Modelling Residential Search and Location Choice

Framework and Numerical Experiments

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Abstract: People only move a limited number of times during their lifetime. Factors such as high financial costs, local social networks, emotional bounds, etc. make that people typically postpone this decision as long as possible, up to the point where the benefit of alternative housing outperforms all these factors. Then things generally have to go fast. This combination of time-pressure, high costs and lack in experience turn residential search and location choice into a complex decision process. This paper presents a model developed to grasp some of this complexity. Households are approached as autonomous decision-makers continuously evaluating whether to search for information, to visit houses for inspection, to start negotiating with the owner of a house for sale or to do nothing and stay in the current house. Households make these evaluations on the basis of beliefs regarding their environment and update these beliefs each time they collect new information on this environment.

1. INTRODUCTION

Dynamic micro-simulation models simulate behaviour on the level of individuals and this over a period of time. Applying this approach to residential search and location choice would allow planners, developers, policy makers, and the like to assess the impact of planned interventions, projects and policies. It would, for example, give a developer, considering constructing housing in a certain area, an indication of the profile of interested buyers, the rate of selling, the prices buyers are willing to pay, etc. all this relative to the required investment.

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For a model to dynamically assess plan proposals, the modelled population should be able to react and even pro-act to these proposals. This makes that modelled individuals thus have incomplete knowledge of their own future and the future of their environment and thus have to make decisions on the basis of beliefs regarding this future. To reduce the uncertainty involved in this decision-making, each individual will search for information. Searching typically involves a series of decisions: when to start searching, when to stop searching, how much information to collect prior to evaluation, which information to remember and which to forget, how much to rely on experience, to name just a few. Search methods and models differ in how these decisions are implemented. For an overview see Chorus et al. [2005].

Models adopting a behavioural approach to searching are generally divided into two categories depending on how they address the above decisions [Baryla et al. 2000, Wadell 2001]. On the one hand there are models that assume individuals to search by first evaluating all available choice alternatives in order to then make the best choice. There is no provision for continued search. Models belonging to this category are known as Fixed Sample Size (FSS) models. For examples in the context of residential search see Blijie [2004] and Ettema [2005]. On the other hand there are models that assume individuals to search by evaluating only one choice alternative at a time, on the basis of which the individual decides whether to continue searching or not. In this approach not all alternatives need to be assessed. Models belonging to this category are known as Sequential Search models [Richardson 1982]. For an example in the context of residential search see Torrens [2001]. FSS models are fast but costly, whereas Sequential Search models are slow but flexible. It is proven that a more realistic way of searching lies somewhere in between these approaches allowing individuals to sequentially evaluate a number of choice alternatives (instead of all or just one) before having to make a decision [Morgan and Manning 1985]. In the context of residential searching, a household might evaluate all the ads in one newspaper to then decide whether to visit an advertised house for inspection or to consult another source of information. It is the aim of this paper to present a model allowing for this type of search-behaviour where households make all the above decisions based on incomplete information, anticipating changes, trading off search-costs and search opportunities; all this in a dynamic fashion. FSS and Sequential Search could then be interpreted as special cases of this behaviour.

In section two, the conceptual framework of the model is introduced and implemented. In section three, a series of simulation results is discussed, assessing the face validity of this framework. The paper ends with some conclusions and suggestions for future research.

2. FRAMEWORK

2.1 Basic decision process

Households make location-choice decisions in a physical and social environment. The physical environment refers to the housing market; the social environment refers to other households. A household might consist of multiple household-members. Each household-member has a series of characteristics, influencing his or her life course. Over time, each member grows older and so its life course changes; apart from this, the environment changes. Assume that each household-member attempts to maximize the utility of his life course. For this reason, the individual member will try to behave strategically, anticipating his own changes and the changes of the environment. This also counts for decisions related to housing. In order to maximize the lifetime utility expected from living in any house, the individual will continuously evaluate whether it would be better to move to a new house or whether to stay in his current house. The individual member will not make this decision alone but does this as a household, having to arrive at a joint choice. In this paper, joint choice is implemented assigning an identical weight to the choice of all household members assuming all to contribute in a similar fashion to each decision. Other, more realistic intra-household relations could be incorporated in future model versions.

When making these decisions households have to rely on partial and even imperfect information on their environment. In order to reduce this uncertainty, households search for information. Searching is implemented as a two-stage process where the individual first collects a series of potentially interesting choice alternatives from an information source to then visit some of these alternatives gaining full information. The assumption is that a household will only decide to buy a house once it has complete information on this house. Once the household made up its mind regarding which house to move to it will have to negotiate with the real-estate agent selling the house to come up with a price at which to buy the house. This process of searching, visiting and negotiating is not necessarily a sequential process; a household might for example decide to start searching again in information sources after already having visited a series of houses. The household thus has to decide, at each moment in time, whether to search, visit, negotiate or do nothing. Because a household cannot predict the outcome of each of these actions with certainty, it will have to make this decision on the basis of beliefs. Each time an action is executed; all household members have access to new information. On the basis of this information all members can then update their beliefs (see Figure 1).

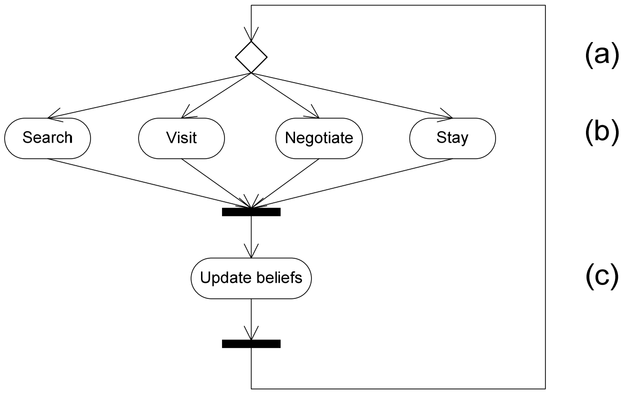

Figure 1. Basic decision process.

2.2 Beliefs and belief updating

A house is defined on the basis of a series of attributes such as housing-typology, size, neighbourhood population, number of rooms, distance to the nearest city centre, price, etc. Each unique combination of attribute values is referred to as a housing-class, denoted as $v = 1,...,V$. Houses for sale are stored in information sources representing newspapers, social networks, estate agents, websites, etc. Each information source has a series of attributes such as number of published houses, composition, quality of information, credibility of information, etc. and could be related to a geographical area, a particular culture, etc. Once a household decides to consult a particular information source it evaluates all the houses advertised in that source. A source typically only provides partial information, meaning that the reader is only certain about the value of some attributes of the houses for sale. On the basis of some attributes that are always known, the household will define housing-categories, denoted as $k = 1,...,K$. Each housing-class v belongs to only one housing-category k . Only after visiting a house for inspection, the household will have full information on the values of all attributes.
Until the household visited the house, it will thus have to rely on beliefs regarding the values of the unknown attributes. In the presented model, we assume individuals to classify phenomena of interest into sets of discrete states/outcomes such as housing-classes and -categories. Beliefs then represent subjective probabilities that the phenomena fall within any of these states. Households have beliefs regarding the probability of finding any housing-category on the housing market, called category-beliefs and denoted as $\Pr(k)$. Households search for houses for sale in information sources. The

actual probability of finding a house belonging to a housing-category k in a source s then depends on the attributes of this source. Suppose we are interested in the probability of *not* finding any house belonging to a housing-category k in source s, denoted as $\Pr(k \notin s)$. This probability equals the probability that all houses of the source belong to another housing-category:

$$\Pr(k \notin s) = [1 - \Pr(k)]^{l''(s)} \tag{1}$$

$l''(s)$ represents the expected number of published houses of source s and is called source-beliefs. Note that $\Pr(k)$ represents the probability of finding a house belonging to category k on the housing market as a whole. The probability of finding a house belonging to category k in source s then becomes:

$$\Pr(k \in s) = 1 - \Pr(k \notin s) = 1 - [1 - \Pr(k)]^{l''(s)} \tag{2}$$

The underlying assumption is that all sources have a housing-category distribution identical to the one of the housing market. $\Pr(k \in s)$ therefore only depends on the expected number of published houses of the source. In future simulations, this assumption will be abandoned so that the composition of the source will also be taken into consideration. The individual evaluates this probability on the basis of expected number of ads $l''(s)$ because at the moment of evaluation, it has no exact knowledge on the actual number $l(s)$ and thus has to estimate it on the basis of beliefs. $l''(s)$ is implemented as the sum of all possible number of ads weighted with the respective beliefs $\Pr(l(s) = l)$:

$$l''(s) = \sum_l \Pr(l(s) = l) l \tag{3}$$

Besides category- and source-beliefs, the individual also has beliefs regarding the probability of finding a house on the housing market belonging to a housing-class v conditional on housing-category k, called class-beliefs and denoted $\Pr(v \mid k)$, and beliefs regarding the probability of successfully buying a house at a price c conditional on housing-category k, called price-beliefs and denoted $\Pr(c \mid k)$.

Beliefs are based on previous experiences and other sources of information, with varying degrees of credibility. For example, each time a household consults a newspaper or visits a house for inspection it has access to new information. On the basis of this new information, the household-members can update their beliefs. We assume this updating to go as follows [Arentze 2005]:

$$\Pr_i^{t+1} = \frac{\Pr_i^t W^t + \delta}{W^t + 1} \tag{4}$$
$$W^{t+1} = \alpha W^t + 1$$

$\Pr_i^t$ expresses the probability that the observed attribute has value i at time t. Parameter $\alpha = [0,1]$ expresses the relative weight an individual assigns to accumulated past experiences W^t. If $\alpha = 1$, full weight is given to previous experiences that is the number of times the individual has made the same observation until $t+1$. In contrast, if $\alpha = 0$, past experiences have no impact at all. One might interpret this as the individual forgetting what he or she has gone through. Parameter δ expresses how certain the individual is about the newly gained information. δ will vary between 0 (perfect incredibility) and 1 (perfect credibility). Recall that the information published in an information source is incomplete. Consulting such a source thus only provides the individual with partial information. Visiting a house for inspection, on the contrary, provides the individual with full information. At the start of simulation beliefs have to be initialized. This will be dealt with in the numerical simulation section.

2.3 Search and choice process

Recall that a household has to decide, at each moment in time whether to search, visit, negotiate or do nothing. The household will select the action maximizing the lifetime utility expected to derive from living in the house acquired through one of these actions. The probability that the household will decide to search is:

$$\Pr(Z) = \Pr[EU^z = \max(EU^z, EU^b, EU^n, U^0)] \tag{5}$$

Z refers to searching, EU^z, EU^b and EU^n refer to the expected lifetime utility related to, respectively, searching, visiting and negotiating, and U^0 refers to the lifetime utility derived from staying in the current house. The decision of which action to pursue can be represented with a Decision-Tree as in Figure 2. A Decision-Tree is a tool to formalize problems in decision-analysis [Neapolitan 1990]. Working with a tree implies, first, evaluating all the actions in this tree to then select and execute the action with the highest expected utility.

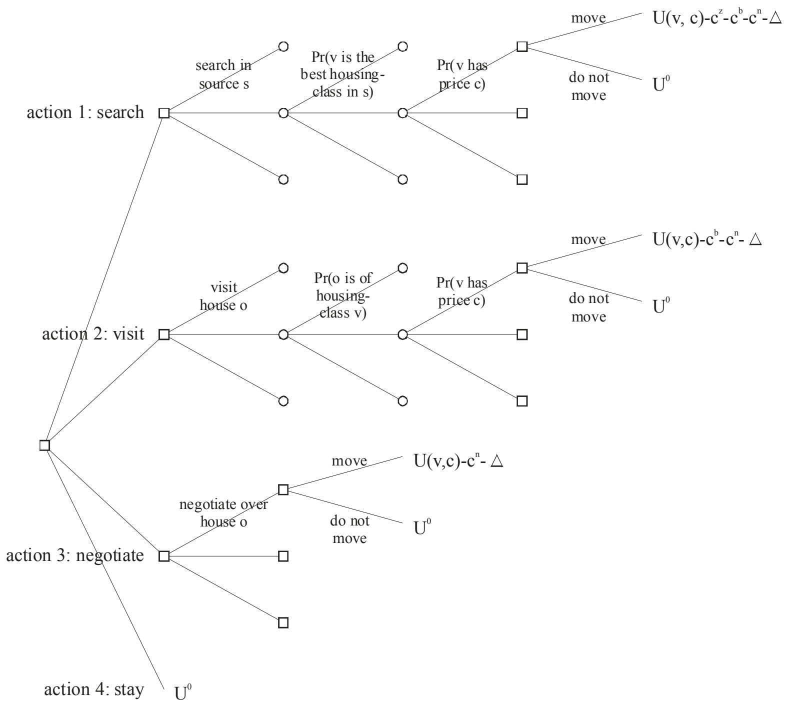

Figure 2. A Decision-Tree illustrating the decision of which action to pursue. Each node implies one decision: in a square node (or decision-node) the decision only depends on the agent, in a round node (or chance-node) the decision depends on what happens in the agents' environment.

Recall from section 2.1 that a household has to visit a house for sale before it can start negotiating and that a household can only visit houses for sale it found during searching. Consider as an example a household that just experienced a change in its life course (e.g. divorced) and for this reason expects to derive more lifetime utility from other houses for sale. It will select the information source it expects to be the best source available and evaluate all published houses for sale, storing potentially interesting houses in a list of houses to visit. In the following decision round, the household will again evaluate all actions, considering whether it would be more beneficial to consult another information source or to visit one of the stored houses for sale. In the same fashion, the household will add houses it visited and finds acceptable to a list of houses to negotiate over. The household thus starts without any experience gaining knowledge with each decision-round.

2.3.1 Action 1: searching

In the search-branch of the Decision-Tree, the individual evaluates the expected utility of all available sources to then select the best one:

$$EU^z = \max_s [EU(s)] \tag{6}$$

$EU(s)$ represents the utility expected of searching in source s. This utility depends on the beliefs of the individual of finding houses belonging to particular housing-classes in this source (the second node in the search-branch). If he or she would perfectly know the contents of a source, then $EU(s)$ would be the lifetime utility the individual expects to derive from living in a house belonging to the best housing-class v available in the source, or belonging to the housing-class it is currently living in:

$$EU(s) = \max_v [EU(v) - c^z] \tag{7}$$
$$c^z = \gamma^z \log(\Delta U) t^\Delta$$

c^z represent the costs related to consulting a source and are defined dependent on the change in utility ΔU due to a change in life course. Such a change might make that a house no longer answers all the needs of the household generating a decrease in experienced utility. t^Δ refers to the time the household is already searching. Assuming the costs to increase with search time, t^Δ is a measure for search-effort. Besides consultation-costs, there are also costs related to visiting a house, called inspection-costs and denoted c^b and costs related to negotiating over a house, called negotiation-costs and denoted c^n. c^b and c^n are defined dependent on c^z: $c^b = \gamma^b c^z$ and $c^n = \gamma^n c^z$, with γ^z, γ^b and γ^n as weight parameters such that $\gamma^n < \gamma^b < \gamma^z < 1$. The underlying assumption is that households with a minor loss in utility will favour searching over visiting and negotiating (c^z and thus c^b and c^n converge to zero). As the loss increases, households will start to prioritize negotiating over visiting over searching so that the costs of visiting and negotiating become relatively lower than those of searching. As such, costs represent a heuristic, making households behave strategically, preventing them from always searching in the same source.

In reality individuals have limited a-priori knowledge about the contents of a source and thus cannot be certain whether any housing-class will be listed or not. Let v_i ($i = 1,...,V$) be an ordered list of all housing-classes theoretically available such that, for the individual $EU(v_1) > EU(v_2) > ... > EU(v_V)$ and let $\Pr(v_1 \in s)$ denote the individuals belief that housing-class v_1 appears in information source s:

$$\Pr(v \in s) = \sum_k [\Pr(v \mid k) \Pr(k \in s)] \tag{8}$$

$\Pr(v \mid k)$ represent the class-beliefs and $\Pr(k \in s)$ is as defined in Equation 2. Recall that a housing-class v can only belong to one housing-category k. The individual will weigh the expected utility of this class with the belief that it is present in the source $\Pr(v_1 \in s) EU(v_1)$. The same for the second favourite class, this time weighing the utility with the belief that the favourite will not be present and the second favourite will be present $\Pr(v_2 \in s)\Pr(v_1 \notin s) EU(v_2)$. Because the individual is uncertain regarding the presence of any housing-class, he or she will repeat this evaluation for all classes V, each time weighing the expected utility with the belief that a particular class will be present and all better ones not. The sum of these weighted utilities then represents the expected utility of the source. Equation 7 then reads:

$$EU(s) = \sum_i \Pr(v_i)[EU(v_i) - c^z] \tag{9}$$

$$\Pr(v_i) = \Pr(v_i \in s) \prod_{j=1}^{i-1} \Pr(v_j \notin s) \tag{10}$$

The lifetime utility an individual expects to derive from a house not only depends on the attributes of this house but also on the price; the higher this price the less resources the individual has left for other activities, lowering his or her overall utility. $EU(v)$ therefore depends on the beliefs the individual holds with respect to the price c he or she expects to pay for this class (the third node in the search-branch).

$$EU(v) = \sum_c \Pr[c(v) = c][EU(v,c) - c^b] \tag{11}$$

$\Pr[c(v) = c]$ represents the belief that a housing-class v can be bought for a price c and c^b represent inspection-costs.

This brings us to the last node of the search-branch where the household has to decide whether to move to a house belonging to housing-class v with cost price c or to stay living in its current house. It will decide to move if the expected lifetime utility of the house for sale exceeds the lifetime utility of the current house U^0:

$$EU(v,c) = \max[U(v,c) - c^n - \Delta, U^0] \tag{12}$$

c^n represent negotiation-costs and Δ refers to a resistance to change incorporating that the expected lifetime utility of living in an alternative house should significantly outperform the lifetime utility of the current house before the household will even consider moving.

Recall from the decision tree that the household will first evaluate all actions to then execute the action with the highest expected lifetime utility. Assume that the household evaluated all actions and that it expects to derive the highest utility from searching in information source s. The household will then consult this source looking for potentially interesting houses for sale. Recall that, while consulting, the household gains full knowledge on the content of the information source. But because the housing market changes continuously, this knowledge is only temporary. The individual can therefore only update his or her category- and length-beliefs (using Equation 4) tuning them to what is available on the market, at that moment. Because of this updating another action might become the best one to choose.

2.3.2 Action 2: visiting

A source only provides partial information making that a household is never completely certain whether an advertised house matches a housing-class, either because the description in the information source is incomplete or because the source is not hundred percent credible. The lifetime utility expected to derive from a house for sale $EU(o)$ therefore depends on the belief that it matches one of all possible housing-classes v:

$$EU(o) = \sum_{v} \Pr(v(o) = v \mid k) EU(v) \tag{13}$$

$\Pr(v(o) = v \mid k)$ represent the class-beliefs as introduced in section 2.2 and $EU(v)$ is the expected lifetime utility of housing-class v as defined in Equation 11. Each house for sale of which the expected lifetime utility exceeds the lifetime utility of the current house, incorporating resistance to change, is added to the list of houses to visit. In the visit-branch of the Decision-Tree, the individual will evaluate the expected utility of all houses for sale stored in this list of houses to visit to then select the best one:

$$EU^b = \max_{o}[EU(o)] \tag{14}$$

$EU(o)$ is as defined in Equation 13. Assume again that the household evaluated all actions and that it expects to derive the maximum utility from visiting a house o. The household will then visit this house for inspection gaining full information on the values of all attributes of this house. On the basis of this acquired information the household members will update their class-beliefs and reassess $EU(o)$. If this reassessed $EU(o)$ exceeds the lifetime utility of the current house, incorporating resistance to change, the household will add the visited house to its list of houses to negotiate over.

2.3.3 Action 3: negotiating

In the negotiation-branch of the Decision-Tree, the individual evaluates the expected utility of all houses for sale stored in the list of houses to negotiate over to then select the best one:

$$EU^n = \max_o[U(o)] \tag{15}$$

$$U(o) = \max[U(v,c) - c^n - \Delta, U^0] \tag{16}$$

At this moment, the household has full information on house o. $U(o)$ thus represents the lifetime utility of a house o belonging to housing-class v and price-class c.

Assume again that the household evaluated all actions of Figure 2 and that it expects to derive the maximum utility from negotiating over a house o. The household will then contact the estate-agent selling the house and start negotiating trying to agree upon a price at which to buy the house. Each negotiation round the buyer has to decide whether to accept the price and buy the house, or reject the price and search for another house or propose a counter-price. The buyer will make this decision on the basis of beliefs regarding the behaviour of the seller and the situation on the housing-market, trading off utility, urgency and availability. The seller, in turn, has to make the same decision. The negotiation stops when both agree upon a price or when one withdraws. As stated in the introduction, the main focus of this paper lies on the search process. The negotiation process is therefore kept as simple as possible: a house will be sold, if the price the buyer proposes exceeds a minimum price defined by the seller. In case of a successful negotiation, the household will move to the house, in case of a failed negotiation, it will remove the house from the list of houses to negotiate over. A model incorporating the negotiation process in full detail is being developed in parallel [Devisch et al. 2005].

2.3.4 Action 4: staying

The lifetime utility of staying U^0 (action 4 in Figure 2) is equal to the lifetime utility derived of living in the current house. Staying is interpreted as passive searching incorporating that individuals are exposed to information, and thus search continuously whether or not they are aware of it. In the current model, passive searching is implemented as active searching, be it in a passive information source.

3. NUMERICAL SIMULATION

The proposed framework is implemented in the context of student housing. The city of Eindhoven in the Netherlands makes up the housing market and the students studying at the Eindhoven University of Technology make up the population. During the simulation students may change residence reacting to changes in their environment, such as cheaper rooms, or reacting to changes in their own life course, such as the need for more privacy. Students can either move away from their parents, move back to their parents, move to another residence or leave the housing market. As students typically do not buy but rent their housing, the applicability of the student scenario is limited. The purpose is therefore only to assess the face validity of the conceptual framework.

Housing Market settings

The housing market is modelled as a collection of neighbourhoods, in turn modelled as a collection of housing-complexes, consisting of a number of housing-units; one unit per student-household. Each housing-unit is defined through a unique set of attributes as illustrated in Table 1: number of rooms and size are defined on the level of the housing-unit, housing-typology and number of housing-units are defined on the level of the housing-complex and neighbourhood-population and distance to the campus are defined on the level of the neighbourhood. Data on these attributes is obtained via housing agencies currently working within the Eindhoven student housing market. Recall from section 2.2 that households classify housing-classes into housing-categories, defined on the basis of attributes that are always known; in this simulation this are housing-typology and size, making up 9 housing-categories.

Table 1. Housing-unit attributes (left) and individual attributes (right).

housing-unit attributes	values
housing-typology	student housing, hospita, appartment
size	small, average, big
number of rooms	1 to 2
number of housing units	low, average, high
neighbourhood population	uniform, slightly mixed, multi-cultural
distance to campus	close, average, far

individual attributes	values
gender	male, female
study-year	1 to 7
budget	200 to 1000
living as a single	yes, no
living with parents	yes, no

Population settings

The student population is modelled as a collection of individuals forming households. Most student-households will only consist of one student. Some students might live together as a couple though. Each individual student is defined through a unique set of attributes as illustrated in Table 1: gender, study-year and budget are defined on the level of the individual student; living with parents and living as a single are defined on the level of the household. As with the housing-units, students are classified into student-categories, be it on the basis of attributes that can change over time as illustrated in Table 2. Data on student attributes is obtained via the database of the university and a questionnaire distributed among 600 students.

Table 2. Student-categories.

	study-year	living as a single	living with parents
student category 1	<=3	yes	yes
student category 2	<=3	yes	no
student category 3	<=3	no	no
student category 4	>3	yes	yes
student category 5	>3	yes	no
student category 6	>3	no	no
student category 7	stopping		

Each student has preferences regarding the kind of housing-unit and neighbourhood he or she would like to live in. Seven preference-profiles have been defined, relative to the housing-typology and size of the housing-unit. A student with preference-profile five, for example, has a preference for living in an apartment and has no preference for any particular size. The utility values matching each preference-profile are estimated on the basis of a stated preference experiment, of which some are illustrated in Table 3.

Table 3. Utility values regarding the housing-unit attribute 'size'.

	housing-unit size			
	small	medium	large	parents
preference profile 1	1.00	1.90	2.20	0.00
preference profile 2	0.00	1.90	2.20	0.00
preference profile 3	1.00	1.90	2.20	0.00
preference profile 4	0.00	1.90	2.20	0.00
preference profile 5	0.80	1.90	2.20	0.00
preference profile 6	0.00	1.90	2.20	0.00
preference profile 7	0.00	0.00	0.00	2.20

Recall that agents anticipate changes in their life course, evaluating decisions on the basis of lifetime utility. A change in life course is modelled as a student changing student-category. With each change, the student might change preference-profile. The lifetime utility the student expects to derive from a housing-unit belonging to a housing-class v and price-category c thus depends on the probability that the student will change to any of the student-categories and/or to any of the preference-profiles.

$$U(v,c) = \sum_{t=0}^{3}[\sum_{i=1}^{7}\Pr^t(i)[\sum_{j=1}^{7}\Pr^t(j \mid i)U(v,c \mid j)]] \tag{17}$$

where $\Pr^t(i)$ expresses the probability that a student will change to student-category i at time t, and $\Pr^t(j \mid i)$ expresses the probability that a student with student-category i will change to preference-profile j at time t. In the simulation, the student anticipates changes over a period of three years.

Belief settings

As explained in section 2.2, each individual has class-, category-, source- and price-beliefs. Class-beliefs are initialized on the basis of the actual distribution of the values of all unknown housing attributes, reflecting that individuals have some knowledge of the housing-market. Category-beliefs are initialized in the same fashion. Recall that the individual uses Equation 2 to calculate the availability beliefs of housing-classes. Source-beliefs are initialized being normally distributed around the actual number of published houses in the source. Price-beliefs are defined exogenously for each housing-category and are, upon initialization, the same for all students.

Experiments

Each experiment is run for 25 years. During each year, each student grows older and might, as a consequence, change student-category and/or preference-profile making that the current house might no longer answer all the needs of the student. Each year consists of 12 evaluation moments at which each student evaluates which action to pursue. Each year old students leave the simulation and new students enter the simulation. The number of incoming students is set so the overall population remains constant. The model records for each student for each year whether it changed student-profile and which actions it pursued. Data is only recorded for students with a full life course, being students that started as first year students and stopped or finished studying. The first 10 years are not recorded to avoid initialization effects.

Table 4 illustrates 4 experiments under different parameter settings: experiment (a) functions as the base case, in experiment (b) all costs c^z, c^b and c^n are set to zero, in experiment (c) the search experience W^t is set to one and in experiment (d) students begin with uniform beliefs regarding $\Pr(v)$ and $\Pr(v \mid k)$. Simulation results are grouped according to how many years the student studied when leaving the simulation (from 1 to 7). What is recorded is the percentage of time each student spent on each action, the average number of moves and the average number of visits per move. The average number of moves is a measure for the success-rate of the search strategy and the average number of visits per move is a measure for the efficiency of the strategy.

Table 4. Experiment results.

years studied	search	visit	negotiate	do nothing	average moves	average visits per move
1	6.05%	3.97%	0.39%	84.17%	0.07	2.95
2	7.35%	4.14%	0.39%	84.85%	0.12	3.01
3	5.38%	3.38%	0.40%	88.49%	0.17	3.03
4	3.68%	3.04%	0.36%	91.09%	0.21	2.56
5	3.16%	2.82%	0.44%	92.07%	0.31	2.40
6	3.52%	2.58%	0.40%	92.23%	0.36	2.17
7	3.01%	2.58%	0.39%	92.91%	0.42	2.07

(a)

search	visit	negotiate	do nothing	average moves	average visits per move
12.07%	3.09%	0.18%	79.23%	0.03	2.46
12.16%	1.95%	0.10%	82.51%	0.03	3.15
13.58%	3.37%	0.14%	80.56%	0.06	3.80
13.26%	4.80%	0.26%	79.84%	0.14	2.92
13.82%	4.93%	0.28%	79.45%	0.21	3.78
10.13%	4.31%	0.18%	84.10%	0.16	4.75
8.81%	4.06%	0.19%	85.84%	0.20	4.49

(b)

years studied	search	visit	negotiate	do nothing	average moves	average visits per move
1	6.87%	3.98%	0.54%	83.20%	0.10	2.76
2	8.69%	3.66%	0.50%	83.86%	0.16	2.73
3	5.55%	2.65%	0.45%	89.01%	0.20	2.79
4	5.09%	3.09%	0.55%	89.42%	0.32	2.21
5	5.31%	3.17%	0.57%	89.43%	0.41	2.35
6	3.90%	2.15%	0.42%	92.26%	0.38	1.99
7	3.36%	1.88%	0.37%	93.28%	0.40	1.87

(c)

search	visit	negotiate	do nothing	average moves	average visits per move
12.61%	1.01%	0.35%	80.63%	0.06	1.88
10.84%	0.92%	0.30%	84.65%	0.09	1.79
10.93%	0.81%	0.33%	85.58%	0.16	1.85
11.05%	0.95%	0.31%	85.84%	0.19	1.77
10.61%	0.96%	0.41%	86.52%	0.33	1.57
7.41%	0.79%	0.32%	90.20%	0.30	1.42
6.54%	0.78%	0.27%	91.30%	0.30	1.58

(d)

The base case (a) illustrates that the longer a student studies, the more he or she does nothing. This is because a student can only change preference-profile a limited number of times. Furthermore, older students seem to move more and do this more efficiently. This might be due to a higher search-experience. In the second experiment (b), costs are not included resulting in an increase in searching. An explanation here is that the market changes continuously, so that when students update their beliefs after searching, they always expect to find more beneficial alternatives then the ones already assessed. Without time-pressure, students thus move less and do this less efficiently. In the third experiment (c), the initial experience W^t is set from hundred to one, making that, initially, students assign all weight to recent observations. Because of the high turnover rate on the housing market, students will thus have a more precise image of this market, resulting in a higher searching and moving percentage than in the base case. In the last experiment (d), students have no beliefs regarding the distribution of housing-categories and –classes. This is implemented as horizontal initial belief-distributions. Over time the students do gain knowledge. The result of these settings is that students search longer and thus visit and negotiate significantly less than in all other cases. Students that do find a house though do this very efficiently. An explanation could be that because of the uniform distribution, students assign average utilities to all houses so that when they finally visit a house for inspection, the utility might exceed this average making that they immediately negotiate over it to buy it.

4. CONCLUSIONS AND FUTURE WORK

The aim of the model was to grasp some of the complexity inherent in residential search and location choice. This is achieved by approaching each household as an autonomous decision-maker making decisions on the basis of beliefs regarding their environment and letting all household members dynamically update their beliefs each time they gains new information on their environment. Experiments show that this approach is able to capture some of the real world complexity in that modelled households behave strategically trading off expected market opportunities against expected costs, in that they learn and use their experience when making decisions and in that they are able to anticipate changes in their life course.

The current experiments are run in the context of the student housing-market. A suggestion for future work could be to run similar experiments in the context of a household housing-market. As mentioned in section 2.2, another suggestion would be to incorporate the composition of the source as an attribute influencing the availability beliefs of households.

5. REFERENCES

Arentze, T.A. and H.J.P. Timmermans, 2005, "Modeling learning and adaptation in transportation contexts", *Transportmetrica*, **1**: 13–22.

Baryla, E.A., L.V. Zumpano and H.W. Elder,2000, "An Investigation of Buyer Search in the Residential Real Estate Market under Different Market Conditions", *Journal of Real Estate Research*, **20**(1-2): 75-91.

Blijie, B., 2004, "A New Theoretical Model for Residential Choice Behaviour and Measuring the Influence of Accessibility", Paper presented at the 17th European Advanced Studies Institute in Regional Science, Croatia.

Chorus, C.G., E.J.E. Molin and B. Van Wee, 2005, "Use and Effects of ATIS: a Review of Literature", Forthcoming in *Transport Reviews*.

Devisch, O., T.A. Arentze, A.W.J. Borgers and H.J.P. Timmermans, 2006, "Bi-level negotiation protocol for multi-agent simulation of transactions and market clearing processes. An application to the housing market", In: Proceedings of the 85th Annual Meeting of the Transportation Research Board, Washington DC., CD-Rom: 16 p.

Manning, R. and P. Morgan, 1985, "Optimal search", *Econometrica*, **53**(4): 92-944

Neapolitan, R.E., 1990, *Probabilistic reasoning in expert systems: theory and algorithms*, John Wiley & Sons, New York.

Richardson, A., 1982, "Search Models and Choice Set Generation", *Transportation Research A*, **16A**(5-6): 403-419.

Torrens, P.M., 2001, "New Tools for Simulating Housing Choices", Paper presented at the Special Fannie Mae Foundation Session: Housing and the New Economy, Washington, D.C.

Waddell, P., 2001, "Towards a Behavioral Integration of Land Use and Transportation Modeling", Paper presented at the 9th International Association for Travel Behavior Research Conference, Queensland, Australia.