INTRODUCTION

Bus network planning often focuses on service coverage to ensure the network provides a minimum spatial accessibility for users. Typically, service coverage is defined by a rule of thumb that the maximum walk distance for bus users is around 400m. However, mode shift towards public transport (PT) is more likely from increases in quality, particularly higher frequencies and journey times more similar to car travel times, better reliability and punctuality and reductions in crowding (for example *(1, 2)*). This lends support to the alternative approach to network planning where resources are concentrated in corridors to provide higher frequency but, for a given budget, necessarily reduces coverage and leads to a longer walking distance to public transport stops. This latter approach has been associated with practice in Europe leading to significant increases in patronage *(3)*.

The research question addressed by this paper is the extent to which travellers are willing to walk further to a more frequent bus service and how this might vary in different metropolitan areas. The results quantify the trade-off between the walk distance to bus stop and service frequency to inform policy as to whether passengers are willing to walk to services concentrated in corridors.

To investigate the travellers' choice between trading between the frequency of bus services and the walking distance to bus stops, a state of the art stated choice (SC) experiment is used together with advanced choice modelling methods. Whilst the focus of this research is the trade-off between walk distance and bus frequency, the choice models also take account of other drivers known to impact on a traveller's behavioural response to bus travel, including journey time and crowding on the vehicles. The experiment was conducted in the Australian capital cities of Brisbane, Sydney, Canberra, Melbourne, Adelaide and Perth; London, UK; and New York, Atlanta, Chicago, and Los Angeles in the USA. The range of cities was chosen to reflect different degrees of known car dependence and to reflect different urban forms.

The literature context is considered next. This review identifies the necessity of posing a hypothetical choice to understand the trade-off between walk distance and frequency within a single mode leading to the design of the SC experiment, described in Section 3. Section 4 presents the choice model specifications and estimation techniques, the results, and their interpretation. The conclusions and the policy implications of this paper are discussed in Section 5.

LITERATURE REVIEW

Walk is the primary access mode for trips from home to PT nodes, be them stations, stops, or wharfs. Access distance has shown to be a significant driver of PT use in the literature. However, the literature also shows that demographics (age, gender), trip purpose and mode choice as well as specific city characteristics may be important *(4, 5, 6, 7, 8)*. In Sydney, almost 90 percent of bus trips from home and 50 percent of train trips are accessed by walking *(6)*. Ewing and Cervero *(9)* reported a meta-analysis with a public transport demand elasticity of -0.29 for distance to the nearest PT stop, suggesting that a 10 percent increase in distance to the nearest PT stop is expected to decrease PT demand by approximately three percent. Agrawal et al. *(10)* found that walk distance is the most important factor influencing rail users' route choice to the local rail station in California and Oregon. Aljoufie *(8)* looked at walking context in the car dependent city of Jeddah, Saudi Arabia, found the highest proportion of survey respondents identified a willingness to walk 5-10 minutes to reach a PT stop although their attitude was influenced by the number of transfers their journey might entail.

Access distance is clearly related to the PT network planning, as service planning usually uses a rule of thumb as to how far people are willing to walk to access PT services. Service planning guidelines for Sydney specify that 90 percent of households in each of the 15 metropolitan bus contract regions should be within 400m of a rail line and/or bus route during the day, and within 800m of a rail line and/or bus route at night time *(11)*. Similarly, Vancouver uses 400m *(12)*, Helsinki uses 300m *(13)*, while Perth uses 500m *(14)*.

Although the "rule of thumb" is commonly adopted in the government planning guidelines, international evidence has found that people walk further to access better PT services. O'Sullivan and

Morrall *(15)* found that people walk further to reach a Light Rail Transit (LRT) station than a bus stop in the city of Calgary, Canada. Alshalalfah and Shalaby *(16)* identified that on average people walk around 170 m to a bus stop with a service headway more than 15 min, whereas the average walk distance to a bus stop is increased to over 200 m if the service headway is less than 10 min with the difference being more significant in suburban areas than in the inner-city. In Brisbane, Australia, the median walk distance to bus stops is 440 m, which is significantly shorter than to train stations (890 m) as identified by Burke and Brown *(17)*. El-Geneidy et al. *(18)* found that the 85th percentile of walk distance to public transport stops in Montreal is around 550 m for buses and 1,212 m for trains. They also identified that the walk distance to public transport stops increases when the stop offers higher service frequency. In Sydney, the average walk distance by public transport users in accessing public transport is 573 m with the 75th percentile of walk distance being 824m *(6)*.

The literature discussed above suggests that PT users are willing to walk further to access PT with better quality of service, where quality of service is substantially weighted by service frequency from the passengers' perspective *(2)*. However, different users have different propensities to use PT and more recent studies have shown how behaviour and choice may be more determined by the desired quality of PT rather than perceptions. Specifically, desired levels of waiting time, cleanliness and comfort are the qualities most valued by users while non-users identifying waiting time and journey time as being particularly important *(19)*. This is confirmed by Redman et al. *(20)* who found reliability and frequency important but that perceptions, particularly to achieve mode switch from the private car, were more important. The importance of waiting time and journey time will be determined by frequency and concentration of services on corridors which will, for a given budget, provide higher frequency.

Different cities take different approaches and part of this is associated with having different urban forms and different amounts of walkability. Whilst approaches in cities vary, there is always a trade-off between coverage and frequency. In NSW, for example, Service Planning Guidelines aim to provide some evenness of coverage, by setting a target for the proportion of households that should be within a distance of 400 m or 800 m of public transport services, depending on the time of day *(11)*. The alternative, evolving from European experience *(3)* has been to exploit the 'network effect' which is identified by concentrating resources and providing high frequency services in corridors. Frequency is particularly important because it reduces wait time, which is heavily weighted in the perception (disutility) of total journey time *(21)*.

Table 1 provides a summary from the increasing diverse revealed preference (RP) literature as to the mean walking distance to PT services in different cities around the world. It includes only literature which has bus as one of the modes investigated. The table identifies the neighbourhood, socio-economic, trip attributes, built environment and natural features that are taken into account in the study. This shows how widely walking distance varies around the world but, as many of the studies are city specific, it is difficult to make a judgment as to whether experience is really different in different world cities when the same factors are taken into account. Moreover, these RP studies are limited by the observed actions of individuals and cannot investigate how people might behave under alternative future service level scenarios which is necessary to address the research question. In addition, many of these previous studies have compared the PT user's walking distance to two or more different modes of public transport, providing evidence that users will walk further to railed-based public transport providing more certain and often higher service frequency than traditional buses. The literature provides little evidence on the extent to which people will walk further to access the same PT service (defined by mode) but with higher service frequency, with Brons et al. *(22)* being the only exception that has investigated this question in relation to rail services in the Netherlands. Brons et al. *(22)* found rail demand is induced more by reducing travel time or travel distance to rail station than by improving service frequency, but this is at the cost of opening new stations to provide better accessibility.

Overall, there is a lack of quantitative evidence investigating the trade-off between the walk distance to bus stops and bus frequency which can be more easily integrated into network planning guidelines given the greater flexibility of bus network. This is, in essence, the research question this paper aims to address. The SP experiment presented in this paper investigates this trade-off in different cities with the results providing an evidence base as to whether the approach of concentrating resources in corridors is a network design that individuals are willing to use.

TABLE 1 Summary of Literature Results on Mean Walking Distances to Public Transport Stops for Studies Including the Bus Mode

Authors	**City/country**	**Mean walking distance (meters)**	**Neighbourhood attributes**	**Socio-economic attributes**	**Trip/travel attributes**	**Modes included**	**Built environment features**
Seneviratne (1985) *(4)*	CBD of Calagry, Canada	643m (from work to home)		Age, gender	Trip purposes, destinations from work, to/from modes of arrival in downtown, trips by genders, time of day, parking cost	Light Rail Transit (LRT), auto driver/ passenger, bus, subway, walk home, commuter rail	Employment population, residential population, area, office space, roadway lanes into downtown, downtown main-line bus routes, express bus routes, LRT routes to downtown, short/long term parking stalls, downtown area assigned for parking, area used by traffic lanes
Koushki (1998) *(5)*	The central area of Riyadh, Saudi Arabia,	859m (mean), 822m (mean, male), 1270m (mean, female)		Age, gender, education, employment status, nationality, population and labour force (Saudi, non-Saudi), annual income	Trip purposes, transport modes, % of trips, origin-destination, to/from mode of arrival in CBD, destinations of work-based trips	Walk home, bus, paratransit, auto driver, taxi	Area (developed, undeveloped)
Soegijoko and Horthy (1991) *(23)*	Bandung, Sole, Magelang, Salatiga, Banjarnegara cities in Indonesia	400m	Community types, access category, area, population, number of private vehicles, trip purposes, transport modes, safety, infrastructure		Trip purposes by cities	Walk, becak (three-wheeled non-motorbike), bicycle, motorcycle, car, minibus	Road network composition and pattern (radial and concentric, grid iron West-East major arterials, linear North-South major arterials), road space utilization, total road length
Rastogi and Krishna Rao (2003) *(24)*	Mumbai, India	910m		Education, occupation, household size, income, number of vehicles/ 1000 people	Trip purposes, access modes, journey distance, time, trip cost, wait time	Walk, bicycle, autorickshaw/ taxi, bus, car/ two - wheeler	Land development (developed, less developed)

Authors	**City/country**	**Mean walking distance (meters)**	**Neighbourhood attributes**	**Socio-economic attributes**	**Trip/travel attributes**	**Modes included**	**Built environment features**
Olszewski and Wibowo (2005) *(25)*	Singapore	187m (bus), 226m (Light Rail Transit – LRT), 608m (Mass Rapid Transit – MRT)		Age, gender	PT modes, travel time, waiting time	Bus, LRT, MRT	Number of road crossings, number of ascending steps, number of traffic conflicts, length of walkways, sidewalks, crossings, % length of rain shelters, barriers for wheelchairs, number of obstructions, surface quality, continuity, congestion, overall waking comfort, security, risk of traffic accident, unnecessary detour
Daniels and Mulley (2011) *(6)*	Sydney, Australia	573m 805m,(train) 461m (bus)		Age, gender, personal income, work status, number of vehicles, driving licence	Trip purposes, transport modes, fare types, ticket types, day of week, time of day, trip duration	Walk, car as driver/ passenger, bus, other (taxi, bicycle, other)	Regions in Sydney Great Metropolitan Area
Jiang et al. (2012) *(26)*	Jinan, Shandong Province, China	475m (arterial-edge corridor type) – 1392m (terminal station function)		Age, gender, income, occupation, car ownership	Trip purposes, trip time, in-group status,	Bus Rapid Transit (BRT)	BRT corridor types (integrated – boulevard, below – expressway, arterial – edge), BRT station context (terminal, transfer, typical), feeder bus routes, distance to CBD, feeder road length
Yang and Diez-Roux (2012) *(27)*	USA	1127m	Regions of residence places. urbanization level of the residence place	Age, gender, income, race/ ethnicity	Trip purposes, number of trips	Transportation mode (car, bus, subway, walk)	

Authors	**City/country**	**Mean walking distance (meters)**	**Neighbourhood attributes**	**Socio-economic attributes**	**Trip/travel attributes**	**Modes included**	**Built environment features**
El-Geneidy et al. (2014) *(7)*	Montreal, Canada	524m (bus), 1259m (rail) (85th percentile)	Populations within 800m, 400m	Age, gender, income, household size, number of vehicles	Transit types, waiting time, trip distance, number of transfer, work trips, AM peak trips	Metro, train, bus	Number of intersections around origins, distance from stations to downtown
Johar et al. (2015) *(28)*	Delhi, India	647m		Age, gender, household/ individual income	Trip purposes	Bus	
Chia and Lee (2015) *(29)*	Queensland, Australia	268 (mean) 670m (maximum)		Age, gender, weekly income, occupation, work status, study status, licence and car availability		Bus	
Poelman and Dijkstra (2015) *(30)*	European cities	417m (bus/ tram) 833m (train/ metro)			Number of departures on a normal weekday	Bus, tram, train, metro	Density of street network, highways, railroads
Aljoufie (2016) *(8)*	Jeddah, Saudi Arabia	333-667m		Age, gender, nationality, education level, monthly income	Preferred PT mode, number of transfers, comfort using PT with family	Car, taxi, bus, metro, bicycle, walking	

SURVEY DESIGN, SAMPLING AND DATA STRUCTURE

The Sample

The data were collected in October 2012 involving respondents residing in the Australian capital cities of Sydney (SYD), Melbourne (MEL), Brisbane (BRN), Adelaide (ADL), Perth (PER), and Canberra (CAN), and in London (LON), England, and New York (NY), Atlanta (AT), Chicago (CHI) and Los Angeles (LA) in the USA during February and March 2013. All these cities have significant and mature public transport systems where English is the main spoken language, allowing for a consistency in approach in data collection.

Participants were selected from the Pure Profile panel (www.pureprofile.com) in Australia, England, and the USA, given growing evidence that a consumer panel can deliver a representative sample if appropriate quota criteria are applied (see *(31, 32)*). Each of the panels have many thousands of participants in the chosen cities and PureProfile will not undertake a project if there is a belief that the target sample is unachievable. Participants were recruited using an online consumer panel (www.pureprofile.com). The total sample consisted of 1,467 respondents with over 100 from each city as shown in Table 2. The average age of the sample ranged from 39.2 (LON) to 47.8 (BRN) years old and in all cities but London the sample consisted of more women than men. In each city, the majority of respondents said they worked fulltime. The sample profiles by city are presented in Table 2.

TABLE 2 Socio-Demographic Characteristics of the Sample

	SYD	MEL	BRN	ADL	PER	CAN	LON	NY	ATL	CHI	LA
Average age (years)	41.3	40.9	47.8	47.6	43.3	42.7	39.2	44.9	42.1	47.0	43.6
% men	42%	39%	44%	40%	27%	49%	50%	39%	40%	31%	38%
Occupation											
Fulltime worker	57%	51%	45%	36%	40%	56%	71%	49%	54%	46%	47%
Part-time worker	18%	23%	21%	20%	24%	18%	11%	11%	12%	16%	15%
Retired	11%	8%	16%	20%	18%	12%	6%	17%	11%	9%	13%
Student	6%	6%	7%	3%	2%	4%	3%	3%	12%	2%	5%
Other type	8%	13%	10%	20%	17%	11%	9%	20%	12%	27%	20%
Household size (average number of people)	2.7	2.7	2.6	2.5	2.7	2.8	2.5	2.9	2.7	2.6	2.9
Number of licences in the household	2.0	2.2	1.9	1.8	2.1	2.0	1.6	2.4	2.1	1.9	2.3
Sample size	*134*	*140*	*183*	*137*	*121*	*119*	*120*	*130*	*121*	*132*	*125*

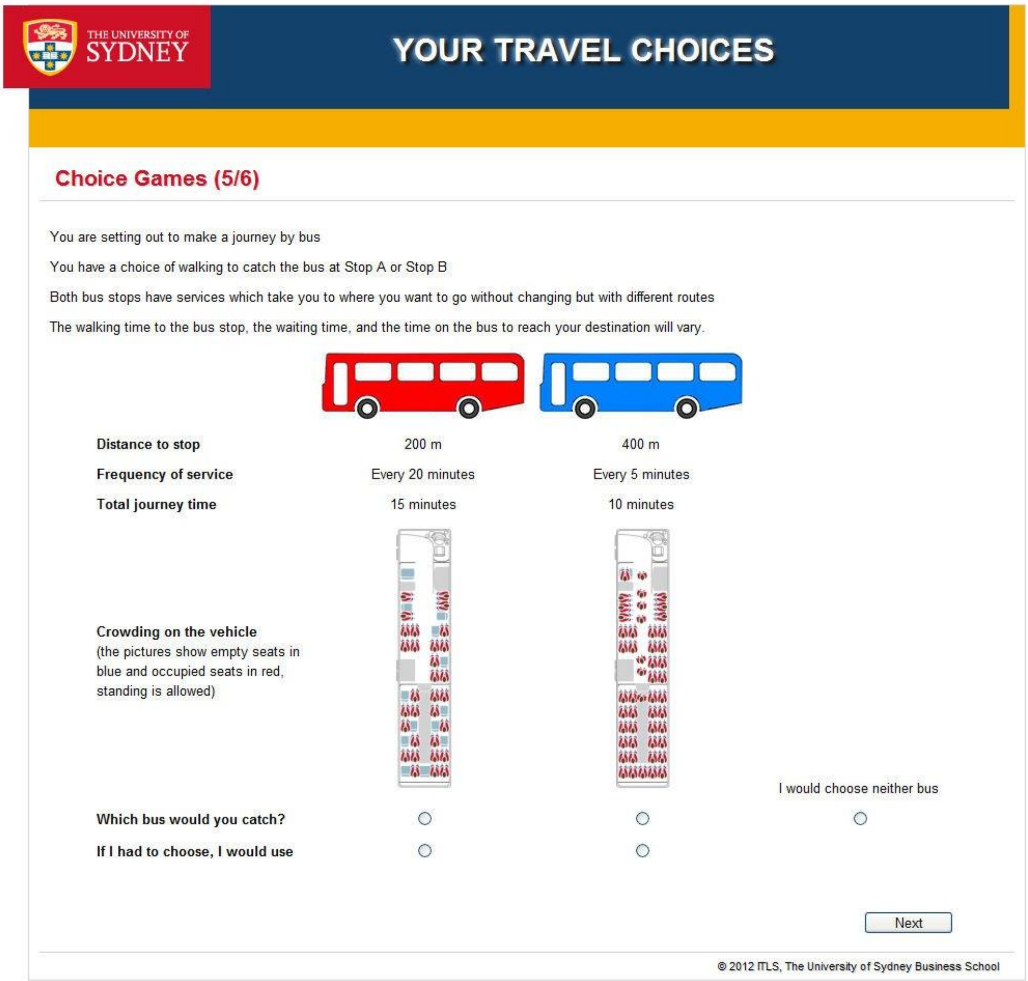
The Stated Choice Experiment

A SC experiment was used to collect data to examine the trade-off between access distance to bus services and service frequencies. An internet based survey instrument was used where respondents reviewed two hypothetical bus alternatives, or one bus and one train/light rail alternative at a time. The inclusion of non-bus alternatives masked the true focus of the survey from respondents and were removed from the current analysis. The alternatives in each task were described by four attributes: distance to bus stop, frequency of service, total journey time, and crowding level. The crowding level was described using pictures showing the number of seats occupied and the number of standing people. Although the overall objective of the study was to determine whether bus users are willing to walk further for a more frequent bus services, the journey time and crowding variables were included partly because these attributes have been shown to be important in the literature and partly because adding in additional attributes prevented respondents guessing the true intention of the survey and introducing bias. Each of these four attributes was then further described by four or more attribute levels, the values as shown in Table 3.

TABLE 3 Attributes Described the Choice Task and their Designed Levels

Attributes	**Number of levels**	**Attribute levels**	
Distance to stop (m)	4	200, 400, 800, 1000	
Frequency of service (min)	5	5, 10, 15, 20, 30	
Total journey time (min)	5	5, 10, 15, 20, 30	
Crowding (% Seat occupied | Number of people standing)	16	25%	0
		50%	0
		60%	0
		70%	0
		80%	0
		80%	5
		90%	0
		90%	5
		100%	0
		100%	3
		100%	7
		100%	11
		100%	15
		100%	19
		100%	23
		100%	27

The experiment used a dual response mechanism *(33)* in which respondents faced both a forced and unforced choice although only the unforced choices are modelled here. Based on the attribute levels of the alternatives, respondents were asked to select the bus they most preferred, or select a no choice alternative. An example choice set is shown in Figure 1.



Choice Games (5/6)

You are setting out to make a journey by bus

You have a choice of walking to catch the bus at Stop A or Stop B

Both bus stops have services which take you to where you want to go without changing but with different routes

The walking time to the bus stop, the waiting time, and the time on the bus to reach your destination will vary.

Distance to stop	200 m	400 m	
Frequency of service	Every 20 minutes	Every 5 minutes	
Total journey time	15 minutes	10 minutes	
Crowding on the vehicle (the pictures show empty seats in blue and occupied seats in red, standing is allowed)			I would choose neither bus
Which bus would you catch?	○	○	○
If I had to choose, I would use	○	○	

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FIGURE 1 An example of a stated choice screen.

The experimental design underlying an SC experiment determines the final results of the study. This study used an efficient design which means that the levels are allocated to the choice tasks in such a way that the elements (or subsets thereof) of the variance-covariance (VC) matrix are expected to be minimised once data is collected. More specifically, a single Bayesian efficient design was generated for this study and consisted of 48 choice tasks blocked into eight sets of six choice tasks. In each set, two choice tasks involved a choice between bus and non-bus alternative, which were later excluded from the sample and analysis. The design was optimised for the unforced choice (consistent with the analysis conducted), and assuming an MNL model specification. Constraints were placed on the attribute level combinations throughout the design so that at least one of the two bus alternatives would have a shorter walking distance than the other, but could not be better on any of the other attributes (some, but not all attribute levels for the remaining attributes could overlap however).

The survey instrument randomly allocated each respondent one set of six choice tasks and asked them to complete all. Given the sample of 1,467 respondent, the total number of observations available for modelling was 5,868 (1467 × 4 = 8,868), after removing the data from the two tasks involving at least one non-bus alternative. Table 4 shows the number of choice tasks per city and the average values of the attributes described these choice tasks. Table 4 shows that the choice tasks assigned to respondents in different cities are very similar (one-way ANOVA test suggests no difference in the means of these attributes). Thus, any behavioural difference found between the cities can be attributed to cultural and/or environmental differences, as opposed to the surveys being different (because they are not).

TABLE 4 Average attribute levels of choice tasks assigned to respondents in different cities

Attributes in choice task	SYD	MEL	BRN	ADL	PER	CAN	LON	NY	CHI	ATL	LA
Distance to bus stop	536	538	534	543	539	539	538	543	535	536	539
Service headway in mins	15	15	15	15	15	15	15	15	15	15	15
Total journey time in mins	22	22	22	22	22	22	22	22	22	22	22
Percent seat occupied	85%	84%	84%	85%	84%	84%	85%	85%	84%	84%	84%
Number of people standing	7	7	7	7	7	7	7	7	7	7	7
Number of choice tasks	**1,080**	**1,120**	**1,464**	**1,096**	**968**	**960**	**976**	**1,048**	**968**	**1,056**	**1,000**

MODEL SPECIFICATION

Model Formulation

The collection of data across a wide number of cities brings about a number of unique modelling challenges. First, such sampling requires that data for each city be treated as a separate dataset because preferences might differ across cities. If the sample indeed comprises of six different datasets then the direct comparison of model parameters obtained from independently estimated models is not generally possible given possible differences in scale (error variance). Likewise, simple comparisons of the log-likelihood functions and other model fit statistics are not possible given the non-nested nature of the datasets. The most common approach to combining multiple datasets is the 'Nested Logit trick' whereby the alternatives are grouped into dataset specific nests with any variance and preference differences being simultaneously estimated *(34, 35, 36)*.

Second, SC experiments provide pseudo panel data. Unlike most data, SC data typically involve the collation of multiple observations from each respondent, albeit during a single session. Failure to properly account for the pseudo panel nature of the data in the econometric modelling will at best affect only the standard errors of the model (and hence tests of parameter statistical significance) and at worst the parameter estimates themselves (see *(37)*). As the NL model fails to account for this aspect of SC data, a panel version of the error component model to approximate the nesting structure of the NL model is used in this paper whilst at the same time also accounting for the pseudo panel nature of the data *(38)*. However, this model assumes heteroskedastic error terms across the subsets of alternatives and this restriction requires that at least one alternative be treated in a separate nest to other alternatives within a dataset for purposes of model identification. In the context of this paper, this means that for a given city, a specification with an error component associated with the two hypothetical bus alternatives can be used but this assumes the no-choice alternative has no associated error component so that the model structure suggests any differences in error variance are between the hypothetical and the no choice alternatives.

Third, some normalisation is required within the specification of error components when combining multiple datasets and accounting for possible differences in the scales of different datasets. If the error components for the no choice alternatives for each data sets are normalised (i.e., constrained to be equal to zero in each city), then it is necessary to constrain the error components of the hypothetical alternatives to be equal across the cities so that the model accounts for differences in the scale between datasets whilst recognising that the same choice tasks (i.e., hypothetical alternative) were used for all cities.

Incorporating the above comments, the modelling can be explained by letting $U_{nsj|d}$ denote the utility of alternative j obtained by respondent n in choice situation s, in dataset d. As is common practice, utility is assumed to be described by a linear relationship of observed attribute levels of each alternative, $x_{nsj|d}$ and $z_{nsj|d}$ and their corresponding parameters, β_d and θ. To identify potential scale differences, it is necessary to constrain at least one parameter to be generic across all datasets. Under this specification, θ represents a vector of parameters which are generic across nests within the overall model structure, whilst β_d represent a vector of dataset specific parameters. Alternative specific constants, $\alpha_{j|d}$ are estimated for all no choice alternatives and are allowed to vary across the datasets. In order to account for potential heteroskedastic error between the hypothetical and no choice alternatives, dataset specific error components, η_n are estimated for the two hypothetical alternatives. The error components, η_n are assumed to follow $N(0,\sigma_n^2)$. The utility specification is shown in Equation (1).

$$U_{nsj|d} = \begin{cases} \alpha_{j|d} + \varepsilon_{nsj|d},\ j = \text{no choice} \\ \beta_d x_{nsj|d} + \theta z_{nsj|d} + \eta_n + \varepsilon_{nsj|d},\ \forall j \neq \text{no choice} \end{cases} \tag{1}$$

Remaining differences in the variance of the error terms associated with different datasets are accounted by the specification of a scale λ_d that interacts with the observed component of the utility as in Equation (2).

$$U_{nsj|d} = V_{nsj|d} + \varepsilon_{nsj|d} = \begin{cases} \lambda_d\left(\alpha_{j|d}\right) + \varepsilon_{nsj|d},\ j = \text{no choice} \\ \lambda_d\left(\beta_d x_{nsj|d} + \theta z_{nsj|d} + \eta_n\right) + \varepsilon_{nsj|d},\ \forall j \neq \text{no choice} \end{cases} \tag{2}$$

where λ_d is the scale of dataset d. As with NL model, this scale parameter needs to be positive to be consistent with random utility theory. For model identification, it is necessary to normalise the scale of one dataset and allow the remaining scale parameters to be freely estimated.

It is important to recognise that in model (2), only the error components η_n are assumed to be randomly distributed. Unlike other models which assume random scale (e.g., the scaled MNL model *(39)* or *(40)*) this model has fixed scale with the remaining preference parameters being treated as fixed so as to avoid issues of preference and scale confoundment *(41)*.

Assuming the error terms $\varepsilon_{nsj|d}$ follows iid Extreme Value type 1 distributions, the probability that respondent n chooses alternative j in choice situation s is given as follows:

$$P_{nsj|d} = \int_{-\infty}^{\infty} \frac{\exp(\lambda_d V_{nsj|d})}{\sum_i \exp(\lambda_d V_{nsi|d})} \phi\left(\sigma_\eta^2\right) d\eta \tag{3}$$

Let $y_{nsj|d}$ be a dummy, equal one if alternative j is the chosen in choice situation s shown to respondent n, and zero otherwise. The panel model version of equation (3) is used in this paper to describe the joint probability that respondent n makes a sequence of choices S. This can be written as:

$$P_{n|d} = \prod_{s=1}^{S} \prod_{j=1}^{J} \left(P_{nsj|d}\right)^{y_{nsj|d}} \tag{4}$$

Model Results

Model (4) was estimated using Python Biogeme 2.5 *(42, 43)* running on an Artemis supercomputer at The University of Sydney. To estimate the standard deviation associated with the error components, we used 500 MLHS quasi Monte Carlo draws *(44)*. For identification purposes, the scale of the Sydney data was normalised at 1. Also, to identify the relative difference in the scale associated with different datasets, at least one parameter must be generic across all datasets; the parameter of the journey travel time was chosen for this purpose since other attributes such as access distance, crowding level, and service frequency are specific to the bus network in each city while a minute travel time is perceived more or less the same by respondents in different cities. Table 5 presents the estimation results of the preferred model. The model fits the data reasonably well (McFadden pseudo R2 of 0.307) with all parameters having the expected sign.

TABLE 5 Estimation results of the error component model for access distance and service frequency trade-off

Variable	**SYD**	**MEL**	**BRN**	**ADL**	**PER**	**CAN**	**LON**	**NY**	**CHI**	**ATL**	**LA**
Journey time (mins)	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031	-0.031
significance level [a]	***	***	***	***	***	***	***	***	***	***	***
Distance to bus stop (100m)	-0.274	-0.226	-0.194	-0.148	-0.165	-0.130	-0.194	-0.145	-0.118	-0.061	-0.062
significance level	***	***	***	***	***	***	***	***	***	**	**
Frequency of service (mins)	-0.067	-0.058	-0.040	-0.030	-0.047	-0.027	-0.071	-0.053	-0.046	-0.023	-0.030
significance level	***	***	***	***	***	***	***	***	***	**	***
% Seats occupied (%)	-1.220	-1.120	-1.600	-1.040	-0.648	-0.525	-0.761	-2.060	-1.660	-1.250	-0.673
significance level	**	*	***	**				***	***	***	
Number of standing people	-0.054	-0.038	-0.036	-0.040	-0.074	-0.036	-0.073	-0.021	-0.020	-0.017	-0.042
significance level	***	**	***	***	***	**	***				***
Distance (100m) × Men	0.055	0.055	0.055	0.055	0.055	0.055	0.020	0.015	0.015	0.015	0.015
significance level	***	***	***	***	***	***					
Distance (100m) × Age 65+	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.088	-0.116	-0.116	-0.116	-0.116
significance level								**	**	**	**
Distance (100m) × Age <20	-0.041	-0.041	-0.041	-0.041	-0.041	-0.041	-0.166	-0.010	-0.010	-0.010	-0.010
significance level											
Constant of no-choice	-6.920	-5.930	-5.560	-4.920	-4.700	-3.950	-6.950	-6.600	-5.650	-3.460	-4.830
significance level	***	***	***	***	***	***	***	***	***	***	***
Scale (λ_d)	1.000	1.090	1.710	1.710	1.260	1.650	1.140	1.160	1.160	1.580	1.430
significance level [b]	*fixed*										
Std dev of error component (η)	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420	3.420
significance level	***	***	***	***	***	***	***	***	***	***	***
Model summary statistics											
Number of observations	5,868										
Number of people	1,467										
LL(0)	-6,447										
LL at convergence	-4,470										
McFadden pseudo-R^2	0.307										

Note: [a] *Parameter significantly different from zero at ***99%, **95%, * 90% level of confidence*
[b] *Scale parameters are compared against 1 instead of 0.*

Table 5 shows that the scale parameters λ_d for all cities are not statistically different from 1 (or from each other) based on t-tests. This suggests that the error variances across the datasets are not statistically different, and hence the datasets could be pooled with the parameter estimates for different cities directly compared. In contrast, the error component is significantly different from zero, supporting the hypothesis expounded within the literature that there exists a greater level of error variance for the hypothetical alternatives of a SC experiment, compared to the no-choice alternative. A statistically significant error component also suggests that there is a higher degree of substitution between the alternatives to which the error component belongs, indicating that respondents are more likely to trade between the two hypothetical alternatives than between one of the bus alternatives and the no-choice alternative.

Turning to the design attributes (distance to stop, journey time, headway (frequency) and crowding), it is expected that an increase in any of these attributes would result in lower utility, and this expectation is confirmed by the model parameters with the negative sign for all design attributes. Specifically, the model suggests that, all else being equal, respondents across all cities prefer shorter journey times, shorter walking distances (i.e., shorter access time), more frequent services (i.e., shorter waiting time), and less crowded buses (greater chance of a seat). The influence of crowding on individual preference was significant in all cities but respondents in different cities perceive crowding in different ways. Specifically, it appears that residents of NY, ATL and CHI cities prefer buses with a lower loading factor (i.e., less seats being occupied) whilst crowding only has a significant impact on bus users in Perth, Canberra, London and Los Angeles cities when the loading factor exceeds 80% and people start standing on the vehicles (i.e., the parameters associated with the number of people standing are significant for these cities while parameters for the percent of seats being occupied are not significant). In contrast, both bus loading factors and number of people standing on the bus have significant and negative impact on bus users in Sydney, Melbourne, Brisbane, and Adelaide cities.

How much further people are willing to walk for a better bus service does depend on socio-demographics and the country of location. Specifically, Australian men are more likely than Australian women to walk further for a better bus services whilst this gender difference is not observed in the USA and England. By contrast, American citizens aged 65+ are significantly less likely than younger Americans to walk further for better bus services. This age effect is observed amongst Australian and British citizens but it is not statistically significant.

To quantify the extent to which bus users are willing to walk further for a better bus service, whether it be more frequent (shorter waiting), quicker (shorter journey time), or less crowded, the marginal rates of substitution (MRS) are presented in Table 6 for each of the sampled cities. The MRS describes how many metres further an individual would willing to walk to a bus stop in exchange for an improvement in other attributes without changing the total utility (i.e., neither being better-off nor worse-off). Table 6 shows that on average, for a more frequent bus service represented by a ten minute decrease in headways, Sydney residents are willing to walk an additional 260 m while the extra walking distances for Londoners and New Yorkers are 370 m and 353 m, respectively. This finding confirms the underlying hypothesis of this paper that people, regardless of which cities they live, are willing to walk further to access more frequent bus services.

TABLE 6 Marginal Rates of Substitution (RMS)

Metres walk further to	SYD	MEL	BRN	ADL	PER	CAN	LON	NY	CHI	ATL	LA
Save 10 mins waiting time	260	277	226	227	302	254	370	353	384	357	475
Save 10 mins journey time	120	147	175	232	197	291	161	204	257	479	494
Have 1% fewer seats occupied	476	536	907	784	415	495	397	1,368	1,383	1,943	1,079
Reduce 10 people standing	209	183	204	301	477	342	379	141	169	270	670

CONCLUSIONS

The research question addressed by this paper is whether bus users with different cultural and environmental settings are willing to walk further to have more frequent bus services. Using a SC experiment to investigate travellers' trade-off between walk distance to bus stops and bus service frequency, this study provides evidence that, in all cities forming part of this paper's empirical setting, individuals are prepared to walk further for a more frequent service.

The extent to which bus users are willing to walk further for a more frequent service varies by country of location. Travellers in Australian capital cities are prepared to walk further by between 226 m and 302 m for a 10-minute reduction in service headways whilst Londoners and American travellers are willing to walk 350 m – 475 m further for the same improvement in service frequency. The policy implications for network planning are that increasing frequency, even if it means travellers have to walk further to bus stops, will attract higher patronage. If budgets are fixed, this suggests that moving from a policy of ' coverage' to the 'European' approach of concentrating frequency in corridors is likely to be a good policy if increasing public transport patronage is desired. Of course, concentrating frequency in corridors will require some travellers to walk further to access bus based public transport and will require policy-makers to consider and implement complementary policies to ensure accessibility is not reduced for those travellers unable to walk the additional distance. This could take the form of lower frequency access services or more flexible services to provide on-demand access to high frequency corridors.

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