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Modeling household residential location choice and travel behavior and its relationship with public transport accessibility

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Abstract

Cities are seeking to reduce the growth of car-based travel by developing public transport networks. Much research asserts that the correct arrangement of built environment will result in the enhancement of public transport utilization. There is, however, debate that this approach results only in ‘self-selection’, that is that only residents willing to travel by public transport will locate in these places with resultant minimal impact on car-user households. If policy solutions towards public transport are to be effective, it is necessary to understand the multi-dimensional relationship between location behavior and travel patterns of residents living in proximity to public transport. This research seeks to model the relationship between residential location and mode choice within a behavioral analysis framework. At this early stage of in the research this paper focuses on the methodological framework.

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Keywords: mode choice; residential location choice; logit model; accessibility; property values.

1. Introduction

The concept of integrated land use and transport (LUTI) has been studied by many researchers. Empirical research has given variable results about how effective policies seeking to integrate land use and transport have been in reducing car-based travel. The nature of the correlation between built environment and transport is also questioned (Scheiner and Holz-Rau [1]; Waddell, Ulfarsson et al. [2]; Rickwood and Glazebrook [3]; Scheiner [4]). Cao, Mokhtarian et al. [5] found in their research that built environment shows a positive effect on travel

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behaviour. They concluded that increasing public transportation accessibility was the most significant factor in the reduction of driving. However, Van Acker, Witlox et al. [6] and Van de Coevering and Schwanen [7] stated that factors other than built environment had a stronger influence such as demographic and household characteristics. Critically, Bhat, C. R. and J. Y. Guo [8] assert the importance of the separation between the causal effect and the spurious relationship among built environment and travel behaviour. One such failure has been the omission the 'self-selection' effect when explaining the relationship between residential location (i.e. built environment attributes) and travel behaviour.

Much of the research to date has exposed the complexity of the land use-transport-travel behavior relationship. As such the primary focus of this paper is in establishing a model that can unlock the complexity, in particular in relation to useful practice based outcomes. In this respect it is deemed important to control for intervening factors relevant to public transport investment. The main research question is thus stated as: "Why households reside near to public transport facility mainly are not regular users of the public transport?" Four sub research questions follow: (1) How the relationship between the choices of residential location and travel mode choice are explained by the relationship between property value and accessibility; (2) How the relationship between residential location choice (as a proxy built environment) and travel behavior (i.e. mode choice) are controlled in terms of the self-selection effect, public transport accessibility, property value capitalization and socio-demographic factors; (3) How significant public transport accessibility is in housing location and mode choice decisions and its impact on the efficiency of travel patterns; (4) What are the range of strategies for effective public transport investment when taking into account the choice behavior of households in the housing location decision and mode choice. The aim will be to apply a logit model by comparing one case study with high public transport accessibility and one case with low/no public transport accessibility. In this first stage of the research a methodological framework is discussed as an approach to reveal the intervening factors within the relationship between the choice of residential location and mode of travel.

The case study will be located in Perth, Western Australia which has recently made a significant public transport network extension. Changes in accessibility can thus be measured as a result of the improvement of public transport, as can any increase the property value around the station precinct or network. Behavior of residents and their choices can be examined in order to explain the hidden or underlying mechanisms that affect mode choice and residential location decisions.

2. Literature review

Households make decisions about where to live will consider property value, accessibility and other factors such as the socio-economic characteristics (income, individual or household life stage, household size and composition), residential tenure (rent or own), housing qualities (e.g. dwelling size per unit, building type) and neighbourhood attributes (Vega, A. and A. Reynolds-Feighan [9]). However, it is not clear which factor is considered important, particularly in relation to areas where public transport accessibility has been improved. Accessibility can be considered as one of the main determinants of property values (Des Rosiers et al, 2000 in Thériault [10]), hence accessibility and property value plays a positive interrelationship in housing decisions. But this relationship is debated: Kryvobokov and Wilhelmssen [11] showed inconsistent results, where access to public transport in terms of the distance to bus stop is the least important variable that impacts on property value and location choice, compared to other location variables such as distance to CBD; Pagourtzi [12] found the reason why people bought property was due to price certainty rather than location and showed no clear relation between income, price, access, and location choice.

One important aspect in assessing housing location decisions is its relation with travel choice (home-work distance, travel route, mode choice) (see Vega, A. and A. Reynolds-Feighan, [9]). This relationship is complex and needs disentangling between the correlation or causality and true or spurious (Bhat, C. R. and J. Y. Guo [8]). Within this framework, the factor considered important is the issue of 'self-selection'. Bhat, C. R. and J. Y. Guo, 2007 [8] and Vance, C. and R. Hedel [13]; all caution for clarity on whether or not the relationship between residential location choice and travel behaviour is due to a 'self-selection' effect.

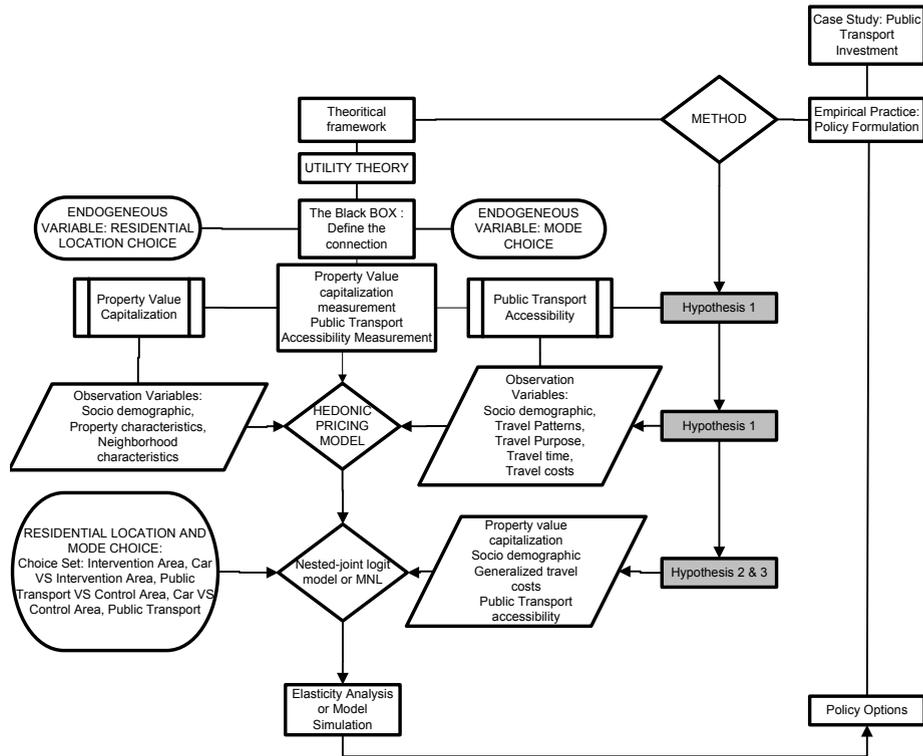


Figure 1: Research frameworks

Self-selection suggests the possibility that households endogenously self-select themselves into neighbourhoods that support their preferences for certain transport modes. For example, the travel preference of an individual/household means they select a location where they can behave in this way – so provided one’s travel preference is to use public transport, she/he will move to a location where this travel mode is catered for. Similarly, if one’s travel preference is to drive everywhere, she/he will live somewhere where driving is unconstrained. In opposition to others argue that residential location and travel choice have a causality relationship where built environment is an as exogenous variable for travel behaviour. This means there is an apparent causality relationship with little consideration on the self-selection bias (Cao, Mokhtarian et al. [5]; Scheiner and Holz-Rau [1]). For example, it has been widely accepted that urban sprawl causes auto-dependence (Cao, Mockhtarian et al. [5]) and compact design encourages walking habits (Jenks [14]), while public transport use and non-motorised journeys increase with increase in density (Barter, P.A, [15]).

Whether or not self-selection exists, it is necessary to explore an alternative approach where some of the confounding factors are controlled for (such as self-selection in residence, accessibility and generalized transport costs) in explaining built environment and travel. In order to establish the true effect of built environment and travel behaviour without self-selection, Bhat, C. R. and J. Y. Guo [8] suggested a comprehensive examination of the impact of built environment, transport network attributes, and demographic characteristics on land use and transport.

3. Research framework

The hypothesis must have some connections with the theoretical background (Blaikie, [16]). Based on a literature review, this research basically hypothesized that the complex relationship of LUTI could be simplified basically into three type relationships, i.e. causality, self-selection, or independent. The framework offers a bridging concept to define the “black box” connection between LUTI (in this case residential location and mode choice), i.e. the public transport accessibility and the concept of property value capitalization. The research framework as shown in figure 1, also offers a multidimensional approach to examine that relationship, i.e. involving several factors consist of socio demographic, property characteristics, neighborhood characteristics, travel characteristics, and factors affecting mode choice decisions. The framework works upon three hypothesis to be examined, i.e. (1) whether or not there is a relationship between property value and public transport accessibility improvement; (2) whether or not the choice of mode of transport being conditioned on the choice of residential location; (3) whether or not the choice of residential location being conditioned on the choice of mode of transport.

4. Modeling approach

4.1. Modeling framework

In terms of the direct output of this research, information about relationship between mode choice and residential location choice are explained by the significance model, whether multinomial logit or nested logit model (figure 2). The nested logit model formulates two different approaches, i.e. considering the mode choice decision conditional on residential location decision, or the other way around, i.e. considering the residential location decision conditional on the mode choice decision. These two approaches have a different theoretical consequence, the former that the LUTI relationship indicates a causality relationship, while the later that the LUTI relationship indicates the self-selection dominance. In the case the nested-joint logit model found to be not significant, the model collapses into simple multinomial logit model, which means there might be no relationship between mode choice and residential location decision (independent relationship), or put another way, there are more important factors other than the mode choice decision factors that affect the decision on the residential location and there are more important factors other than the residential location decision factors that affect the decision on mode choice.

As stated in the methodological framework, the method used in this research to examine the hypothesis is a multinomial logit model and nested logit model (with joint logit model). Those two models form part of the random utility model categorization, as disaggregate type of modelling with the assumption of maximization of utility in choice decision. The next section provides description about multinomial logit and nested logit model.

4.2. Nested –joint logit model and multinomial logit model

Nested-joint logit model is a joint logit model developed in the form of nested model. Nested-joint logit model develops in this research purposed to examine two things:

- To what extent the modeling choice of mode of travel and residential location has causality effect of each other (second hypothesis);
- To what extent the modeling choice of mode of travel and residential location has introduced the self-selection effect (third hypothesis). The model is straightforward, i.e. using the basic model of joint logit model and attach it to the nested structure. Joint logit is a technique where the analyst has a multidimensional choice sets with shared observed attributes. A discussion on the Joint Logit Model could be found in Ben-Akiva and Lerman [17]. The formula for nested logit model presented here is taken from Ben-Akiva and Lerman [17], Hensher, D.A, et.al [18] and Train [19]. In the case that the nested joint logit model is not proven to be significant, the model collapses into a simpler multinomial logit model develops, which will examine two things:
 - The current market share of mode and the current distribution of residential location. The model gives information about choice factors determine the share of mode and residential location.
 - To what extent the modeling choice of mode of travel and residential location, both as independent model.

The methodological framework follows the structure of MNL introduced by Ben-Akiva and Lerman [17]. The model structure for each nested-joint logit (causality test), nested joint logit (self-selection bias test), and multinomial logit (independent test) are illustrated in the figure 3a-d. Following the model structure as in figure 3, the choice sets then derived and the formulation of utility and probability functions are stated in the table 1-4. As discussed in Ben-Akiva and Lerman [17] and also in Train [19], the nested structure divided into the marginal probability, and conditional probability, with an additional of joint probability attached into the nested structure. The possible choice sets then derived from this structured which is defined in the table 1-4. The number of possible choice sets derived from this structure consisted of 13 choices in model 1 (nested joint logit for causality testing); 15 choices in model 2 (nested joint logit for self-selection testing), and 5 choices in model multinomial logit (independent testing). The number of choices among choice set would be depend on the revealed preference data, i.e. the model will only include the feasible choice for households based on the overlays GIS on combination of pattern of property value capitalization, public transport enhancement, and household socio demographic characteristics. Knowing the share of choice from the significant model, the analysts would reveal the tendency of household behavior and its underlying mechanism. Controlling the intervening factors such as public transport accessibility enhancement; the important of property value enhancement for household; household socio demographic such as household income level, the analyst would reveal the true relationship of residential location characteristics and travel behavior characteristics. Next, analysis of the proper policies in LUTI based on the model outcome would be conducted based on the most sensitive factors affecting the tendency of household into utilizing the public transport service, taking into account their behavior in choosing the housing location.

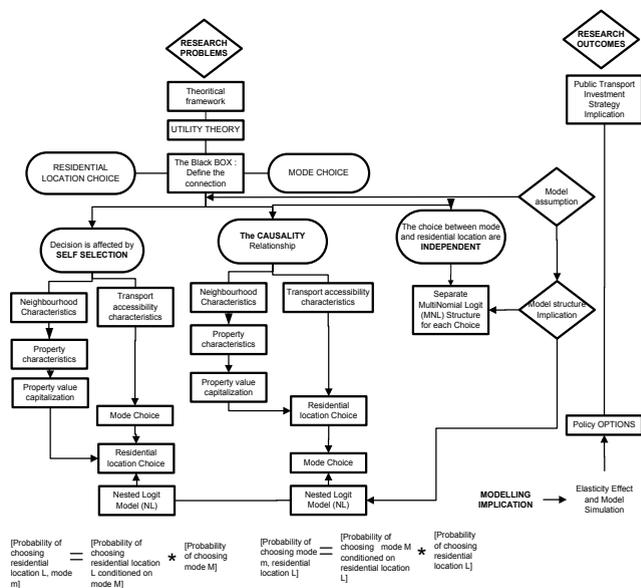


Fig. 2 The modelling framework

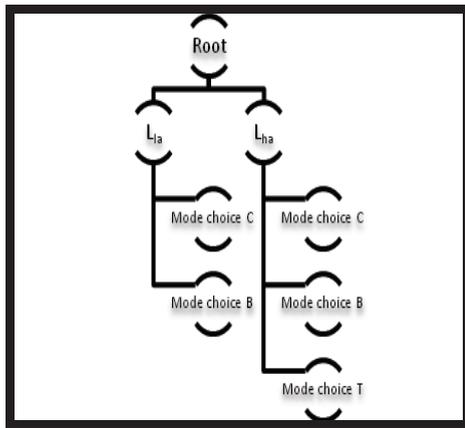


Fig. 3a. Structure of Nested-Joint logit model for causality relationship

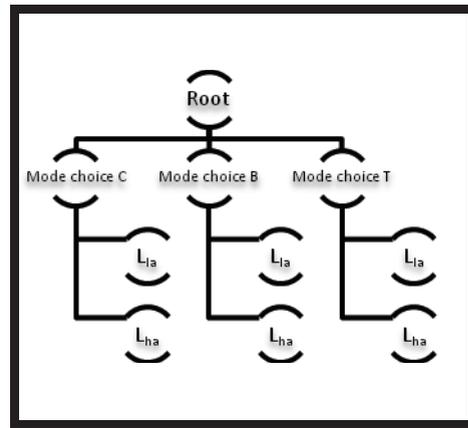


Fig. 3b. Structure of Nested-Joint logit model for self-selection bias

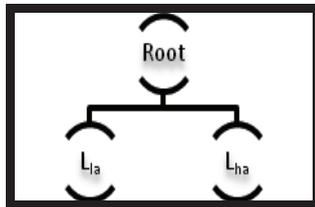


Fig. 3c. Structure of MNL for Residential location

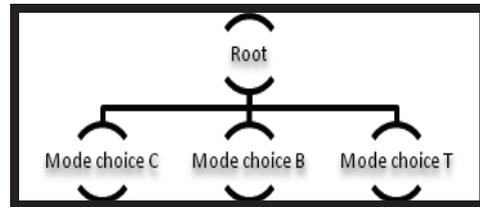


Fig. 3d. Structure of MNL for Mode choice

Table 1. Marginal probability choice description

Model	Choice set	Utility and probability function
Nested-joint logit	Model 1: Causality Relationship	The utility function as illustrated for choice as HH choose to relocate in location with low accessibility:
	<ul style="list-style-type: none"> Marginal probability, that consists of two possible choices; i.e L1a (residential location with low public transport accessibility) and Lha (residential location with high public transport accessibility) 	$V^j_{Llan} = \beta_{0Llan} + \beta_{1Llan}f(X_{1Llan}) + \beta_{2Llan}f(X_{2Llan}) + \dots + \beta_{KLlan}f(X_{KLlan}) + \beta_{K+1Llan}f(IV_{K+1Llan})$ <p>Whereas: V^j_{Llan} is the utility value of choosing to reside in residential location with low accessibility by household n within subset choice 1; B is parameter value; f(X_{1Llan}) to f(X_{KLlan}) is the attribute of choice of location L1a in regards to the characteristics of household n and characteristics of location L1a; IV is the inclusive value or logsum or the composite cost is equal to $\log(\exp V^j_{cn} + \exp V^j_{bn})$, in which Train ([19], p.699) stated that the inclusive value is a parameter estimate used to establish the extent of dependence or independence between linked choices Marginal probability value labelled as $P_n(L_{1a},n)$:</p> $P_{n(L1a,n)} = (e^{V^j_{1Llan}}) / (e^{V^j_{1Llan}} + e^{V^j_{2Llan}})$
	Model 2: Self Selection Bias	
	Marginal probability, that consists of three choices: car (C), bus (B), and train (T)	With the utility value V as stated in the above formulation.

Table 2. Conditional probability choice description

Model	Choice set	Utility and probability function
Nested joint logit	<p><u>Model 1: Causality Relationship</u> The conditional probability, that consists of five possible choices: C Lla (car conditional on residential location with low public transport accessibility); B Lla (bus conditional on residential location with low public transport accessibility); C Lha (car conditional on residential location with high public transport accessibility); B Lha (bus conditional on residential location with high public transport accessibility); T Lha (train conditional on residential location with high public transport accessibility).</p> <p><u>Model 2: Self Selection Bias</u> Conditional probability, that consists of six possible choices combinations within three subset: residential location with low public transport access conditional on choosing car (Lla C) and residential location with high public transport access conditional on choosing car (Lha C); residential location with low public transport access conditional on choosing bus (Lla B) and residential location with high public transport access conditional on choosing bus (Lha B); residential location with low public transport access conditional on choosing train (Lla T) and residential location with high public transport access conditional on choosing train (Lha T).</p>	<p>Utility formulation as illustrated for choice of using car, labeled as V:</p> $V^{LlaCn} = \beta_{0Cn} + \beta_{1Cn}f(X_{1Cn}) + \beta_{2Cn}f(X_{2Cn}) + \dots + \beta_{KCn}f(X_{KCn})$ <p>Whereas: V^{LlaCn} is the utility value of choosing to use car as mode of travel by household n within subset choice 1; B is parameter value; $f(X_{1Cn})$ to $f(X_{KCn})$ is the attribute of choice of car in regards with the characteristics of household n and characteristics of car;</p> <p>Conditional probability value labeled as $P_n(C Lla)$:</p> $P_n(C Lla) = (e^{V^{LlaCn}}) / (e^{V^{LlaCn}} + e^{V^{LlaBn}})$ <p>With the utility value V as stated in the above formulation.</p>

Table 3. Joint probability choice description

Model	Choice set	Utility and probability function
Nested joint logit	<p><u>Model 1: Causality Relationship</u> Joint Probability consists of five possible choices: LlaC (residential location with low public transport accessibility, car); LlaB (residential location with low public transport accessibility, bus); LhaC (residential location with high public transport accessibility, car); LhaB (residential location with high public transport accessibility, bus); and LhaT (residential location with high public transport accessibility, train).</p> <p><u>Model 2: Self Selection Bias</u> Joint probability, that consist of six possible choices combinations within three subsets: car, residential location with low public transport access conditional on choosing car (C,Lla) and car, residential location with high public transport access conditional on choosing car (C,Lha); bus, residential location with low public transport access conditional on choosing bus (B,Lla) and bus, residential location with high public transport access conditional on choosing bus (B,Lha); train, residential location with low public transport access conditional on choosing train (T,Lla), and train, residential location with high public transport access conditional on choosing train (T,Lha).</p>	<p>Utility formulation as illustrated for choosing to reside in location with low public transport access while choosing car as mode of travel, labeled as V:</p> $V^{LlaCn} = \beta_{0Llan} + \beta_{0Cn} + \beta_{0LlaCn} + \beta_{1Llan}f(X_{1Llan}) + \beta_{1Cn}f(X_{1Cn}) + \beta_{1LlaCn}f(X_{1LlaCn}) + \beta_{2Llan}f(X_{2Llan}) + \beta_{2Cn}f(X_{2Cn}) + \beta_{2LlaCn}f(X_{2LlaCn}) + \dots + \beta_{KLlan}f(X_{KLlan}) + \beta_{KCn}f(X_{KCn})$ <p>Whereas: V^{LlaCn} is the utility value of choosing to reside in location with low public transport access and use car as mode of travel by household n within subset choice 1; B is parameter value; $f(X_{1Llan})$ to $f(X_{KLlan})$ is the attribute of choice of residential location in location with low public transport access in regards with the characteristics of household n and the characteristics of location; $f(X_{1Cn})$ to $f(X_{KCn})$ is the attribute of choice of car in regards with the characteristics of household n and the characteristics of car; Probability value for joint logit assumed the joint choice applied when the disturbances are independent and identically Gumbel distributed, is as follows:</p> $P_n(Lla, C) = e^{V^{Lla} + V^{C} + V^{LlaC}} / \sum (LlaC) e^{V^{Lla} + V^{C} + V^{LlaC}}$ <p>With the utility value V as stated in the above formulation.</p>

Table 4. Multinomial logit model

Model	Choice set	Utility and probability function
Multinomial logit	<p>Model 3: Independent Relationship</p> <ul style="list-style-type: none"> Choice set of mode choice consist of 3 type, i.e. car, bus, and train, or stated as C, B, and T. Choice set of residential location will decide from the result of GIS and hedonic price model. Generally, the choice set will consist of area of high public transport access and area with poor or no public transport access, or stated as L_{ha} and L_{la} or location with high access and location with low access. 	<p>The utility Function as illustrated for car choice:</p> $V_{(C,n)} = \beta_0 + \beta_c X(z_{Cn}, s_n)$ <p>Whereas :</p> <p>$V_{(C,n)}$ is the utility value of choosing car as mode of travel;</p> <p>B_0 is parameter value; relate to the value of unobserved factors;</p> <p>B_c is parameter value; relate to the value of observed factors;</p> <p>$X(z_{Cn}, s_n)$ is the attribute of car choice in regards to the characteristics of household n and characteristics of car;</p> <p>Whereas the probability function as illustrated for car choice:</p> $P_n(C) = e^{V_{Cn}} / (\sum_j e^{V_{jn}})$ <p>With the utility value V as stated in the above formulation.</p>

5. Conclusion

The proposed methodological framework introduces the structure of a ‘self-selection -causality – independent’ relation-based concept to explain the relationship between choice of mode and residential location. The models attempt to control intervening factors such as socio demographics, self-selection bias, property value capitalization, and enhancement of public transport accessibility. Since the model is at the early stage of development, the process of verification and validation of the models has yet to be conducted. It is considered that such a model will be useful in informing the most appropriate policies from a LUTI perspective after the underlying mechanism of LUTI has been revealed under the proven hypothetical statements.

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