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INTRODUCTION

Residential mobility and location choice is one of the driving forces of urban dynamics. The outcomes of household's choices impact social structure, spatial segregation, transportation flows, the supply of labor and the demand for amenities such as housing, education, shopping and recreation *(1)*.

The characterization of residential mobility and location choice lends itself to be described by discrete choice models. Initial studies considered households which move to a certain zone or area *(2, 3)*. More recent studies *(4, 5)* have shown that considering the residential unit as choice alternative, instead of the zone, and including building specific attributes, explains the residential location choice of households better.

Most spatial choices are made from a large pool of potential alternatives; residential location choice is no exception to this rule. The manner in which residential alternatives are considered and assumed to be processed, depends on the researchers' assumptions regarding the underlying decision process.

Choice set generation and selection is commonly applied in residential location choice studies to decrease the number of alternatives. Most studies either consider the universal choice set of the decision-maker or sample from the universal choice set *(6, 7, 5, 4, 8–10)*. More recently, hazard based choice set formation models have been used *(11, 12)* with thresholds on acceptable property price and commuting times. These studies conclude that random sampling outperforms both the models with a universal choice set and a generated choice set with thresholds on commuting time, and that choice set formation did not sufficiently capture the trade-off between housing cost and commute time.

This study evaluates choice sets based on households' self-reported search preferences as a new alternative to the issue at hand. These preferences are drawn from a recently conducted residential mobility and location choice survey for Singapore. Choice sets are constructed incorporating temporal, locational, affordability, and market preferences. Residential location choice models are estimated with different choice sets constrained by these search preferences and compared with model results from model estimated with a conventionally sampled choice set.

DATA & METHODOLOGY

Data

Given the lack of (publicly) available data sources on residential mobility and location choice, a survey was developed to obtain insight in moving triggers and location in Singapore. In total, the survey obtained over 7,000 complete responses. Over 1,000 respondents stated to have moved house in the 3 years prior to the survey and participated in the second part of the survey. Respondents were asked a series of questions concerning the search process for their current residence. Questions included the price range, the size range, and the number of rooms respondents preferred. To assess the preference for living close to parents and friends questions were included where respondent's parents resided, where their five closest friends resided, and where they met these five friends for the last time.

Transaction data was obtained from several sources. HDB resale transactions were obtained from the open data portal of Singapore government *(13)*. Transaction data was available at the unit-level. from January 1, 2000 until May 31, 2016.

Methodology

A choice set generation process that accounts for households' search criteria was devised. Figure 1 highlights this choice set generation process. Inputs in the choice set generation process are shown on the right hand side. These inputs include the decision-makers, a series of alternatives (to be presented in the next section) and spatial information. The set of alternatives is considered to be the universal choice set. Subsequently, a series of criteria is applied to the universal choice set. These include the temporal criteria, criteria concerning the market segments, spatial constraints, dwelling size constraints and affordability constraints. These constraints can either be based on statistical models, or can be deterministic constraints based on the responses of the decision-maker. These constraints combined result in a set of feasible alternatives. Dependent on the number of feasible alternative, it might be necessary to sample from this set, either by random sampling or weighted sampling *(e.g 7, 14)*. As a final step, the feasible alternatives are enriched with attributes that are dependent on the decision-maker socio-demographic characteristics such as ethnicity of the household, distance to work, distance to primary school and distance to social contacts.

FINDINGS

Choice set generation process

A visual example of the output is presented in Figure 2. The figure shows an example of choice sets generated for a household choosing for an HDB resale flat; only 3,000 randomly sampled HDB resale alternatives are shown. If no criteria are applied to the choice set generation, alternatives are present in all HDB towns. A clear shift can be observed in the distribution of the alternatives over the island by introducing different constraints; by introducing price constraints there are only few alternatives available at the southern side of the island, which is located closer to the Central Business District. In this case, the respondent has indicated to only consider one area for HDB resale. By introducing a spatial criterion, all sampled alternatives are located at the eastern end of the island.

Results

Base model

Table 1 reports three base models estimated for this study for : (1) a base model, without spatial variables, (2) a model containing spatial variables describing the block, and (3) a model containing variables describing the dwelling, block, and spatial variables dependent on the household. Respondents opting for HDB Resale dwellings have been considered and only HDB Resale alternatives have been included in the choice set generation process.

On average, households prefer more smaller rooms than fewer large rooms. Contrary to expectation, households prefer a higher price per square meter in two model specifications. The negative parameter for the number of rooms per person households indicates that households prefer not to have an excess of rooms.

Including variables describing the block in which a dwelling is located improved model performance. Of the spatial variables tested, blocks located within 1 kilometre distance to top primary schools proved to have a significant and positive influence on the choice for a dwelling. This preference was similar for households with and without children.

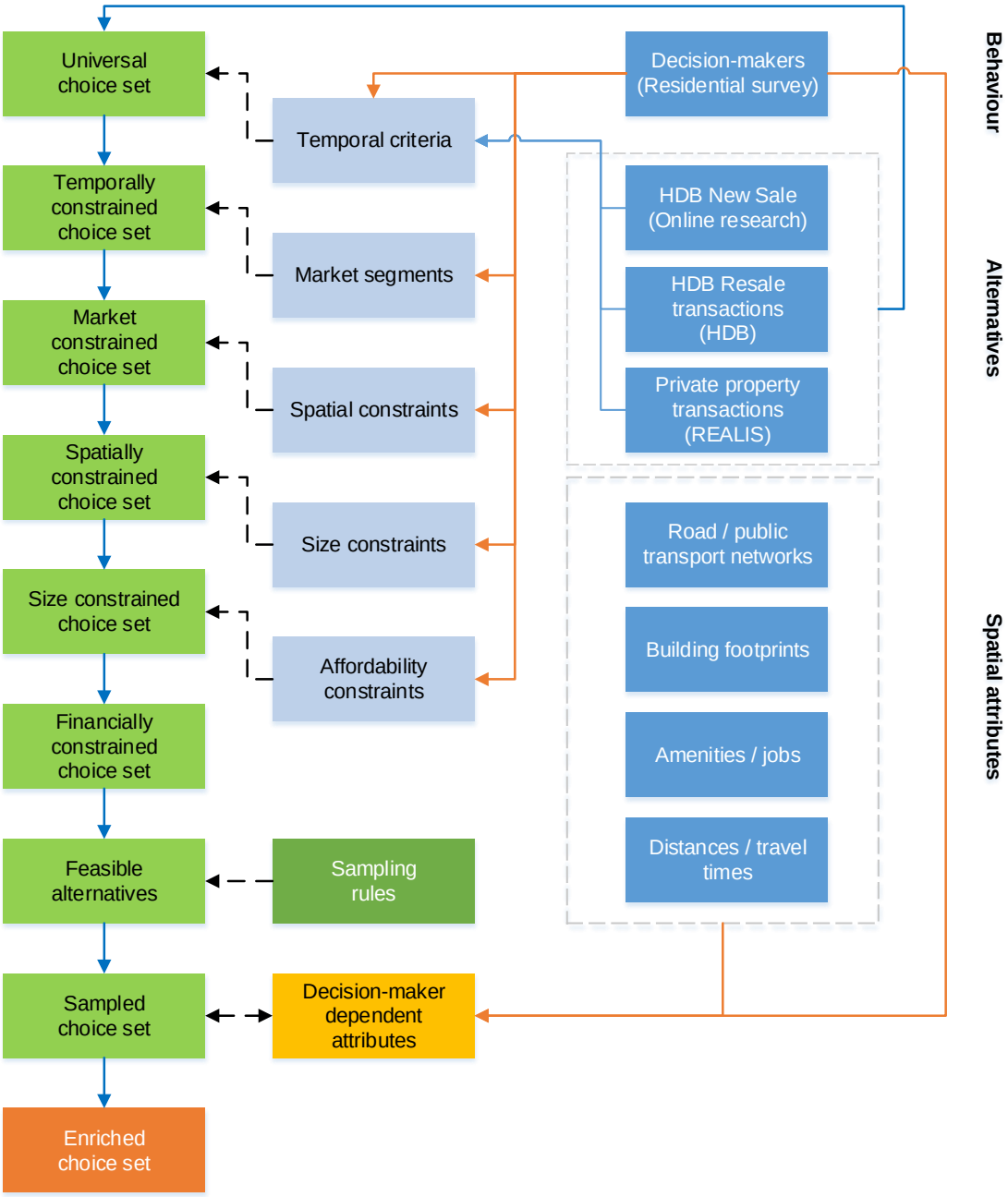

FIGURE 1 Choice set generation process

Preference constrained choice sets

Table 2 reports the results when using different choice sets, based on household's stated search preferences.

Incorporating size preferences in the choice set formation process does not have a significant impact on model results, as compared to a model considering the universal choice set. All parameters have the same sign and order of magnitude; floor level being the only variable that yields an insignificant parameter estimate.

(a) Dwelling size preferences (b) Price preferences (c) Locational preferences

FIGURE 2 Preference constrained choice sets of a single respondent

TABLE 1 Residential location choice: base models (1,000 randomly sampled alternatives)

	Base model Estimate (t-test)	Spatial - Block Estimate (t-test)	Spatial - Block and social Estimate (t-test)
Dwelling			
Size [sqm]	0.042 (5.01)	0.043 (5.10)	0.044 (5.01)
Size per room [sqm / room]	-0.109 (-2.36)	-0.121 (-2.55)	-0.123 (-2.45)
Price psm [log]	1.390 (3.32)	1.270 (2.97)	-1.300 (-2.33)
Price hh income ratio	-0.156 (-4.01)	-0.158 (-4.02)	-0.175 (-3.95)
Room per person, no children	-1.530 (-4.08)	-1.530 (-4.04)	-1.480 (-3.74)
Room per person, children	-1.720 (-2.41)	-1.720 (-2.40)	-1.770 (-2.33)
Floor level between 1 and 6	-	-	-1.300 (-1.70)
Block			
Between 10 and 20 years old	-	-	0.403 (2.40)
Spatial - block			
MRT Station within 400m		-	0.421 (2.31)
Top primary school within 1000m		0.264 (2.27)	0.283 (2.22)
Spatial - social			
Distance to employment [avg, km]			-0.136 (-4.76)
Distance to parents [km]			-0.144 (-4.20)
Distance to social contacts, meeting [km]			-0.287 (-7.70)
Statistics			
Number of decision-makers	229	229	229
Max number of alternatives	1000	1000	1000
Rho-square	0.009	0.010	0.122

When including only dwellings in the preferred price range changes can be observed in the model estimates. A higher price per square meter is perceived positive instead of carrying the expected negative sign.

CONCLUSIONS

Commonly, alternatives are sampled from the universal choice set. In this paper model results were presented with alternatives sampled from the universal choice set. Estimated parameters carry the expected sign, one exception being the sign for the price per square meter. In a model

TABLE 2 Residential location choice models: Preference constrained choice sets

	Size constrained	Price constrained	Spatially constrained	Size, location, price constrained, 9 months
	Estimate (t-test)	Estimate (t-test)	Estimate (t-test)	Estimate (t-test)
Dwelling				
Size [sqm]	0.064 (5.09)	0.082 (7.65)	0.049 (4.81)	0.102 (2.03)
Size per room [sqm / room]	-0.193 (-2.52)	-0.096 (-1.74)	-0.160 (-2.79)	-0.154 (-2.68)
Price psm [log]	-0.961 (-1.64)	3.100 (4.39)	-	4.570 (5.42)
Price hh income ratio	-0.195 (-3.40)	-	-0.155 (-3.42)	-
Room per person	-	-0.922 (-1.89)		-
Room per person, no children	-1.29 (-2.10)	-	-1.71 (-3.60)	-
Room per person, children	-2.10 (-1.54)	-	-2.18 (-2.40)	-
Floor level between 1 and 6	-	-0.252 (-1.83)	-	-0.214 (-1.54)
Between 10 and 20 years old	0.412 (2.55)	0.479 (2.70)	0.292 (1.57)	0.487 (2.69)
Spatial - block				
MRT Station within 400m	0.404 (2.19)	0.406 (2.20)	0.277 (1.59)	0.387 (2.03)
Top primary school within 1000m	0.258 (2.05)	0.279 (2.20)	-	-
Spatial - social				
Dist to employment [avg, km]	-0.140 (-6.39)	-0.138 (-4.82)	-0.0784 (-2.13)	-
Dist to parents [km]	-0.144 (-4.20)	-0.146 (-4.28)	-	-
Dist to social contacts, meeting [km]	-0.287 (-7.70)	-0.289 (-8.02)	-	-0.246 (-3.82)
Statistics				
Number of decision-makers	229	229	229	229
Maximum number of alternatives	1000	1000	1000	1000
Rho-square	0.121	0.185	0.011	0.106

estimated without constraints, but including spatial parameters, the price per square meter is negative. This is also the case in the model estimated with choice sets that are constrained in dwelling size.

By imposing more constraints on the choice set formation process an insignificant parameter (spatially constrained model) or strongly positive parameter (price and fully constrained) for the price per square meter is obtained. A similar effect was observed when the choice set was constrained by reported commute times *(12)*. They argue that this initially counter-intuitive result is the result of a screening process in which initially unaffordable dwellings are filtered out of the choice set, and that among the affordable dwellings unobservable quality attributes are present. For Singapore, this screening process by households include most likely the location of parents and the social network, judging by the impact of these variables on model performance.

Models estimated included significant parameter estimates for spatial variables describing a household's most important locations. This finding is in line with conclusion of previous studies *(15–17)*. Furthermore, Singapore's Ministry of National Development found that recently married Singaporeans preferred to live in the same neighbourhood (42%) or the same area (16%) as their parents *(18)*.

Spatial variables other than variables based on a household's most important locations were included in model specifications. Of these variables, it was found that a MRT station within

400 meters was preferred. Also, it was found that a top primary school within one kilometre is preferred; households residing within one kilometre have an increased chance of being enrolled in a primary school.

The differences in sign for relevant attributes for policy and forecasting, such as price, highlights the need for alternative choice set generation processes. The relevance of the distance to important spatial anchor points, such as parents, social contacts and employment highlight that such a process could constitute of an anchor based sampling approach. While such preferences can be drawn from surveys, an additional challenge is to capture these preferences in models for subsequent applications.

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