.897	1.614
South	Mandurah	Rockingham	1.571	-0.729	1.614
South	Mandurah	Warnbro	1.674	-1.248	1.614
South	Mandurah	Wellard	0.614	-0.729	0.927
East	Midland	Ashfield	-1.034	-0.158	-0.901
East	Midland	Bassendean	0.558	1.416	0.545
East	Midland	Bayswater	0.530	1.416	-0.901
East	Midland	East Guildford	-1.036	-0.729	-0.901
East	Midland	East Perth	-0.187	0.361	0.559
East	Midland	Guildford	-0.254	1.416	-0.901
East	Midland	Maylands	-0.401	1.416	0.506
East	Midland	Meltham	-0.416	0.361	-0.901
East	Midland	Midland	1.270	-0.729	1.259
East	Midland	Mount Lawley	-0.441	1.416	-0.901
East	Midland	Success Hill	-1.036	-0.729	-0.901
East	Midland	Woodbridge	-1.036	0.361	-0.901

Table A2: Model selection

		LL	BIC(LL)	AIC(LL)	Npar	Class.Err.
Model1	1-Cluster	-4,175.156	8,438.927	8,378.311	14	0
Model2	2-Cluster	-3,730.887	7,702.303	7,537.774	38	0.038
Model3	3-Cluster	-3,468.073	7,328.589	7,060.146	62	0.044
Model4	**4-Cluster**	**-3,271.621**	**7,087.598**	**6,715.242**	**86**	**0.054**
Model5	5-Cluster	-3,167.512	7,031.294	6,555.024	110	0.076

Note: The latent class model was estimated with LatentGold software package.