Object-fine choice models for long-term decisions: which level of granularity is necessary? A review of literature

VAN EGGERMOND Michael A.B.[*], ERATH Alexander[*], and AXHAUSEN Kay W.[**]

[*]Future Cities Laboratory (FCL), Singapore ETH Centre.
[**]Institute for Transport Planning and Systems (IVT), Federal Institute of Technology Zurich.

April 30, 2012

Contents

1 Introduction **2**

2 Decision-making **3**

2.1 Perspectives on decision-making . . . 3

2.2 Choice-set formation . . . 4

3 Accessibility **5**

4 Residential location choice **6**

4.1 Introduction . . . 6

4.2 Considered dimensions . . . 6

4.3 Applied methodologies . . . 7

4.4 Choice set formation . . . 8

4.5 Level of granularity . . . 9

4.6 Household characteristics . . . 9

4.7 Accessibility & density . . . 9

5 Case study: Singapore **22**

5.1 Background . . . 22

5.2 Initial insights . . . 22

5.3 Available data . . . 23

6 Defining the scope of the research **23**

6.1 Conclusion . . . 23

6.2 Research questions and contributions . . . 24

6.3 Research methods . . . 24

References **25**

1 Introduction

Motivation

Transport demand and land use models are increasingly moving to a smaller unit of analysis. State-of-the-art models consider the individual-decision maker and parcels or buildings as the atomic unit, or object, in contrast to traditional four-step models, which consider the zone as unit of the analysis. In this way intra-zonal diversity is taken into account by explicitly modeling an individuals' decision-making process.

Within the transport land use system, individuals carry out numerous decisions across multiple decisions, such as mode choice, mobility tool ownership and residential (re)location choice. Business choose to relocate, open a new outlet or develop a new property.

This paper presents a literature review of residential location choice. This section continues with a brief overview on transport and land use modeling and an introduction to residential location choice. Section 2 discusses decision-making theories. Section 3 continues with an overview of accessibility measures. Section 4 presents a literature review of residential location choice studies. Section 5 discusses the focus of our study: the city-state Singapore. Section 6 concludes with directions for future research.

Transport and land use

Current transport demand models fully deploy the activity-based approach (see Axhausen and Gärling, 1992; Ettema and Timmermans, 1997; Bowman and Ben-Akiva, 2001). MATSim is one example of a model that puts the activity-based approach in practice and contains a fully integrated traffic flow simulation to calculate the generalized costs implied by the activity schedule.

Land use patterns offer opportunities and impose constraints to carry out activities; transport offers the means to realize these opportunities. Changes in land-use , such as a new residential area or a shopping mall, offers new opportunities, as do changes in transportation networks, such as a new road or a subway extension. The mediating factor between transport and land-use is generally accepted to be accessibility. In general terms, accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome this spatial separation (Hansen, 1959).

Researchers and urban planners have developed integrated transport land-use models in order to model this interaction between land use and transport. One of the first spatial-interaction models to have been developed was the Pittsburgh model by Lowry (1964). Subsequently, a series of land use models has been developed. Comprehensive reviews can be found in Wegener (2004), Hunt et al. (2005), Timmermans (2006) and Iacono et al. (2008).

As is the case with transport demand models, land use models are moving to a smaller unit of analysis. Whereas in the first models highly aggregated zones were considered, later land-use models use an increased number of zones and household types (MUSSA, Martínez, 1996) or consider a parcel as basic unit of analysis (UrbanSim Waddell, 2002; Waddell et al., 2010). Traditionally, land use models have either been coupled or have incorporated four-step transport demand models. First steps have been made to combine activity-based transport models with land use models. UrbanSim has been coupled with the San Francisco activity-based transport model SF-Champ (Waddell et al., 2010); as well as with MATSim (Nicolai et al., 2011).

Residential location choice

One aspect of research within land use models concerns residential location, a long term decision for most households: where do individuals and households choose to live and in which can this be captured in a model. Besides being relevant for land use models, residential location models give insight in factors of relevance to developers and urban planners, such as price, environmental aspects and value of nearby amenities (see Ben-Akiva and Bowman, 1998; Guo and Bhat, 2002; Pagliara et al., 2010).

Most studies agree on importance of income, crime levels and other house related factors and locational on residential location. Accessibility plays a role, but to a lesser extent (Weisbrod et al., 1980; Molin et al., 2003). Accessibility is usually measured on an aggregated level and from the perspective of the location; not from the decision-maker's perspective. Studies by Ben-Akiva and Bowman (1998) and Dong et al. (2006) form an exception. In addition, most studies use cross-sectional data, capturing residential location as a static choice and not take into account the differences to the previous residential location. This can either be because of the lack of appropriate data or because in a zonal context no information exists on the previous residential context. Studies by Chen et al. (2008), Habib and Miller (2009), Belart (2011) and Iacono and Levinson (2012) however find evidence that the previous location plays a role in choosing a new location. Also, residential location studies have not reached the level of detail found in hedonic pricing studies.

2 Decision-making

2.1 Perspectives on decision-making

Maximisation

Common in micro-economics is to view an individual as a utility-maximizing rational agent; the standard model of micro-economics (e.g. Mas-Collel et al 1995). This view has gained tremendous popularity within quantitative transport modeling judging by the number of studies applying discrete choice modeling. Within the discrete choice framework, a decision-maker chooses from a set of alternatives. Each alternative is assumed to have a number of attributes. Each attribute has a level of utility or disutility, which capture the costs and benefits of an alternative. However, the analyst is assumed to have incomplete information and, therefore, this measurement error must be taken into account. Four sources of uncertainty can be recognized: unobserved alternative attributes unobserved individual characteristics, measurement errors and proxy variables. In order to reflect this fact the error is modeled as a random variable.

Initially, Multinomial and Nested Logit models have been applied (see McFadden, 1974; Ben-Akiva and Lerman, 1985). More recent studies apply Mixed Logit models (Train, 2003), which aim to capture heterogeneity amongst decision-makers.

Bid-rent

Alonso (1964) assumes each individual to have a bid-curve. The residential bid price curve is the set of prices for land the individual could pay at various locations while deriving a constant level of satisfaction. Market prices are determined by the equilibrium condition; no household should be better off by changing location. Martínez (1992) proves the consistency between the discrete choice approach and the bid-rent approach under equilibrium circumstances.

Behavioural economics

Within economics and psychology a set of theories has emerged as a reaction to the assumptions underlying the utility maximization approach. Simon (1955) introduced the term bounded rationality and asserted that individuals do not extensively evaluate on all available alternatives; instead decision-makers search for information until they are satisfied and make a decision subsequently. Tversky (1972) discusses the heuristic elimination by aspects; the most important attribute is determined and a cutoff value is retrieved by the decision-maker. All alternatives with a value below that cutoff are eliminated. Prospect theory (Kahneman and Tversky, 1979) describes the decision-making process in two stages. In the first stage alternatives are framed: a reference point is set against which alternatives are evaluated. In the second stage alternatives are evaluated against this reference point in terms of gains and losses.

2.2 Choice-set formation

Every choice is made from the set of the alternatives. These alternatives need be mutually exclusive from the decision maker‘s perspective. Choosing one of the alternatives implies not choosing any of the other alternatives. Also, the choice set must be exhaustive, in a way that all possible alternatives are included. Finally, the number of alternatives must be finite (Train, 2003).

The environment of the decision maker determines the universal set of alternatives. Any single decision maker considers a subset of this universal set of alternatives, the choice set or consideration set. The identification of the list of alternatives is usually referred to as choice set generation or choice set formation. Choice set formation is the result of a behavioral process of an individual and results in the consideration set of the individual.

Several approaches are discussed in literature to determine the choice set which contains the alternatives that were available to the decision maker. On the one hand, Swait (2001) proposes to formulate several choice sets (a set of choice sets) and estimate the probability of a choice set being the true choice set. This work uses the two stage characterization of the choice process of Manski (1977). On the other hand an attempt can be made by following heuristics considered by the decision-maker and thus acknowledging that choice set formation is a dynamic search process. Bovy and Stern (1990) provides such a framework for the case of route choice. Another way to avoid the burden of working with extremely large choice sets is to estimate parameters from a subset from alternatives in the MNL model where the independence of irrelevant alternatives (IIA) is assumed, as demonstrated by McFadden (1978).

3 Accessibility

In general terms, accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome this spatial separation or 'the potential of opportunities of interaction' (Hansen, 1959).

Geurs (2006) identifies four components that are relevant when measuring accessibility:

1. The *land-use component* reflects the land-use system, consisting of a) the amount, quality and spatial distribution opportunities supplied at each destination and b) the demand for these opportunities at origin locations, c) the confrontation of supply and of demand for opportunities, which may result in competition for activities.

2. The *transportation component* describes the transport system, expressed as the disutility for an individual to cover the distance between an origin and destination using a specific transport mode; included are the amount of time, costs and effort.

3. The *temporal component* reflects the temporal constraints, i.e. the availability of opportunities at different times of the day and the time available for individuals to participate in certain activities.

4. The *individual component* reflects the needs, abilities and opportunities of individuals. The individuals' characteristics influence the access to transport and the spatially distributed opportunities.

An ideal accessibility measures would take these four components into account. These four components all have in common that they relate to the destination and the ease of reaching those destinations. Five main types of accessibility measures have emerged in literature, all containing one or more of these four components. Bhat et al. (2002) provide an overview of these five types:

1. *Spatial separation*: The only dimension used in this measure is the distance; it does not consider attractions. However, the most general of these measure consists of the weighted average of the travel times to all other zones under consideration.

2. *Cumulative opportunities*: This measure takes into account both the distance and the objective of a trip; a travel time or distance threshold is defined and uses the number of potential activities within that threshold as the accessibility for that spatial unit.

3. *Gravity measures*: This measure includes an attraction factor as well as a separation factor. While the cumulative-opportunities measure uses a discrete measure of time or distance and then counts up attractions, gravity-based measures use a continuous measure that is then used to discount opportunities with increasing time or distance from the origin.

4. *Utility measures.* Two groups of utility measures exist:

   – *Generalized cost measures* estimate total travel costs to go from an origin to a destination, including all relevant time aspects, out-of-pocket costs and the comfort quality aspect.

   – *Logsum measures* are based on random utility theory and interpret accessibility as the outcome of a set of transport choices. This is calculated by taking, for an individual n, the expected value of the maximum of the utilities (U_{in}) over all alternative spatial destinations i in choice set C. The utility is determined by taking the logsum of V_{in}. This is a linear function with elements representing factors related to accessibility such as the quality of the attraction and the travel costs associated with reaching that attraction.

5. *Time / space measures* are founded in the space-time geography of Hägerstrand (1970). He used a three-dimensional prism of the space and time available to an individual for partaking in activities. The motivation behind this approach to accessibility is that individuals have only limited time periods during which to undertake activities. As travel times increase, the size of their prisms shrink.

4 Residential location choice

4.1 Introduction

The discrete choice framework was first introduced to residential location choice by McFadden (1978). Initial studies considered households which move to a certain zone (Weisbrod et al., 1980; Anas, 1982). Each zone was attributed characteristics, such as housing price, employment level, crime rate and accessibility to other zones or employment. This trend has persisted in later studies; Guo (2004) lists a comprehensive overview of studies concerning residential location choice. Her literature overview served as a template for Table 1; the column 'Choice set' has been added, other columns in the table proivde the study, region, sample, dimensions considered, applied methodologies, household, accessibility &density attributes and main findings. The table presents a provisional summary of recent studies concerning residential location choice. The ensuing sections will discuss the similarities and differences found in the reviewed studies by the different column headings.

4.2 Considered dimensions

The majority of the reviewed studies consider solely residential location choice (Lee and Waddell, 2010a; Habib and Miller, 2009; Chen et al., 2008; Guo and Bhat, 2007; de Palma et al., 2007; Guo and Bhat, 2002; Srour et al., 2002). In addition, several studies considering residential relocation and location choice (Lee and Waddell, 2010b; Eluru et al., 2009) are included. Two studies are included considering residential location and activity pattern (Eliasson, 2010; Ben-Akiva and Bowman, 1998); Eliasson (2010) finds that incorporating the activity pattern improves model results, whereas Ben-Akiva and Bowman (1998) do not see any improvement and atribute this to unobserved factors and an insufficient sample. Residential location and auto ownership is researched by (Weisbrod et al., 1980). Pinjari et al. (2011) cover the entire spectrum of choices: Residential location, auto ownership, bicycle ownership, commute tour mode choice. Based on their model estimations, they argue that it is necessary to cover the entire spectrum.

4.3 Applied methodologies

Discrete choice

The majority of studies towards residential location choice has applied the MNL model (Eliasson, 2010; Lee and Waddell, 2010a; Chen et al., 2008; Tu et al., 2005; Guo and Bhat, 2002; Srour et al., 2002) or a NL model (Lee and Waddell, 2010b; Zondag and Pieters, 2005; Ben-Akiva and Bowman, 1998; Weisbrod et al., 1980). In order to capture hetereogenity amongst households and individuals several studies apply random coefficients and Mixed Logit models (Pinjari et al., 2011; Eluru et al., 2009; Habib and Miller, 2009).

Most studies use cross-sectional data, capturing residential location as a static choice and not take into account the differences to the previous residential location. This can either be because of the lack of appropriate data or because in a zonal context no information exists on the previous residential context. Studies by Chen et al. (2008), Habib and Miller (2009) and Iacono and Levinson (2012) however find evidence that the previous location plays a role in choosing a new location. Habib and Miller (2009) conclude that their reference dependent Mixed Logit outperforms their conventional MNL model.

Guo (2004) introduces the Multi-Scale Logit (MSL) model. In this model, variables of a different spatial scale can enter the utility function. Guo and Bhat (2007) investigate three spatial aggregation units. The three different models differ in the variables that are significant and the spatial scale at which these variables are significant.

In an equilibrium condition, i.e. housing supply meets housing demand, each of the alternatives will be chosen by some household and prices will clear the market. It can however occur that markets housing supply is limited and that this is not fully accounted for by prices; a realistic assumption in the short-term, where disequilibrium is common. UrbanSim therefore implements a capacity-constrained market mechanism where the housing market is cleared on a first come, first served basis. de Palma et al. (2007) discusses that coefficients estimated in markets with availability constraints will be biased as consumers must make subobtimal choices from unconstrained alternatives. They have developed an availability constrained estimation technique for the MNL model and shows that parameters estimate differ for the Paris housing market. This approach has been implemented in UrbanSim (Waddell et al., 2010) as well.

Critiscm

Critiscm exists on applying the discrete choice framework for residential location choice. Timmermans (2006) questions the suitability of the multinomial logit model for modelling residential choice behaviour. Under the discrete choice framework it is assumed that individuals and households can only calculate utility by experiencing options, evaluating rewards and derive stable utility equations. These conditions hold for mode choice and to a lesser extent for destination choice. Households however move only a few times in their life, have limited information on the housing markets and search behavior will be limited. In addition, residential location choice is often a family decision process.

Alternative approaches

An alternative approach to model residential location is microsimulation. Here there is no equilibrium assumption. The relocation process of households is modeled at the microlevel. Decision such as moving, bidding and relocating are modeled sequentially and contain a mix of the first two approaches. Habib and Miller (2008) introduce a conceptual framework to model the decision to move (household mobility) and the spatial search process. Both panel logit and hazard models are applied to model residential mobility in time-driven respectively event-driven microsimulations. Hurtubia and Bierlaire (2011) propose a model that is able to account for the auctioning process and location process within a microsimulation. Timmermans however acknowledges that microsimulation approaches could resolve some of the aforementioned issues.

4.4 Choice set formation

Most studies either consider the universal choice set of the decision-maker or sample from the universal choice set (Eliasson, 2010; Lee and Waddell, 2010b,a; Habib and Miller, 2009; Chen et al., 2008; Guo and Bhat, 2007; de Palma et al., 2007; Guo and Bhat, 2002). More recently research has been conducted towards choice set formation in a spatial context, most notably towards destination choice Zheng and Guo (e.g. 2008) and route choice (e.g. Frejinger et al., 2009).

Rashidi and Mohammadian (2010) and Zolfaghari et al. (2012) propose a behavioral model for choice set formation in a residential location choice context; they apply a hazard based model and set thresholds on acceptable property price and commuting times. They find that random sampling outperforms both the models with a universal choice set and a formated choice set; choice set formation not sufficiently captured by housing cost and commute time.

Pagliara et al. (2011) propose a methodology to identify dominance attributes which may be defined in different ways, possibly in accordance with the specific choice context, and which way they can be introduced as perception attributes in random utility models. They apply it to residential location choice by defining specific dominance attributes. Their estimation results show a generally high significance of all these attributes and a considerable improvement in the model's goodness-of-fit statistics. The use of dominance variables has been also tested as a sampling technique. In particular, dominance variables have been used as sampling approach. Their results show that the weighted sampling gives parameters' estimates "closer" to those obtained with full choice set.

4.5 Level of granularity

Traditionally, residential location choice studies have considered the zone as level of analysis (Zolfaghari et al., 2012; Pinjari et al., 2011; Chen et al., 2008; de Palma et al., 2007; Zondag and Pieters, 2005; Guo and Bhat, 2002; Ben-Akiva and Bowman, 1998; Weisbrod et al., 1980; Srour et al., 2002). More recenlty, a series of studies has analyzed the neighbourhood (Guo and Bhat, 2007), the parcel (Srour et al., 2002), the building (Lee and Waddell, 2010a,b) or the dwelling unit (Eliasson, 2010; Habib and Miller, 2009). In the study by Lee and Waddell (2010a) the building can also be considered the unit as 91% of the residential buildings are single familiy units and there is a large overlap between the building and housing unit representations.

Guo and Bhat (2007) investigates units of analysis and the spatial differences within these units of analysis. For example, a census unit consists of blocks, block tracts and tracts. On these different spatial scales different preferences can be observed and should therefore be accounted for.

One advantage of considering the dwelling unit as level of granularity that it is possible to incorporate unit characteristics, such as number of bedrooms and floorspace. Eliasson (2010) found these variables to have significant effects. Also, Habib and Miller (2009) found that the difference between the previous unit and the current unit increased model performance. They attribute this to fact that it possible to capture changes in lifestyle and / or household composition.

4.6 Household characteristics

Almost all studies include some measure of income as variable in the utility function. Some studies consider disposable income by substracting (estimated) annual housing costs from annual household income (Lee and Waddell, 2010a,b; **?**). Other studies consider the difference between household income and zonal income to estimate segregation effects (Pinjari et al., 2011). In addition, income is interacted with variables as household size and commuting time. In general, it is found that households with a higher income tend to commute longer or are insensitive to commuting.

Household composition is a second variable most studies consider. Large households or households with kids tend to move less (Lee and Waddell, 2010b; Eluru et al., 2009). Racial background is considered in several studies. In some cases cluster preferences were observed (Pinjari et al., 2011; Guo and Bhat, 2007).

4.7 Accessibility & density

Accessibility

The studies considered all take into account a form of accessibility. This can include commuting time to work, accessibility to employment or recreational opportunities. Some studies rely on an aggregated zonal accessibility measure (Guo and Bhat, 2007, 2002) for zones. Other studies consider a cumulative opportunities measure (Srour et al., 2002).

Weisbrod et al. (1980) apply a generalized cost function to measure Ben-Akiva and Bowman (1998) consider a logsum measure based on the activity schedule of an individual and discuss the advantages of this approach: (1) it allows one residential location to have greater accessibility for one person than for another person when the two have different characteristics, (2) by measuring preferences among available activity schedules, this definition takes the view that accessibility depends primarily on activity opportunities, (3) by considering activity schedules instead of trips, the measure accommodates individuals' desires to participate in a variety of activities. Eliasson (2010) consider the direct utility from the optimal activity pattern. Besides accessibility to employment, he considers accessibility to services and shops and concludes that this is necessary to include. Chen et al. (2008) also include accessibility to open space and find that this is positive for households with kids. However, the role of accessibility is smaller than that of other factors such as income and other household related factors (Weisbrod et al., 1980; Molin et al., 2003).

Commute time, not so much accessibility, but access, is found to play a role in residential location choice as well. Commute times by transit are found to be more important than commute times by private transport (de Palma et al., 2007). Pinjari et al. (2011) find that heterogeneity between households towards commuting times. Chen et al. (2008) find that preference to commuting time depends on the experience with commute time from the previous residential location; households with commuting experience don't mind to do so in their next location. This is in line with the findings by Zolfaghari et al. (2012), who conclude that residential choice set formation is not sufficiently captured by commute time. Habib and Miller (2009) find that households consider travel costs and level of service more important than

Lee and Waddell (2010a) apply a time space prism measure to calculate shop accessibility and a highly disaggregated work travel time measure. These two measures are highly significant and have a relatively large influence. They argue that these factors are being considered by decision-makers and should be included in residential location models.

Density

In addition to accessibility, most studies consider a form of density, such as street blocks per acre, roads per acre, etc. Partially, this an artifact of zonal based modeling, as these variables capture the differences between zones. Dependent on the household income and composition households prefer either a dense or less dense environment. High income households do not prefer a dense street block and population zone (Pinjari et al., 2011; Guo and Bhat, 2007), whereas low income households prefer a dense environment (Guo and Bhat, 2007).

In the reviewed studies, no more advanced density measure was applied to the knowledge of the authors, such as an entropy measure such as proposed by Cervero and Kockelman (1997) and applied by Potoglou and Kanaroglou (2008) in the case of car ownership and Martínez and Viegas (2009) in the case of hedonic prices.

Land mix

In general, zones with a high land-mix are not preferred. Zones characterized by higher percentages of water area, parkland and residential area are preferred as residential locations.

Zones characterized by higher percentages of office space are less preferred to those with more residential or other land use purposes (Guo and Bhat, 2002). Households with young children value open space more (Chen et al., 2008).

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Zolfaghari et al. (2012)	- Greater London - 12,836 households	- Choice set formation - Residential location	TAZ	Hazard-based model, MNL	861 alternatives in Universal Choice Set, 389 alternatives in Deterministic Constraint (DC), Simple Random Sampling (SRS)	- Log of zonal area - Average household size - Housing price - Diff. household income and annualised rent - Diff. household size and avg. household size - Hansen-based accessibility to employment, shopping, health care and recreational on a zonal level - Transit accessibility - Road density (miles road per square mile) - Number of residents per hectare - Percentage of zonal area occupied by domestic	- Log of zonal area positive, households more likely to locate in zone with a large number of housing opportunities. - Number of resident per hectare positive - Interaction of avg. household size with household size negative; households tend to cluster - Accessibility to employment negative, more desirable neighbourhoods are located far from employment centers - Households tend to reduce their commute time - Parameter switch observed between UCS and DC with interaction income and zonal housing price. Households leave out unaffordable residences in DC. - SRS outperforms both UCS and DC. Choice set formation not sufficiently captured by housing cost and commute time

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	**Region & sample**	**Dimensions**	**Level of granularity**	**Model**	**Choice set**	**Household, accessibility(A) & density(D) attributes**	**Main findings**
Pinjari et al. (2011)	- San Francisco Bay Area - 5,147 households	- Residential location - Auto ownership - Bicycle ownership - Commute tour mode choice	Traffic analysis zone	MOL for residential location	?	- Median housing value in zone - Diff household income and median zonal income - Number of commuters in households within 30 min by transit - Race composition in neighbourhood interacted with race household - Log number of households in zone - Households per acre - Jobs per acre - Fraction commercial land area - Land-use mix - Number of recreation centres - Street block density - Bicycle facility density - Total commute time in household and variation	- Zones with commercial or mixed land-use less likely to be chosen - Households with similar income and race tend to cluster - Availability of recreational opportunities increases attractivity - Street block decreases attractivity, especially for higher income households - Bicycle ownership - Households tend to live close to their workplace - Both income and commute time heterogeneity
Eliasson (2010)	- Stockholm region - Cross-sectional	- Residential location - Activity pattern	Dwelling type	MNL	20 alternatives sampled from 3 segments (rented & owned apartments, owned houses)	- Dwelling type per household segment - Room density over 7 household segments (measure for floorspace vs roomspace) - Income - Floorspace - Work and school trips (A) - Discretionary trips (A) - Logsum accessibility (A)	- Accessibility to work, school and discretionary trips positive - Income positive - All segment prefer more rooms and floorspace

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Lee and Waddell (2010a)	- Puget Sound, Seattle - 4,739 households, representing 10,516 persons. Selection of 1,677 who moved in a 5 year period - Longitudinal	- Residential location choice	Building	MNL	29 alternatives sampled from UCS, all alternatives weighted equally	- Residential units in building - Same area type as previous location - Same area as previous location - Zonal population density - Annual income less imputed rent per unit - Interaction of income and size - Interaction of income and condo - Number of kids - Dummy for young households - Zonal average logsum, weighted by proportion of zone-to-zone trips, for AM home-based-work drive alone trips - Log of sum shopping type jobs within 600m - Individual worker travel time for AM HBW trips - Log of number of shopping-type jobs - Time space prism (TSP) log number of shopping-type jobs in time-space prism for the work-to-home leg of the HBW tour (max value between two workers)	- Dwelling characteristics tend to dominate over accessibility indicators - Work travel time plays an important role - Time space prism for shops important; highlights the value of access to nonwork activities. TSP was able to account for trip chaining
Lee and Waddell (2010b)	- Puget Sound, Seattle - 4,739 households - Longitudinal	- Residential mobility - Residential location	Buildings	NL	29 alternatives sampled for stayers, 28 alternatives sampled for movers	- Avg. household adult age - Household with kids - Household with workers - Household who are home owners - Log annual income less annual imputed rent - Individual worker specific zonal travel logsum for AM HBW drive alone trips (max value of member)	- Older households more likely to stay - Household with kids and workers less likely to move - More disposable income is positive - Good access to work is positive factor for both mobility and location choice - Log annual income less annual imputed rent - Individual worker specific zonal travel logsum for AM HBW drive alone trips

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Eluru et al. (2009)	- Zurich - 1,012 individuals - 2,590 move records - Longitudinal	- Residential relocation - Stay duration	Reasons for moving, 4 duration categories	Random coefficients MNL for moving, independent random & correlated random multinomial ordered model for stay duration	7 alternatives relocation, 4 alternatives for stay duration	- Gender - Age - Household size - Household type - Household tenure - Transport mode to work - Distance to work	- Females are more likely to move because of personal reason - Between 31-45 are less likely to move - Larger households less likely to move - Modes other than car are more likely to move - Stay duration depends on age bracket - Individuals in larger households tend to stay longer - Parameters for stay duration do not vary among reasons to move
Habib and Miller (2009)	- Greater Toronto Area - 290 households - Longitudinal	- Residential location	Dwelling	Mixed Logit, reference dependent attributes	18 alternatives listed for sale	- Gain / loss in number of beds - Loss in avg commute time - Loss in transit commute time - Loss in commute travel cost - Loss in distance to nearest highway - Gain / loss in percentage of open area - Gain / loss in percentage of industrial area - Gain / loss in unemployment rate - Variable for attached house - Log of dwelling price	- Reference dependent mixed model performs better than conventional logit model - Gain in bedrooms positive, households concerned about loss. - Positive to gains in open area, loss aversion attitude to loss in open areas - Preference for decreased portion of industrial land - Households only sensitive to loss in level of service attributes - Price of dwelling perceived negative

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Chen et al. (2008)	- Puget Sound Region, Seattle - 1,455 households - Longitudinal	- Residential location	Zones	MNL accounting for prior location	713 alternatives	- Commute distance - Retail land use - Open space for households without and with kids - Recreational land use - School quality for household without and with kids	- Model that takes into account prior location outperforms traditional model - Preference to commute distance depends on prior distance - Households with young children value open space more - High accessibility to open space at the prior location would value accessibility to open space less than those who have low prior accessibility to open space.

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Guo and Bhat (2007)	- San Francisco Bay Area - 4,791 residences	- Residential location	Network, census and circular units as alternatives, dwelling unit as aggregated unit (?)	Multi-scale logit	9 randomly selected non-chosen alternatives	- Commute time interacted with gender & full/part-time - Commute time interacted with race - Commute time interacted with household income - Employment accessibility - Shopping accessibility - Residential segregation effects - Density - Diff zonal income household income - Diff zonal household size and household size - Share of owner occupied housing - Share of commercial land-use - Share of residential land-use - No. of service employment	- Households tend to locate themselves closer to the work locations of the workers in the household. In particular, households locate themselves close to the workplace of the female workers in the household - Single-person households are found to locate in closer proximity to regional employment opportunities than other types of households. - Lower income households tend to locate themselves closer to employment centres - Neighborhood design parameters among the three models is very mixed. Circular-unit and network- band models indicate that high population density within close proximity (0.4 km in terms of air or network distance) of households' residence generally has a positive influence on households' residential location choice. Density has a negative influence on high income households

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
de Palma et al. (2007)	- Greater Paris Region - 11,786 movers	- Residential location	Municipality	Capacity constrained MNL	100, 200 and 500 alternatives	- Same district as before move - Price - Price interacted with income - Number of railway and subway stations - Distance to highway - Average commute time - Household composition - Foreign head of household - Density - Population	- Explanatory power increases when number of alternatives increases - Housing price has a negative effect on location preference for a commune - Price effect increases with the age of the household head and decreases as the household income increases. - Increase of the average travel time by public transit decreases equally the preference of households headed by a man or by a woman. On the opposite, location is not sensitive, to the average travel time by private car, or to the distance to highway. - Demand is not sensitive either to the number of subway (metro) or railway stations. This may also be explained by a large correlation with the "Paris" dummy. - After accounting for the price effect, a large fraction of alternatives still had excess demand, imposing availability constraints on consumers that ultimately must make suboptimal choices from unconstrained alternatives.

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Tu et al. (2005)	- Singapore - 200 households	- Upgrading mobility behaviour - Revealed preference, sociodemographics collected over survey	Public / private	MNL	2 alternatives	- Occupation: Professional, Technical - Head's age - Divorced - Household size - Executive flat - Household income - Household savings - Accessibility to type of housing index - Several affordability indexes, relating to mortgage and income	- Household who owns the largest public housing unit has the highest probability to upgrade - Large household with more than four members is unlikely to upgrade - Managerials and professional are more likely to upgrade - Housing affordability index for mortgage loan including income, mortgage rate, housing price and borrowing years gives best model performance
Zondag and Pieters (2005)	- Netherlands - 74,000 households for relocation, 12,000 location	- Residential mobility - Residential location	Regions and zones, six household types	NL(Move / Stay, Region, Zone)	?	- Average price of houses in a zone - Number of vacant houses in a zone - Neighbourhood Type (4) - Travel time between origin and destination - Water and green per zone (ha) - Services and employment in a zone - Residential density in a zome - Percentage households with middle and high incomes - Logsum for all travel purposes (aggregated variable summarizing the accessibility for all purposes and all households at that location) - Logsum for commuting - Logsum for purpose other - Logsum for purpose education	- For all household types, the most dominant variables in the model estimations were the number of vacant houses and travel time between the current and the new location. Even within a region, household moves are mainly a quite local process and most households settle down in the same municipality. This variable captures factors such as imperfect information about alternatives, social networks at the old location, and location of employment. - The results show a significant but further modest positive influence of accessibility on residential location choice. - Demographic developments, neighborhood amenities, and especially housing attributes appear to be more dominant explanatory variables.

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Guo and Bhat (2002)	- Dallas-Fort Worth - 1,472 households	- Residential location choice	Transport analysis and processing (TAP) zone	MNL	5 alternatives random sampled from UCS consisting of 919 alternatives	- Household income - Family status - Number of workers - Race - Age, gender and education of workers - Zonal population density, income similarity and racial composition - Zonal employment, recreation and shopping accessibility. Calculated as Hansed-based index with impedance based on in-vehicle time, out-of-vehicle time and costs	- Zones characterized by higher percentages of water area, parkland and residential area are preferred as residential locations. - Zones characterized by higher percentages of office space are less preferred to those with more residential or other land use purposes. - School quality has a significant impact on households' residential location choice. - There is evidence of racial segregation. - Other socio-demographics are found to have an important role in residential location choice.
Srour et al. (2002)	- Dallas County - 1,215 households	- Residential location choice	Census and parcel	MNL	?	- Dist. head to work - Avg. Lot value - Avg. Home value - Avg. Lot size - Avg. Home size - Avg. Home age - Bathrooms - Logsum employment - Logsum park - Logsum shop - COAI employment - COAI Park - COAI Shop	- Dist. head to work highly significant - COAI preferred over logsum - Employment accessibility more important than shop and park accessibility

Table 1: Selection of discrete choice studies concerning residential relocation and location choice

Study	Region & sample	Dimensions	Level of granularity	Model	Choice set	Household, accessibility(A) & density(D) attributes	Main findings
Ben-Akiva and Bowman (1998)	- Boston - 1,259 households	- Residential location choice - Activity scheduling decisions	TAZ	NL	20 alternatives sampled from 3 segments	- Size correction term - Est. income remaining after housing expenses - Violent crime rate - School educational performance - Residential tax rate	- Expected utility of daily activity schedule - Residential density - Composite impedance measure for commute - CBD dummy - Proximity to industrial acreage - Worker's accessibility positive influence - Composite impedance better variable than expected utility - School educational performance, proximity to industrial acreage, town's expenditure on culture and recreation, residential tax rate, and a CBD dummy were dropped
Weisbrod et al. (1980)	- Minneapolis, St. Paul - 487 households	- Residential location - Housing type - Auto ownership	Zones	NL	14814 alternatives (?)	- Squared distance from previous residence - Crime relative to previous residence - Squared positive/negative income differential - Taxes - % Elderly - Net residential density (100 persons/acre) - Per worker: Weighted function of in-vehicle travel time, out-of-vehicle time, and out-of-pocket cost for all major modes available to the workplaces of employed members of the household.	- a 5% reduction in automobile commute time equivalent to a 1.5% decrease, a 3.8% decrease in home value, an 8.4% or a 28% decrease in the rate of assaults and robberies per capita. - a 5% reduction in bus commute time equivalent to a 0.3% decrease in monthly rent, a 0.5% decrease in home value and a 1.1% decrease in local property taxes, a 3.8% decrease in the rate of assaults and robberies per population.

5 Case study: Singapore

5.1 Background

Singapore is a small city state in Southeast Asia with a land area of 712 km^2 a resident population of 3.77 million and a total population of 5.08 million in 2010, compared to respectively 697 km^2 3.27 million and 4.03 million in 2000. GDP per capita amounts to S$59,813$(US$ 45,200, 2010), which makes it own of the most wealthy countries in (Southeast) Asia.

Phang (2007) provides a comprehensive overview of the Singapore property market, which can be divided into a private and a public sector. The Housing Development Board (HDB) is responsible for public housing estates. Private property varies from condominiums to houses with land (i.e. mostly family houses); normally, only households with higher incomes can afford these. HDB allows Singapore citizens to apply for a new flat if they meet certain requirements. The HDB resale market is open for Singaporean and permanent residents. HDB apartments can be resold on the private market after a specified number of years. In addition, both private and HDB apartments can be rented from private investors. Approximately 80% of building stock is HDB flats. Of the remaining 20%, more than half consists of private condominiums. HDB flats are mostly aggregated in so-called "new towns" and are located on a ring around the central water catchment area.

Land use planning is carried by the Urban Redevelopment Authority (URA). URA publishes a 10 yearly concept plan and a 5 yearly master plan. The latter contains a detailed land-use designation (e.g. white collar, residential) and plot ratio per parcel.

5.2 Initial insights

Modeling results (Lehner, 2011; Lehner et al., 2012) show that it is possible to estimate hedonic house prices by both both using readily available asking prices and transaction prices, combined with data collecting from several online and offline sources.

Second, the effort to collect spatial variables, such as bus stops, supermarkets and other attributes, in combination with spatial autoregressive models, proves to yield better results than traditional ordinary least squares. However, the most important driver in house prices remains the floor area and the distance to the CBD, which is in line with other hedonic studies. Asking listings of private properties overestimate actual prices significantly, in turn leading to artificially higher estimates.The scaled coefficient for distance to nearest MRT is small as compared to the other variables. The relative large scaled coefficient for distance to CBD also indicates the strong central structure of Singapore which is strongly focused on the CBD, and the main private residential districts lying around the CBD. The main transport aterials, both public and private, are designed to support this. Other locational variables also have a small influence: the estimate for number of bus lines is positive albeit small for models concerning the HBD market, but negative for private dwellings, a bus stop between 200 and 600 meters is considered positive. Proximity to top primary and secondary schools is valued positively across all market segments. The determinants differ substantially between market segments. Price elasticities of different structural and locational characteristics are highly overestimated in asking prices, but also vary substantially depending on the characteristics. This creates negotiation room for potential buyers.

5.3 Available data

In the context of the Future Cities Laboratory programme of the Singapore ETH Centre several datasets have been collected:

- *Activity plans* are available from the Household Interview Travel Survey (HITS) 2008. This is a four-yearly survey conducted by the Land Transport Authority (LTA).
- *Land use data* is available in the form of the URA Masterplan 2008.
- *Building footprints* are both available from the Singapore Land Authority (SLA) and from the NAVTEQ navigation network.
- *Road network data* is available from NAVTEQ and is combined with data from the Land Transport Authority.
- *Public transport data* is available from LTA and is merged with the road network. This dataset contains bus and train stops, bus services, train services and their frequency.
- *Points of interest* are collected from numerous sources, such as StreetDirectory, Yellow Pages, supermarket websites and several other online resources.
- *Private property transactions* are available from REALIS, a website that lists property transactions on a unit level.
- *HDB resale transactions* are available from HDB on a unit level.
- *Property listings* are available from the online property portal PropertyGuru.

6 Defining the scope of the research

6.1 Conclusion

In this paper an overview was presented of residential location models. Special attention was paid the choice set formation, dimensions considered, accessibility and density. A considerate amount of studies considers the zone as the object to be chosen by the decision-maker. That this level is considered is both the result of available data and research objectives: if residential location choice models are applied in land-use models, the zonal level is appropriate. Recent research has shown that building attributes play a role and decision-makers take into account attributes inherent of the building level, such as commute times. These studies have been carried out in an environment where the building level to a large extent can also be considered the unit. However, in a dense urban environment variety between units exists: view, noise and sun exposure lead to large heterogeneity between units.

6.2 Research questions and contributions

In the light of Future Cities Laboratory project at the Singapore ETH Centre we aim to extend the one-day MATSim with a land-use component to support decision-makers, urban planners and researchers with an integrated activity-based transport land-use model. This land-use component makes it possible to run a single day over multiple years. Between each year, population changes occur, individuals move and business will relocate.

MATSim operates on the level of the individual and the building. Our goal is to further refine this level of granularity for residential and retail location choice in order to capture the choices of individuals . A building in a dense urban environment can contain a high diversity of units; an individual carries out a decision based on the unit and not the building in case of residential choice.

In order to extend MATSim with a long-term component for residential location choice we aim to research the following issues:

1. In which can demographic processes be adequately captured to model residential mobility?
2. How can the spatial and temporal search behavior by households be modeled and quantified so that representative and behavioral consistent choice sets are generated?
3. When modeling individual units the degree of similarity between the alternatives will increase; how can similarity between alternatives best be captured?
4. In which way can the location of the employer be taken into account or should this considered to be fixed over a number of years?
5. Which accessibility indicators should be computed and added to the decision-maker's utility function?
6. Does the decision-maker take into account an activity-based utility measure?
7. Urban density has been simplified to zonal density measures; how does density and urban environment nearby influence residential location choice and how can it be defined?
8. The Singaporean property market consists of clear sectors with separate rules, directives. How can the can residential location process within and between these groups be modelled?
9. Is it possible to take into account a household's previous location in a large scale framework?

6.3 Research methods

In order to model residential location choice a chosen alternative, a set of non-chosen alternatives and information on the alternatives is required. Preferably data on the before situation and after situation is required and the set of considered alternatives. Several approaches are envisaged:

1. In the private property (REALIS) data set information is known on the unit level, including a binary variable indicating if the buyer upgrades from a HDB flat to a private flat. It would be possible to address a survey to the buyer with questions about their activity-plan, sociodemographic characteristics and generate choice sets either based on online property listings or transactions. A similar approach has been followed by Tu et al. (2005). They addressed 400 households for a study concerning HDB upgrade behavior. Response rates are not provided for in their paper but descriptive statistics concern 200 households. In their survey they asked for the household's sociodemographic characteristics.
   The advantage of following this approach is that households would be addressed who changed in residential location. A disadvantage is that only property owners moving to a private property are surveyed.

2. The Household Interview Travel Survey (HITS) will be conducted in 2012. A question regarding change in residential location in the last two years can identify respondents who moved recently. A follow-up survey could be conducted in which the recent movers would be contact. However, it is not clear if this is possible due to the privacy reasons. The advantage would be that comprehensive sociodemographic characteristics would be available in addition to trip information of one day. The disadvantage would be that it is harder to a choice set, but could be done with property transactions.

3. A third approach could be to solely use revealed preference data. However, all of the reviewed studies have shown that it is necessary to include household characteristics to obtain valid results.

References

Alonso, W., 1964. Location and Land Use. Harvard University Press.

Anas, A., 1982. Residential Location Markets and Urban Transportation. Academic Press.

Axhausen, K. W., Gärling, T., 1992. Activity based approaches to travel analysis: Conceptual frameworks, models and research problems. Transport Reviews 12 (4), 323–341.

Belart, B., 2011. Wohnstandortwahl im Grossraum Zürich. Master's thesis, ,.

Ben-Akiva, M. E., Bowman, J. L., 1998. Integration of an activity-based model system and a residential location model. Urban Studies 35 (7), 1231–1253.

Ben-Akiva, M. E., Lerman, S. R., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT Press.

Bhat, C. R., Handy, S. L., Kockelman, K., Mahmassani, H. S., Gopal, A., Srour, I. M., Weston, L., Oct. 2002. Development of an Urban Accessibility Index: Formulations, Aggregation, and Application. Tech. Rep. Report 7-4938-4.

Bovy, P. H. L., Stern, E., 1990. Route Choice and Way Finding in Transport Networks. Kluwer.

Bowman, J. L., Ben-Akiva, M. E., 2001. Activity-based disaggregate travel demand model system with activity schedules. Transportation Research Part A: Policy and Practice 35 (1), 1–28.

Cervero, R., Kockelman, K., 1997. Travel demand and the 3Ds: Density, diversity, and design. Transportation Research Part D: Transport and Environment 2 (3), 199–219.

Chen, J., Chen, C., Timmermans, H. J. P., 2008. Accessibility trade-offs in household residential location decisions. Transportation Research Record 2077, 71–79.

de Palma, A., Picard, N., Waddell, P. A., 2007. Discrete choice models with capacity constraints: An empirical analysis of the housing market of the greater Paris region. Journal of Urban Economics 62 (2), 204–230.

Dong, X., Ben-Akiva, M. E., Bowman, J. L., Walker, J. L., 2006. Moving from trip-based to activity-based measures of accessibility. Transportation Research Part A: Policy and Practice 40 (2), 163–180.

Eliasson, J., 2010. The Influence of Accessibility on Residential Location. In: Pagliara, F., Preston, J., Simmonds, D. (Eds.), Residential Location Choice: Models and Applications. Advances in Spatial Science. Springer, pp. 137–164.

Eluru, N., Sener, I. N., Bhat, C. R., Pendyala, R. M., Axhausen, K. W., 2009. Understanding residential mobility: A joint model of the reason for residential relocation and stay duration. Transportation Research Record 2133.

Ettema, D. F., Timmermans, H. J. P. (Eds.), 1997. Activity-Based Approaches to Travel Analysis. Pergamon.

Frejinger, E., Bierlaire, M., Ben-Akiva, M. E., 2009. Sampling of alternatives for route choice modeling. Transportation Research Part B: Methodological 43 (10), 984–994.

Geurs, K. T., May 2006. Accessibility, land use and transport. Ph.D. thesis.

Guo, J. Y., Dec. 2004. Addressing spatial complexities in residential location choice models. Ph.D. thesis.

Guo, J. Y., Bhat, C. R., 2002. Residential location choice modeling: Accommodating sociodemographic, school quality and accessibility effects. Tech. rep., Department of Civil Engineering, University of Texas, Austin, Texas.

Guo, J. Y., Bhat, C. R., 2007. Operationalizing the concept of neighborhood: Application to residential location choice analysis. Journal of Transport Geography 15 (1), 31–45.

Habib, K. M. N., Miller, E. J., Jan. 2008. Modeling residential mobility and spatial search behavior: Estimation of continuous-time hazard and discrete-time panel logit models for residential mobility. In: TRB (Ed.), 87th Annual Meeting of the Transportation Research Board.

Habib, K. M. N., Miller, E. J., 2009. Reference-dependent residential location choice model within a relocation context. Transportation Research Record 2133, 92–99.

Hansen, W., 1959. How Accessibility Shapes Land Use. Journal of the American Institute of Planners 25 (2), 73–76.

Hägerstrand, T., 1970. What about people in regional science? Papers of the Regional Science Association 24 (1), 7–21.

Hunt, J. D., Kriger, D., Miller, E. J., 2005. Current operational urban land use transport modelling frameworks: A review. Transport Reviews 25 (3), 329–376.

Hurtubia, R., Bierlaire, M., May 2011. Bid rent model for simultaneous determination of location and rent in land use microsimulations. In: STRC (Ed.), 11th Swiss Transport Research Conference.

Iacono, M., Levinson, D., Jan. 2012. Accessibility dynamics and location premia: Do land values follow accessibility changes? In: TRB (Ed.), 91th Annual Meeting of the Transportation Research Board. pp. 1–18.

Iacono, M., Levinson, D., El-Geneidy, A., 2008. Models of Transportation and Land Use Change: A Guide to the Territory. Journal of Planning Literature 22 (4), 323–340.

Kahneman, D., Tversky, A., 1979. Prospect theory: An analysis of decisions under risk. Econometrica 47 (2), 263–291.

Lee, B. H. Y., Waddell, P. A., 2010a. Reexamining the influence of work and nonwork accessibility on residential location choices with a microanalytic framework. Environment and Planning A 42 (4), 913–930.

Lee, B. H. Y., Waddell, P. A., 2010b. Residential mobility and location choice: A nested logit model with sampling of alternatives. Transportation 37 (4), 587–601.

Lehner, M., 2011. Modelling housing prices in Singapore applying spatial hedonic regression. Master's thesis, ,.
URL `http://www.ivt.ethz.ch/docs/students/sa307.pdf`

Lehner, M., van Eggermond, M. A. B., Erath, A., Axhausen, K. W., 2012. Expected and revealed housing preferences in Singapore: A comparison of asking and transaction price data using spacial autoregressive models. Forthcoming.

Lowry, I. S., 1964. A model of metropolis. Tech. rep.

Manski, C. F., 1977. The structure of random utility models. Theory and Decision 8 (3), 229–254.

Martínez, F., 1992. The bid choice land use model: an integrated economic framework. Environment and Planning A 24, 871–885.

Martínez, F., 1996. Mussa: A land-use model for santiago city. Transportation Research Record 1552, 126–134.

Martínez, L., Viegas, J. M., Jan. 2009. Effects of transportation accessibility on residential property values: A hedonic price model in the Lisbon metropolitan area. In: TRB (Ed.), 88th Annual Meeting of the Transportation Research Board.

McFadden, D., 1974. Conditional logit analysis of qualitative choice-behaviour. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, pp. 105–142.

McFadden, D., 1978. Modeling the choice of residential location. In: Karlqvist, A. (Ed.), Spatial Interaction Theory and Residential Location. North-Holland, pp. 75–96.

Molin, E. J. E., Oppewal, H., Timmermans, H. J. P., 2003. Conjoint modeling of residential group preferences: A comparison of hierarchical information integration approaches. Journal of Geographical Systems 4 (4), 343–358.

Nicolai, T., Wang, L., Nagel, K., Waddell, P. A., 2011. Coupling an urban simulation model with a travel model - a first sensitivity test. Tech. Rep. 11-07, ,.

Pagliara, F., Preston, J., Simmonds, D. (Eds.), 2010. Residential Location Choice: Models and Applications. Advances in Spatial Science. Springer.

Phang, S.-Y., 2007. The Singapore model of housing and the welfare state. Research Collection School of Economics Singapore 596, 15–46.

Pinjari, A. R., Pendyala, R. M., Bhat, C. R. a., 2011. Modeling the choice continuum: an integrated model of residential location, auto ownership, bicycle ownership, and commute tour mode choice decisions. Transportation 38 (6), 933–958.

Potoglou, D., Kanaroglou, P. S., 2008. Modelling car ownership in urban areas: A case study of hamilton, canada. Journal of Transport Geography 16 (1), 42–54.

Rashidi, T. H., Mohammadian, A. K., Jan. 2010. Behavioral housing search choice set formation: A hazard-based screening model of property value and work distance. In: TRB (Ed.), 89th Annual Meeting of the Transportation Research Board.

Simon, H., 1955. A behavioral model of rational choice. Quarterly Journal of Economics 69, 99–118.

Srour, I. M., Kockelman, K., Dunn, T. P., 2002. Accessibility Indices: Connection to Residential Land Prices and Location Choices. Transportation Research Record 1805, 25–34.

Swait, J., 2001. Choice set generation within the generalized extreme value family of discrete choice models. Transportation Research Part B: Methodological 35 (7), 643–666.

Timmermans, H. J. P., 2006. The saga of integrated land use and transport modelling: How many more dreams before we wake up? In: Axhausen, K. W. (Ed.), Moving Through Nets: The Physical and Social Dimensions of Travel. Elsevier, pp. 219–248.

Train, K. E., 2003. Discrete Choice Methods with Simulation. Cambridge University Press.

Tu, Y., Kwee, L. K., Yuen, B., 2005. An empirical analysis of singapore households' upgrading mobility behaviour: from public homeownership to private homeownership. Habitat International 29 (3), 511–525.

Tversky, A., 1972. Elimination by aspects: A theory of choice. Psychological Review 79 (4), 281–299.

Waddell, P. A., 2002. UrbanSim: Modeling urban development for land use, transportation, and environmental planning. Journal of the American Planning Association 68 (3), 297–314.

Waddell, P. A., Wang, L., Charlton, B., Olsen, A., 2010. Microsimulating parcel-level land use and activity-based travel: Development of a prototype application in San Francisco. Journal of Transport and Land Use 3 (2), 65–84.

Wegener, M., 2004. Overview of Land Use Transport Models. In: Hensher, D. A., Button, K. J., Haynes, K., Stopher, P. R. (Eds.), Handbook of Transport Geography and Spatial System. Elsevier, pp. 127–146.

Weisbrod, G., Ben-Akiva, M. E., Lerman, S. R., 1980. Tradeoffs in residential location decisions: transportation versus other factors. Transport Policy and Decision Making 1 (1).

Zheng, J., Guo, J. Y., Jan. 2008. Destination choice model incorporating choice set formation. In: TRB (Ed.), 87th Annual Meeting of the Transportation Research Board.

Zolfaghari, A., Sivakumar, A., Polak, J. W., 2012. Choice Set Pruning in Residential Location Choice Modelling: A Comparison of Sampling and Choice Set Generation Approaches in Greater London. Transportation Planning and Technology 35 (1), 87–106.

Zondag, B., Pieters, M., 2005. Influence of accessibility on residental location choice. Transportation Research Record 1902, 63–70.