Explaining walking distance to public transport: the dominance of public transport supply

Rhonda Daniels[1] and Corinne Mulley[2]

[1]Senior Research Fellow in Public Transport rhonda.daniels@sydney.edu.au
[2]Chair in Public Transport corinne.mulley@sydney.edu.au

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Australia

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Abstract

Potential influences on explaining walk distance from home to access public transport are investigated including trip and demographic characteristics and public transport supply. In Sydney, Australia, people walk further to train than to bus, the distributions of walk distances are different for each mode, and the trip and demographic characteristics of train and bus users are different. Given the decision to walk to public transport, demographic characteristics such as age, gender, income and labour force status and trip characteristics such as trip purpose, time of day and week, fare and ticket type and trip duration are not significant in explaining walk distance to each mode of public transport. The mode of the public transport trip is the most important determinant of walking distance, reflecting the different supply and spacing of each mode in which there are many more bus stops than train stations. The differences between train and bus users suggest that accessibility initiatives for public transport may not be the same for each mode.

1. Introduction

Public transport has a key role in ensuring accessibility to activities and services. There are many influences on the use of public transport including spatial access, cost, physical accessibility, information and attitudes which all contribute to people's ability and motivation to use public transport. This research focuses on spatial access as understanding influences on walking distance to public transport is a key element of establishing equitable access to public transport.

Guidelines for public transport planning usually specify access to public transport in terms of spacing between public transport stops or distance to stops. Average walk distances are typically longer to access rail than to access bus. But it is important to go beyond averages, and understand, given the current spacing and distribution of public transport, how walking distances vary by characteristics of public transport users and their trips. This has important implications for providing accessibility to the community by recognising differences within the community. Understanding the characteristics and variability of the walk access trip is important to add to an evidence base which has often subsumed this element of the public transport trip as part of the total trip.

From the existing literature on walking, potential influences on the characteristics and variability of walk distance as an access mode to public transport include trip purpose, demographics, built environment, local geography and public transport supply. The research uses Sydney, Australia as a case study to investigate the potential influences on walk distance from home to access public transport, once the decision to walk has been made.

The paper is structured as follows: section 2 reviews the policy context for public transport planning, and the previous research on influences on walking distance to public transport; section 3 describes the data for Sydney; section 4 presents analysis on influences on walking distance; and section 5 discusses the results and draws conclusions.

2. Policy context and literature review

This section provides the policy context for the interest in understanding how far passengers walk to access public transport, followed by a review of possible influences on walking distances.

2.1 Public transport and accessibility

Public transport is important for social inclusion, for providing access to participation in life opportunities and to reach activities and services such as work, education, health, shopping and social-recreational activities (Currie et al. 2007, Lucas 2005, Lucas 2010). Accessibility planning to improve social inclusion in the UK focuses on improving access by public transport (Daniels and Mulley 2010a). Recognising the importance of public transport, many government strategic plans publicly set goals and targets for public transport availability and use. For instance, the strategic land use and transport plans for Sydney Australia (NSW Government 2005, 2010a, 2010b and 2010c) include a broad accessibility target of increasing the proportion of the population with access within 30 minutes by public transport to one of a set of centres which is large enough to provide a range of activities and services (Daniels and Mulley 2010a).

In delivering public transport accessibility goals and targets, service planning makes assumptions about walk distance to access public transport. Guidelines often use ¼ mile or 400 m, or multiples such as ½ mile or 800 m, as key distances in network and service planning. The empirical origin of these commonly used "rules of thumb" is unclear, although Neilson and Fowler (1972) found that 70% of elderly bus users in a low density Florida

retirement area lived with 1/8 mile of the bus route, and bus usage at a total walking distance of 1/8 mile was three times greater than the usage at a distance of ¼ mile.

Service planning guidelines for Sydney (NSW Ministry of Transport 2006) specify that 90% of households in each of the 15 metropolitan bus contract regions should be within 400 m of a rail line and/or bus route during the day (commuter peaks, inter peak and weekend day time), and within 800 m of a rail line and/or bus route at night time. This is measured as the straight line distance, not road or walking distance. Similarly, Vancouver uses 400 m (Greater Vancouver Transport Authority 2004), Helsinki uses 300 m (HKL 2008), while Perth uses 500 m (Public Transport Authority 2003).

Walk distance is important because walk is the primary access mode for trips from home to public transport and because walking distance has a significant impact on public transport use. In Sydney, walking is the access mode for almost 90% of bus trips from home and for about half of train trips from home (Table 1). Ewing and Cervero (2010) reported a meta-analysis with a public transport demand elasticity of -0.29 for accessibility measured as distance to a public transport stop, suggesting a 10% increase in distance to a stop decreases public transport use by approximately 3%.

Table 1 Access modes from home to bus and train in Sydney on average weekday, 2008[1]

Access mode from home	To Bus	To Train
Walk	89%	50%
Car as driver	2%	17%
Car as passenger	9%	17%
Bus	-	14%
Other (taxi, bicycle, other)	0%	2%
Total	100%	100%
Total access trips per average weekday	309,664	381,704

Source: Household Travel Survey, Bureau of Transport Statistics, Data request no. 10/332.
[1] Based on pooled data from 3 years (2006/07, 2007/08, 2008/09), weighted to 30 June 2008 population. Sydney is Sydney Statistical Division, Illawarra Statistical Division and Newcastle Statistical SubDivision.

Assumptions about distances that people will walk to access public transport or “rules of thumb” are used by transport planners to determine stop spacing, particularly for buses as these are more flexible, but also by land use planners for urban design to achieve walkable cities and plan transit oriented developments (TODs).

2.2 Influences on walking distance

This section reviews the literature on influences on both walking as a mode and on walk as an access mode to public transport to identify possible explanatory variables for use in the analysis including purpose of the trip, socio-demographic characteristics, the built and natural environments, and mode of public transport. Transport planning research has focused on mode choice, not on access to different modes, and there is a less well-established literature on how far pedestrians walk and the factors that influence their route choice (Agrawal et al. 2008). There is increasing interest in the relationship between walking and health from public health researchers, with studies on walking as a mode by Corpuz et al. (2005), Lee and Moudon (2006) and Merom et al. (2010) and on walk time to meet physical activity requirements (Besser and Dannenberg 2005).

For walk as a mode in itself, there is some evidence that recreation walk trips, which include trips for exercise and fitness, are longer than for other purposes (Corpuz et al. 2005, Iacono et al. 2008), although Iacono et al. (2008) noted that distance decay functions are similar across trip purposes. The impact of socio-demographic factors has mostly been studied in

the context of being a differentiating factor in choice of travel behaviour. Corpuz et al. (2005) found that in Sydney, females walk more than males, that older and younger age groups walk more, and that people with low car ownership walk more. For access to public transport, Wibowo and Olszewski (2005) found that men were more likely to access Mass Rapid Transit (MRT) stations in Singapore by walking compared to women although walking distance was the most significant factor in models of walking choice to access MRT stations.

The many elements of the built environment from density, diversity and design to micro-level details such as ambience and aesthetics have an influence on walking. Cervero et al. (2009) cited Handy et al. (2002) and Frumkin et al. (2004) to assert that the characteristics of the built environment including permeability, footpaths, lighting, security, density, and mixed land use can influence walking both as a transport mode, and as an access mode to public transport. Evidence on the geographical location and attributes of the built environment on walking trips needs to be qualified by the interdependence identified above by Iacono et al. (2008). Corpuz et al. (2005) identified differences in walking behaviour by geographical location in Sydney: residents of highly urbanised areas tended to walk more and the distribution between walk and car trips was associated with differences in the supply of public transport. In Bogota Cervero et al. (2009) found that road facility designs like street density, connectivity and proximity to Ciclovia (cycleway) lanes were associated with physical activity, while other attributes of the built environment, like density and land use mixtures, were not. However, Cervero et al. (2009) noted neighbourhoods in Bogota are uniformly compact and mixed in their land use. In a rare study on egress trips from public transport, Townsend and Zacharias (2010) found the only variables to display significant correlation with walking distance from rail rapid transit stations in Bangkok were destination types, a proxy for both land use and activity.

Amenity and aesthetics are also potential influences on walk distance. But in assessing the impact of a range of factors including aesthetics on choosing a route for walking, Agrawal et al. (2008) found that the primary consideration for commuters walking to five rail transit stations of the study in California and Oregon was minimising the time and distance walked. Safety (from traffic, rather than crime) was a secondary factor in route choice, while environmental appearance such as attractive landscaping or buildings was less of a concern.

Natural environment elements such as climate and topography have been cited as factors that may influence walking, but the evidence is mixed. For walk as a mode, Burke et al. (2006) examined the influence of climate and topography on walking trip rates in Brisbane, Australia and concluded that natural environmental conditions appeared to have little influence on the propensity of people to walk. Lee and Moudon (2006) found the physical environment contributed significantly in explaining the probability of walking in Seattle. Hills were negative for transportation walking, not recreational walking, possibly because “transportation walking has more to do with reaching a certain place along the shortest route rather than the quality of the route, while recreational walking can be more flexible and people may choose certain routes based on route qualities (Lee and Moudon 2006, p. S95).

Considering walk as an access mode to public transport, Walton and Sunseri (2010) examined public transport users in New Zealand cities Auckland and Wellington to understand factors influencing the decision to walk to public transport and concluded that impediments to walking found in research elsewhere almost all disappeared except chance of rain. In contrast, Wibowo and Olszewski (2005) found that the effort of walking to access MRT stations in Singapore was affected not only by walking distance but also by characteristics of the walking route such as number of road crossings, ascending steps and conflict points.

In relation to public transport supply, Burke and Brown (2007) found that in South East Queensland, Australia, walking distance to bus stops was significantly shorter than to train stations or to ferry terminals, there were statistically significant differences in the variances of

the walk distance distributions to bus stops and train stations, and a greater proportion of travellers walking very short distances (less than 500 m) to bus stops which was attributed to the greater number and availability of bus stops compared to train stations. Similarly, Alshalalfah and Shalaby (2007) concluded that the density of the public transport route network in downtown Toronto, Canada resulted in lower walk access distances than in other parts of the city.

A consistent finding of walking distance research including Agrawal et al. (2008) in California and Oregon, Alshalalfah and Shalaby (2007) in Toronto Canada, and Ker and Ginn (2003) to access rail in Perth, Australia is that people walk considerably further to access public transport than commonly assumed “rules of thumb”. This finding has implications for both transport and land use planning, including transit oriented developments (Canepa 2007). People also walk further than assumed for purposes other than access to public transport (Iacono et al. 2008, Larsen et al. 2010).

In summary, previous research suggests that walk distance to public transport may be influenced by the purpose of the overall trip, by demographic factors, particularly age and gender, and by the location of the access trip in terms of built environment and natural environment, although the impacts are variable. It is difficult to disentangle the effect of the built environment on walk access to public transport because of the interdependencies between access distances and supply of services. Overall, it appears that built and natural environment factors determine the ease of walking but the supply of public transport, including type of mode, may be more of a factor in determining how far people walk to public transport, once the decision to walk to public transport has been made.

3. Data for Sydney

Sydney has an extensive public transport network and travel data available from the Sydney Household Travel Survey. Sydney’s rail network has 307 metropolitan stations including over 200 stations in Sydney and Central Coast and the rest in the adjoining regions of Hunter, Illawarra and Southern Highlands, and the bus network has over 35,000 bus stops in the equivalent area. Over 10% of trips each weekday in Sydney are made by public transport, with a similar proportion of trips by train (5.2%) and by bus (5.8%), although train trips are longer and account for a higher proportion of total distance travelled (Transport Data Centre 2010). The Sydney Household Travel Survey (HTS) is a one day travel diary covering the Greater Metropolitan Area comprising the Sydney Statistical Division, Illawarra Statistical Division and Newcastle Statistical Subdivision, running continuously since 1997/98 (Transport Data Centre 2010). The face-to-face interview survey for data collection ensures high data quality and maximises response rates.

3.1 Walk trips and walk distance

Data from the last 3 years (2006/07, 2007/08 and 2008/09) of the HTS was used, due to changes in the estimation of walk distance since 1997. For the three years of pooled data, 24,806 people were interviewed from 9,561 households (66% household response rate), giving a total of 105,391 trip records (Transport Data Centre 2010, p. 45). Due to very small mode shares for ferry, monorail and light rail and the very uneven spatial distribution of these modes, the research focused on access from home to bus and train. In the 3 year sample there were a total of almost 2,000 walk trips from home to access either a bus stop or train station.

The Household Travel Survey records the street address of each household which is then geocoded to x,y coordinates. For the first trip away from home by public transport on the interview day, the interviewer asks for the location of the public transport stop. For walk trips to train, the station named by the respondent is recorded by the interviewer and the x,y

coordinates are known. For walk trips to bus, the respondent may identify the Transit Stop Number or, more usually, describe the location of the bus stop in terms of streets which is recorded by the interviewer. A hierarchy of geocoding methods is then used to identify the x,y coordinates. For privacy and confidentiality reasons, the exact home address and public transport stop location were not provided in the dataset, only the estimated walking distance from home to the train station or bus stop.

Calculation of walking distance from home to the public transport stop is a significant issue for this research. The current method of distance estimation in the HTS is based on each trip origin and destination being coded to an x,y coordinate and road network distance calculated using ARCGIS. This is an approximation of the distance actually walked for several reasons. Walkers may not use the road network, as they may walk through parks and open space or use pedestrian-only links which reduce their walk distance. Alternatively they may walk longer than the shortest road network distance, depending on the facilities for crossing roads, and their ability and confidence. Walkers may also choose a longer route than the shortest road distance because the longer route is more attractive or avoids negative elements.

For the data used in this analysis, for bus users living within 100 m of a bus stop, a walk distance of 50 m has been imputed. For train trips, almost all walk trips are longer than 100 m as the location of the train station is represented by the centre of the station platform which is usually 200 m long. The dataset of 1,952 trips included only a few very long walk trips from home with 97.6% of trips less than 2 km and only 3 trips over 5 km. For the purposes of further analysis, only trips less than 2 km were included, reducing the dataset to 1,906 trips. Figure 1 shows the frequency distribution for walk trips to public transport less than 2 km.

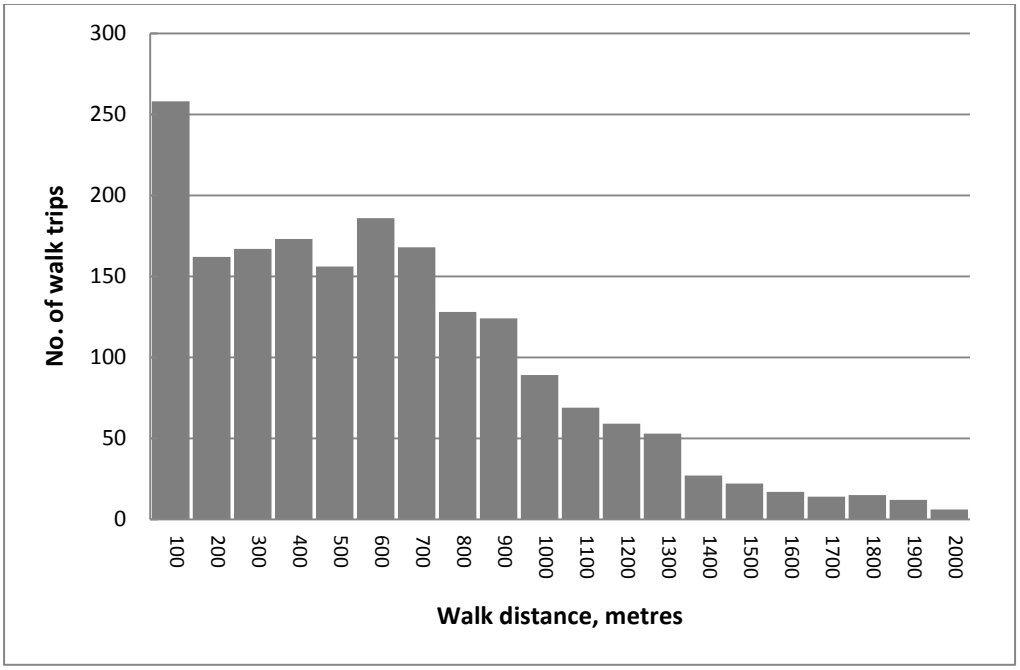

Figure 1 Frequency of walk distance from home to public transport for walk trips less than 2 km (n=1,906)

3.2 Explanatory variables

A range of potential explanatory variables are collected as part of the Household Travel Survey and these were provided for each walking trip. The dataset used is summarised in Table 2.

Table 2 Potential explanatory variables from Sydney Household Travel Survey

Type of variable	Variables and categories
Trip characteristics – walk trip from home	• Distance of walk trip (calculated from origin and destination x,y coordinates, using ARCGIS road network distance between these points) • Destination of walk trip: train, bus (govt or private bus), school bus • Day of week of walk trip: weekday, weekend • Time of day of walk trip: am peak, interpeak, pm peak, evening • Location of bus stop or train station: Local Government Area
Trip characteristics – public transport trip after walk trip	• Purpose of trip: work, education, social/recreational, shopping, personal business • Duration of trip (mins) • Type of public transport: train, bus (govt or private), school bus • Fare type for trip: full fare, concession fare, free (school pass) • Ticket type for trip: single, return, periodical, multi-trip ticket etc
Demographic characteristics	• Age: under 19 years, 19-29 years, 30-49 years, 50-64 years, 65 years and over • Sex: male, female • Personal income per year: which for analysis was grouped as less than $13,000, $13,000-$41,599, $41,600-$83,199, $83,200 and over • Labour force status: full-time work, part-time work, economically inactive, post-school education, school student • Household size: number of persons • Driving licence holding: yes, no • No. of vehicles in household • Physical disabilities restricting walking: yes, no
Other	• Reason for public transport use for work trip: avoids parking problems, cheaper, faster, do not have car, less stressful than other forms, live or work close to public transport, don't drive/no licence

The location of the walk trip was considered in several ways for analysis. The location of the walk trip was known in terms of the Local Government Area (LGA), which was the basis for defining other spatial variables. There are over 50 LGAs in greater Sydney which vary in spatial and population size. Each LGA was categorised as inner Sydney, outer Sydney, Sydney fringe, Central Coast, Newcastle or Illawarra. Inner Sydney and outer Sydney are defined by the Department for Local Government, with inner Sydney including 21 LGAs in the inner ring around the Sydney CBD. Based on the LGA, each trip was also assigned to a bus contract region, with some LGAs split across more than one bus region. Other location variables included population density in each LGA from Census data, and the proportion of all trips in each LGA made by public transport from the Household Travel Survey. Correlations between the locational variables are discussed in the next section.

As an indicator of public transport supply, the proportion of households in each bus contract region within 400 m of a bus stop with a defined level of service was calculated by the Bureau of Transport Statistics using network and population data, although this does not fully measure the quality of the public transport (where the bus service goes, how long it takes to get there, or what activities the bus service provides access to). Figure 2 shows access to bus stops by bus contract region.

Other variables which may have been useful but were not available include the locational characteristics of the walking trip such as presence of a footpath, quality of the walking environment, the gradient of the walk trip, and the weather at the time and location of the walk trip.

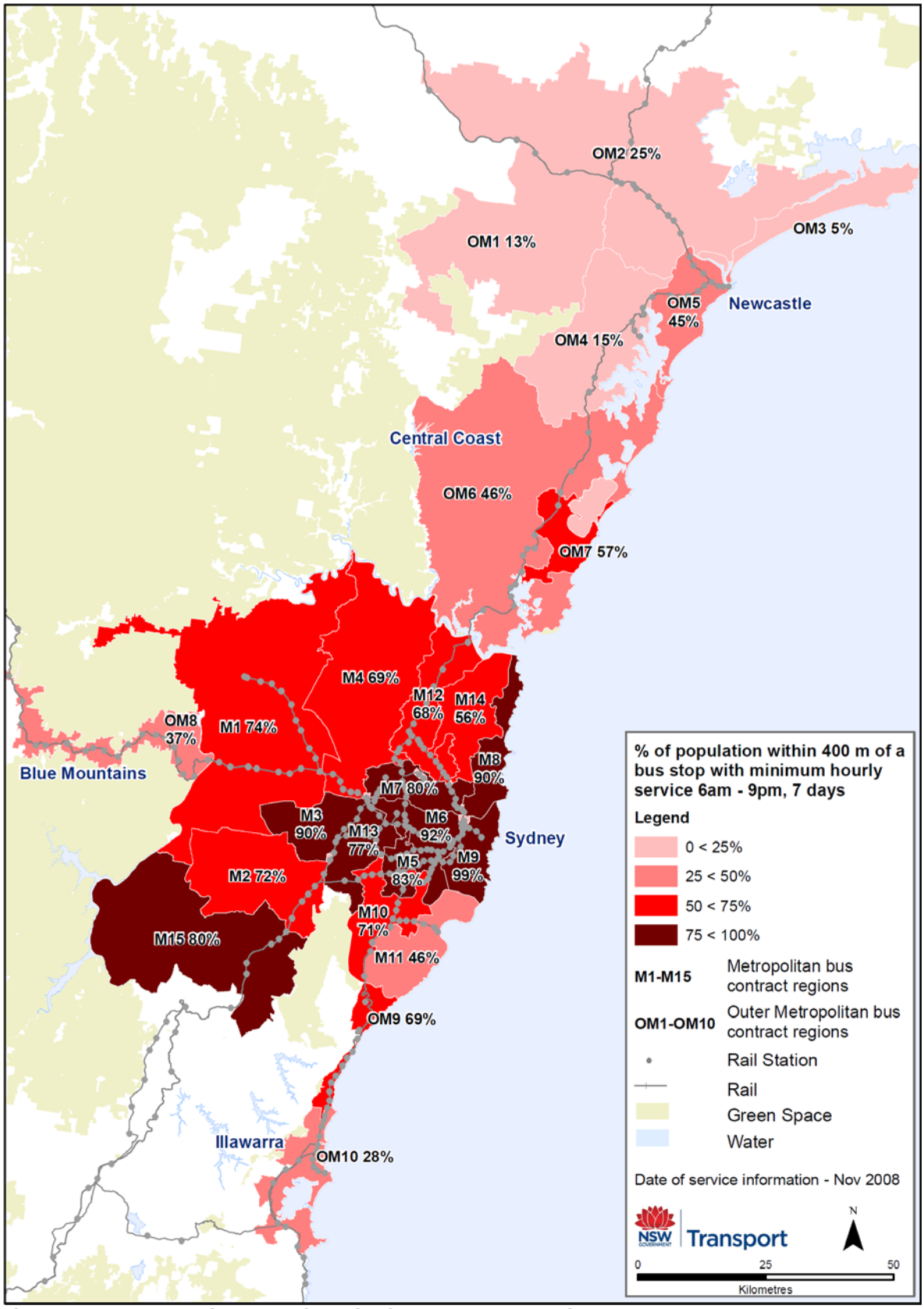

Figure 2 Access to bus services by bus contract region

Source: Bureau of Transport Statistics (Metropolitan contract regions: Data request 09/377; Outer metropolitan contract regions: Data request no. 10/287).

4. Influences on walking distance to public transport

Analysis of influences on walking distance to public transport was conducted in three stages. Firstly, walking distance was described in terms of its central tendency and shape. Secondly, the relationship between walking distance to public transport and possible explanatory variables was analysed. Finally, the potential causal relationship between walking distance to public transport and the characteristics of the walk trip, the characteristics of the walker, and characteristics of public transport was investigated.

4.1 Describing the distribution of walk distance

Mean walk distance

Table 3 reports the mean walking distance and quartiles calculated for each explanatory variable described in Table 2. Overall average walking distance to public transport is 573 m, with 25% of trips less than 235 m and 75% of walking trips less than 824 m. Table 3 also reports the comparison of mean walk distance for each category of explanatory variable where the mean walk distance was compared to a base chosen for each category of variables and a p-value reported for a 2-tailed t-test of statistical significance. For many of the variables, there was a statistically significant difference in mean walk distance when comparing the base to other values of the explanatory variable.

Differences by trip characteristics included:

- Walk trips to train are significantly longer than walk trips to bus, while walk trips to school bus are significantly shorter than walk trips to bus.
- Walk trips in Central Coast and Newcastle and Sydney fringe are significantly shorter than walk trips in inner Sydney, while walk trips in outer Sydney are significantly longer than walk trips in inner Sydney.
- Walk trips for education and shopping/personal business are significantly shorter than walk trips for work.
- Walk trips in the evening are significantly longer than trips in the am peak.
- Walk trips for public transport trips more than 45 minutes long are significantly longer than walk trips for public transport trips less than 15 minutes.

Differences by demographic characteristics included:

- Walk trips by the young (under 19 years) and elderly (65 years and over) are significantly shorter than trips by 30-49 year olds.
- Walk trips by the economically inactive and school students are significantly shorter than trips by full-time workers.
- Walk trips using a school pass or pensioner concession ticket are significantly shorter than trips paying full fare.

These findings are generally consistent with known characteristics of public transport use. The longer walk trips in the evening (after 6 pm) reflect the Sydney planning guidelines (NSW Ministry of Transport 2006) which set different access standards for daytime and evening, with an aim that 90% of households are within 400 m of a train station or bus stop (with a certain level of service) in the daytime, and within 800 m of a train station or bus stop outside the peak and inter-peak daytime.

Table 3 Walk distance from home to public transport (metres) [1]

Variable	Category[2]	N	Mean[3]	p-value[4]	SD[5]	LQ[5]	Median	UQ[5]
Total	-	1906	573	-	417	235	518	824
Trip characteristics								
Transport mode	Train	667	805	****0.000**	375	539	749	1018
	Bus	1084	461	Base	382	162	364	655
	School bus	155	360	****0.002**	386	50	185	600
Region	Inner Sydney	968	570	Base	385	273	520	785
	Outer Sydney	638	636	****0.003**	452	261	572	922
	Sydney Fringe	46	446	***0.034**	429	50	342	781
	Central Coast	69	327	****0.000**	338	50	185	611
	Newcastle	85	435	****0.002**	435	52	285	676
	Illawarra	56	518	0.322	421	144	421	805
Trip purpose	Work	695	646	Base	418	316	582	900
	Education	471	483	****0.000**	412	97	400	778
	Shopping/Pers business	394	501	****0.000**	383	179	429	738
	Social/Recreation	295	639	0.817	429	304	582	878
Fare type	Full fare	952	636	Base	419	312	580	889
	Free: school pass	333	425	****0.000**	393	50	320	679
	Concession: pensioner	251	485	****0.000**	372	202	403	685
	Concession: student	189	643	0.832	411	318	582	921
Ticket type	Single or return	636	632	Base	425	287	582	906
	Periodical pass	569	645	0.599	425	313	581	886
	Multi-trip ticket	257	454	****0.000**	322	206	394	654
Day of week	Weekday	1638	569	Base	417	227	513	824
	Weekend day[6]	268	601	0.251	416	285	555	826
Time of day	Am peak	1164	554	Base	410	208	508	812
	Inter-peak	532	587	0.135	420	263	511	814
	Pm peak	83	593	0.404	392	256	570	825
	Evening	127	682	****0.003**	461	330	633	1008
Public transport trip duration	Up to 15 minutes	782	545	Base	384	234	501	775
	15 – 29 minutes	689	567	0.300	419	235	518	790
	30 – 44 minutes	267	604	0.057	451	229	520	922
	45 minutes and over	168	680	****0.001**	480	292	644	1012
Demographic characteristics								
Sex	Female	977	563	Base	421	223	505	813
	Male	929	584	0.270	411	250	531	844
Age	Under 19 years	498	505	****0.000**	423	117	425	779
	19 – 29 years	445	634	0.587	416	303	570	889
	30 – 49 years	528	619	Base	400	305	583	870
	50 – 64 years	241	600	0.547	448	265	511	836
	65 years and over	194	452	****0.000**	352	181	383	664
Labour force status	Full time work	685	644	Base	422	313	586	889
	Part time work	194	627	0.632	404	316	548	903
	Economically inactive	385	488	****0.000**	378	208	397	693
	Post school education	194	621	0.512	408	290	570	902
	School	429	484	****0.000**	417	78	398	775
Personal income pa	Less than $13,000	545	579	***0.023**	432	208	531	848
	$13,000 – $41,599	522	574	***0.012**	410	256	502	812
	$41,600 – $83,199	367	644	Base	410	319	597	901
	$83,200 and over	187	619	0.479	398	313	581	850
Vehicles in household	0	521	573	0.569	405	256	512	795
	1	750	587	Base	421	255	528	839
	2 or more	632	559	0.226	421	196	507	839
Driving licence	Yes	1007	611	Base	414	287	568	864
	No	614	573	0.077	420	233	515	818

1. Total is all HTS walk trips from home to public transport of less than 2 km in 2006, 2007 and 2008.
2. Categories with less than 40 respondents or undefined ("other") are excluded from this table.
3. Mean walk distance is compared to a chosen base for each variable using a standard 2-tailed t-test.
4. *significant with p<0.05, **significant with p<0.01 (all tests are two tailed tests).
5. SD = Standard deviation; LQ= Lower quartile threshold (25%); UQ = Upper quartile threshold (75%).
6. Weekends include public holidays.

Distribution of walk distance

Figure 3 and Figure 4 demonstrate the large difference in average walking distance to train compared to bus and show that the distributions are skewed. Not only do walkers to the different modes have different means, but walk distances are differently distributed for each mode as shown in Figure 3. The distribution of walk distance to train is approximately normal, whereas the distribution of walk distance to bus is almost triangular. The conclusion is that, in relation to the walking distances in Sydney, train and bus users appear to be different populations both in terms of mean and distribution. This is explored further in the next section.

The distributions reflect both the nature of the supply and spacing of train stations and bus stops and the distribution of land uses around stations and stops. The few short walk trips of less than 200 m to a train station reflect the distance estimation to the centre of the platform and the nature of station catchments. While train stations do have residential development around them, the immediate catchment is more likely to be non-residential with rail corridor uses, commuter parking, and commercial and retail uses. For instance, a 50 m wide rail corridor containing tracks, embankments, maintenance access, signalling and civil engineering structures occupies 15% of a 200 m catchment around a station.

In contrast, a higher proportion of the 35,000 bus stops are in residential areas and are immediately surrounded by residential development which reflects the planning guidelines' aim that 90% of people are within 400 m straight line distance of a station or bus stop (with a defined level of service) in daytime. Walk distance to school bus services has the most skewed distribution, reflecting that school bus services are provided where other scheduled bus services are not available or convenient, and are planned based on the known home location of school students to minimise walking distance.

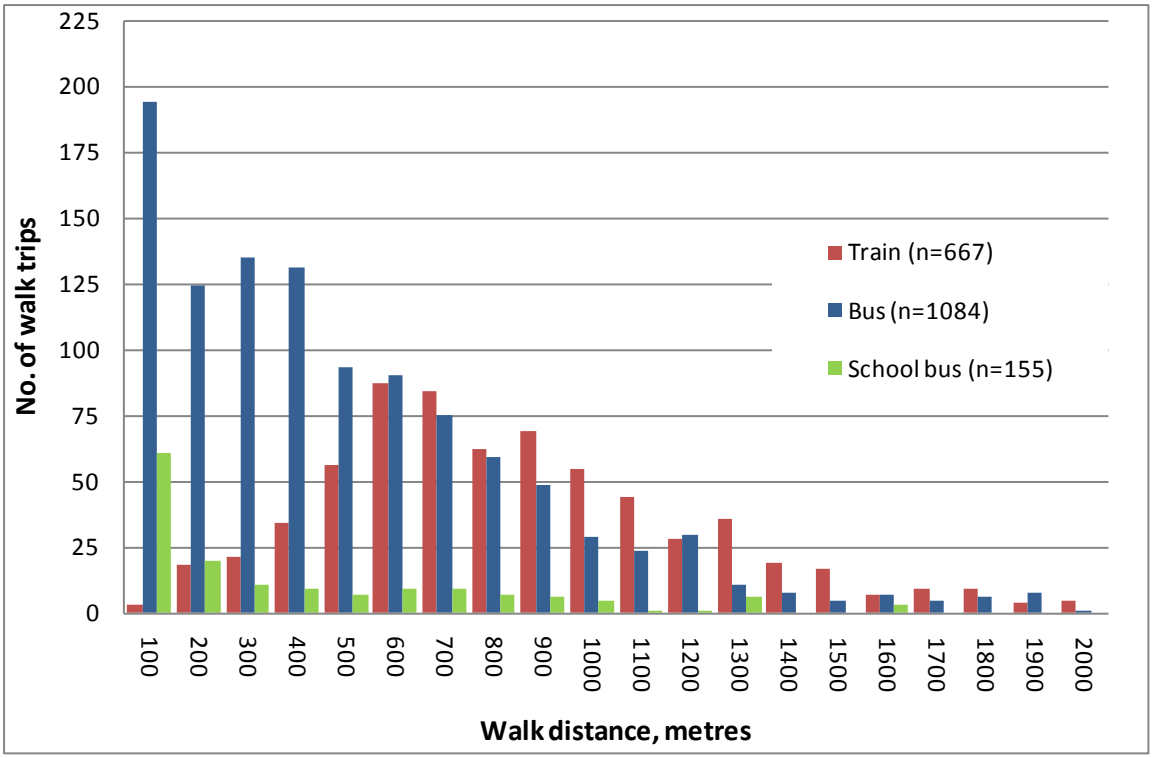

Figure 3 Distribution of walk distance by public transport mode

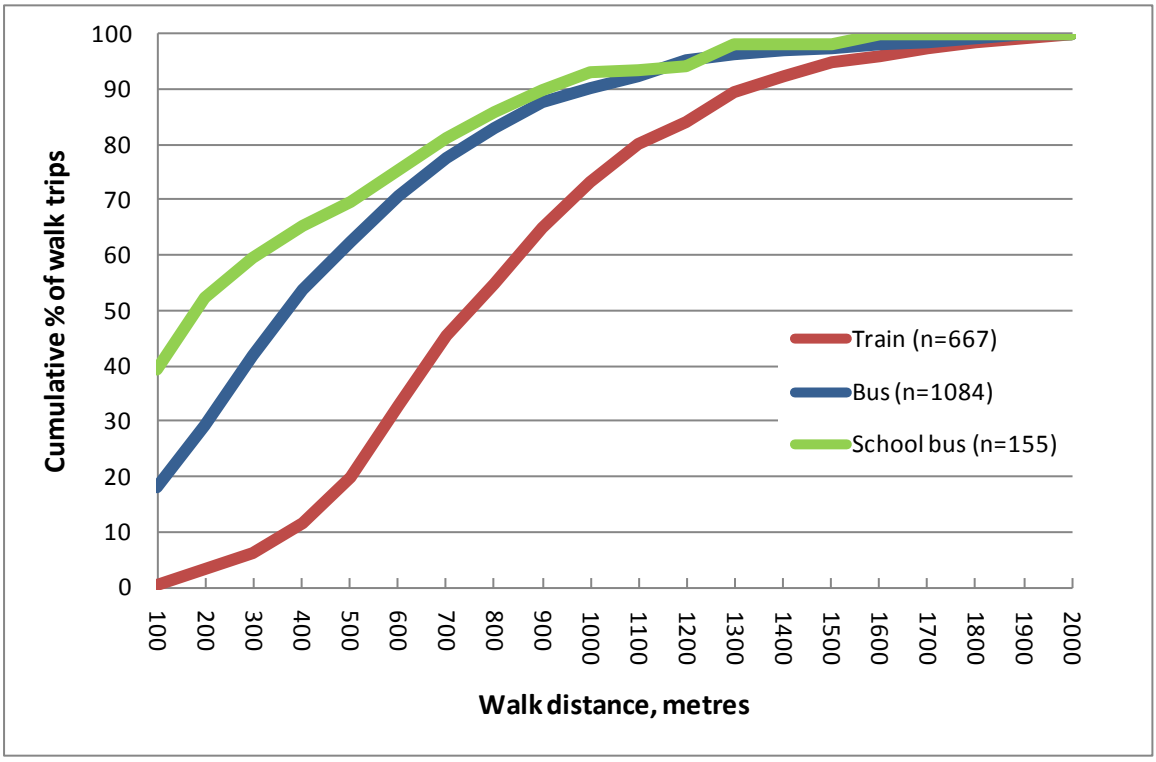

Figure 4 Cumulative frequencies for walk distance by public transport mode

4.2 Understanding differences between train and bus users

Following the many significantly different means identified in Table 3 and to better understand differences between train and bus users, Chi-squared tests were used to identify whether there were statistically significant differences between train and bus users in terms of trip and demographic characteristics. School bus users were excluded from any further analysis because these trips have a unique set of related characteristics: all trips are undertaken by a specific age group (school children) for a specific and compulsory purpose (education) in the am peak on weekdays. As all data are categorical, the Chi-squared ($\chi^{2)}$ significance reported in Table 4 relates to a contingency table between mode (bus or train) and the variable under consideration comparing the observed count with the expected count in each cell. Table 4 shows that train and bus users do vary in their trip and demographic characteristics, with statistically significant differences.

Table 4 Chi-squared tests of relationship between train and bus users (excluding school bus) and other variables

Variable	χ^2 sig.	Relationship	
		Train predominant	Bus predominant
Trip characteristics			
Trip purpose	0.000	Work	Education, Shopping
Weekday/weekend	0.008	Weekend	-
Time of day	0.002	-	Inter-peak period
Fare type	0.000	Full fare	Concession fare
Ticket type	0.000	Periodical ticket	Multi-trip ticket
Trip duration	0.000	Longer trips	Shorter trips
Demographic characteristics			
Age	0.000	19-49 years	Under 19 years, 65 years and over
Sex	0.013	Men	Women
Labour force status	0.000	Full-time work, Post-school education	All others
Personal Income	0.000	-	Low income groups
Cars in household	0.112	-	-
Driving licence	0.000	With licence	Without licence

Differences by trip characteristics included:

- Train users are more likely to be travelling for work, and bus users for education or shopping.
- Train users are more likely to be travelling on weekends.
- Train users are more likely to be travelling on a full fare, and bus users on a concession fare.
- Train users are more likely to be making a longer trip by public transport, and bus users a shorter trip.

Differences by demographic characteristics included:

- Train users are more likely to be aged 19-49 years, and bus users aged under 19 or over 65 years.
- Train users are more likely to be male, and bus users female.
- Train users are more likely to be in full-time work or tertiary education.
- Bus users are more likely to have low personal income.
- Train users are more likely to have a driving licence, and bus users not have a licence.

This pattern of relationships is internally consistent with train users having a set of characteristics associated with being employed and bus users with characteristics associated with not being employed. It is also consistent with other analysis on train and bus users using Household Travel Survey data which highlights differences between the two groups (Transport Data Centre 2002, Transport and Population Data Centre 2003).

Given the differences between train and bus users shown in Table 4, Table 3 has been disaggregated for train and bus and presented separately in Table 5 and Table 6. These tables show that very few of the significant differences in walk distance remain. The analysis of means, distributions and Chi-squared analysis confirms that people walking to bus and train are two different populations with respect to walk distance and their trip and demographic characteristics. This finding influences the approach to the regression models in the next section.

Table 5 Walk distance from home to train (metres)[1]

Variable	Category[2]	N	Mean[3]	p-value[4]	SD[4]	LQ[4]	Median	UQ[5]
Total	Train	667	805	-	375	539	749	1018
Trip characteristics								
Region	Inner Sydney	371	759	Base	360	512	688	963
	Outer Sydney	259	873	****0.000**	386	590	829	1113
	Sydney Fringe	Less than 20 trips						
	Central Coast	Less than 20 trips						
	Newcastle	Less than 20 trips						
	Illawarra	Less than 20 trips						
Trip purpose	Work	341	810	Base	383	540	711	1037
	Education	97	830	0.614	377	543	508	1050
	Shopping/Pers business	102	754	0.156	337	519	745	930
	Social/Recreation	107	819	0.832	379	582	750	1038
Fare type	Full fare	457	809	Base	380	534	748	1029
	Free: school pass	40	725	0.176	315	503	671	913
	Concession: pensioner	40	718	0.144	342	502	673	861
	Concession: student	69	882	0.135	340	593	856	1130
Ticket type	Single or return	278	815	Base	357	549	785	1034
	Periodical ticket	287	810	0.872	392	541	721	1038
	Multi-trip ticket	Less than 20 trips						
Day of week	Weekday	546	805	Base	379	538	748	1017
	Weekend day	121	804	0.995	357	541	748	1050
Time of day	Am peak	396	795	Base	371	538	727	997
	Inter-peak	176	807	0.718	381	532	743	1080
	Pm peak	30	772	0.744	359	543	749	943
	Evening	65	873	0.118	389	607	804	1079
Public transport trip duration	Up to 15 mins	258	759	Base	372	499	707	1008
	15 – 29 mins	211	801	0.221	363	546	737	963
	30 – 44 mins	108	891	****0.002**	389	581	848	1167
	45 mins and over	90	842	0.067	374	571	824	1085
Demographic characteristics								
Sex	Female	318	801	Base	381	526	748	1037
	Male	349	808	0.810	369	551	748	1011
Age	Under 19 years	99	854	0.250	388	577	791	1066
	19 – 29 years	216	789	0.691	363	528	722	1005
	30 – 49 years	241	803	Base	368	550	750	1036
	50 – 64 years	86	814	0.806	417	512	758	1019
	65 years and over	25	727	0.328	327	564	716	836
Labour force status	Full time work	328	807	Base	383	538	743	1022
	Part time work	96	801	0.883	376	524	723	1045
	Economically inactive	74	716	0.063	346	490	702	859
	Post school education	93	828	0.634	355	569	814	1048
	School	69	846	0.442	367	582	785	1045
Personal income pa	Less than $13,000	159	837	0.467	359	568	794	1051
	$13,000 – $41,599	202	779	0.468	388	502	717	1011
	$41,600 – $83,199	177	808	Base	383	539	761	1035
	$83,200 and over	80	815	0.893	361	574	698	959
Vehicles in household	0	190	767	0.181	370	509	721	999
	1	290	813	Base	366	552	745	1049
	2 or more	184	839	0.462	384	568	799	1020
Driving licence	Yes	424	799	Base	378	538	728	1009
	No	194	824	0.440	370	549	763	1052

1. Total is all HTS walk trips from home to train of less than 2 km in 2006, 2007 and 2008.
2. Categories with less than 40 respondents or undefined ("other") are excluded from this table.
3. Mean walk distance is compared to a chosen base for each variable using a standard 2-tailed t-test.
4. *significant with p<0.05, **significant with p<0.01 (all tests are two tailed tests).
5. SD = Standard deviation; LQ= Lower quartile threshold (25%); UQ = Upper quartile threshold (75%).
6. Weekends include public holidays.

Table 6 Walk distance from home to bus (excluding school bus) (metres)[1]

Variable	Category[2]	N	Mean[3]	p-value[4]	SD[5]	LQ[5]	Median	UQ[5]
Total	Bus	1084	461	-	382	162	364	655
Trip characteristics								
Region	Inner Sydney	586	454	Base	353	189	371	624
	Outer Sydney	371	502	0.070	422	155	394	756
	Sydney Fringe	Less than 20 trips						
	Central Coast	38	314	***0.017**	310	50	167	541
	Newcastle	48	404	0.363	458	50	257	645
	Illawarra	28	416	0.578	312	200	355	647
Trip purpose	Work	354	488	Base	390	188	388	702
	Education	224	414	***0.023**	357	81	350	604
	Shopping/Pers business	289	414	***0.014**	359	125	318	615
	Social/Recreation	186	537	0.174	424	240	411	757
Fare type	Full fare	494	475	Base	387	167	372	676
	Free: school pass	151	403	***0.041**	372	50	322	624
	Concession: pensioner	209	440	0.255	363	182	318	642
	Concession: student	113	519	0.286	389	204	415	755
Ticket type	Single or return	351	491	Base	421	159	392	699
	Periodical ticket	278	480	0.726	391	194	370	664
	Multi-trip ticket	253	448	0.150	321	202	366	641
Day of week	Weekday	938	466	Base	381	165	371	660
	Weekend day[6]	146	430	0.298	386	125	330	607
Time of day	Am peak	616	447	Base	366	152	359	632
	Inter-peak	353	477	0.242	397	183	370	681
	Pm peak	53	491	0.406	376	191	479	758
	Evening	62	480	0.508	448	158	353	620
Public transport trip duration	Up to 15 mins	467	442	Base	340	169	366	635
	15 – 29 mins	420	480	0.135	398	167	371	692
	30 – 44 mins	136	443	0.986	398	105	326	639
	45 mins and over	61	517	0.271	511	50	381	860
Demographic characteristics								
Sex	Female	583	462	Base	392	156	352	661
	Male	501	459	0.892	370	171	374	639
Age	Under 19 years	248	452	0.671	380	107	377	700
	19 – 29 years	229	486	0.554	411	171	393	665
	30 – 49 years	286	466	Base	359	189	376	655
	50 – 64 years	154	482	0.674	421	188	343	656
	65 years and over	167	410	0.103	339	159	309	601
Labour force status	Full time work	357	492	Base	399	188	378	727
	Part time work	97	461	0.480	356	167	412	664
	Economically inactive	308	434	0.052	367	171	318	631
	Post school education	101	429	0.154	358	150	344	617
	School	209	453	0.254	387	93	382	699
Personal income pa	Less than $13,000	332	481	0.777	412	156	381	683
	$13,000 – $41,599	317	445	0.178	371	171	344	608
	$41,600 – $83,199	190	491	Base	375	208	412	702
	$83,200 and over	107	471	0.651	359	187	332	721
Vehicles in household	0	327	461	0.631	383	171	338	636
	1	420	448	Base	388	156	343	615
	2 or more	337	477	0.301	372	159	407	736
Driving licence	Yes	554	479	Base	383	186	384	669
	No	392	458	0.423	388	159	359	654

1. Total is all HTS walk trips from home to bus (excluding school bus) of less than 2 km in 2006, 2007 and 2008.
2. Categories with less than 40 respondents or undefined ("other") are excluded from this table.
3. Mean walk distance is compared to a chosen base for each variable using a standard 2-tailed t-test.
4. *significant with p<0.05, **significant with p<0.01 (all tests are two tailed tests).
5. SD = Standard deviation; LQ= Lower quartile threshold (25%); UQ = Upper quartile threshold (75%).
6. Weekends include public holidays.

4.3 Explaining walking distance

Alternative location/geographical variables were included in regression models to identify if public transport supply (measured by the proportion of households in each of the bus contract regions within 400 m of a bus stop with a defined level of service), population density at the LGA level, and the proportion of all trips made by public transport in an LGA were significant factors in explaining walking distance, once the choice of walk mode had been made. As might be expected, there were strong correlations between these three variables (as shown in Table 7), suggesting multicollinearity would be an issue if all variables were included in the regression. As a result, only one of these variables was included at a time in the regression analysis reported below.

Table 7 Correlations between alternative locational variables in modelling

	Pearson Correlation coefficient	
	% of trips in LGA using public transport	**% of pop. within 400 m of bus stop**
LGA population density	0.753*** (N=1751)	0.658*** (N=1738)
% of trips in LGA using public transport	-	0.589*** (N=1738)

*** Significant at p<0.0005

Modelling distance to train and bus combined

Although the previous section (Section 4.2) identified the distribution of walk distance to train is different from walk distance to bus, initial investigation to explain walk distance tested a regression model with a dummy variable to distinguish between train and bus users. This approach revealed two problems. First, the dominant feature was the explanation given by the mode dummy variable to the exclusion of any contribution from the wide variety of potential explanatory variables. Second, and more importantly, combining two different distributions, of which the walking distance to bus distribution is highly non-normal, meant the residuals were significantly non-normal and thus any statistical tests of significance would be unreliable. Both these reasons indicated that separate regressions to explain walking distance to train and walking distance to bus would be a better approach.

Modelling distance to train and bus separately

Separate regressions to explain walk distance to train and walk distance to bus using demographic and trip characteristics and location/geographical variables were undertaken.

For walk distance to train, a number of model formulations were investigated including spatial, trip and demographic factors as potential explanatory variables. It was not possible to improve on a regression model with a single explanatory variable of the proportion of trips in an LGA by public transport which had a very low $R^2 = 0.008$. The interpretation is that the greater the proportion of trips made by public transport in an area, the shorter the walk distance to train. In this case, proportion of trips by public transport is not an explanatory variable as such, but more a measure of accessibility and public transport supply.

For walk distance to bus, as with walk distance to train, the distribution of walk distance is heavily skewed as shown in Figure 3, so walk distance was transformed to the square root of walk distance to ensure the regression residuals were normally distributed. A number of model formulations were investigated including spatial, trip and demographic characteristics as potential explanatory variables for walk distance to bus. All regressions displayed low adjusted R^2 even though in many cases the F test confirmed that the adjusted R^2 was significantly different from zero. The best fit was a model with a very low adjusted $R^2 = 0.02$.

In summary, the attempts to model the mode-specific data with the demographic and trip-related variables resulted in little extra explanation of walk distance variance. Indeed, the fact that the analysis was unable to find good independent variables to explain walk distance to train and walk distance to bus confirms that, once the decisions to take public transport and walk to public transport have been made, the choice of train or bus is the dominant factor, with demographic and trip related variables not playing a significant role in explaining walking distance.

5. Discussion and conclusions

Analysis of the Sydney Household Travel Survey data with almost 2,000 walk trips showed that the main influence on walking distance from home to public transport, once people have made the decision to walk, was the mode of public transport walked to, whether train or bus. People walk further from home to access train than to access bus. Average walk distance to public transport demonstrated significant differences in relation to demographic and trip-type variables, as shown in Table 3. But further analysis showed that use of bus or train mode itself is strongly associated with a number of trip-type and demographic variables.

But the contribution of this research is to move beyond a comparison of means. It shows that, once the choice of using public transport has been made, the only real explanation of walking distance is the mode of public transport used. Variability in walking distance largely reflects differences in the supply of each mode of public transport. Walk distances to train and bus reflect the different number and spacing of train stations and bus stops: people have to walk further to reach one of the 300 train stations than to reach one of the 35,000 bus stops. In addition, train stations are more likely to be immediately surrounded by non-residential land uses in their close catchment, compared to bus stops.

Given the walk distances to train, it is likely some people walk past a bus stop to access a train station, and choose to do so due to total access time and cost, and the destinations served by train compared to bus. Train trips are also usually longer than bus trips, in both distance and time. The Sydney HTS data does show that train trips are longer in distance (average 19 km for train, 6.4 km for bus) and longer in duration than bus trips (average 34 mins for train, 23 minutes for bus) (TDC 2010). This suggests train has more of a regional travel role, whereas bus has more of a neighbourhood role. While both train stations and bus stops allow users to access public transport, the modes are not necessarily interchangeable in the current Sydney network.

As well as differences in the number of train stations and bus stops, there are also differences in facilities between train stations and bus stops, with a higher level of facilities for users at train stations than at bus stops which may influence users. In Sydney, train stations are usually staffed, have shelter, seating, lighting, printed and electronic timetable information, a public telephone and help points. Very few if any bus stops have all of these characteristics. At a minimum, bus stops have a post with a sign. Some bus stops have facilities such as timetables, seats, and shelter, but not all. The research focused on people who had already chosen to walk to access public transport, and thus it did not model choice of access mode to public transport. While 90% of bus users do walk to the bus stop, only half of train users walk to the train station from home.

The results support evidence from other research that people will walk further than 400 m to access public transport, once they have decided to walk. However, equally important, it is not known how many more people would have used public transport or walked to the stop or station, if the stop or station was closer to home. The Household Travel Survey includes two relevant questions which provide some information on this issue: reasons for mode choice for the work trip, and difficulty using any form of transport, including walking, because of a physical condition or disability. One in five (18%) public transport users say they travel to work by public transport because they live or work close to public transport, and 12% of car

commuters say they travel to work by car because public transport is unavailable here (Transport Data Centre 2010, p. 28). In terms of difficulty using any form of transport including walking because of a physical condition or disability, only 3.3% of respondents in the dataset of walking to public transport trips had a condition restricting walking, which is similar to all respondents in the Household Travel Survey (3.7%) (Bureau of Transport Statistics 2010).

The research also highlights well-known difficulties in measuring pedestrian accessibility to public transport, particularly inaccuracies associated with using radial catchments of population within 400 m of a stop or station. Not all households in the 400 m catchment will actually have a walk of less than 400 m: the actual walking distance to the stop may be substantially longer for many households, depending on the road network and topographical barriers. It is more difficult to incorporate these factors into measures using available data sources, even though the importance is well-recognised. Iacono et al. (2010) noted that difficulties in calculating non-motorised accessibility measures include data quality, zonal structure of transport planning models, and the adequacy of models and travel networks for describing and predicting travel by non-motorised modes. However, recently Foda and Osman (2010) have developed ideal and actual stop-accessibility indices to measure the accessibility of a bus stop considering the actual pedestrian road network, and a stop coverage ratio index, while Alam et al. (2010) showed that an alternative method for calculating accessibility indices, using a gravity-based measure of accessibility, is more accurate than traditional measures of the proportion of travel zones with a quarter mile buffer of public transport.

It is an important result that, for those who have chosen public transport as a means of travel, walking distance is not affected by significant demographic characteristics such as age. It suggests that the most important feature of walking distance is the availability of stops and stations. But increasing the number of stops and stations to reduce access distance is expensive and transport subsidy budgets are usually more or less fixed. Innovative ways of expanding access to public transport such as providing flexible transport services as an access mode to more distant public transport services, as discussed by Daniels and Mulley (2010b), might increase the mode share of public transport.

Perhaps more importantly, closing the spatial element of the accessibility gap for conventional public transport is often argued to be more important in areas with a larger older population or higher non-car ownership. But these demographic factors do not appear to influence differences in walking distance, once people have decided to walk to public transport. To ensure equity in accessibility, it may be more important to ensure good access to public transport for all, regardless of the demographic characteristics of an area. The differences between train and bus users also suggest that accessibility initiatives for public transport may not be the same for each mode.

To better understand influences on walking distance to public transport and identify implications for service planning guidelines, future research requires more detailed information on the characteristics of the built and natural environment of the walk trip, and on the attitudes of walkers such as whether they value the walk distance as a contribution to meeting their daily health requirements for physical activity. Further research areas include the maximum distances people are prepared to walk, and whether people walk further to more frequent services. Data from household travel surveys is the main source of data for walking distance research. But alternative methods such as pedestrians drawing their actual walking route on a map, as used by Agrawal et al. (2008), or tracking routes with on-person GPS devices as used in some travel surveys, would assist research by measuring distance more accurately and identifying the characteristics of the walking route.

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