Analysis and Planning of Bicycle Parking for Public Transport Stations

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Abstract

This study investigates bicycle parking behaviour at public transport stations. It advises in the provision of bicycle parking spaces at stations, including their siting at the station and selection between different bicycle parking devices. The insight can improve bicycle parking patronage at public transport stations.

The study utilises revealed preference data collected jointly by the Roads & Maritime Services of Australia and Parsons Brinckerhoff during October and November 2008. This data was obtained through field visitation to 146 of New South Wales' train stations, whereby observations of bicycles parked outside in the open-air were made. The observations included counts of parked bicycles, counts of bicycle parking spaces, parking distances to station entrances, and the presence of streetscape features surrounding parking locations.

The study also utilises similar revealed preference data of bicycle parking in secure bicycle lockers, collected in May 2011. The NSW government provides bicycle lockers for lease at 102 Sydney train stations. This parking data was obtained by visiting the official NSW Government bicycle locker website (NSW Government, 2011).

Data segmentation and graphical comparison finds bicycles parked outside in the open-air follow different behaviour to those parked in secure bicycle lockers. Regression analyses find significant relationships between various streetscape and train station characteristics upon bicycle parking levels. Station patronage, appropriate distancing of bicycle parking infrastructure, and presence of passive & active surveillance were factors found predictive of bicycle parking. Ultimately, the study has implications on the provision, placement and selection of bicycle parking infrastructure at public transport stations.

KEYWORDS: bicycle parking, public transportation

1. INTRODUCTION

Integrating bicycles and transit through bicycle parking brings among all economic, environmental and social benefits to communities. This is achieved through expediting a shift from car use to bicycles & transit. Bicycle-transit is a time competitive alternative to unimodal car travel directly to destinations (Martens, 2007) as well as car travel to public transport stations (Martin and den Hollander, 2009b). Standing evidence of this time-competitiveness lies in the significant proportion of bicycle parkers replacing their car trips with bicycle-transit in Australia (Martin and den Hollander, 2009b; Parker, 2002; Third Wave Cycling Group Inc. et al., 2010) and the international context (Martens, 2007) after provision of bicycle parking spaces. Bicycle parking is also a more space-efficient, cheaper alternative to car parking for attracting transit patronage (Martin and den Hollander, 2009b).

However, when bicycle parking facilities are provided at public transport stations, especially in the Australian context, they are not necessarily utilised. For example, open-air bicycle parking facilities (open-air bicycle parking in this study refers to any bicycle parking that is not within secure enclosed devices) provided in Sydney's (Australia) train stations are found with a mean occupancy of 31% and standard deviation of occupancy at 35% (data provided by the Roads and Maritime Services & Parsons Brinckerhoff, 2008). Also, secure enclosed bicycle locker assemblages provided by the New South Wales Government at public transport stations hold a mean lease rate of 42% with a standard deviation of lease rate at 34% (NSW Government, 2011). Bicycle parking enclosures called "Bike Stations" implemented in the San Francisco Bay Area likewise experience widely dissimilar utilisation, ranging from 11% to 100% (Pucher and Buehler, 2009).

There have been several efforts to predict latent demand for bicycle parking facilities so that when facilities are provided, they are utilised (Bachand-Marleau et al., 2011; Chen et al, 2012; Hochmair, 2015; Keijer and Rietveld, 2000; Lehman et al., 2009; Martens, 2004; Martin and den Hollander, 2009a; Rietveld, 2000). The studies have examined seminal traveller and urban form attributes. However despite these efforts, there still stands significant barriers to realising bicycle parking usage and hence the benefits arising from usage. For one, private bicycles left at a station face the possibility of theft and vandalism, which has been a significant deterrent to bicycle parking (Austroads, 2008; Martin and den Hollander, 2009a; Parker, 1992; Parker, 2002; Pucher and Buehler, 2009). It has also been shown that excessive walking access distances from parking spots to station entrances encourages station access modes other than cycling (Chen et al., 2012).

Therefore a study is necessary to address such barriers, and it is considered fitting by the authors to do so through investigating appropriate provision of bicycle parking spaces for public transport stations. In particular the number of bicycle parking spaces to provide, their suitable siting at the station, and the selection between appropriate bicycle parking device alternatives are investigated. Through such investigation, a realisation of latent demand for bicycle parking may be achieved.

Available literature provides coarse qualitative advice for siting of bicycle parking spaces and selecting between classes of bicycle parking devices for public transport stations. Such advice is provided without a strong foundation in empirical evidence.

Generic suggestions for siting bicycle parking spaces at stations are provided (Austroads, 2008). Among all, it is suggested bicycle parking devices be placed in public view and as close as possible to destinations, within 100m distance. Similarly a set of criteria has been employed for siting Melbourne's 'Parkiteer' bicycle parking cages (Martin and den Hollander, 2009a, p.13) which includes: "Cages should be located close to the entry/exit of the station. This provides quick arrival and departure by cyclists and also good passive surveillance against vandalism and theft". It is evident available siting principles lack a level of precision to definitively guide infrastructure implementation.

In terms of selecting between classes of bicycle parking devices to implement at stations, Austroads (Austroads, 2008) suggests taking into account a station's level of surveillance against bicycle theft and vandalism. This surveillance refers to passive surveillance from passing pedestrians and active surveillance from station staff. Secure bicycle lockers are recommended when there is low surveillance and where there is significant surveillance, open-air bicycle racks are regarded suitable. Hence there is some guidance to select between bicycle parking devices based on bicycle surveillance. However, Austroads does not make clear what constitutes a level of bicycle surveillance. It would be useful if there was a significant proxy variable(s) to delineate between different levels of bicycle surveillance. The study presented in this paper investigates this.

The study methodology is set out as follows. The 'Field Surveys' section details the data and surveys performed for the study. The 'Analysis' section discusses the segmentation and predictive analyses used to investigate and compare where cyclists choose to park their bicycles. Finally a summary discussing implications for bicycle parking at public transport stations is included.

2. FIELD SURVEYS

2.1 Open-Air Bicycle Parking

Open-air bicycle parking in the study refers to bicycle parking that is not within secure enclosed devices. It is parking at street furniture such as fences & street poles, and also at provided bicycle rungs, racks, rails & hoops.

The Roads and Maritime Services (formerly the Roads and Traffic Authority) and Parsons Brinckerhoff jointly collected the open-air bicycle parking data during October and November 2008. The data was collected by field visitation to 146 major passenger train stations in Greater Metropolitan Sydney. This represents about half of the 307 stations in the passenger rail network connecting Sydney, Newcastle and Wollongong, the three largest cities of New South Wales.

Each visitation collected counts of parked bicycles, counts of provided parking spaces (racks, rungs, rails and hoops) and observed site attributes where cyclists chose to park their bicycles in the open-air. These attributes include among all the presence of shelter, CCTV (Closed Circuit Television) cameras, bus stops and shops. The comprehensive list of attributes recorded is detailed in Table 1.

The data collection took place over six weekdays, between the hours of 9am to 3pm. About 20 minutes was allocated to survey each train station and only bicycles parked within 150m walking distance to station entrances were included in the survey, to ensure timely data collection.

A total of 754 bicycles were found parked in the open-air across the 146 train stations. A total of 1079 spaces were provided at rungs, racks, rails and hoops. 202 parking locations were observed, where a parking location was taken as a discrete area where one or more bicycles were parked together.

2.2 Secure Bicycle Parking

Secure bicycle parking in the study refers to bicycle parking that is within secure enclosed devices.

The NSW government leased secure bicycle lockers at 102 Sydney train stations as of May 2011 (time of data collection). By visiting the official NSW Government bicycle locker website (NSW Government, 2011), the amount of provided bicycle lockers, amount leased and parking distance to the nearest station entrance of all locker assemblages were obtained.

A total of 1044 bicycle lockers were provided as of May 26th 2011, with 492 leased. The lockers are implemented in clusters, namely assemblages, of which there were 126 assemblages.

The NSW Government leased the lockers at 50 AUD for three months and 120 AUD for one year. Each bicycle locker provides secure storage for one bicycle, with some additional space to store bicycle gear.

3. ANALYSIS

3.1 Population segmentation

Select segments of the bicycle parking population were compared to show where different cyclists parked their bicycles.

3.1.1 Open-air and secure bicycle parking distances

Cumulative patronage and supply of open-air and secure bicycle locker devices were plotted against parking distance. Eighty percent of open-air bicycles were parked within 30m walking distance to the nearest station entrance. This proximate behaviour may reflect a profound preference for bicycle visibility to passing station patrons (passive surveillance). It may also reflect cyclists wanting to park as close as possible to minimise walking distance. The cumulative patronage and supply is plotted in Figure 1.

The result coincides with Martens (2007) who shows cyclists placed considerable value to parking location at bus transit stops. Cyclists preferred parking ad hoc on the side of the road close to bus stops than at dedicated covered parking facilities located just across the road or 100m walking distance away.

A comparison is made to the leases of secure bicycle lockers juxtaposed in Figure 1. It is deduced such parking proximity for bicycle locker spaces is in relative terms less important. This could be because bicycles parked in secure devices are enclosed against bicycle theft & vandalism, and consequently do not need to be parked at such proximity to gain passive surveillance. These bicycle parkers may chiefly concern themselves with minimising walking distance.

A design implication could be that if any bicycle parking devices cannot be placed in proximity to station approaches (for example due to space issues), secure bicycle parking devices may be a more suitable device to implement.

3.1.2 Segmentation of stations into quintiles

The sample of 146 train stations was ordered into quintiles, according to the daily number of passengers entering the station. Passenger patronage data of each train station was included through the Bureau of Transport Statistics (BTS, 2011). The quintiles were numbered 1 to 5, where quintile 1 has stations with the smallest daily number of passenger entries and quintile 5 has the largest. They are tabulated in Table 2, alongside select quintile characteristics.

The top quintile of stations has almost a 50% share of all bicycle parking (the sum of open-air bicycle parking and locker leases). The bottom quintile has a 6% share of all bicycle parking.

It is interesting to note for each quintile the difference in occupancy across open-air bicycle parking spaces and bicycle locker spaces. Bicycle locker spaces generally have a higher occupancy than open-air spaces, despite requiring a fee for lease. When considering the ratio of locker occupancy against that of open-air spaces, it is the bottom two quintiles that have the largest values. Hence secure bicycle parking spaces may be especially superior at smaller public transport stations. These stations are characteristic of less passive surveillance from less passengers passing by. Figure 2 presents as a histogram the occupancy of spaces at each station against the number of passenger entries at the station.

3.2 Regression analyses

Ordinary Least Squares (OLS) regression was used to investigate predictors associated with where bicycles were parked. Predictors deduced significant would aid in the suitable provision of bicycle parking infrastructure at public transport stations.

OLS regression minimises the sum of squared deviations between observed responses in the dataset and responses predicted by a linear estimation. The linear estimation is given by:

$$y = \boldsymbol{X}\beta + \varepsilon$$

Where y, β and ε are vectors of observed responses, estimated coefficients and random errors respectively. $\boldsymbol{X}$ is a matrix of predictors.

Several OLS regression models were formed.

Predictors used in the models were categorised by either location, station or zonal attributes. Census data (Australian Bureau of Statistics, 2011) was used to include the zonal predictors. The zonal predictors included motor vehicle ownership, age, employment, income, and commuter bicycle mode share of suburbs the stations are located in. They are described in Table 1.

3.2.1 Open-air bicycle parking

The dependent variable was made the count of open-air bicycles parked at each location (totalopenbicycle). As aforementioned there were 202 observed parking locations, where a parking location was a discrete area where one or more bicycles were parked together.

This dependent variable was the sum of bicycles parked at provided rungs, racks, rails & hoops and bicycles parked at street furniture such as fences & street poles. For example, a count of two bicycles parked at rungs and four bicycles parked at a fence would be six bicycles at the location.

Two reduced models were arrived with results displayed in Table 3. Their adjusted r-squared values are 0.28 and 0.25.

The number of daily passengers entering the station (stationentries) was found positively associated with the number of bicycle parkers ($p<0.01$). It admits the intuitive understanding that the number of bicycle parkers increases with the number of station passengers. It similarly admits also the intuitive understanding that a greater number of passengers provides greater people-traffic to watch over unattended bicycles, and this encourages cyclists to park.

The number of motor vehicles per person (motorperson) was found negatively associated with the number of bicycle parkers ($p<0.01$). The predictors 'stationentries' and 'motorperson' however could not coexist in the same model, because of collinearity between public transport and private car modes. A pairwise correlation matrix indicated correlation between these predictors was -0.6. Therefore the additive effect of these two predictors should not be considered on bicycle parking level based on the data collected.

The presence of a nearby bus stop ('busstop', $p<0.05$) was predictive of the dependent variable indicating possibly the generation of frequent pedestrian movement and stopover encourages parkers their bicycles are being surveilled against theft & vandalism.

Partial or full visibility of parked bicycles by a CCTV camera (cctvany) was significant ($p <0.10$) and corresponded positively with bicycle parking levels.

The provision of open-air bicycle parking spaces (openspaces), namely the number of spaces at rungs, racks, rails and hoops, corresponded positively with bicycle parking levels ($p<0.01$). The coefficient suggests that for every four provided bicycle parking spaces, there was one bicycle parked in the open-air.

However causation of this variable (openspaces) is yet ascertained. Possible reasons why provision of open-air bicycle parking spaces was found positively associated with bicycle parking levels are:

i) Provision of bicycle parking spaces increases the parking supply, and this supply increase accommodates latent demand for bicycle parking (cause-effect), OR

ii) Bicycle parking spaces have been provided reactively by local authorities, only after observing existent bicycle parking levels (association and not cause-effect).

It must be noted that the supply of open-air bicycle parking includes fences and street poles, not only provided spaces (rungs, racks, rails and hoops). Therefore a cause-effect relationship between the number of provided spaces and bicycle parking level is plausible, if the supply of fences and street poles around station entrances is not adequate. However the supply of fences and street poles around station entrances was not counted during the field surveys.

A further regression model was developed where the occupancy of provided rungs, racks, rails and hoops was the dependent variable (occupancyopen). The occupancy was taken as the number of bicycles parked at the provided spaces (rungs, racks, rails and hoops), divided by the number of spaces they provide.

The results of the reduced model are displayed in Table 3. The adjusted r-squared value was 0.14 which is a smaller goodness-of-fit than the count models. There is a smaller goodness-of-fit because the occupancy measures correspondence between demand and provided supply, whereas the count measures only demand. The correspondence between demand and provided supply was apparently more difficult to explain.

Despite the relatively small adjusted r-squared value, several predictors were found significant. It was found that parking distance from the nearest station entrance was significant (p-value = 6.7%), and corresponded negatively with the occupancy of open-air devices.

The presence of shops and visibility from station platforms were marginally significant as well against the occupancy (p-values 9.9% and 12.5% respectively), and positively associated.

Further, income level was found significant in the model ($p < 0.01$), corresponding positively with occupancy. Income may be a surrogate for bicycle theft, aligning with Parkin et al. (2008).

3.2.2 Bicycle parking in secure bicycle lockers

The occupancy of bicycle locker assemblages was made the dependent variable (occupancylockers). The occupancy was taken as the number of lockers leased divided by the sum of lockers leased & unleased in the assemblage.

A reduced model was arrived, with adjusted r-squared value of 0.15. The results are displayed in Table 4. There is a smaller goodness-of-fit than the count models (which are described following) because the occupancy measures correspondence between demand and supply, whereas the count measures only demand. The correspondence between demand and supply was apparently more difficult to explain. Despite this, there were predictors found statistically significant in the model.

Station passenger patronage (stationentries) was found predictive, and corresponded positively to bicycle locker occupancy ($p<0.01$).

Parking distance (parkingdistance) was found negatively associated with bicycle locker occupancy ($p<0.05$). The coefficient suggests a 100m increase in parking distance corresponded with a 20% decrease in occupancy.

Age was also significant (p-value = 1.1%), where the proportion of population aged between 20 to 39 (age2039) was negatively associated with locker occupancy. This may indicate this younger age group is more risk prone and thusly less likely to invest in a secure device for their bicycles.

Further regression models were developed where the dependent variable was the count of bicycle lockers leased at each bicycle locker assemblage (lockersleased). Two reduced models were arrived with results displayed in Table 4. The adjusted r-squared values were 0.64 and 0.65.

The independent variable ‘capacitylocker’ was included to control for the different number of lockers provided at each assemblage.

It was found that parking distance of the locker assemblage to the nearest station entrance (parkingdistance) was marginally significant in reducing the magnitude of lockers leased (p values = 7.8% and 8.2% in the models).

The station patronage and motor vehicles per person were significant ($p<0.05$). Yet again, these variables could not coexist in the same model. Station patronage was positively associated and motor vehicle ownership was negative associated.

3.3 Artificial neural networks prediction

The explanation of the full suite of zonal predictors was not substantial in the OLS models.

Artificial neural networks (ANN) prediction was used to gain further insight about their importance against bicycle parking levels. The same set of predictors was used against the occupancy of open-air and secure bicycle locker devices.

Artificial neural networks are able to learn linear and non-linear relationships in data. They are an abstraction of biological neural networks and take the form of interconnected units called neurons. Each neuron receives scalar inputs and performs a mathematical operation to produce a scalar output. The output is dependent upon the transfer function employed by the neuron.

$$a = f(\boldsymbol{W}\boldsymbol{p} + b)$$

Where $\boldsymbol{p}$ is an input matrix, $\boldsymbol{W}$ is a matrix of weights, b is a bias constant for the neuron and f is the transfer function.

Multilayer perceptron network models were developed using the SPSS v. 22 statistical package. 100% of the dataset was assigned to training the models, and the batch training procedure was used given the datasets were relatively small. The scaled conjugate gradient optimisation algorithm was employed to estimate the synaptic weights.

The optimal architecture for the neural networks was selected automatically by SPSS. A single hidden sub layer architecture was selected, with three neurons in the hidden layer. The hidden layer neurons employed the hyperbolic tangent transfer function.

The neural networks prediction produced models with better goodness of fit than the OLS regression models, indicated by the smaller sum of squared errors. Further, the predictors found most important in the models did not coincide completely with the OLS modelling results. The predictors most important in the ANN models were attributes of residents. Their importance was displayed through normalised importance values. Normalised importance is a relative measure of a predictor's importance against the dependent variable, amongst the independent variables in the dataset. The results are displayed in Table 5.

It was found the employed proportion of the population was important to the occupancy of open-air bicycle parking devices. Work has been found a prominent travel purpose in bicycle-transit trips (Chen et al., 2012; Lehman et al., 2009; Martens, 2004; Rietveld, 2000). In particular, Lehman et al. (2009) show 84% of bicycle parkers were commuting for work.

The proportion of residents aged 40 to 59 was important to the occupancy of open-air bicycle parking devices. An Australian survey found 35% of bicycle parkers were 40 to 60 years of age, 4% were over 60 years of age, and 54% were aged 18-39 (Lehman et al., 2009). The sign for this predictor could thusly be negative given the 40 to 59 age range captures residents who are towards 60 years of age. Further, this age group may be risk averse to leaving their bicycles outside in the open-air.

Income levels were important to the occupancy of open-air bicycle parking devices. In particular the proportion of residents with income above 800 AUD per week (incomeabove800), and above 400 AUD per week (incomeabove400) were important. The sign for income against cycling has not been clear in literature however (Heinen et al., 2010). The sign may be positive for open-air bicycle parking as economic deprivation may be a proxy for bicycle theft (Parkin et al., 2008). This idea is reinforced as income predictors were not important in the ANN model for occupancy of secure enclosed bicycle lockers.

The proportion of residents in secondary and tertiary education (schoolabove), and the proportion of residents in tertiary education (tertiaryprop), were important to the occupancy of secure bicycle lockers. The sign of these predictors may be negative as students have found lease fees for lockers to be expensive (Ministerie van Verkeer and Waterstaat, 1997, pp. 114–115).

4. DISCUSSION

The study investigated revealed preferences of bicycle parking at public transport stations. The paper provides advice about the number of spaces, their placement and the type of bicycle parking device to implement at public transport stations.

The number of patrons entering public transport stations was important in predicting levels of observed bicycle parking. With an increase in station patronage there is an associated increase in bicycle parking patronage.

The study indicates parking distance to the nearest station entrance is an important aspect of bicycle parking patronage. It is evident bicycle parkers prefer to park as close as possible to the station entrance, so as to minimise walking access distance. However parking distance may also carry specific significance for the bicycles parked in the open-air. Parking proximity for these bicycles may provide pedestrian visibility to safeguard against bicycle theft & vandalism.

The understanding of parking distance has implications on the placement of bicycle parking infrastructure. Open-air bicycle parking facilities are suggested placed conspicuously to the public eye, which according to the study is found generally to be within 30m of station entrances. Secure bicycle facilities, although preferably placed at such proximity, may be placed at a further parking distance if available station space is an issue. This is because secure bicycle parkers do not need such passive surveillance for their bicycles.

The presence of bus stops, shops, visibility from station platforms and CCTV cameras in the streetscape were important in encouraging open-air bicycle parking. This makes sense as they provide surveillance for unattended bicycles which safeguards against bicycle theft & vandalism. As a result, open-air bicycle parking facilities may benefit being placed near such streetscape features.

A station’s passenger patronage may be a suitable indicator as to the kind of bicycle parking device suitable to provide at a public transport station. It was found smaller stations have particularly higher occupancy of secure bicycle parking than their open-air bicycle parking despite fees for their lease.

This indicates secure bicycle parking devices may be more competent than open-air devices particularly at smaller stations to encourage bicycle parking.

The study found income was important to the occupancy of open-air bicycle parking devices. Economic deprivation could serve as a proxy for bicycle theft which discourages bicycle parking, aligning with Parkin et al. (2008).

Competition between open-air and secure bicycle parking was not discussed in the main body of the paper. Quantifying competition between these parking groups was difficult as there was positive correlation, rather than competition, between counts of open-air bicycle parking and secure bicycle locker leases at stations (p-value = 2.7%, n= 65 stations, using OLS regression). In order to quantify competition between different parking devices, a microscopic approach may be required where stated responses are used to determine the utility associated with alternatives.

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Table 1. Descriptive Statistics of Predictors and Dependent Variables used in the Predictive Analyses

Predictors and dependent variables	Definition	Open-air bicycle parking		Bicycle parking in lockers		Total bicycle parking at the station (open-air+lockers)	
		Mean	Std. Dev.	Mean	Std. Dev	Mean	Std. Dev
Dummy parking location attributes [1or0]							
Shop	Visible to a nearby shop	0.25	0.434				
ticketwindow	Visible to a nearby ticket window	0.031	0.174				
taxirank	Visible to a nearby taxi rank	0.084	0.278				
Busstop	Visible to a nearby bus stop	0.234	0.424				
footpath	Visible to a nearby footpath	0.425	0.495				
houseapartment	Visible to a nearby houses or apartments	0.047	0.212				
street	Visible to a nearby street	0.45	0.498				
offices	Visible to a nearby office	0.047	0.212				
carpark	Visible to a nearby car park	0.294	0.456				
hiddenbywall	Hidden by a wall	0.019	0.136				
platform	Visible to a nearby train platform	0.031	0.174				
lighting	Adequate lighting	0.822	0.383				
Shelter	Protected by shelter	0.225	0.418				
cctvany	Partial or full visibility by CCTV	0.363	0.481				
cctvfull	Full visibility by CCTV	0.131	0.338				
Continuous parking location attributes							
Parkingdistance	Parking distance to closest station entrance(m)	33.61	38.61	67.65	46.61		
Openspaces	Number of spaces at rungs, racks, rails &hoops	3.422	5.573			7.441	10.717
Atopenspaces	Number of bicycles at provided spaces	0.994	2.408			2.193	4.397
Atstfurniture	Number of bicycles at fences, street poles	1.147	2.526			2.531	4.414
totalopenbicycle	Total open-air bicyles at location or station	2.141	3.545			4.724	6.796
Occupancyopen	atopenspaces/openspaces (%)	31.07	34.58				
Totallockers	Number of lockers at the assemblage or station			8.286	6.957	5.752	8.847
lockersleased	Number of lockers leased at assemblage or station			3.905	5.277	2.683	5.012
occupancylocker	lockersleased/ capacitylocker (%)			42.06	33.93		
totalbikes	totalopenbicycle + lockersleased					7.407	9.508
Public transport station attributes							
stationentries	Number of daily passengers entering station barriers (2011)	4657	4958	4409	5376	3811	4636
stationdistance	Distance of station to Central Station (km)	39.95	34.62	43.95	29.7	43.02	40.21
Zonal characteristics of suburb							
motordwelling	Motor vehicles per dwelling	1.269	0.254	1.282	0.261	1.274	0.261
Motorperson	Motor vehicles per person	0.497	0.078	0.512	0.081	0.501	0.083
employedprop	Employed proportion	0.457	0.07	0.454	0.061	0.455	0.075
incomeabove600	Weekly income above $600 AUD, proportion of residents	0.36	0.077	0.356	0.067	0.358	0.082
incomeabove400	Weekly income above $400 AUD, proportion of residents	0.448	0.07	0.448	0.059	0.447	0.076
incomeabove800	Weekly income above $800 AUD, proportion of residents	0.278	0.082	0.273	0.071	0.276	0.085
averageage	Average age	37.35	2.995	37.8	3.572	37.45	3.115
age2039	Proportion of residents aged 20 to 39	0.312	0.085	0.302	0.095	0.311	0.088
age4059	Proportion of residents aged 40 to 59	0.258	0.029	0.256	0.035	0.258	0.03
Tertiaryprop	Proportion of residents partaking tertiary education	0.083	0.038	0.08	0.046	0.082	0.039
schoolabove	Proportion of residents in secondary school or tertiary education	0.144	0.035	0.14	0.04	0.143	0.036
bicyclecomm	Proportion of employed population riding a bicycle to work	0.652	0.689	0.532	0.45	0.649	0.746
bustrain	Percentage of employed population riding a bus then riding a train to work	2.003	1.266	1.729	1.29	1.894	1.262
drivetrain	Percentage of employed population driving a car then riding a train to work	1.205	0.616	1.173	0.644	1.133	0.625
passtrain	Percentage of employed population being a car passenger then riding a train to work	0.546	0.32	0.536	0.33	0.516	0.319
cartrain	drivetrain+passtrain	1.751	0.868	1.71	0.916	1.649	0.879
Number of observations		201		126		145	

Table 2. Public Transport Station Quintiles ordered according to Daily Number of Passenger Entries

Station quintile, according to daily number of passenger entries	Daily passenger entries (mean of quintile)	Occupancy of open-air spaces [%] (mean of quintile)	Occupancy of locker assemblages [%] (mean of quintile)	Open-air parking at provided spaces, percentage share [%]	Supply of open-air spaces, percentage share [%]	Locker leases, percentage share [%]	Supply of locker spaces, percentage share [%]
1	444.64	13.22	30.13	3.48	8.62	9.77	14.15
2	1129.66	18.32	41.28	12.34	14.06	13.88	13.67
3	2148.92	32.31	40.4	16.14	17.53	12.34	14.63
4	3775.52	32.62	50.52	17.72	17.33	23.91	25.9
5	11385.52	35.72	54.68	50.32	42.46	40.1	31.65
	Average = 3811	Average = 31	Average = 42	Total=100	Total=100	Total=100	Total=100

Table 3. OLS Regression Models of Open-air Bicycle Parking

	Dependent variable		
	totalopenbicycle	**totalopenbicycle**	**occupancyopen**
	Coefficient[p-value]		
Dummy parking location attributes			
shop			11.33034[0.099]
busstop	1.307705[0.018]	1.437007[0.011]	
platform			25.87653[0.125]
cctvany	0.9199704[0.072]	0.9123137[0.085]	
Continuous parking location attributes			
parkingdistance			-0.158952[0.067]
openspaces	0.2456418[0.000]	0.2737809[0.000]	
Public transport station attributes			
Stationentries	0.0001782[0.000]		0.0011806[0.043]
Zonal characteristics of suburb			
motorperson		-9.099299[0.004]	
incomeabove400			153.3178[0.003]
constant value	0.7190425[0.088]	5.959102[0.000]	-45.30502[0.052]
number of observations	198	195	120
adjusted r-squared value	0.278	0.2501	0.1445
sum of squared errors	2209.655	2282.925	118731.323

Table 4. OLS Regression Models of Bicycle Parking in Secure Bicycle Lockers

	Dependent variable		
	lockersleased	**lockersleased**	**occupancylocker**
	Coefficient[p-value]		
Continuous parking location attributes			
parkingdistance	-0.011890[0.078]	-0.011885[0.082]	-0.196293[0.005]
Totallockers	0.5936809[0.000]	0.5995235[0.000]	
Public transport station attributes			
Stationentries	0.0001492[0.014]		0.0023961[0.006]
Zonal characteristics of suburb			
motorperson		-10.6677[0.022]	
averageage		0.2082173[0.036]	
age2039			-111.555[0.011]
bustrain			5.630777[0.119]
constant value	-0.819498[0.181]	-2.58449[0.443]	69.49865[0.000]
number of observations	116	118	114
adjusted r-squared value	0.6397	0.6447	0.1522
sum of squared errors	1190.325	1168.438	110307.725

Table 5. Normalised Importance Values for Neural Network Models of Occupancy

Predictor	Normalised importance for occupancy of open-air devices [%]	Normalised importance for occupancy of locker assemblages [%]
age4059	100.0%	49.80%
incomeabove400	86.8%	52.50%
stationdistance	81.0%	
employedprop	79.8%	66.90%
motordwelling	78.9%	68.60%
incomeabove800	77.8%	46.50%
bustrain	75.6%	36.80%
schoolabove	74.7%	100.00%
age2039	71.7%	67.50%
incomeabove600	68.3%	68.30%
bicyclecomm	67.0%	34.80%
platform	59.6%	
averageage	56.3%	63.00%
drivetrain	53.4%	65.10%
passtrain	53.2%	51.80%
motorperson	47.0%	50.20%
shop	46.9%	
footpath	42.4%	
hiddenbywall	42.4%	
carpark	42.4%	
ticketwindow	41.5%	
offices	33.6%	
shelter	33.2%	
cartrain	33.2%	40.90%
lighting	32.7%	
tertiaryprop	31.8%	68.40%
street	31.2%	
cctvfull	29.7%	
houseapartment	29.6%	
taxirank	29.5%	
cctvany	27.6%	
busstop	24.7%	
stationentries	23.1%	86.30%
parkingdistance	12.0%	48.50%
observations	119	114
sum of squared errors	38167.184	48696.692

Table 6. Network Information for Neural Network Models

Input layer		
Number of units (excluding the bias unit)	34	18
Rescaling method for covariates	Standardized	Standardized
Hidden Layer(s)		
Number of Hidden Layers	1	1
Number of Units in Hidden Layer 1 (excluding the bias unit)	3	3
Activation Function	Hyperbolic tangent	Hyperbolic tangent
Output Layer		
Dependent Variable	occupancyopen	occupancylockers
Number of Units	1	1
Rescaling Method for Scale Dependents	Standardized	Standardized
Activation Function	Identity	Identity
Error Function	Sum of squares	Sum of squares

Figure 1. Cumulative Bicycle Parking and Bicycle Parking Supply

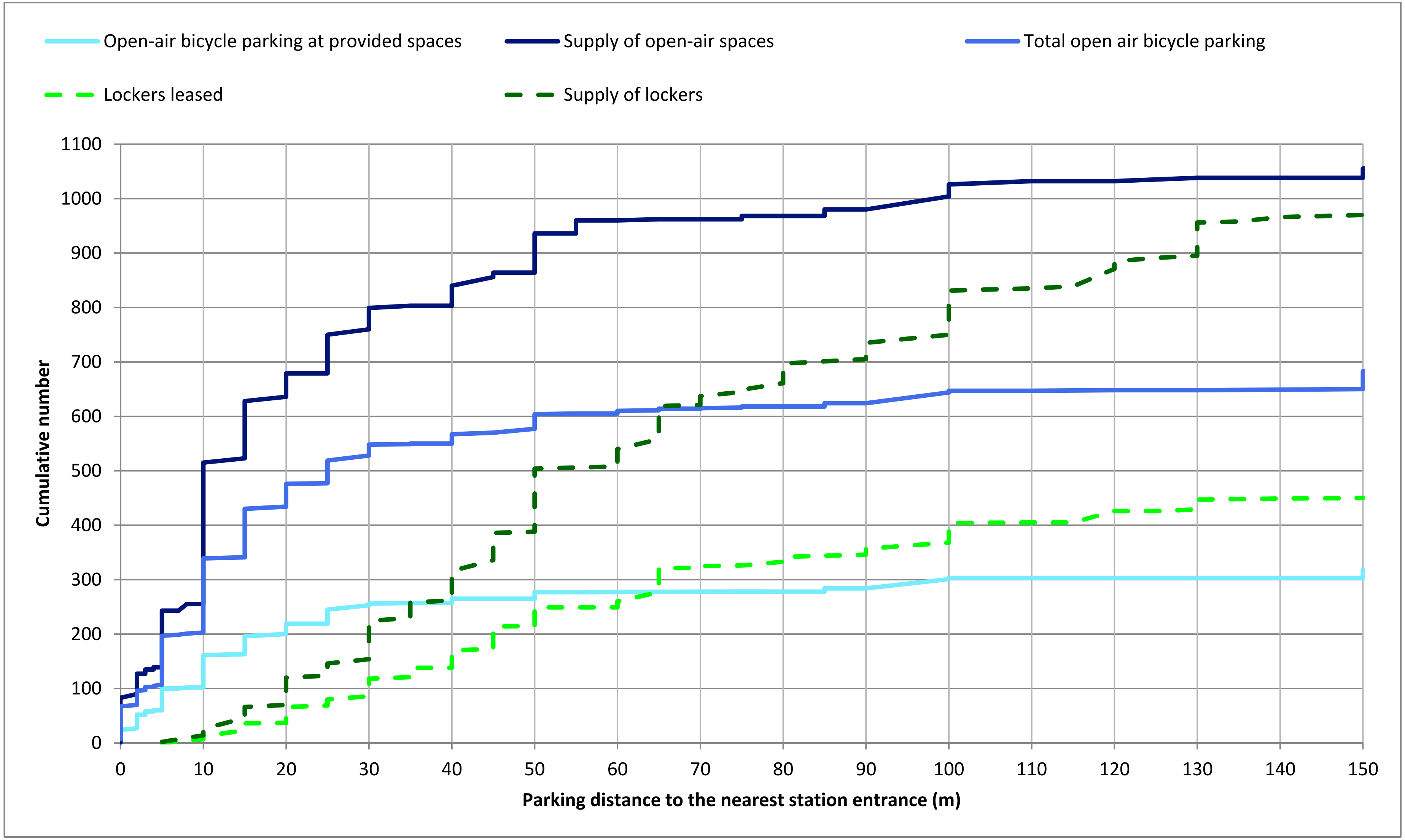

Figure 2. Occupancy of parking spaces at the station against the number of daily passenger entries. Occupancy here is taken as the total number of bicycles parked at spaces divided by the total number of spaces, at the station.