


Residential search and location choice in Singapore

Conference Paper**Author(s):**

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Publication date:

2018-01

Permanent link:

<https://doi.org/10.3929/ethz-b-000193146>

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1 **Residential search and location choice in Singapore**

2 Date of submission: 2017-08-01

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8 Words: 5479 words + 4 figures + 4 tables = 7479 word equivalents

1 **ABSTRACT**

2 As many spatial choices, residential location choices are made from a large pool of potential
3 alternatives. This study evaluates choice sets based on households' search preferences as a new
4 alternative to the more commonly applied random or weighted sampling, using a recent movers
5 survey conducted in Singapore. Residential units are taken as the unit of analysis.

6 Descriptive analysis reveals that households search in a limited area and in a limited number
7 of markets. Subsequently, a choice set generation algorithm is proposed that evaluates the
8 number of alternatives available to a household based on self-reported search preferences. To
9 a large extent the size of the universal choice set is influenced by the temporal and spatial
10 dimension of the search process.

11 Model results are presented that with alternatives sampled from the universal choice set.
12 Additionally, models are presented with choice sets that take into account households' self-
13 reported search preferences that include dwelling size, dwelling price and possible areas. Models
14 including spatial variables describing the social environment, combined with choice sets only
15 including alternatives within the preferred price range, perform best. The social environment
16 consisted of variable describing a household's average distance to work, the distance to their
17 parents and the average distance to the locations where they most frequently meet their five
18 closest contacts. Other significant spatial variables included the distance to a top primary school,
19 as well as the proximity to a mass rapid transit. Given the significance of these variables it is
20 proposed to further evaluate anchor and distance-based sampling.

1 INTRODUCTION

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

6 The characterization of residential mobility and location choice lends itself to be described
7 by discrete choice models: the choice whether to move, and the residential areas and dwelling
8 units are clearly demarcated alternatives; this approach has found wide acceptance amongst
9 transportation researchers. Initial studies considered households which move to a certain zone
10 (2, 3). Each zone was attributed characteristics, such as housing price, employment level, crime
11 rate and accessibility to other zones or employment; a choice is made between all zones based
12 on the zonal attributes and the socio-economic characteristics of the household.

13 More recent studies (4, 5) have shown that considering the residential unit as choice alternative,
14 instead of the zone, and including building specific attributes, explains the residential location
15 choice of households better.

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

20 Choice set generation and selection is commonly applied in residential location choice studies
21 to decrease the number of alternatives. Most studies either consider the universal choice set of
22 the decision-maker or sample from the universal choice set (6, 7, 5, 4, 8-10).

23 More recently, hazard based choice set formation models have been used (11, 12) with
24 thresholds on acceptable property price and commuting times. These studies find that random
25 sampling outperforms both the models with a universal choice set and a generated choice set with
26 thresholds on commuting time; choice set formation did not sufficiently the trade-off between
27 housing cost and commute time.

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

35 The next section continues with an overview of choice set formation and generation in
36 general, and in a housing context specific. Subsequently, the data & methodology is outlined.
37 The paper continues with modelling results. The paper concludes with a discussion in the final
38 section.

1 LITERATE REVIEW

2 Choice set formation & generation

3 Two streams of research can be recognized in this context: choice set formation and choice set
4 generation. Whereas choice set formation is a behavioural process executed by the decision-
5 maker, choice set generation is usually referred to as the process carried out by the analyst either
6 to mimic the choice set formation process or to limit the number of alternatives for computational
7 purposes and tractable model estimates.

8 The set of all possible alternatives is commonly dubbed the universal choice set. A recurring
9 question is which alternatives are considered immediately prior to the choice and how these
10 alternatives were selected from the universal choice set.

11 One possible distinction of different types of choice sets is the distinction between the
12 awareness set, the consideration set and the choice set (13). The awareness set consists of the
13 alternatives choice set of which the decision-maker is aware. The consideration set contains
14 alternatives that meet the decision-makers criteria. The choice set contains the alternatives
15 considered immediately prior to the decision. Either way, several different choice set notions
16 exist; varying in name, but similar in definition (*e.g 14, 15*).

17 Three approaches to choice set generation can be recognized in literature (16, *p. 271*) : (1)
18 the use of heuristics or deterministic choice-set generation rules which permit the exclusion of
19 certain alternatives, (2) the collection of choice-set information directly from surveys, simply by
20 asking respondents about their perception of available options, (3) the use of random choice
21 sets, whereby choice probabilities are considered to be the result of a two- stage process: first, a
22 choice-set generating process, in which the probability distribution function over all possible
23 choice sets is determined; and secondly, conditional on a specific choice set, a probability of
24 choice for each alternative is determined (17, 18).

25 Choice set formation & generation in a housing context

26 In a housing context, the total number of housing opportunities available to the households can
27 be denoted as the vacancy set (19). On one hand, the consideration set, is limited due to housing
28 policies, price, number of rooms and other criteria is denoted as the possibility set. On the
29 other hand, the consideration set is formed by the households awareness space: the locations
30 within the total urban space of which the potential mover has knowledge (20). This information
31 is obtained through the daily activity space of the household, and information derived through
32 secondary channels, such as newspapers, advertisements, social media and the social network.

33 Within the three-stage choice decision process different parameters are of relevance for the
34 search stage: the search of housing is performed within a certain search space and with a certain
35 search intensity (19). The search space can be operationalized in several ways. A starting point
36 for the spatial extent of the search space can be found in the bid-rent concept, originating in
37 Von Thünen's work (21) on agricultural land use and later applied by Alonso (22) to residential
38 location. Here it is assumed that each individual has a bid-curve. The residential bid price
39 curve is the set of prices for land the individual could pay at various locations while deriving a
40 constant level of satisfaction. Market prices are determined by the equilibrium condition; no
41 household should be better off by changing its location. Alonso assumes a mono-centric city: all
42 employment is located in the city centre and location is a function of transportation and housing
43 costs. The search space can then be seen as radiating outwards from the city centre.

1 Barrett (23) measures search behaviour and shows households examine a few properties
2 within a limited spatial extent of search. A clear search space is not found; however the extent
3 differs for within city movers and movers moving between suburbs. It is hypothesized that
4 this difference is due to residential supply; more vacancies would be available in the suburbs
5 and movers needed to perform more effort for these properties. Therefore, they would aim to
6 schedule visits to multiple properties while in the area.

7 Huff (24) introduces the constrained choice set model, in which households are limited to
8 certain areas due to vacancies meeting their criteria. This model is further refined with the area
9 based search model and an anchor based search model. In the area-based model, households
10 first select an area and subsequently search for vacancies. In the anchor-based model, vacancies
11 surrounding one or more anchor points (for instance, a households work and education locations)
12 are included in the search process.

13 It is possible that these anchor points are not specific to the households' activity space but
14 specific to urban form. Moving away from a monocentric city with a single employment centre,
15 it is possible that a household search space includes the city centre, but as no suitable vacancies
16 can be found, subcentres are preferred above locations close to the city centre (*e.g.* 25). These
17 subcentres are preferred as they contain similar amenities as the main centre and provide good
18 access to the centre.

19 If the alternative is considered to be the individual residential unit, it becomes necessary to
20 review the choice set formation and generation for residential location models. By considering
21 the residential unit as alternative, the number of alternatives available to the decision-maker
22 will increase strongly and limiting the choice set becomes necessary to obtain behaviourally
23 and computationally tractable model estimates. Wrongly specifying the choice set can lead to
24 incorrect model estimates or wrongly predicted market shares (26).

1 DATA & METHODOLOGY

2 Data

3 *Study area*

4 Singapore became self-governing in 1959 after being under the colonial rule of the United
5 Kingdom since 1819. After briefly being part of the Malaysian Federation, full independence
6 came in 1965. In the 50 years since its independence, Singapore has witnessed tremendous
7 economic growth. Singapore in 2010, has a land area of 712 km², a permanent population of
8 3.77 million citizens and permanent residents and a total population of 5.08 million, compared
9 to respectively 697 km², 3.27 million and 4.03 million in 2000. GNI per capita amounts to US\$
10 54,580 (2013), which makes it one of the wealthiest countries in Asia.

11 Two main institutions have shaped the Singaporean housing market: the Housing and
12 Development Board (HDB) and the Central Provident Fund (CPF). HDB was set-up in 1960
13 to replace the Singapore Improvement Trust (SIT) as the national housing provider, which
14 failed to meet the housing demands of the growing population. Whereas the SIT built an
15 estimated 20,907 units in the post-war period between 1947 and 1959, HDB planned and did
16 build 110,000 units between 1960 and 1970 (27). Until the early 2000's, HDB built based on
17 estimates and not on actual demand. This ensured a relatively short waiting queue for prospective
18 home-owners. In 2002 HDB changed its construction policy: instead of constructing ahead of
19 demand, construction only begins when at least 70% of the flats of the proposed site are sold.
20 This is known as Build-To-Order (BTO).

21 Condominiums were introduced in Singapore in 1974. The high-rise and high-density nature
22 of condominiums has become a key planning strategy to optimize scarce land resources in
23 Singapore (28); condominiums are mostly built on land obtained in government land sales on a
24 99-year leasehold basis. Condominiums are often better designed and possess a higher building
25 quality than HDB flats. Furthermore, they are equipped with a full range of recreational facilities,
26 such as a gym and swimming pools.

27 *Residential survey*

28 Given the lack of (publicly) available data sources on residential mobility and location choice a
29 survey was developed to obtain insight in moving triggers and location in Singapore. The survey
30 consisted of two major parts: (1) an incidence survey targeted towards the general population,
31 and (2) the main survey, targeted towards recent movers. In total, the survey obtained over
32 7,000 complete responses. Over 1,000 respondents stated to have moved house in the 3 years
33 prior to the survey and participated in the second part of the survey.

34 First, a number of questions was included to assess the overall representativeness of the
35 respondents. These questions included gender, ethnicity, personal income, household income,
36 household size, year of birth, dwelling type, tenure and residential location. Eligible respondents
37 were routed to the second, longer, part without being aware of being selected to participate in the
38 second part. First, respondents were asked for more detailed information on the current dwelling.
39 Subsequently, respondents were faced with a series of questions concerning the search process
40 for their current residence. Questions included the price range, the size range and the number of
41 rooms respondents preferred. For each of the property market strata, they were asked whether
42 they considered this strata, and in which areas they considered properties.

43 To assess the preference for living close to parents and friends questions were included where

1 respondent's parents resided, where their five closest friends resided, and where they met these
2 five friends for the last time.

3 *Transaction data*

4 HDB projects constructed under the build-to-order (BTO) scheme were compiled from two
5 sources (29, 30). HDB BTO projects typically consist of several blocks, and several types of
6 units with a different number of rooms and sizes.

7 HDB resale transactions were obtained from the open data portal of Singapore government
8 (31). Transaction data was available at the unit-level. from January 1, 2000 until May 31,
9 2016. For each transaction, the block number, street name, storey range, flat model, floor
10 area, transaction month, lease commence date and resale price is given. All transactions were
11 geo-coded based on the block number and street name provided.

12 Private market data transactions were downloaded from URA's Real Estate Information
13 System (REALIS) (32). REALIS contains property transactions at the unit-level. Fields stored
14 in REALIS include the property name, property address, unit number, floor level, floor area and
15 tenure.

16 *Matching transactions and survey data*

17 Only 65 % of the households who stated to have moved to HDB new sale dwellings could be
18 matched HDB BTO and DBSS projects, despite the number of criteria being limited.

19 Nearly 88% of households who stated to have moved to HDB resale flats were matched to
20 HDB resale transactions; nearly 75 % of households who have moved to private property could
21 be matched to a transaction in REALIS.

22 **Methodology**

23 The following criteria and constraints were included in the choice set generation process:

- 24 • *Temporal supply constraints:* Temporal supply constraints increase or reduce the time a
25 dwelling was on the market, and thus determine the time window a dwelling was available
26 for. In this case, a deterministic approach was followed: the availability of all dwellings
27 was increased or decreased simultaneously in monthly intervals, varying from one month
28 to 12 months. In the analysis presented in this section a default value of 3 months has
29 been used.
- 30 • *Temporal demand constraints:* Temporal demand constraints, or search time constraints,
31 decrease or increase the time a household is on the market for a new dwelling. This period
32 was increased in monthly intervals, varying from one month to 12 months. In the analysis
33 presented in this section a default value of 3 months has been used. The usage of the time
34 of the market of the respondent has been evaluated.
- 35 • *Affordability constraints:* Affordability constraints indicate the lower and upper bound of
36 the price of a new dwelling. This constraint can be directly given by the respondent, but
37 can also be based on affordability or purchasing power. No upper or lower limit on the
38 dwelling price is used in the default case.
- 39 • *Locational constraints:* Locational constraints reduce the spatial extent of the search area.
40 It is possible to impose deterministic constraints or model stochastic constraints based on
41 distance to work, distance to school or distance to parents. By default, no constraints have

1 been imposed on the dwelling. In this case, the preferred locations by the respondent have
2 been evaluated in the choice set generation process based on areas respondents preferred.

- 3 • *Market segment constraints:* Market segments constraints include constraints limiting the
4 access to market segments (e.g. HDB New sale, HDB resale, private) due to regulation or
5 self-reported preferences.
- 6 • *Dwelling constraints:* Dwelling constraints limit the type of dwelling as well as the size
7 and number of rooms a dwelling has. By default, no constraints have been imposed on the
8 dwelling. However, dwelling constraints mentioned by the respondent have been used in
9 the choice set generation. process.

10 Figure 1 highlights this choice set generation process. Inputs in the choice set generation
11 process are shown on the right hand side. These inputs include the decision-makers, a series of
12 alternatives (to be presented in the next section) and spatial information. The set of alternatives
13 is considered to be the universal choice set. Subsequently, a series of criteria is applied to
14 the universal choice set. These include the temporal criteria, criteria concerning the market
15 segments, spatial constraints, dwelling size constraints and affordability constraints. These
16 constraints can either be based on statistical models, or can be deterministic constraints based
17 on the responses of the decision-maker. These constraints combined result in a set of feasible
18 alternatives. Dependent on the number of feasible alternative, it might be necessary to sample
19 from this set, either by random sampling or weighted sampling (*e.g 7, 33*). As a final step,
20 the feasible alternatives are enriched with attributes that are dependent on the decision-maker
21 socio-demographic characteristics such as ethnicity of the household, distance to work, distance
22 to primary school and distance to social contacts.

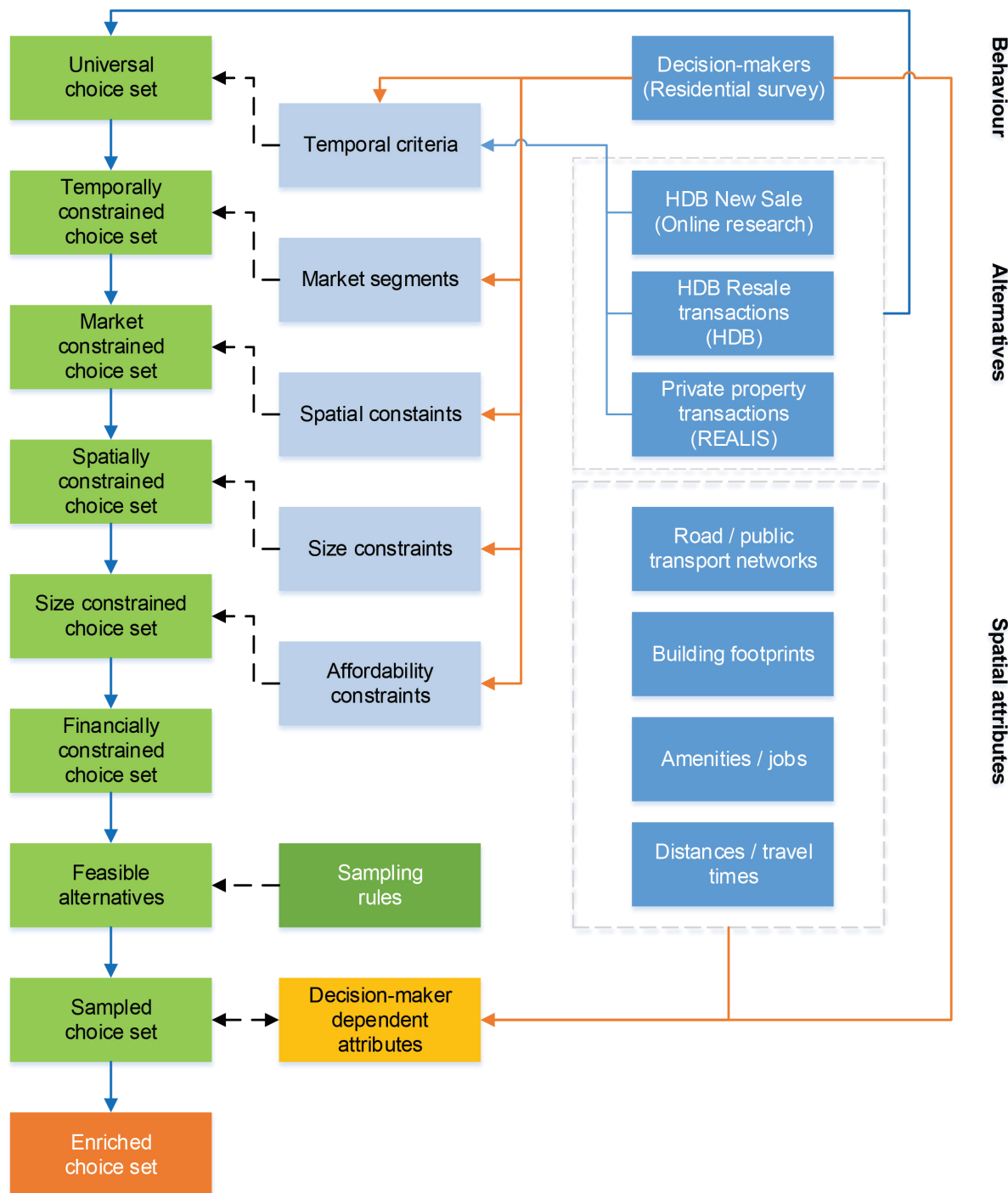


FIGURE 1 Choice set generation process

1 **RESULTS**

2 **Choice set generation**

3 To evaluate the influence of the choice set generation process on the choice set size, as well as
 4 the average level price level in the choice set and the effect on a set of distance distributions in
 5 the choice set generation process the constraints have been applied piece-wise to the choice set
 6 generation process.

7 A visual example of the output is presented in Figure 2. The figure shows an example of

1 choice sets generated for a household choosing for an HDB resale flat; only 3,000 randomly
 2 sampled HDB resale alternatives are shown. If no criteria are applied to the choice set generation,
 3 alternatives are present in all HDB towns. A clear shift can be observed in the distribution of the
 4 alternatives over the island; there are only few alternatives available at the southern side of the
 5 island (Queenstown, Gmih Moh), which is located closer to the Central Business District. In
 6 this case, the respondent has indicated to only consider one area for HDB resale. By introducing
 7 a spatial criterion, all sampled alternatives are located at the eastern end of the island.

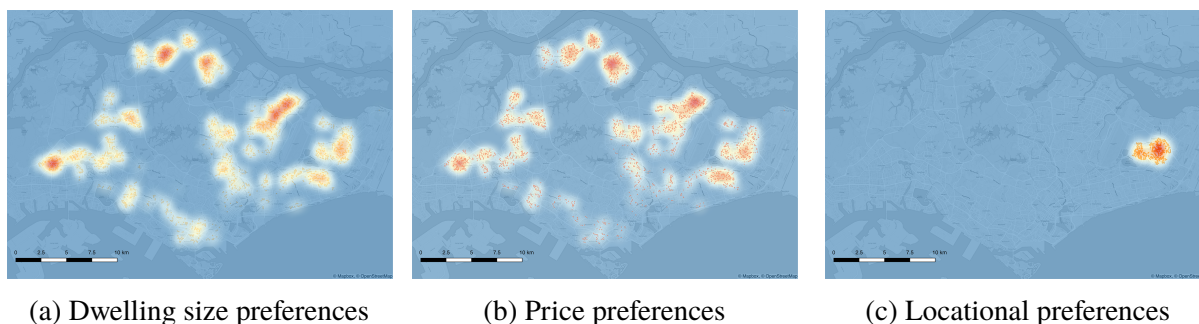


FIGURE 2 Preference constrained choice sets of a single respondent

8 *Choice set size*

9 Figure 3 shows the median number of alternative in the choice set per chosen dwelling type; a
 10 breakdown is given by the number of alternatives per market.

11 In all cases, a dwelling is assumed to be on the market for three months; a household is
 12 assumed to be active in the three months prior to the purchase date. By not including any
 13 constraints other than the availability of the dwelling, and the presence of the household on
 14 the market, the choice set of respondents choosing HDB new sale consists of approximately
 15 25,000 HDB new sale units, 12,000 HDB resale units and 13,000 private units. The number
 16 of alternatives of respondents opting for a dwelling on the HDB resale market as well as
 17 the private market are in the same order magnitude, albeit a bit smaller. Introducing a price
 18 criterion further limits the number of alternatives, most notably of alternatives in HDB resale
 19 and the private market; introducing dwelling size criteria reduces the size of the choice sets.
 20 The size of the choice set is most influenced by limiting the number of areas based on the
 21 household's preferences; especially for households opting for HDB new sale, the number of
 22 private alternatives becomes very low, indicating a low availability of private dwellings in the
 23 areas that these respondents preferred. Introducing temporal criteria based on the households'
 24 search time (temporal demand constraints) decreases the size of the choice set even further.

25 *Geographic dispersion*

To quantify the search extent of households the standard distance is calculated (*e.g.* 34): the
 geographical dispersion of the areas considered by each household. The standard distance is
 calculated as:

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n} + \frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (1)$$

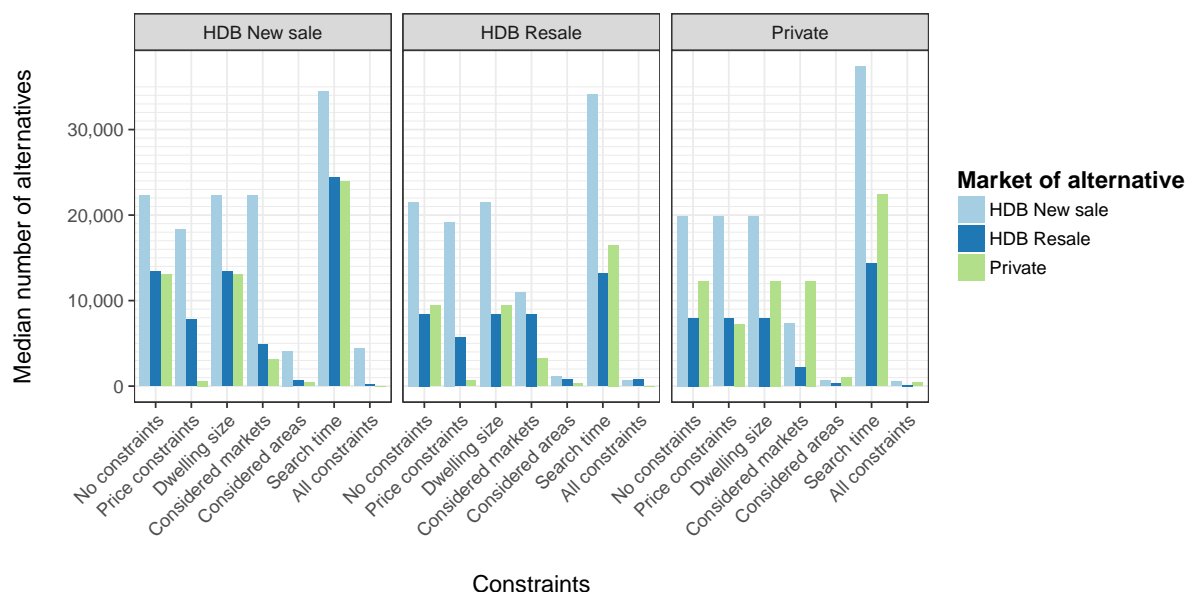


FIGURE 3 Median choice set size with different choice set generation constraints

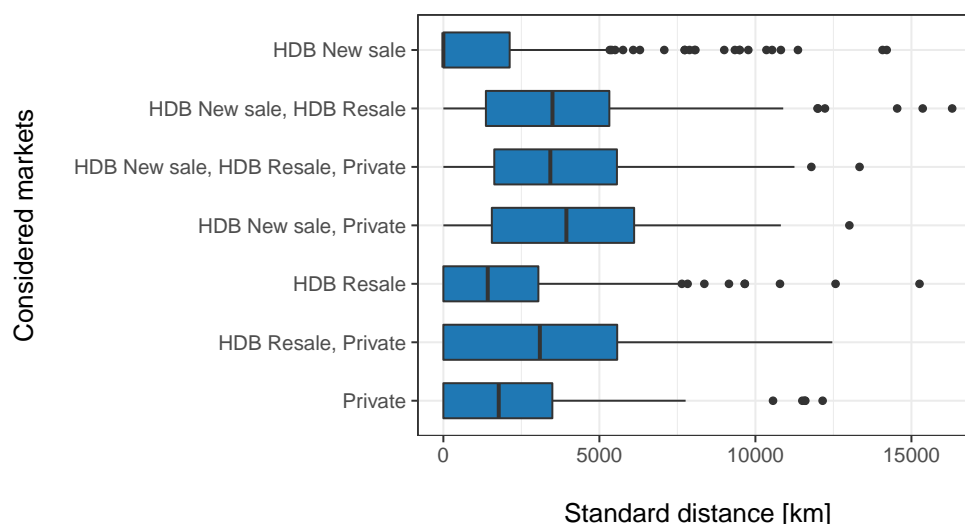


FIGURE 4 Standard distances per considered market

1 where x_i and y_i represent the coordinates of the centroid of the area, \bar{X} and \bar{Y} are the
 2 mean values, and n represents the number of areas considered. Figure 4 shows the calculated
 3 standard distances per set of markets considered by recent movers. Households considering either
 4 HDB resale or private property reveal to have an average search distance of approximately two
 5 kilometres, indicating that the considered areas are in close proximity. Households considering a
 6 combination of two markets (HDB new sale & HDB resale, HDB resale & Private) reveal to have
 7 an average search distance of approximately four kilometres. It is hypothesized that this difference
 8 is the result of the spatial separation of HDB new sale dwellings, and the other property types,
 9 which are built as infill development. The limited standard distance for households considering
 10 HDB resale and private property shows that households select areas in close proximity to each
 11 other, and that these areas offer both types of properties.

1 **Model specification**

2 Table 1 summarizes the variables that have been considered in the different choice models that are
3 presented in this section. A distinction has been made between variables describing the dwelling,
4 variables describing the block (the apartment block in which the dwelling is located), variables
5 describing the block's surroundings, variables describing the household's spatial relationships,
6 such as the distance to employment as well as the distance to the social network and variables
7 describing the neighbourhood's accessibility.

8 In the remainder of this section only respondents opting for HDB Resale dwellings have been
9 considered and only HDB Resale alternatives have been included in the choice set generation
10 process. This has been done for the following reasons:

- 11 • A descriptive analysis has shown that households opting for an HDB resale flat consider
12 either solely either HDB resale, or HDB resale and HDB new sale, or HDB resale and
13 private dwellings.
- 14 • A residential mobility model (not presented) clearly showed which households choose to
15 move to HDB new sale and private properties, but did not reveal a clear profile of movers
16 to HDB resale.

17 Model variables have been entered in a step-wise fashion to a constant only model. All model
18 estimations have been performed with Biogeme (35); models have been specified as multinomial
19 logit (MNL) models with the dwelling a respondent moved to as the chosen alternative and
20 alternatives available on the market prior to the transaction date as alternatives present in the
21 universal choice set; subsequently, the choice set generation process has been applied. The MNL
22 model is the most commonly applied model in residential location choice studies and has shown
23 to yield consistent parameter estimates when estimated on a subset of alternatives. In this case, a
24 subset of maximum 1,000 alternatives is used, as this provided tractable computation times and
25 thus allowed for experimenting with a range of model specifications.

26 **Results**

27 *Base model*

28 Table 3 reports three base models estimated for this study: (1) a base model, without spatial
29 variables, (2) a model containing spatial variables describing the block, and (3) a model containing
30 variables describing the dwelling, block, and spatial variables dependent on the household. In
31 all cases, 1,000 alternatives have been sampled from the dwellings being transacted on the HDB
32 resale market in the three months prior to the transaction date of the purchased dwelling.

33 It is found that households prefer a larger dwelling. On average, households prefer more
34 smaller rooms than fewer large rooms. Contrary to expectation, households prefer a higher
35 price per square meter in two model specifications. The negative parameter for the number of
36 rooms per person households prefer not to have an excess of rooms. This parameter differs for
37 households with and without children; households without children mind an excess of rooms
38 less, which can indicate that a family expansion is still expected. No preference for floor level
39 could be found in two of the model specifications.

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

TABLE 1 Variables considered in residential location choice models

Variable	Explanation	Hypothesis
<i>Dwelling</i>		
Transaction price	The transaction price of the dwelling as listed in the data source [100,000 SGD]	Negative
Price per psm	Price per square meter (psm), dwelling size is given	Negative
Price household yearly income ratio	Price per square meter, dwelling size is given	Negative
Dwelling size	Size of the dwelling in square meters	Positive
Number of rooms	Number of rooms as given by the household	Positive
Rooms per person	Number of rooms as given by HDB divided by number of persons in household	Negative
Square meter per room	Square meter per room	Positive
Floor level	Floor level, provided as range	
<i>Block</i>		
Completion year	Construction year of dwelling, entered as number of years on remaining on lease at time of purchase	Negative
<i>Spatial - block</i>		
Distance to MRT	Euclidean distance to train station, entered as both continuous variable and step-wise, with and without vehicle	Negative
Highway within 50 meters	Distance to highway, only considered when it is unobstructed	Negative
Above grade metro within 50 meters	Above grade railtrack within 50 meters of dwelling, only when unobstructed	Negative
Distance to primary school	Primary school within 1 km, euclidean distance, and between 1 km and 2 km	Positive
Distance to top primary school	Top primary school	Positive
Greenery	Percentage park within 300 meters	Positive
Building density	Percentage built-up within 200 meters	Negative
Diversity	Diversity of amenities within 300 meters	Positive
Walk indices	Walk indices to daily needs, stores, parks, healthcare	Positive
<i>Spatial - social</i>		
Distance to employment	Euclidean distance to parents for respondents having lived in Singapore previously and not living with parents	Negative
Distance to parents	Average euclidean distance to the subzones where respondents and household members are employed	Negative
Distance to household employment	Average euclidean distance to the subzones where respondents meet their 5 closest contacts	Negative
Distance to social contacts, meeting	Average euclidean distance to the subzones where the 5 closest contacts live	Negative
Distance to social contacts, living	Average euclidean distance to the subzones where they meet with the 5 closest contacts	Negative
<i>Accessibility</i>		
PT employment accessibility	Number of jobs accessible in 40 minutes by public transport	Positive
Private accessibility employment	Number of jobs accessible in 30 minutes by private vehicle	Positive
PT accessibility to commercial GFA	Commercial gross floor area accessible within 20 minutes by public transport	Positive
PT accessibility to sports & park	Sports and parks accessible within 20 minutes by public transport	Positive

TABLE 2 Choice set constraints: hypotheses on model outcomes

Choice set constraints	Hypotheses
Size constraints	Dwelling size related variables will have a lower impact as dwellings that are not desired are filtered out of the choice set.
Price constraints	Price related attributes might switch to positive as unaffordable alternatives are filtered out of the choice set.
Spatial constraints	Spatial variables describing the location of a dwelling relative to anchor points will lose their significance. The increased number of alternatives in the preferred area can result in significant variables describing the immediate environment of the block, including destination diversity, but also variables capturing negative externalities such as noise and emissions.
Size, price, spatial constraints	Spatial variables describing the location of a dwelling relative to anchor points will lose significance. In addition to the expected impact of variables describing the direct environment of the block, it is expected that variables describing the dwelling unit, such as floor level, will have a higher impact.

TABLE 3 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)
<i>Dwelling</i>			
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)
<i>Block</i>			
Between 10 and 20 years old	-	-	0.403 (2.40)
<i>Spatial - block</i>			
MRT Station within 400m		-	0.421 (2.31)
Top primary school within 1000m		0.264 (2.27)	0.283 (2.22)
<i>Spatial - social</i>			
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)
<i>Statistics</i>			
Number of decision-makers	229	229	229
Max number of alternatives	1000	1000	1000
Rho-square	0.009	0.010	0.122

1 Including variables describing the relationship of the household to the locations improves
2 model performance greatly. In the final specification, these variables include the average crow-fly
3 distance to employment, the distance to the respondent's parents and the average crow-fly distance
4 to the location where respondents last met their social contacts. In this model specification,
5 the negative parameter for the price per square meter indicates that households do not prefer
6 dwelling with higher price per square meter. Furthermore, households do not prefer dwellings
7 located on a lower floor level and prefer blocks that were between the 10 and 20 years old at the
8 time of moving. A MRT station within 400 meters is preferred by households that own and do
9 not own a vehicle. The negative parameter estimate for the distance to employment indicates
10 that households attempt to live close to their workplace. Households prefer to be close to their
11 parents. Also, households prefer to live close to places where they meet their 5 closest social
12 contacts. Other spatial variables reported in table 1, such as accessibility by public transport
13 proved not have a significant influence on residential location choice. Including the distance to
14 current primary school of a household did improve model performance, but has been excluded
15 from the model specification: due to educational policies, it is highly likely that children will go
16 to a school in proximity to their dwelling.

17 *Preference constrained choice sets*

18 Table 4 reports the results when using different choice sets, based on household's stated search
19 preferences, are used in the model estimations. The considered search preferences include the
20 considered dwelling size of a dwelling, the considered price range, the considered areas and a
21 combination of the considered dwelling size, price range and considered areas.

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

26 When including only dwellings in the preferred price range changes can be observed in
27 the model estimates. A higher price per square meter is perceived positive instead of carrying
28 the expected negative sign. The parameter estimated of the ratio between dwelling price and
29 household income is not significant and no difference could be found between the preference
30 for the number of rooms per person for households with and without children. Judging by the
31 rho-square, a choice set including only dwellings within the preferred price range, provides the
32 highest explanatory power.

33 Reducing the search space of households to the areas that household's indicate a preference
34 for model results in several changes. The estimated parameter the price per square is not
35 significant (but negative) in combination with the ratio between household and income. A top
36 primary school within 1 kilometres of the chosen residence is not considered of relevance. The
37 parameters for the distance to parents, as well as to meeting places of social contacts, are not
38 significant.

TABLE 4 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)
<i>Dwelling</i>				
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)
<i>Spatial - block</i>				
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)	-	-
<i>Spatial - social</i>				
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)
<i>Statistics</i>				
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

1 DISCUSSION

2 Residential search

3 To a large extent the size of the universal choice set is influenced by the temporal dimension of the
4 search process. Households opting for HDB resale would have 14,000 HDB resale alternatives
5 in their choice set and 15,000 private dwellings if their self-reported search time is taken into
6 account. However, if households are assumed to be active on the market for only three months,
7 and household's other criteria are being accounted for the number of alternatives in the universal
8 choice set drops to less than 1,000 dwellings. This decrease in the number of alternatives can be
9 mainly attributed to the limited spatial extent that households consider when searching for a new
10 dwelling; this is most limiting criterion in choice set size.

11 Still, households state to have visited up to five properties and seriously consider three
12 properties. The fact that households only consider a limited amount of properties is in line with
13 empirical evidence. The number of properties inspected in Toronto was found to be five (23); in
14 another region households saw 15 vacancies in a small number of areas (24).

1 **Residential location choice**

2 This paper has presented residential location choice models for Singapore and has focused on the
3 choice of Housing Development Board (HDB) resale flats based on revealed housing decisions.
4 When modelling the choice of a dwelling unit based on revealed preference the analyst is faced
5 with the challenge of determining the choice set available to the decision-maker; the pool of
6 alternatives in spatial location choice models is generally too large to directly include it in model
7 estimations, and additionally, it is unrealistic to assume that the household knows all available
8 alternatives in the market.

9 Commonly, alternatives are sampled from the universal choice set. In this paper model
10 results were presented with alternatives sampled from the universal choice set. Additionally,
11 models estimated were presented with choice sets that take into account household's actual search
12 preferences that include dwelling size, dwelling price and possible areas. Models including
13 spatial variables describing the social environment, combined with choice sets only including
14 alternatives within the preferred price range.

15 Estimated parameters carry the expected sign, one exception being the sign for the price per
16 square meter. In a model estimated without constraints, but including spatial parameters, the
17 price per square meter is negative. This is also the case in the model estimated with choice
18 sets that are constrained in dwelling size. Usually, an unexpected parameter estimate occurs
19 when endogeneity is present, i.e., when the independent variable is correlated with the error
20 term due to the omission of dependent variables (36). In the case for movers to HDB resale flat,
21 relevant variables include the distance to employment, the distance to parents and the distance
22 to the social network. By imposing more constraints on the choice set formation process an
23 insignificant parameter (spatially constrained model) or strongly positive parameter (price and
24 fully constrained) for the price per square meter is obtained. A similar effect was observed
25 when the choice set was constrained by reported commute times (12). They argue that this
26 initially counter-intuitive result is the result of a screening process in which initially unaffordable
27 dwellings are filtered out of the choice set, and that among the affordable dwellings unobservable
28 quality attributes are present. For Singapore, this screening process by households include most
29 likely the location of parents and the social network, judging by the impact of these variables on
30 model performance.

31 When limiting the choice set spatially most spatial attributes lose their significance, despite
32 the spatial boundary being a planning area and households opting for HDB resale considering
33 up to 4 planning areas.

34 Households prefer dwellings located in blocks between 10 and 20 years old; no other
35 preference for the age of a block could be observed. A descriptive analysis of resale prices
36 revealed that no significant difference in price for blocks between the 20 and 40 years could
37 be observed (37). Anecdotally, older blocks in Singapore are preferred in Singapore due to
38 the fact that they are more spacious, are located more centrally and have a higher chance of
39 being considered for redevelopment under the selective en-bloc redevelopment scheme (SERS).
40 However, it has to be mentioned that no HDB block in Singapore has lived until the end of its
41 lease and there is no clear government policy on this topic yet. Theoretically, blocks that reach
42 the of their lease will have no resale value.

43 Hedonic pricing models for Singapore revealed that prices of HDB dwellings located on
44 higher floors are generally higher than transaction prices of HDB dwellings located on lower
45 floors. (38). The model results presented in this paper show that households do not prefer
46 dwellings located on lower levels when using the price constrained choice set and the fully

1 constrained choice set. However, no clear preference for higher floor levels was observed. An
2 individual who had purchased an HDB dwelling commented in her blog: '*the premium (... for*
3 *higher floors ...)* is overpriced, and can be used instead for improving the interior' and '*A benefit*
4 *of my low floor is having a garden view. It is fun to see the people walking in the garden, ,*
5 *children playing hide and seek,*'. Attributes such as the quality of view were not generated
6 as the collected data does not include the exact floor level and the location of a dwelling inside a
7 block. Additionally, given the limited amount of observed choices it is imaginable that there
8 would not be sufficient observations of households considering a dwelling based on such quality
9 attributes.

10 Models estimated including spatial variables describing a household's most important
11 locations, expect for the spatially constrained choice set. Indeed, the majority of the households
12 stated to first select a location and then search for a dwelling meeting their criteria. On one
13 hand, it can be argued that household's adjust their job location and the locations where they
14 meet their social contacts based on the their residential location. Nevertheless, social contacts
15 and the employment location are elements that are likely not to change over longer span of
16 time. These findings are in line with conclusion of previous studies. Previous research indicated
17 that households relocate in small area around their previous dwelling (39); other research has
18 found that households prefer to live close to friends and relatives (40, 41) for the canton of
19 Zurich. Furthermore, Singapore's Ministry of National Development found that recently married
20 Singaporeans preferred to live in the same neighbourhood (42%) or the same area (16%) as
21 their parents (42). The findings of the presented residential location choice model confirm the
22 findings of this survey.

23 Spatial variables other than variables based on a household's most important locations were
24 included in model specifications. Of these variables, it was found that a MRT station within
25 400 meter was preferred. Also, it was found that a top primary school within one kilometre is
26 preferred; households residing within one kilometre have an increased change of being enrolled
27 in a primary school. Hedonic models for Singapore did also reveal a price premium for these
28 attributes (38). Variables describing local accessibility, including destination diversity and other
29 walk indices, were not significant, despite that these could be a proxy for meeting locations with
30 social contacts.

31 Dominance variables could be incorporated in the choice set generation process (33). For
32 Singapore, a dominance variable should include distance to work for each household member, the
33 distance to parents, and to distance to social contacts; this dominance variable can be used for
34 weighted sampling.

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

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