

# Uncertain Housing Moves

A System Dynamics Study, exploring the effects of uncertainties on the position of low income households in the Dutch Social Housing Sector

**Name:** André de Groen

**Student number:** 1311654

**Graduation date:** 17-06-2011

**Graduation Committee:**

- Chairman: prof. dr. ir. M.G. Elsinga (TPM, Policy, Organisation, Law and Gaming)
- First Supervisor: dr. H.F.J.M. Boumeester (OTB, Housing Systems)
- Second Supervisor: dr. E. Pruyt (TPM, Policy Analysis)
- External Supervisor: F. van Dugteren (Ministry of Internal Affairs, department Knowledge and Exploration)

**Delft University of Technology**

Faculty of Technology, Policy and Management.

Study: MsC SEPAM (Systems Engineering, Policy Analysis and Management)

Graduation Section: OTB, Housing Systems.

## **Executive Summary**

### *Objective*

The objective of the research is to explore the effects of economic, demographic and institutional uncertainties on the distribution of income groups in the social housing market in the North Wing of the Randstad.

### *Scope*

Institutional uncertainty is caused by four announced or already implemented policy changes which are laid down (among other policy changes ) in the Coalition Agreement of the current Cabinet:

1. Rent increase of 5 % a year for high income households (>€43.000) in the social housing sector.
2. Higher maximum rent based on scarcity of houses of a region.
3. Buy-option for renters.
4. European Directive: 90% of free stock should be allocated to low income households.

These are all reforms on the social housing market; therefore a system dynamics model is made to analyse the effects of the uncertainties on the social housing market. The North Wing of the Randstad is chosen as sub regional housing market under research

### *System Dynamics Model*

A system dynamics model is developed to assess the influence of the uncertainties on housing move behaviour of households. System dynamics conventions are: (1) system structure drives system behaviour, (2) feedback loops among variables create dynamics and (3) a stock flow structure is used to model reality. The model tries to simulate the housing moves of households on the housing market. Households are specified to sector, composition and income level. A simplified household life cycle is coupled to the different household types. The income of household also develops over time. Because the model uses aggregates, no moving chains are present. Instead, a transaction rate and the ratio supply demand determines the amount of housing moves.

### *Results and Next Steps*

The four policy changes decrease the size of the social housing and focus the social housing sector on the target group, lower income households. The effects are not immediately noticeable, it takes some time till the effects on the performance indicators becomes significant, however the effect continues steadily. So, it is not possible to couple short-term objectives to this policies; effects of the policy changes take two or more government terms. Demographic and economic uncertainty have a limited effected on the performance indicators.

The policies do not improve the situation for low income households in the social housing sector. Instead, the allocation of housing in the social housing sector becomes more efficient, having the same amount of low income households in a smaller housing stock.

The model has some limitations because it is focused on the social housing market, however it has still a lot of potential. New uncertainty structures can easily be integrated because of the solid housing move framework. It is also possible to extend the model with a model focused on the home ownership sector.

## Content

1. Introduction.....	6
1.1 Uncertain Housing Moves .....	6
1.2 Research Question .....	7
1.3 Scope: Social Rental Market in the North Wing of the Randstad .....	7
1.4 Structure of the Thesis .....	8
2. The Dutch Housing System.....	10
2.1 Dutch Housing Market.....	10
2.2 Social Housing Market in the North Wing of the Randstad.....	10
2.2.1 Social Housing Market .....	10
2.2.2 Housing Allowance System .....	11
2.2.3 Regional Housing Markets: Randstad .....	11
2.3 Moving Behaviour .....	11
2.4 Institutional Developments .....	12
3. Methodology .....	15
3.1 Uncertainty .....	15
3.2 System Dynamics Modelling Technique.....	15
3.2.1 Feedback Loops .....	16
3.2.2 Stock-flow Diagrams .....	17
3.2.3 Delays.....	17
3.2.4 Graph Function.....	18
3.3 Uncertainty Structures .....	18
3.3.1 Parameter Uncertainty .....	18
3.3.2 Function Uncertainty .....	19
3.3.4 Structure and Scenario Uncertainty .....	20
3.4 Risk Assessment: Latin Hypercube Simulation .....	20
3.5 Suitability of SD for Answering Research Question .....	20
3.6 SD Models Dutch Housing Market .....	21
4. Data .....	22
5. Model Description.....	23
5.1 Modelling Choices .....	23
5.2 General Elements of the Model .....	23
5.2.1 Moving by Change in Household Composition .....	23
5.1.2 Moving by Change in Income.....	24

5.1.3 Moving by Change in Housing Sector .....	25
5.3 General Structure of the Model.....	27
5.3.1 Demand.....	28
5.3.2 Supply and Feedback Loop Newly Built Houses.....	28
5.3.3 Feedback Loop Starter Substitution .....	28
5.3.3 Transaction Rate.....	29
5.3.4 Feedback Loop Disappointed Households .....	29
5.3.5 Influence of Uncertainties.....	30
5.4 Detailed Description of Uncertainty Structures .....	30
5.4.1 Institutional Uncertainties .....	30
5.4.1.1 <i>Rent Increase High Incomes</i> .....	30
5.4.1.1 <i>Extra WWS points</i> .....	31
5.4.1.3 <i>Buy Option</i> .....	32
5.4.1.4 <i>European Directive</i> .....	32
5.4.2 Demographic Uncertainty.....	33
5.4.3 Economic Uncertainty.....	33
5.5 Start Situation of the Model .....	35
6. Model Validation.....	37
6.1 Direct Structure Tests.....	37
6.1.1 Parameter Values .....	37
6.1.2 Equations .....	37
6.1.3 Parameter Dimensions .....	38
6.1.4. Relevance of Parameters .....	38
6.2 Structure Oriented Behaviour Tests.....	38
6.3. Conclusion Validation.....	38
7. Uncertainty Analysis.....	39
7.1 Performance Indicators .....	39
7.1.1. Presence of Target Group in the Social Housing Sector (% of Total Social Housing) .....	40
7.1.2 Average Income of Households in the Social Housing Sector.....	40
7.2 Simulation Time .....	40
7.3 Scenario Building.....	40
7.4 Results .....	41
7.4.1 Results of Dynamic Analysis.....	41
7.4.2 Results of Static Analysis.....	44

8. Conclusions.....	47
8.1 Answering the Research Question.....	47
8.2 Recommendations .....	48
8.3 Limitations of the model .....	48
8.4 Opportunities of the model .....	49
9. Reflection: Project Proposal versus Thesis.....	50
Bibliography.....	51
Appendix A: Characteristics COROP Regions Randstad .....	54
Appendix B: Details about Household development.....	55
Appendix C: Uncertainty Ranges.....	56
Appendix D: Equation Analysis and Extreme Conditions .....	57
Appendix E: Extreme Conditions (Output) .....	60
Appendix F: Results.....	62

## 1. Introduction

The Dutch housing market is a dynamic and complex system due to many actors, uncertain household behaviour and market imperfections: new housing estate is inelastic and delayed, demand and supply are unequally divided over regions and the government disturbs the market by regulation (Centraal Planbureau, 1999). Examples of government regulation are housing allowance, mortgage interest deduction, real estate transfer tax and land policy. It is difficult to get a clear picture of the delayed effects of combined policy changes due to the complexity and dynamics of the housing market.

### 1.1 Uncertain Housing Moves

Recently, the new Cabinet proposed four policy changes which influence the social housing market (CDA and VVD, 2010):

1. Landlords in the social housing sector are allowed to increase the rent by 5%/year + inflation for households having a gross annual income higher than €43.000.
2. Landlords are enabled to add, based on the scarcity of the region, 25 WWS-points (the WoningWaarderingsStelsel ( Housing Assessment System) is used to calculate the maximum rent price) to a house.
3. Buy option: tenants are offered the possibility of buying their rented house for a reasonable price.
4. The allocation of social dwellings is limited to lower income groups. This is imposed by a European Directive: at least 90% of inflow of social housing should contain households having a gross annual income lower than €33.000.

The second policy change, adding location dependent WWS points, will be introduced in July 2011 (Donner, 2011). The European Directive is active since January 2011. The rent increase for high incomes is planned to be implemented in July 2012 (Donner, 2011). In March 2011, ruling party VVD asked Donner to speed up the introduction of the buy-option. It is still unknown when the buy option becomes available for renters.

These institutional changes affect the already unpredictable housing move behaviour of households. Besides the effects of these policy changes, housing demand is influenced by economic and demographic uncertainty. The success rate of policy changes is dependent of moving behaviour of households. The coalition agreement emphasized that the social housing sector should focus on those households who have no alternatives other than social housing. However, due to the uncertainties in the social housing market it is unknown to what extent the policy changes contribute to this objective of the coalition. Policy makers should have insight in how, and to what extent, above mentioned policy changes influence the position of low income households in the social housing sector.

## 1.2 Research Question

The Ministry of Internal Affairs and Kingdom Relations (Dutch abbreviation: BZK) is the virtual problem owner; the project is not commissioned by the Ministry, instead an employee of the Ministry has accompanied the project process. The research is focused on the social housing market of the North Wing of the Randstad. The question which will be answered for the Ministry is the following:

*What are possible effects of institutional, economic and demographic uncertainties in the Dutch Housing Market on the position of low income households in the social rental housing market in the North Wing of the Randstad?*

This thesis answers this question by developing a simulation model which is able to process the range of effects of all uncertainties. When this question is answered, policy makers are able to explore the robustness of housing policies, and they are enabled to reflect on different scenario's and their effects. Statements can only be made about the ranges of the effects and the differences or overlap between scenarios. It is not possible to forecast the future by using the model.

## 1.3 Scope: Social Rental Market in the North Wing of the Randstad

The model concentrates on developments in *'the social rental housing market in the North Wing of the Randstad'*. The Randstad is a high-density area in the Netherlands, where economical activities are concentrated around four big cities: Amsterdam, Rotterdam, Den Haag and Utrecht. The geographical delineation is chosen because modelling the whole housing market on a sufficient detail level is not possible within the time limits for a master thesis. This is caused by the existence of overlapping, interacting regional submarkets. Modelling the whole Randstad would result in working with a meaningless average. The North Wing of the Randstad represents a high-density submarket with a scarcity of housing. The exact demarcation is based on COROP<sup>1</sup> regions. Groot-Amsterdam, Flevoland (Almere) and Utrecht are the basis of the North Wing. Also surrounding COROP regions are chosen based on location and ratio home ownership/rent sector. These ratio and the selection procedure is described in Appendix A. The selected regions are coloured red in Figure 1.



FIGURE 1: GEOGRAPHICAL DEMARICATION: NORTH-WING OF THE RANDSTAD (RED AREA).

Also a content-related delineation is made: the social rental housing market is studied. Currently, policy changes of the Cabinet concentrate mostly on this market. A social rental housing market in a housing system mainly functions as safety net for the lower income groups. The Dutch housing system has a relatively large social housing stock in relation with other housing systems in Europe

<sup>1</sup> COROP regions are part of a regional zoning system based on governance borders and are used in statistical research.

(Elsinga and Wassenberg, 2007). Also households which are financially able to purchase market housing occupy a social dwelling. This is because of the size of the Dutch social housing system transcends the number of households in the target group of social housing largely.

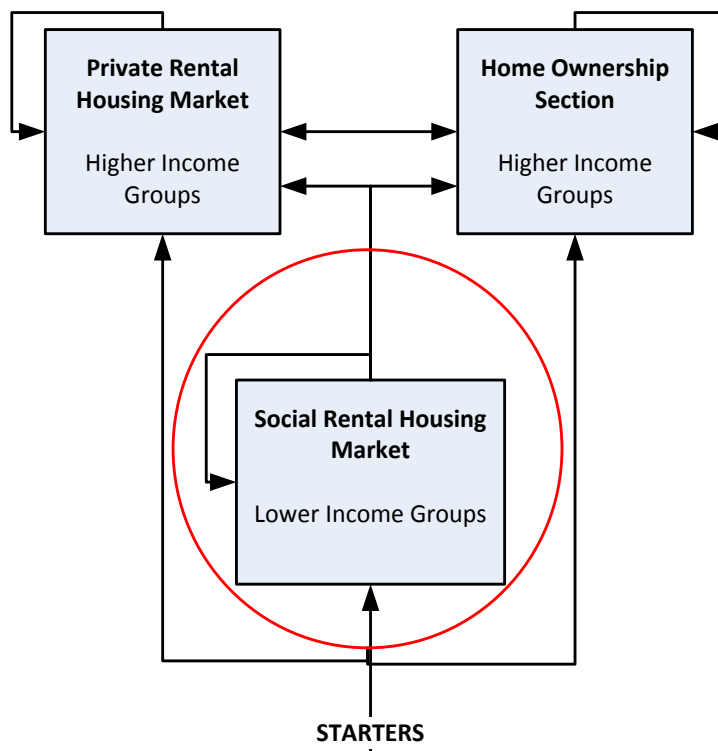


FIGURE 2: SOCIAL HOUSING MARKET (RED CIRCLE) IN THE DUTCH HOUSING SYSTEM

Figure 2 shows which part of the housing system is studied. For starters, roughly three options are available: Social rent, Market Rent, and Home Ownership sector. The policy changes concentrate on the inflow and the outflow of the social rental housing sector. The effects of the uncertainties are analysed by examining the distribution of income groups in the social housing sector. This distribution is affected by the inflow of starters and the outflow to other sectors. The distribution of income groups shows whether the current Dutch social housing sector transforms to a safety net for low income households and whether the low income households benefit from this development.

The model contains the whole housing market system, because the social rental housing market cannot be examined separately; interaction with the homeownership and market rental sector and other regional submarkets are also modelled. Assumptions for modelling these markets are made to serve the objective of the model: examination of the distribution of income groups in the social housing market.

#### 1.4 Structure of the Thesis

The thesis continues with describing the Dutch housing market (especially the social housing market in the North Wing of the Randstad) and theory about housing move behaviour. This theory chapter is followed by an explanation of the method used to answer the research question: System Dynamics. Chapter four writes down the data sources which are used as input of the model. The fifth chapter describes the model structure and principles in detail. Results of model validation and verification are



formulated in chapter 6. The most striking results of the uncertainty analyses are presented and interpreted in chapter 7. The research question is answered and also limitations and possibilities of the model are discussed in chapter 8. The thesis ends with a reflection on the outcomes in relation with the original research proposal.

## **2. The Dutch Housing System**

This chapter starts with a short description of the political discussion concerning the Dutch housing market, which is the context of the research area. After this description, the research area is explained in more detail: the social housing market, the housing allowance system and the Randstad are clarified. Section 2.3 describes the relation between institutions and moving behaviour, and also enumerates other aspects of housing moves. The insights of the first three sections are used to discuss the four policy changes from the introduction in section 2.4.

### **2.1 Dutch Housing Market**

The Dutch housing market is currently a prominent topic on the political agenda for several reasons. First of all because of the costs of all type of government regulation. Mortgage interest deduction for home-owners and housing allowances for low income households in the social rent sector weigh heavily on the finances of the government. Second reason is the current financial crisis which points the society on the weak parts of our economic system, for example the role of risky financial innovations/activities introduced by banks (Priemus, 2010a). A decline in consumer trust stopped one of the driving forces of the economic system, the housing construction market. Furthermore, high income households in subsidized dwellings and the widening financial gap between social renting and market rent/owner occupied housing lock up the housing market.

The urgent situation on the housing market provided inspiration for several parties to write overall-advice (Koninklijke Vereniging voor de Staathuishoudkunde, 2008, CSED, 2010, VROMRAAD, 2007, Commissie heroverwegingen, 2010) but these were never followed by a Cabinet in charge. A decent housing market program ought to be coalition-proof, because the execution of such a program will take longer than the existence of a Cabinet (Priemus, 2010b). The most clear reforms of the new Cabinet concentrate on the social housing market. These are discussed in section 2.4.

### **2.2 Social Housing Market in the North Wing of the Randstad**

Main characteristics of the Dutch Housing Market are a relatively (in relation with the rest of Europe) large social housing stock, an important role of private housing associations in this social housing stock (Elsinga and Wassenberg, 2007), and a large mortgage debt of home-owners (as percentage of Gross Domestic Product) (IMF, 2011). The focus of this research is on the regulation concerning the social housing stock of the North Wing of the Randstad. Subsequently the social housing market, the subsidy system and the housing market in the Randstad are discussed.

#### **2.2.1 Social Housing Market**

Housing associations are financially independent since they were financially separated of the government (after the grossing and balancing operation in 1995), however, they are still responsible for securing enough social housing for the target group of the government (indicated by housing allowances limits) and to increase livability of the communities wherein these houses are placed. Around 500 housing associations possess almost the whole social housing stock (Elsinga et al., 2008). Housing associations are admitted to the government through the BBSH (Besluit Beheer Sociale Huursector, Social Housing Management Decision); housing associations are not allowed to quit this construction. In return they receive several advantages of the government, wherefrom the most important are the different types of aid of the CFV (Centraal Fonds voor de Volkshuisvesting, Central Fund for Housing), the guaranteeing of loans by WSW (Waarborgfonds Sociale Woningbouw, Social

Housing Guarantee) or by municipalities, and the charging of lower land costs for land purchase by municipalities.

### **2.2.2 Housing Allowance System**

The rents are regulated by the government to secure affordability of the sector for the target group of social housing, low income households. The rent regulation decreases the effect of economic influences on the social housing market, because several parameters are set by the government; the home ownership sector is more sensitive for economic changes (Oort et al., 2008). The government regulates the rent levels in several ways. First, a points-system determines the maximum rent level (only applicable below the liberalization limit). Second, the government set each year the yearly rent increases for houses below the liberalisation limit. Furthermore, households receive subsidy based on household composition (type and age), income and capital.

The housing subsidy is organized as follows. First, *the basic rent level* (which everyone has to pay) is set by the government: minimal circa **€210** a month including a 'target amount' (Dutch: taakstellingsbedrag). Second, below *the quality discount level*, which is circa **€362** a month, all households receive the difference between their personal basic rent level and the quality discount level. This is also the maximum rent level for people younger than 23 years old and some other exceptions: rents transcending this level does not get any housing allowance at all. Third, *the top-off limits* are, depending on the housing composition, respectively circa **€518** and **€555** a month. The remaining households receive 75% allowance on the part between the top-off limit and the quality discount level. Fourth, *the maximal rent level* amounts to **€652** a month. Elderly and singles are compensated for 50% of the part between the maximal rent level and top-level. All households renting above the maximal rent level do not receive any housing allowance. Also households having much capital or income do not receive any housing allowance. The income limit varies from €20.325 (gross annual income) for single elderly to €29.350 for a 'more-persons' household.

### **2.2.3 Regional Housing Markets: Randstad**

The Randstad is the most developed region in the Netherlands, and of great economic value. The four biggest cities in the Randstad (Amsterdam, Rotterdam, Den Haag and Utrecht) contain almost 30% of the total housing stock; regions among these four cities are overflow areas of these four cities (Oort et al., 2008).

The Dutch housing market consists of several regional housing markets. Causes for the existence of regional housing markets are given by Oort et al. (2008): differences among regions in added economic value, in demand-supply relations and in average household income. An underlying cause for these differences could be economic activity: more economic activity boosts the productivity of a region, which delivers jobs, which attracts more households, and by the economic possibilities these households have together a higher average income.

## **2.3 Moving Behaviour**

Several actors are active on the housing market. Besides housing associations, private landlords, banks, provinces and municipalities, also *households* or *persons* have an important role on the housing market. A constant flow of housing moves in the market is indispensable. A free dwelling activates a moving chain which is ended when a starter enters a dwelling. Past half century several theories were published about the incentives of housing moves. Rossi (1955) described in his book '*Why families move*' that changes in household composition are incentives for housing moves. For

example, a single which started in a small house in the social housing sector is inclined to move after a marriage. So, households are busy to replace the current housing situation for a desired housing situation. Brown and Moore (1970) introduced a threshold model, where changes in household composition and (negative) changes in the living environment are added together till a certain point is reached, at when a household wants to move to another house, another sector or both. Also other reasons for housing moves are mentioned in literature, for example divorces and job employment (Mulder, 1996). Clark and Dieleman (1996) linked life cycles of age, household structure, job career and housing career to housing move behaviour.

Besides motives to move, also resources are needed to move, for example income and capital. These are influenced by economic cycles (Mulder and Hooimeijer, 1999). The confidence of households in the economy and the housing market is affected by the way how society perceives the effects of economic cycles. This is shown by the 'Eigen Huis Marktindicator' (Boumeester and Lamain, 2010). In the book 'Motoriek van de Economie' (Groot et al., 2004) several economic cycles are described. For modelling the economic uncertainty, two cycles can be used: the Kondratieff<sup>2</sup> cycle and the Juglar<sup>3</sup> cycle. In general there is consensus about the existence of business cycles, however they are not perceived as being predictable by repetition. Resources are also influenced by institutions (Haffner and Boumeester, 2010). Accessibility and affordability are influenced by the already explained housing subsidy system. Accessibility is also influenced by the allocation mechanism of social housing associations, which gives priority to lower income households. Mortgage interest deduction is an instrument meant to increase the affordability of houses in the home ownership sector. The relationship between regulation and income can be summarized as follows: the less income, the more housing subsidy (housing allowance in social housing sector); the more income, the more housing subsidy (mortgage interest deduction in the home ownership sector) (Priemus, 2010b).

There are different types of households searching for a suitable house. Regular movers are households which already possess a house and want to move to another house in the same or in another sector. Their housing move is less urgent than the housing move of starters, because movers have also another option: stay in the current dwelling. Meanwhile, starters have no house yet and search more actively; therefore, starters have a higher moving success than regular movers (Planbureau voor de Leefomgeving, 2008). A market under pressure of high demand is less attractive for starters, because of the perceived competition of other starters/movers (Planbureau voor de Leefomgeving, 2008). When starters are not able to find a suitable dwelling, two options are left: substitution of demand or postponement of entrance in the market (Priemus, 1984). Substitution is possible on several aspects of housing: location, sector type or housing type.

## 2.4 Institutional Developments

As already mentioned in the introduction, four policy changes are part of the institutional uncertainty in this research and are summarized below:

1. Rent increase of 5% a year for high income households (>€43.000) in the social housing sector.
2. Higher maximum rent based on scarcity of houses of a region.
3. Buy-option for renters.
4. European Directive: 90% of free stock should be allocated to low income households.

---

<sup>2</sup> The Kondratieff cycle has a duration of 45-60 years and is supercharged by radical innovations.

<sup>3</sup> The Juglar cycle has duration of 7-11 years, and is supercharged by investments in industry.

The effects of these policy changes on the distribution of income groups in the social housing sector are reasoned using the insights of section 2.2 and 2.3. The effects of the policy changes are visualized in Figure 3.

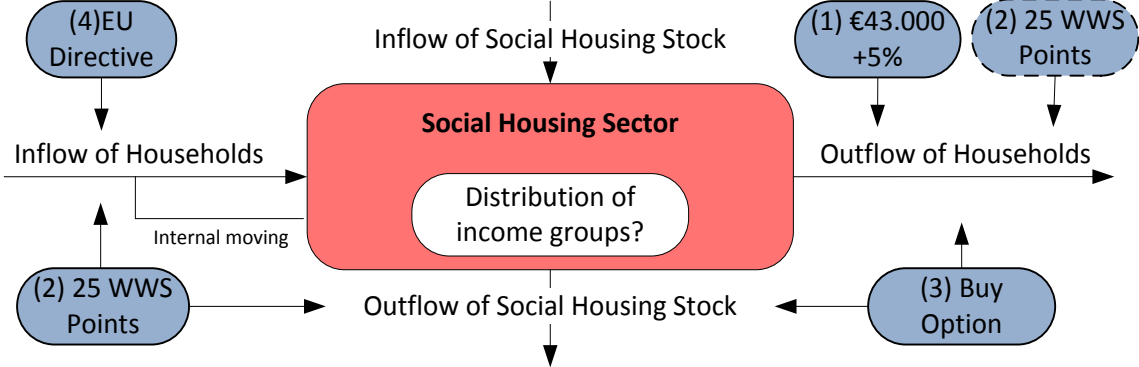


FIGURE 3: EFFECTS OF POLICY CHANGES ON SOCIAL HOUSING SECTOR

The first policy change affects the expenditure for housing of high income households in the social housing sector and intends to fill the gap between the social renting sector and market sectors. When the financial advantage of subsidized housing decreases, high income households will move more quickly to market sectors.

The second policy change, adding WWS points, gives the housing associations the possibility to increase the maximum rent. This could worsen the position of high income households when this is combined with the first policy change: a higher maximum price gives the housing associations the possibility to continue the rent increase for some more years, till the maximum rent is attained. The effect of this policy change for households which do not receive housing allowance becomes noticeable when they move from one to another house in the social housing sector, due to the harmonisation effect: changing rent price after mutation. This discourages housing moves from one to another house in the social rent sector. For starters, the effect is immediately noticeable. An increasing harmonisation effect brings rent levels to an higher segment. When the rent of a house is already close to the liberalisation limit, it is possible that the house flows into the market rent sector after mutation. So, this policy change influences the inflow of the housing stock (starters), internal moving in the social housing stock, outflow of the social housing stock (to market rent) and outflow of households (because the measure intensifies the effect of the 5% a year rent increase for high income households).

Policy change three, the buy option, influences the size of the housing stock: household and house move to another sector. A possible propensity to move to the home ownership can be fulfilled by the buy option. This also generates income for housing associations; property can be cashed. (Possible profits for housing association as the result of measure 1,2 and 3 cannot be spent on the housing market, since housing associations have to pay circa 75% of the €760 million levy on the rental housing market, till 2015). Landlords (having more than 10 dwellings) partly finance the costs of housing allowance by paying this levy to the government.

The fourth policy change is imposed by the European Commission. The privileges of private housing association discussed in section 2.2.1 are brought up for discussion: according to the EC these privileges contain state aid because social landlords also perform commercial activities (Priemus, 2006). In 2005, the European Commission asked the Netherlands to ensure that only services of general economic interest (services which have a public aim) were supported by the government in the case of social housing associations. This resulted in the directive which came into force 1 January 2011: among other measures, social landlords are obliged to allocate 90% of the free social housing stock to households having a gross annual income lower than €33.000. This affects the accessibility of the social housing stock, especially households having a gross annual income just above the limit of €33.000.

### 3. Methodology

From the desire to predict the future and to calculate the various effects of policy changes concerning the housing market several quantitative and qualitative models for the housing market are made. This is for example recently done by CPB (Centraal Plan Bureau, Central Planning Bureau)(CPB, 2010). These type of models are mostly mathematical and based on questionable assumptions, and do not contain uncertainties. Many uncertainties, for example housing move wishes of households, economic development and changing household demographics, cannot be totally covered by these models. The methodology 'System Dynamics' is able to insert uncertainty ranges for parameters in a model.

In this research, a system dynamics model is developed including uncertainty structures. Next, the effects of the uncertainty structures are researched separately and combined. This chapter starts with an introduction of uncertainty (3.1), followed by an explanation about SD models (3.2). Then, several options to model uncertainty are discussed (3.3) and the risk assessment technique used to analyse the uncertainty ranges of scenarios is clarified (3.4). When this is explained, the methodology choice is substantiated in section 3.5. Last, section 3.6 writes down some recent SD models concerning the Dutch Housing Market.

#### 3.1 Uncertainty

Among others, Delft University of Technology and RAND<sup>4</sup> are working on applications of the EMA (Exploratory Modelling and Analysis) theory. One of these applications is to use a System Dynamics model as 'exploratory model'. Examples of combinations of SD and EMA (which combined becomes ESDMA) are developed by Pruyt and Hamarat (2010a, 2010b). *Exploratory Modelling and Analysis* emphasizes the presence of deep uncertainty: "that is where analysts do not know, or the parties to a decision cannot agree on, (1) the appropriate conceptual models that describe the relationships among the key driving forces that will shape the long-term future, (2) the probability distributions used to represent uncertainty about key variables and parameters in the mathematical representations of these conceptual models, and/or (3) how to value the desirability of alternative outcomes" (Lemmert et al., 2003). Deep uncertainty cannot be modelled objectively or without guessing. When building a detailed model, decisions are made on uncertain structures or uncertain parameter values. Instead of building such a model, the first step is to build an 'explorative model'. This model should be validated and verified having the objective of the model in mind: explore system behaviour by producing thousands runs for different scenarios, by running the model with a range of parameter values (uncertainty range) or even with different model structures. It is not possible to link detailed probability statements to behaviour plots, only ranges (minimum, average and maximum) and difference in behaviour patterns can be discussed. Behaviour is assessed qualitatively, not quantitatively. Techniques like full factorial design, Latin Hypercube Sampling and Monte Carlo Analysis can be used for both activities. In this research, SD is more dominant than EMA. However, several principles are used for model building: uncertainty structures and the analysis of uncertainty ranges.

#### 3.2 System Dynamics Modelling Technique

The System Dynamics methodology is initiated by J.W. Forrester. In his article 'The Beginning of System Dynamics' (1989) he describes how initial knowledge on electric systems led to a wide

---

<sup>4</sup> contraction of **R**esearch **a**nd **D**evelopment

applied methodology. The application of system dynamics in the field of urban research was also initiated by Forrester, by publishing 'Urban Dynamics' (Forrester, 1969). After publication of this book, Forrester got many negative reactions because he wrote that the policy of creating low-cost housing created more poverty in the United States of America. So, system dynamics is able to expose possible negative effects of policy changes. However, concerned parties do not always agree with the outcomes of a model.

An important assumption of System Dynamics is that the structure of a system is responsible for the behaviour of the system. A structure of a system consists of institutions, actors, relations among actors and strategic behaviour of all these actors. The system under research is translated to a system dynamics model. Four important building blocks of System Dynamics will be explained in the next four sections: feedback loops, stock-flow structures, delays and graph functions.

**3.2.1 Feedback Loops**

A system can be described by a feedback loop scheme of the system. A feedback loop is a chain of relations between two or more variables. In a feedback loop with 3 connected variables the first variable directly influences the second variable (positive or negative), the second variable directly influences the third variable and the third again the first variable. Figure 4 visualizes a simple feedback loop scheme concerning the topic of this thesis. This is just a simple example and has no connection with the final model.

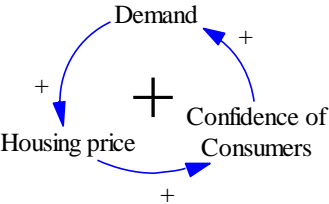


FIGURE 4: POSITIVE FEEDBACK LOOP

More demand causes higher prices. Increasing prices stimulate the confidence of consumers to invest in a dwelling, because of the expected value development. This results in more demand, and so on. This is an example of a positive feedback loop. By changing one variable, the feedback loop can become negative (Figure 5).

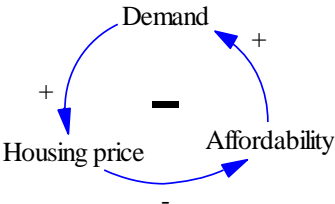


FIGURE 5: NEGATIVE FEEDBACK LOOP

Higher housing prices have a negative effect on the affordability of housing of low income households. Demand of low income households to housing is negatively influenced, which has a negative effect on the housing price. Combined feedback loops produce different types of behaviour. For example, oscillatory behaviour is produced by a negative feedback loop and delay(s) (Daalen et al., 2007).



### 3.2.2 Stock-flow Diagrams

Feedback loops can be translated to a stock-flow diagram. A stock-flow diagram consists of stocks, in- and outflows, auxiliary variables, constants and causal relationships between these variables (expressed in formulas). For example, a housing stock shows the amount of houses in an area. Inflow of this stock is newly built housing, outflow is demolished housing.

Figure 6 (left) shows how such a structure is displayed in Powersim<sup>5</sup>. This is also just a simple example and has no connection with the final model.

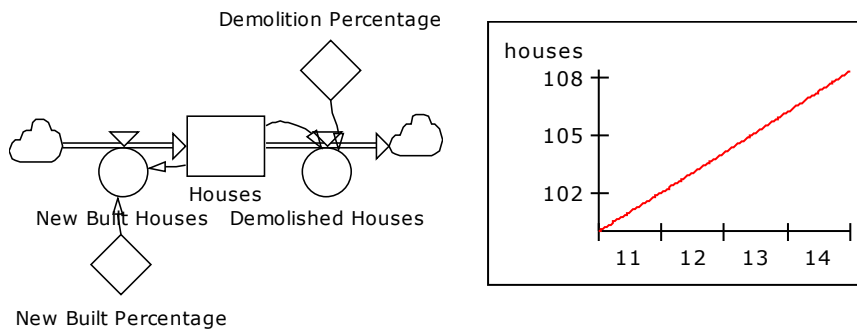


FIGURE 6: EXAMPLE STOCK FLOW DIAGRAM (LEFT) AND GRAPH OF THE STOCK 'HOUSES' (RIGHT)

The new built percentage is a constant (diamond), 5%/year. The inflow (left circle) is equal to the housing stock (rectangle) multiplied by the new built percentage. The same structure is used for demolition of houses, however the demolition percentage amounts to only 3% a year. A stock is the integral of the difference between incoming and outgoing flows. Mathematical, a SD model could be seen as a collection of integrals or differential equations (Pruyt, 2010). In the example, the inflow of the housing stock is higher than the outflow, so the total stock increases (Figure 6, right).

### 3.2.3 Delays

Delays occur when an effect is not 'effective' immediately. There are several delay orders. This is visualized by Figure 7.

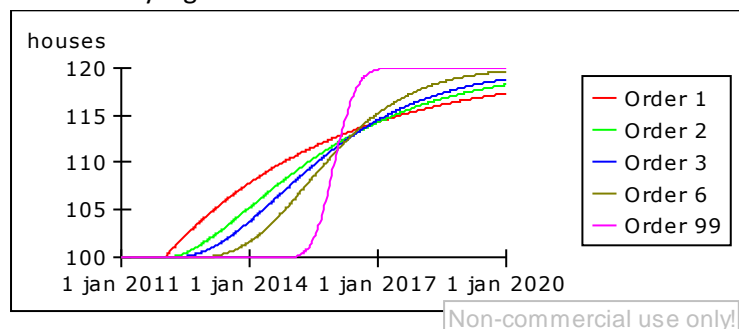


FIGURE 7: SEVERAL DELAY TYPES

Continuing the simple example of paragraph 3.2.2, the housing stock amounts to 100 houses initially. In 2012, 20 extra houses are planned to be added to the housing stock. The delay of this addition is four years. This is modelled by using a delayed step function. Several delay orders are used to show the difference between them. The red line is a first order delay which has a logarithmic form. The other delays have different type of S-Shape forms. Building a house always needs a minimum amount of time (planning and construction time), circa 3 year. By using delay order 1, 2, or

<sup>5</sup> Powersim is a software tool which can be used to construct SD-models.

3 houses are finished before this minimum time, so a higher order demand is more suitable in this case.

### 3.2.4 Graph Function

A graph function or a look-up function can be used to model non-linear causal relations between variables. The x-axis is the input variable; the y-axis displays the effects corresponding to the values of the input variable. An example of such graph function is shown in Figure 8. This graph function is not used in the final model.

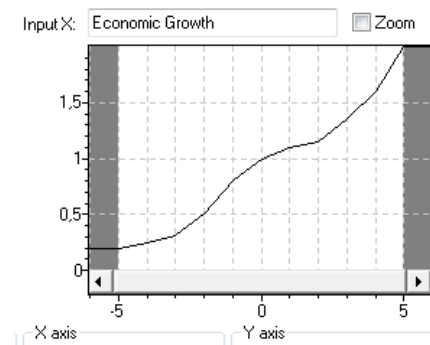


FIGURE 8: GRAPH FUNCTION: EFFECT OF ECONOMIC GROWTH ON CONFIDENCE

This graph function shows the effect of economic growth on confidence of households. The output of the graph is a multiplier between 0 and 2, which is multiplied with the basis confidence of households in economy. The economic growth is between min 5 percent and plus 5 percent. Negative Economic growth leads to less confidence of households in the economy, positive economic growth has a positive effect on the confidence level. For each input (x-axis) the graph function matches the corresponding effect (y-axis) on the confidence level.

## 3.3 Uncertainty Structures

There are many ways to model uncertainty. The ways used in this research can be categorized in four groups: parameter, function, structure, and scenario uncertainty.

### 3.3.1 Parameter Uncertainty

This is the most simple way to model uncertainty. For each model run, a value is taken from an uncertainty range. For example, the uncertainty range of housing move delay is 1-3 months. During run 1, the housing move delay is 1.3 months, run 2 delivers a delay of 2.8 months and the third run the delay amounts to 2.5 months.

It is also possible to vary the strength of the effect of a development in one run. For example, the number of marriages grows exponentially, but not smoothly. A random randomizer is used which multiplies the effect (the trend) with a continuously changing value between for example 0.9 and 1.1. A random randomizer takes each time step a random number from a range constructed by a random minimum and a random maximum (see formula below). The result of the function below is shown in Figure 9.

RANDOM (Lowest value; Highest value) -> RANDOM(RANDOM(0.9;1);RANDOM(1;1.1))

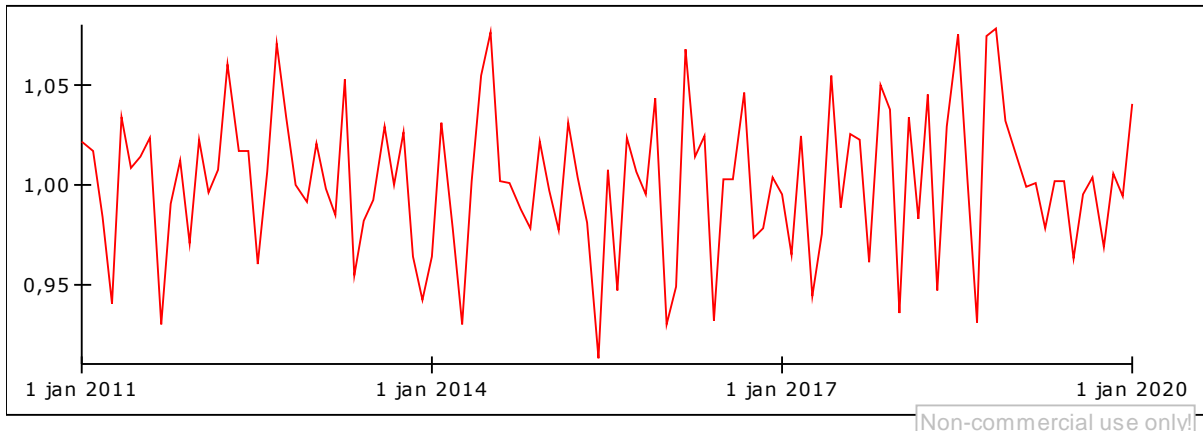


FIGURE 9: OUTPUT OF A RANDOM RANDOMZIER

### 3.3.2 Function Uncertainty

A graph function can be used to model the effect of one variable on another one. Instead of a graph function also a mathematical function can be used. By varying the parameters of a function, it is possible to use different functions for separate simulation runs. Function uncertainty can be used for generating different types of S-Shapes. This type of function is chosen because of its suitability to differ its form, and because it is possible to keep the effect in predetermined borders: an S-Shape has a maximum and a minimum (asymptotes). These maximum and minimums can be used to keep the effect realistic.

The formula of an S-Shape (among others) is:

$$1/1 + e^{(SShapeDirectionAndSlope * (InputVariable))} / StrengthEffect + 1 - (0,5 * (1 / StrengthEffect))$$

Without the last part (where 'StrengthEffect' is involved), an S-Shape from 0 to 1 would be produced. When the outcome of the function is used as multiplier, the S-Shape should move above and below one (positive and negative effect). By adding 0.5 to the function, an S-Shape from 0.5-1.5 is produced. By dividing the total function by 2, an S-Shape from 0 to 0.5 is produced. An addition of 0.75 to the function is needed to have a course around 1 (0.75-1.25). By varying 'SShapeDirectionAndSlope' the direction and slope of the S-Shape can be varied. Three possible variations are shown in Figure 10.

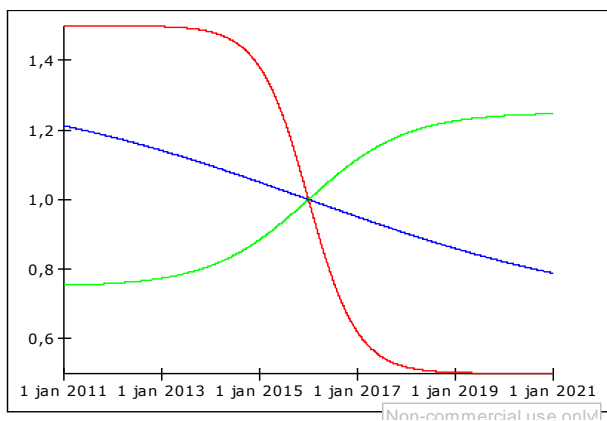


FIGURE 10: DIFFERENT FORMS OF S-SHAPES

### 3.3.4 Structure and Scenario Uncertainty

Structure and scenario uncertainty are integrated in the scenario building process in this research. Structures, for example structures which determine the size of the effect of a policy change on model variable, are switched on or off dependent on the content of the scenario.

### 3.4 Risk Assessment: Latin Hypercube Simulation

Latin Hypercube Simulation, founded by McKay (1979), is used to equally cover the uncertainty space of  $x$  combined parameters over the number of runs of the risk assessment. When the values are chosen randomly, it is possible that the uncertainty space is not equally covered. This method is used during the risk assessment of the modelling software, Powersim. The risk assessment consists of a number of runs. When the graphs of these runs are calculated, the program calculates several aggregates: 95%, 90%, 75%, 50%, 25%, 10% and 5%. For example, the graph of the 75% aggregate indicates that 75% of the runs were below this graph. Besides percentages, also the average, highest and lowest run is displayed. An example is given in Figure 11.

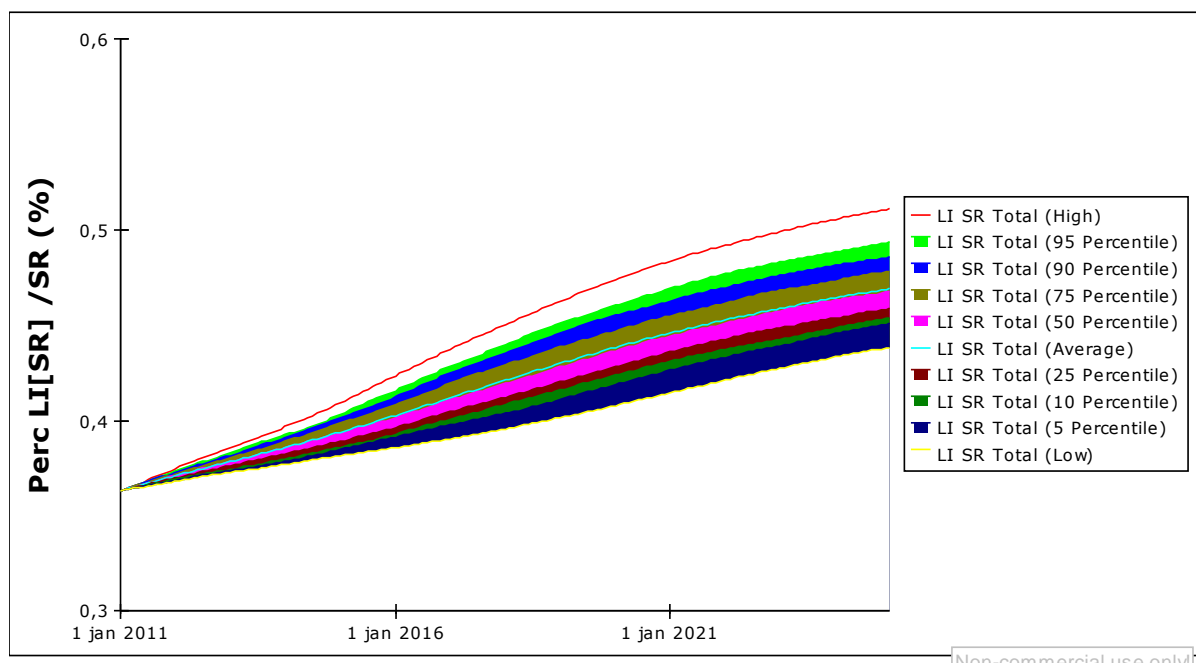


FIGURE 11: OUTPUT OF RISK ASSESSMENT

This graph shows the possible outcomes of the percentage of low income households in the social housing market. The graph is created by performing a Latin Hypercube Analysis of 250 runs.

### 3.5 Suitability of SD for Answering Research Question

Instead of the just described methodology, the research question could also be answered by constructing an agent-based model, a statistical model, or literature research. However, the housing market seems to be well-suited to capture in an SD-model: it is a complex system with many delays and uncertainties influencing the housing move behaviour of households. In other words: *delays* and *uncertainties* influence the *inflows* and *outflows* of housing *stocks*. These cursive terms are covered in the described methodology: SD is a well-suited method which uses stock-flow diagrams, delays, but also uncertainties. By using scenarios the uncertainty space is explored in an efficient way. This should not restrict the research to obvious scenarios by ignoring the seemingly impossible scenarios, these are just as interesting.

There are also some restrictions to the application of models to this kind of research questions. Firstly, a model is always wrong, it is always a simplification of reality. The complexity of the model is limited by the modelling skills of the modeller, which are always less complex than the real world complexity. Secondly, the model is influenced by the modellers' interpretation of the system. Therefore it is important to list all the assumptions made in the modelling process. The model in this research tries to contain few assumptions with a value judgement, and tries to only make assumptions to simplify reality. Third, a model should only be made to serve problem solving and policy making in reality. A model without reflection on reality is a life on its own, wherein nobody (except the modeller) is interested.

### 3.6 SD Models Dutch Housing Market

In the Netherlands, various projects are known where System Dynamics Methodology (also in combination with Group Model Building) is applied to the Dutch Housing Market. Eskinasi, Rouwette and Vennix (Eskinasi et al., 2009) did this for a regional social housing market, focusing on the aspects of urban renewal. One of these writers, Eskinasi, is working on a simulation model of the Dutch Housing Market. His model, called Houdini, concentrates on the effects of different actors on the housing stock development. Another project was a collaboration between the consultancy group Significant and the Ministry of Housing, Spatial Planning and Environment. For various reasons this project ended after the first phase wherein a reasoning model (without quantification) was developed with a group of stakeholders.

Recently, two students from the faculty Technology Policy and Management (TU Delft) developed a model (Varga, 2010, Huisman, 2009). Varga researched the influence of government policies on population composition in 'Aandachtswijken' (neighbourhoods which needs extra attention of the government). Huisman emphasized also low scale developments, by examining policies which fight neighbourhoods deterioration.

None of these studies contained a detailed supply/demand model, which is able to show effects on the distribution of income groups over different housing sectors and markets. The uncertainty aspect is not as strongly represented in recent modelling efforts as it is in this research. It can be concluded that this research has an added value to the current SD modelling efforts concerning the Dutch housing market.

## 4. Data

According to Forrester (1980), different types of data can be used in a System Dynamics model: mental data (from observation of the modeller or of an expert), written data (articles, books), and numerical data. The relation between these types of data is visualized by a funnel (Figure 12): down the funnel, the information becomes less informative, i.e. it is not possible to question the data source. All types of data are used for the model.

*Mental data* is gathered during project meetings with the supervisors: both the first supervisor and the graduation professor are specialists on issues concerning the Dutch Housing Market. Also the input of the policy maker, an employee of the Ministry of Intern Affairs, department Housing, Neighbourhoods and Integration, is used in the model. This information is, together with *written data* from articles and books, used to build the structure of the model, and for making the assumptions in the model.

Two data sources are used for retrieving *numerical data* of the housing market: WoON 2009<sup>6</sup> and CBS. WoON 2009 is used to collect demand, current housing allocation, affordability and other variables specified to type household, type income, type sector for a specific geographical demarcation. However, WoON 2009 is a snapshot of housing move propensities in a period which is influenced by the former political and economic situation. The model uses this data as starting point.

CBS Databank is used as input for demographic variables like marriages and divorces a year. This data is used as input for the simplified theory of household life cycles. Only the official ways to cohabit are registered: partnership registration and marriages. In the model, other ways are not included. First because of the lack of data, second because these types of living together are perceived being more volatile, and has a limited influence on the model.

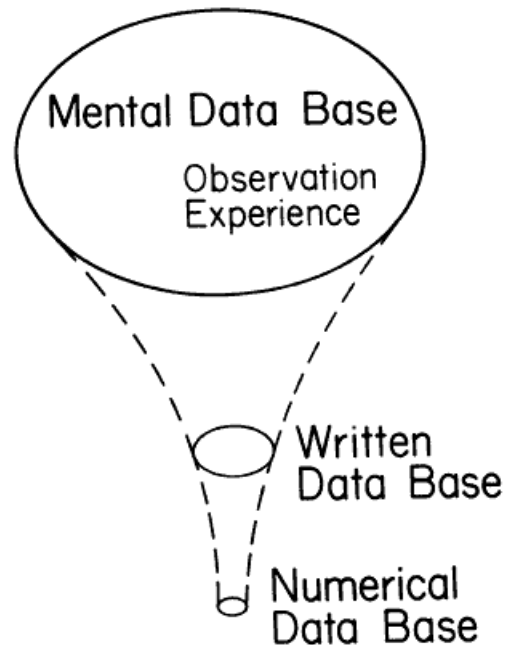


FIGURE 12 :DATA FUNNEL (SOURCE: FORRESTER(1980))

---

<sup>6</sup> WoON (WoonOnderzoek Nederland, Dutch Housing Research) is commissioned by the Ministry each 3- 4 years. The main goal of this research is to collect statistical information about the current, previous and desired housing situation of households.

## 5. Model Description

The model description is divided in three parts. First, the modelling choices are explained. Then, different types of moving and the corresponding general elements in the model are discussed. This is followed by the general structure (conceptualisation of the housing market) of the system dynamics model. Furthermore, the uncertainty structures and their effects on the model are described in detail. The chapter ends with a description of the start situation of the model.

### 5.1 Modelling Choices

Chapter 2 (The Dutch Housing System) provides enough elements to choose from for constructing a model:

- Persons (education level, gender, age,...)
- Households (single, senior single, single and child(ren), Pair,...)
- Incomes (low, high, modal,...)
- Sectors (owner occupied, private rent, social rent, below liberalisation limit, above....)
- Housing environments (urban, rural)
- Housing markets (regional)
- Housing moves (Leavers, starters, movers, students, urgent, not-urgent...)

During the project, the model gradually evolved to the current state. The first model contained three sectors (social rent, market rent and home-ownership), wherefrom only social rent was specified into four income groups. The second model contained four household types, four income groups and three sectors, the final model added one household type and two sectors.

Housing moves are caused by a fixed percentage (which can be influenced by uncertainties), but is not generated by factors like housing satisfaction, job career, household development, etcetera. This is done indirectly, by making a snapshot of WoON 2009 concerning housing move wishes specified to household type, income and sector. When a household changes in composition or in income level, it receives a housing move propensity corresponding to the new characteristics of the household.

### 5.2 General Elements of the Model

Three ingredients were chosen from the list above: Household types (5), Sectors (5) and Income groups (4). The classification in household, income and sector gives the possibility to specify the effects of several uncertainties to a sector or income group in a sector. There are in total  $5*4*5 = 100$  household stocks. Among these stocks, all kind of flows continuously reallocate households. Households are reallocated by changes in household composition, by income development of a household and by housing moves from one to another sector. These three type of moving in the model are discussed in the next three sections.

#### 5.2.1 Moving by Change in Household Composition

Household types are chosen because of the influence of the household life cycle on housing move wishes. Households are favoured above persons, because households are exchangeable with houses (a household lives in a house, a house is occupied by a household). Also household development can be used to specify the effects of demographic uncertainty. Table 1 shows the five different household types which are present in the model.

TABLE 1: MODEL NAMES OF HOUSEHOLD TYPES AND DESCRIPTION

Household Type	Description
<b>T1 (Type 1)</b>	Singles age <65 year old, also singles with children are included in this group
<b>T2</b>	Pair without children, age head resident < 65 year
<b>T3</b>	Pair with children, age head resident < 65 year
<b>T4</b>	Single >65 year
<b>T5</b>	Senior pair, head resident > 65 year

Only the most important household transformations are modelled, these are shown in Figure 13.

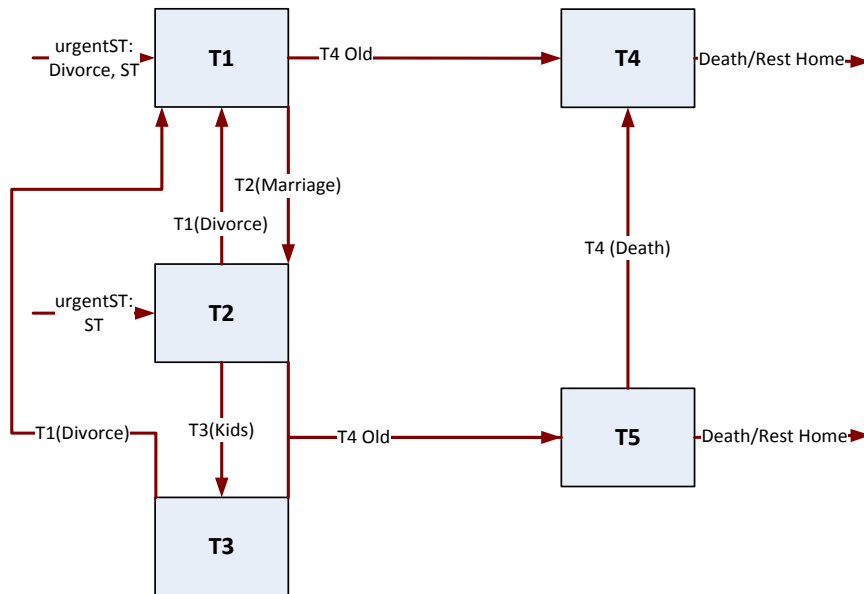


FIGURE 13: MOVING BY CHANGE IN HOUSEHOLD DEVELOPMENT

Several life cycle assumptions are made *to simplify* the life cycle of households:

- Seniors (T4 and T5) do not marry or divorce.
- 'Young' households (T1, T2 and T3) do not die.
- Only singles with the same income and from the same sector marry.
- After a divorce, the person with the highest income stays in the house.
- There is no movement from T3 to T2: It is assumed that when all kids are gone, the parents are more or less senior.
- After a certain time-period a young household become a senior household. For T1 this period amounts to 45 years, for T2 40 years and for T3 35 years.

More detailed information about household transformations is given in Appendix C.

Starters form a special group in the model, because they do not belong to a sector before entering the housing market. After their first housing move they belong to household type T1 or T2.

### 5.1.2 Moving by Change in Income

Income groups are chosen because the current and the expected regulation clearly focus on income groups: the EU-Directive provides a €33.000 limit, the Cabinet rule to stimulate high incomes to leave the social housing market gives a €43.000 limit, and current housing allowance regulation delivers limits dependent on household type. Income groups are indispensable because the research question emphasizes the distribution of incomes in the social housing sector.



There are four classes of income which are explained in Table 2. The values assigned to the limits of the income groups seem to be not familiar to the values from policy changes. This is because of a correction from taxable income 2011 to gross income 2009 (the dataset is from 2009).

TABLE 2: MODEL NAMES OF INCOME TYPES AND DESCRIPTION

Income Type	Description
<b>LI</b>	Low income, from negative to housing allowance limit(0-20.000/27.000). T1/T4 (singles) have 20.000 as limit, other household types have 27.000 as limit.
<b>MLI</b>	Middle Low income, from housing allowance limit to EC Directive limit (20.000/27.000-30000)
<b>MHI</b>	Middle High income, from inflow frontier till Cabinet rule frontier (30000-40000).
<b>HI</b>	High income, from Cabinet rule frontier till end (40000 - ∞).

Assumed is that households earn more money over time. Otherwise, the income of households should become after a long time period equally to the income distribution of starters. It is assumed that 1% of LI goes to MLI, 1% of MLI to MHI and 1% of MHI to HI each year for all household types and sectors, excluding senior households.

Incomes are also redistributed by household development, which is clarified in Appendix B. The income of a household determines the number of houses financially feasible for the household. The following assumptions for affordability are made, after consulting several internet calculators: a household receives a mortgage of maximum 4,5 \* its yearly gross income<sup>7</sup> and a household can rent a dwelling when its monthly income is 4 times the monthly rent of a dwelling<sup>8</sup>. To compute the affordability, each time the upper limit of the income group is chosen. This results in the following affordability limits: €70.000 (singles)/€121.500 (pairs), €135.000 and €180.000 (Home Ownership sector), and €650, €833 (market rent sector). Table 3 shows the affordable range of housing for each type of income, for both the home ownership and the market rent sector..

TABLE 3: HOUSEHOLD INCOMES AND AFFORDABLE HOUSING STOCK

Income group/Sector	Home Ownership	Market Rent
<b>LI (Low income)</b>	€0-€70.000/€121.500	-
<b>MLI (Middle low income)</b>	€70.00/€121.500-€135.000	-
<b>MHI (Middle high income)</b>	€135.000-€180.000	€650-€833
<b>HI (High income)</b>	€180.000+	€833+

### 5.1.3 Moving by Change in Housing Sector

The last element, sector, is indispensable in a housing market model: the social housing sector is researched, so it should be possible to analyse this sector within the model. The different sectors also contain different dynamics. Market sectors are more sensitive for economic changes than social rental housing. Table 4 describes the different sectors which are present in the model.

<sup>7</sup> Examples of mortgage calculators: <http://www.berekenhet.nl/hypotheek/maximale-hypotheek-berekenen.html>; [http://www.rabobank.nl/particulieren/producten/hypotheken/bereken\\_uw\\_maximale\\_hypotheekbedrag](http://www.rabobank.nl/particulieren/producten/hypotheken/bereken_uw_maximale_hypotheekbedrag)

<sup>8</sup> Example of maximum rent calculators: <http://www.vesteda.com/nl/particuliere-verhuur/goed-om-te-weten/bereken-maximale-huur.aspx>.  
[https://www.rabowoonlastencalculator.nl/pages.php/woonlasten\\_huur.html?pid=238&fid=61](https://www.rabowoonlastencalculator.nl/pages.php/woonlasten_huur.html?pid=238&fid=61)

TABLE 4 MODEL NAMES OF SECTORS AND DESCRIPTION

Sector	Description
SRL	Social Rent Liberalisation limit, all rental houses with a gross rent above the top limit and below the liberalisation limit (€550-€650 a year).
SRT	Social Rent Top-limit, all rental houses with a gross rent above the quality limit and below the top limit (€350-€550 a year).
SRQ	Social Rent Quality limit, all rental houses with a gross rent above the minimum rent level and below the quality limit (€200-€350 a year).
MR	Market Rent Sector, all rental houses with a gross rent above the liberalisation limit.
HO	Home Ownership Sector.

Distinction in the rental housing market is made based on rent price and not based on landlord (social housing association or private), because this is exactly the same limit for application of rent regulation. Also, private tenants are bound to municipal arrangements which rule that housing below the liberalisation limit should be allocated to lower income groups.

The model simulates movements among sectors. These movements are indicated by the blue arrows in Figure 14. 'Lux' means that the movement is a luxury movement instead of an urgent movement (movers versus starters). This movement can be from the research area to outside the research area, vice versa, and within the research area. Tenants are able to buy the house of their landlord (Buy HO).

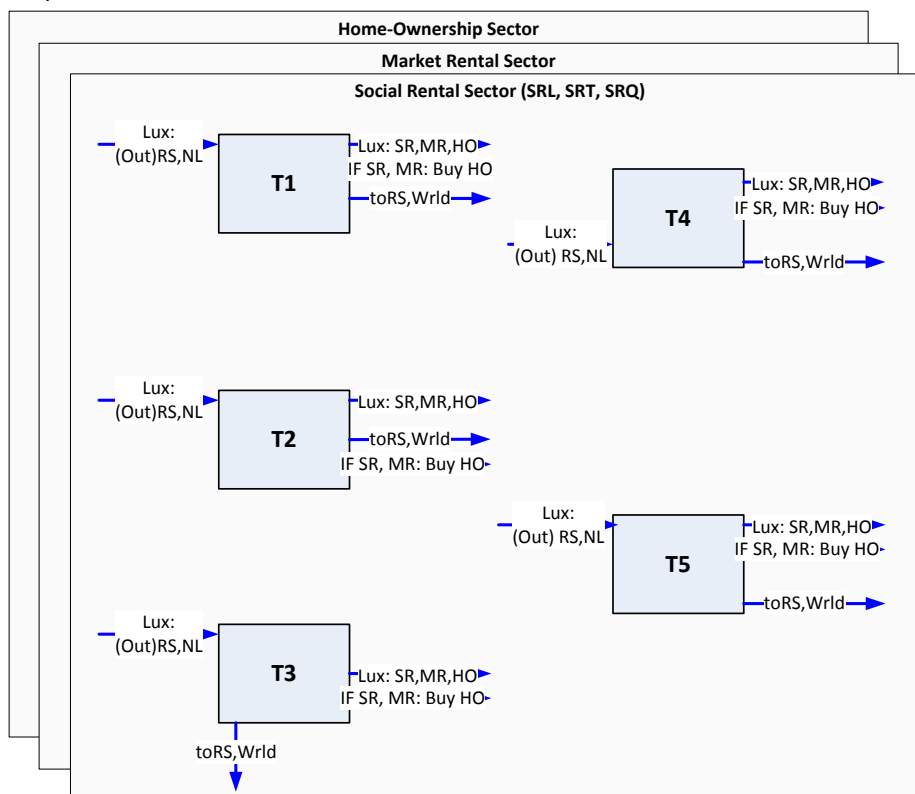


FIGURE 14: HOUSING MOVES TO ANOTHER SECTOR/REGION

Section 5.2 is summarized in Figure 15. This figure shows moves by changes in household composition (red links), by income development (green links), and by housing move to another sector (blue links).



in the feedback loop structure are followed by [...]. '[E]' means 'influenced by economic uncertainty', '[I]' means 'influenced by institutional uncertainty' and '[D]' means 'influenced by demographic uncertainty'.

Dynamics in the housing market is caused by differences among sectors. There are differences between *Transactions Rates* and *Disappointment Rates*. Also the ratio supply/demand differs for each sector and income group.

Several elements of this scheme will be discussed subsequently: demand, supply and feedback loop new built supply, feedback loop starter substitution, transaction rate, feedback Loop disappointed households, and the influences of uncertainties.

### **5.3.1 Demand**

The model uses aggregates to simulate the housing moves on the housing market. It is not possible to trace back the activity of a particular household. All households are divided into 100 groups: 5 household types, 4 income groups and 5 housing sector. Each possible combination has its own propensity to move. These 100 possible combinations represent households possessing a house in the North Wing of the Randstad. Other household groups acting on the housing market of the North Wing of the Randstad are movers from outside the North Wing of the Randstad and starters. The *Propensities to Move* of all these groups is calculated from data of WoON 2009, both qualitative (to which sector) and quantitative (percentage). Households which want to move flow into the demand stock of their desired sector. The start values of all these demand stocks is calculated from WoON, by analysing the households which answered the question 'do you want to move within 2 years?' positively. The absolute start values are translated to a percentage and multiplied with 0,5 (from 2 years to 1 year) to calculate the yearly inflows of the demand stocks. These propensities to move are limited by the accessibility of sectors for income groups. For example, the European Directive causes an accessibility of 0% of the social housing sector for high income groups.

### **5.3.2 Supply and Feedback Loop Newly Built Houses**

The start values of the supplies are based on a friction percentage (1,5-2%), which is needed to keep housing move dynamics in a housing market. It is assumed that each year 30.000 houses are added to the housing stocks in the North Wing. The amount of demands for a sector determines in which sector the building activities concentrate. All demands to all sectors are summed up, then demands to one sector is divided by this summation. This delivers a percentage which is multiplied by the 30.000 houses a year. The result of this calculation is added to the concerning housing stock in one year. So, when the *Demand* increases, the *New Built Supply* increases (delayed because of building time). More supply results in a higher *Supply/Demand Ratio*, which attract more switching starters which causes increasing demand. However, the extra supply causes also more housing moves which decreases the demand. *Ceteris paribus*, this feedback loop is positive.

When a household buys the house of the landlord, it moves to another sector while keeping the same house. This movement occurs simultaneously in the housing stock model, because the household *and* the house switch from sector.

### **5.3.3 Feedback Loop Starter Substitution**

*Ratio Supply / Demand* is the centre of the feedback loop scheme. This ratio is calculated by dividing the total *Supply* of a sector, affordable for a specific income group, by the total *Demand* of all income groups to this supply. When a specific sector has a relatively (in relation with other sectors) low ratio

supply/demand, starters substitute their first choice sector for the more accessible sector. This is because starters are urgent movers on the housing market. Contrary to movers, they are less bound to a specific sector. Moreover, starters are entrants on the housing market, and are therefore more flexible. The substitution is delayed, because it takes time for starters to experience the difference in pressures among sectors. So, a higher *Ratio supply/demand* results in more *Starter Sector Substitution*, which increases the *Demand to the original sector*, which decreases the Ratio Supply / Demand.

The comparison between sectors is modelled as follows: Ratios are divided by each other, as in the formula below.

$$\frac{\sum_{i=2}^5 \frac{Supply\_Sector\_i}{Demand\_Sector\_i}}{\sum_{i=2}^5 \frac{Supply\_Sector\_1}{Demand\_Sector\_1}} = \sum_{i=2}^5 \frac{Ratio\_Sector\_i}{Ratio\_Sector\_1}$$

From the perspective of for example Sector 1, the ratio supply/demand should be compared with the ratios of sector 2-5. Dependent of the outcome of the divisions, a graph function determines the amount of starters that switch. The formula below shows how the amount of switching starters for sector 1 is calculated.

$$\frac{\sum_{i=2}^5 Ratio\_Sector\_i}{Ratio\_Sector\_1} * GraphFunction [\%] * Demand\_Sector\_1 [houses] * SwitchDelay [yr] * SwitchPercentage [\%]$$

When the outcome of the division of ratios is equal or smaller than 1, no substitution occurs. The graph function can be logarithmic or exponential, the switch delay and switch percentage is also uncertain. These two types of graph functions are chosen because the relation between availability of housing in a sector and substitution behaviour is uncertain.

### 5.3.3 Transaction Rate

The model uses aggregates, so it is not possible to simulate moving chains. Instead, a transaction rate determines the size of the share of the total supply which is allocated to households in the demand stocks. When in a specific month *Supply* equals 50.000 houses and the *Transaction Rate* amounts to 10%, then 5000 transactions are made in that month. The transaction rate is influenced, dependent of which sector, by the economic situation and by the ratio supply/demand. When the ratio is high, i.e. there is more choice for households, the transaction rate is lower: households become more selective waiting for finding their dream house. In another situation, when the ratio is low, households are more willing to accept a dwelling, also when the dwelling does not meet all requirements. For urgent movers, for example starters or just divorced households, the transaction rate is higher: higher urgency results in higher acceptance. Also the transaction rates of market sectors are lower than the transaction rates of the social sector, because of the allocation mechanism of the social sector.

### 5.3.4 Feedback Loop Disappointed Households

Demand decreases by the total demand divided by a disappointment time each year. When in a specific year the total demand is 40.000 houses, and the disappointment time amounts to 4 years,

then 10.000 (=40.000/4) houses leave the demand stock that year. For starters and social dwelling demand this is the only way of decreasing demand besides housing moves. For market sectors, (market rent and home ownership), the amount of potential movers also decreases by  $(1 - \text{Transaction Rate}) * \text{Supply} * \text{'Effect of Ratio'}$ . This is modelled to represent the disappointed movers due to few supply (not in the right region, sector, etc.). This amount of extra disappointed movers is influenced by the ratio supply/demand. In a low-pressure market (high ratio), no potential movers will stop searching, having trust to find the right dwelling. In a high-pressure market (low ratio), potential movers are earlier disappointed and discouraged by high competition of other potential movers.

### **5.3.5 Influence of Uncertainties**

Economical, demographic and institutional uncertainties influence several variables of the housing move structure.

Institutional uncertainties are caused by the policy changes described in section 2.4. First, the European Directive causes a shift in demand by limiting the accessibility of the social housing sector: (middle) high income households cannot move to the social housing sector anymore. It is unknown which percentage of the original demand to social housing will switch to market rent. Second, the rent increase for high income households has an uncertain influence on the propensity to move of high income households in the social sector towards the market sector (market rent or owner occupied). Third, adding WWS points influence the intern social housing moves in an uncertain way. Due to harmonization effects (rent increase after mutation), a significant price difference causes a financial threshold to move within the social housing sector. Also rent levels will flow to a higher segment due to the harmonization effects. Last, a buy-option for tenants will increase the number of successful housing sales to renters.

Demographic uncertainties are modelled as an exponential function having a varying direction (positive or negative). The demographic development follows the trend capriciously. Demographic uncertainties influence the number of households (by divorces, marriages, births, deaths etc.) and thereby the demand to different sectors.

Economy is modelled by totalling up two sinuses, which represent two economic waves (Kondratieff and Juglar) and a trend of 2-3% growth. It is also assumed, as simplification, that the variables housing price, interest, inflation and income follow the economy with different delays, delay types and amplitudes. These variables are used to calculate effects on among others affordability, propensities to move, attractiveness of sectors and number of houses added to the housing stocks.

## **5.4 Detailed Description of Uncertainty Structures**

Uncertainties are modelled for three themes: Institutions, Economics and Demographics. How these uncertainties are modelled, i.e. how the uncertainty is represented in the model, and in which way these uncertainties influence model variables is described in the next three sections.

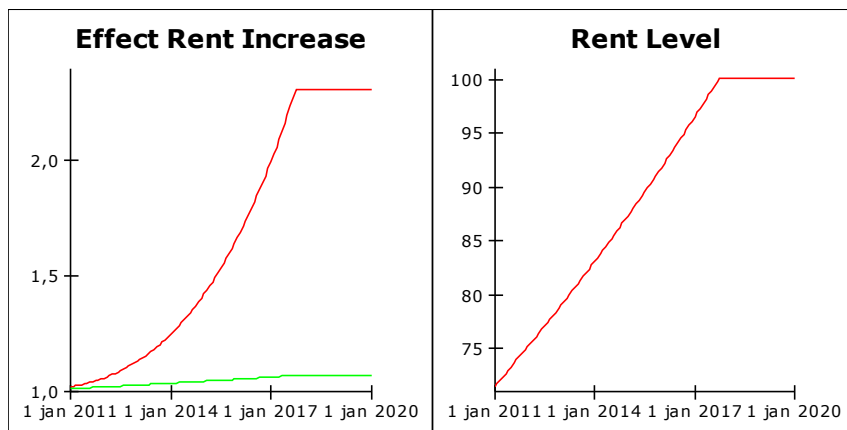
### **5.4.1 Institutional Uncertainties**

The policy changes described in Section 2.4 are implemented in the model. These are described subsequently.

#### *5.4.1.1 Rent Increase High Incomes*

The *Rent Level* is expressed as a percentage of the maximum rent level. According to the data of WoON 2009, the *Start Rent Level* of high income households in the North Wing of the Randstad amounts to circa 71.5% of the maximum rent price. Each year, the *Rent Level* increase is equal to the

*Price Increase* multiplied by the current *Rent Level*. So the absolute increase is higher in 2014 than in 2013. This inflow remains till the *Maximum Rent Level* is achieved. The *Rent Level* is input for the graph function *Effect Rent Level on propensities to move*. The relationship between the *Rent Level* and propensities to move of high income households is assumed to be exponential. The strength of this relationship is uncertain. The first 5% rent increases delivers an effect of  $1+(1^{\text{Uncertainty Strength Rent Level}})/100$ . The second 5% delivers an effect of  $1+(2^{\text{Uncertainty Strength}})/100$ , and so on. *Uncertainty Strength Rent Level* varies from 1 to 2,5. Figure 17 shows the range of possible effects (space between red and green line).



**FIGURE 17: UNCERTAINTY BANDWIDTH EFFECT RENT INCREASE (LEFT) AND RENT INCREASE (RIGHT)**

It is expected that the maximum rent price is obtained after 2017. A couple of simplifications were made: the rent increase affects the households in the social sector (below the liberalization limit). Also households who rent their house from a private landlord below liberalization limit experience the rent increase (while the rules are only obliged for social housing associations). Also, households having already a harmonized rent level and labelled as HI household by income development receive also a higher propensity to move, while their rent level is not in accordance with the rent level where the effect is based on. These simplifications are inevitable because the model uses aggregates.

When this measure is executed simultaneously with the addition of extra WWS points, the maximum rent level will increase from for example 100% to 115% (percentage of the maximum rent level 2011). This gives the social housing association the possibility to increase the rent of high income households for a longer period.

#### 5.4.1.1 Extra WWS points

The maximum effect of adding extra WWS points is a rent increase of €120 after mutation. It is assumed that the addition of points results in a higher harmonization effect, i.e. a larger difference between rent level after- and before mutation. Internal moving in the social housing sector becomes from financial perspective less attractive. The propensities to move of households in the social sector towards another house in the social sector are multiplied by factor below 1. This factor differs for the four income groups: it is assumed that MLI households are more influenced by financial measures than HI households, because the total money spent on housing of MLI households is relatively higher. Low income households are not influenced because they receive rent allowance. The uncertainty ranges of the effects for LI, MLI, MHI and HI are respectively (1-1), (0,75-0,90), (0,90-0,95), (0,95-1).

These effects become smaller over time, in an uncertain manner: Figure 18 shows two possible groups of effects.

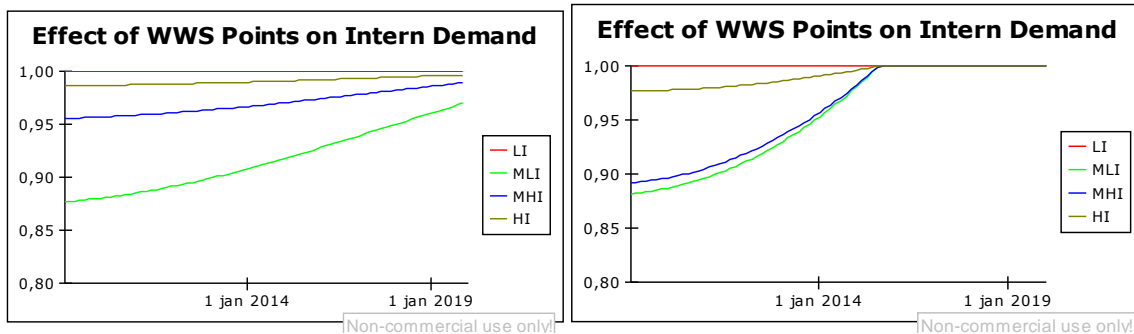


FIGURE 18: TWO POSSIBLE OUTCOMES OF EFFECT OF ADDITION OF 25 WWS POINTS ON INTERN SR DEMAND

Another consequence of this measure is that houses move from one to another rental sector. For example, a dwelling of €600/month receives after mutation €100 extra rent and goes from the social sector (SRL) to market rent. This will not happen at once, but slowly and in an uncertain manner. In the model this rate is assumed to be 1% a year for each segment without policy changes. Addition of WWS points increases this percentage by 5-15 % a year.

#### 5.4.1.3 Buy Option

Whether a household buys a house is modelled in a simple way. Propensities to buy are imported from WoON 2009, specified to household type, income, and sector. It is assumed that at the moment not all households are successful in their buy-attempt. The buy success is influenced by the income of a household. The uncertainty ranges of buy success of LI, MLI, MHI and HI households are respectively (0.7,0.8,0.9,1\*[15-25%]) at the start of the simulation. These percentages increase with uncertain speed to an uncertain maximum (50-100%). Figure 19 shows two possible effects on Buy success.

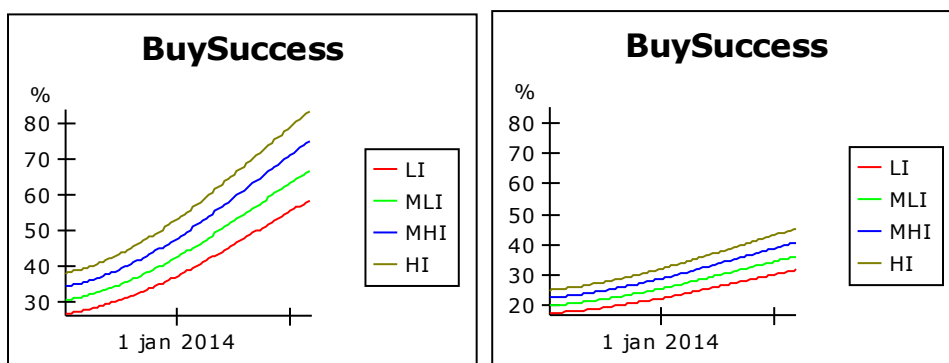


FIGURE 19: TWO POSSIBLE EFFECTS OF POLICY CHANGE BUY OPTION ON BUY SUCCESS HOUSEHOLDS

Two dynamic developments are ignored. First, the measure could maybe increase the propensities to buy of households. Second, propensities to buy do not become saturated. This does not heavily influence the quality of the model because the simulation time is around 10 years.

#### 5.4.1.4 European Directive

The European Directive orders that 90% of the inflow consists of low income households, the model assumes 100%, because of the high demand of LI households in the North Wing of the Randstad. This



has a clear effect on the specific housing move wishes of several income groups. First, it is important to mention that during the creation of WoON 2009, households were not bound to this Directive already. So, it is possible that a high income household wants to move to the social sector, while in practice this is not possible anymore due to the European Directive. Therefore, all housing move percentages to the social sector of HI and MHI households are multiplied with zero. All start values of demand stocks are also cleaned. Next, an uncertain percentage transform the original demand to the social rental sector to the market rental sector. This is modelled in such a way that it is possible to execute these calculations by turning a switch on or off.

**5.4.2 Demographic Uncertainty**

All demographic developments are assumed to increase or decrease exponentially. The strength of this exponential development is uncertain. In year one, the demographic variable is multiplied with  $(1+(1^{Uncertainty\ Strength})/100)$ . The second year results in a multiplication with  $(1+(2^{Uncertainty\ Strength})/100)$ , and so on. This trend is multiplied with a random randomizer: A random value between a random lowest value and random highest value.

This is applied to percentages concerning divorces, marriages, first births, deaths, seniors to rest home, delay of transitions of households (T1, T2, T3 to T4, T5). Also a non-demographic variable, attractiveness of North Wing has the same uncertainty function. Figure 20 shows a possible combination of different developments.

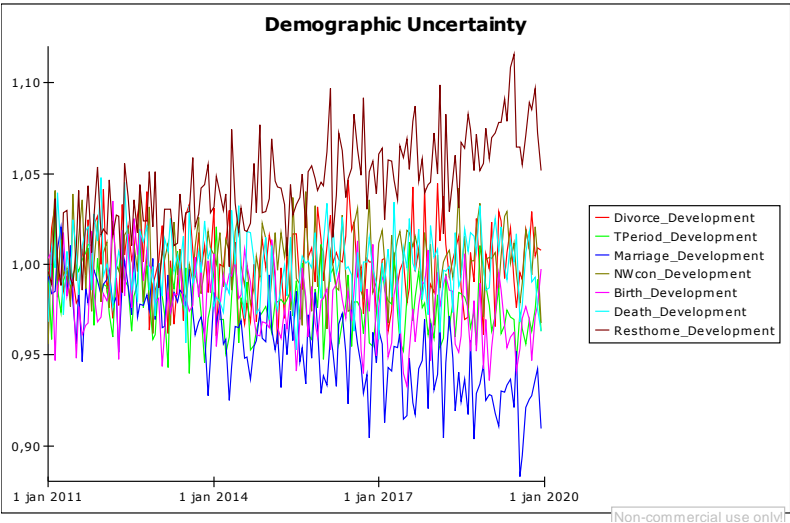


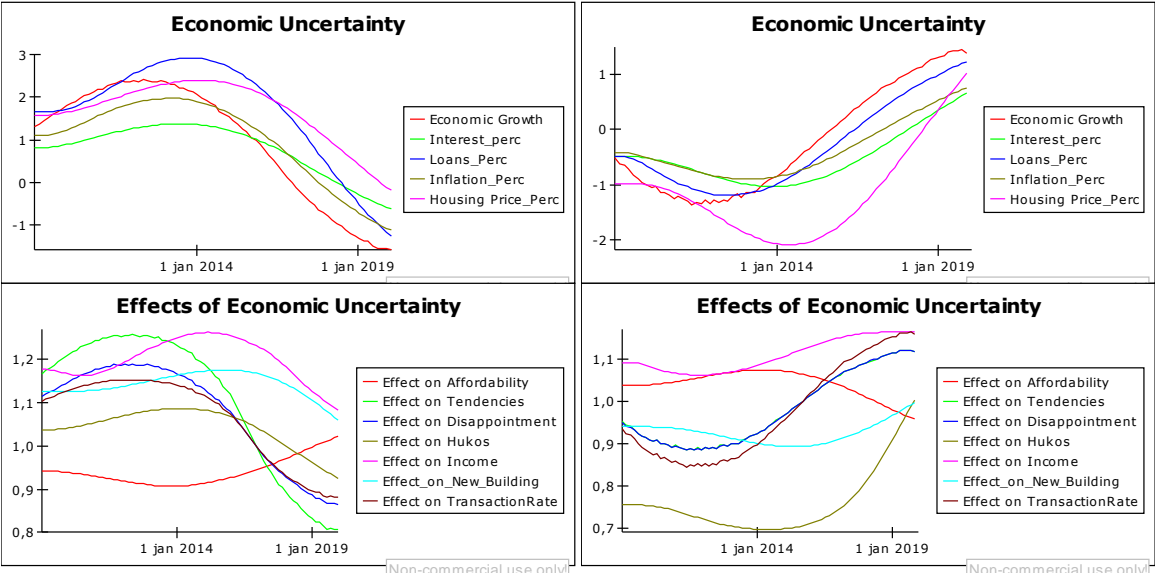
FIGURE 20:RESULT OF EIGHT RANDOM EXPONENTIAL DEVELOPMENTS COMBINED WITH RANDOM RANDOMIZER

**5. 4.3 Economic Uncertainty**

Economic growth is represented by the summation of two sinuses and a trend. One sinus is the Kondratieff cycle: duration of 45-60 years. The other is the Juglar Cycle which has a duration of 7-11 years. Start values of amplitude, period and starting point are chosen from an uncertainty range. All uncertainty ranges are listed in Appendix C. Each ¼ period the amplitude of the Juglar Cycle is changed with an uncertain value between -0,25 and + 0,25 and the period is changed with an uncertain value between -0,75 and 0,75.

In this very simple representation of economic development, four other economic variables, interest, inflation, income and housing prices follow economic growth with uncertain delay lengths and

uncertain delay types. Figure 21 shows two possible economic situations and the corresponding effects, which are described next.



**FIGURE 21: TWO POSSIBLE ECONOMIC SITUATION (ABOVE) AND CORRESPONDING EFFECTS (BELOW)**

The differences between the sinuses cause the dynamics. It is chosen to model the effects as S-Shapes, which are varied using the techniques described in section 3.3.2. This construction is used to determine the effect of economic growth on new buildings (including delay), propensities to move, transaction rates (for market sectors) and disappointment rates.

The assumptions behind the relations are: Economic growth results in more dwellings (more investments), higher propensities to move (more confidence), longer search times (or lower disappointment rate), and higher transaction rates for market sectors (more confidence in economy). Because of the expected return on investment, higher housing prices boost the percentage of households which want to move to the homeownership sector. The effect on income (income/inflation) and affordability (Housing Price \* Interest) is determined by a graph function. The effect on income is multiplied with the start value of income development, which is described in section 5.1.2 (1% a year). The effect on affordability is multiplied by the affordability percentages of the home ownership sector. An overview of all the effects is provided by Figure 22.

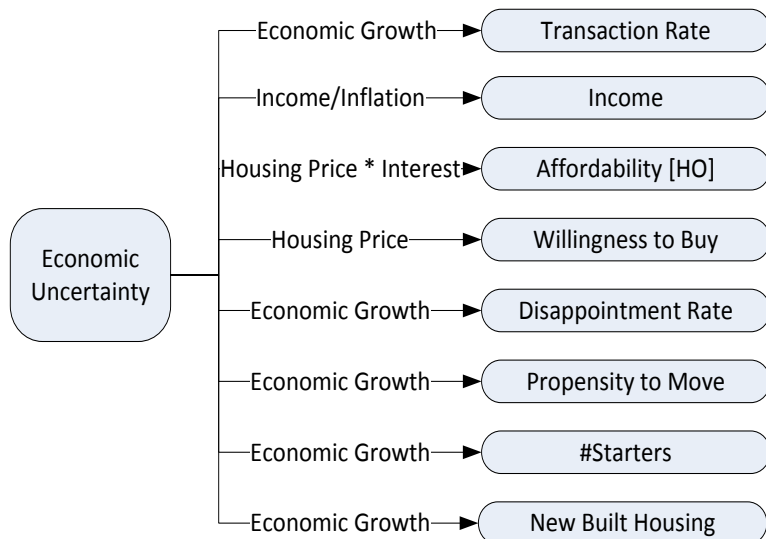


FIGURE 22: EFFECTS OF ECONOMIC UNCERTAINTY

## 5.5 Start Situation of the Model

The start situation of the model is determined by the input of WoON 2009. Table 5 gives an overview of the number of households present in North Wing of the Randstad, specified to income groups and sector.

TABLE 5: OCCUPANCE OF HOUSING STOCK, SPECIFIED TO INCOME GROUPS AND SECTOR

Income/Sector	SRQ	SRT	SRL	MR	HO	Total
LI	107.211	126.406	34.371	13.687	62.110	343.790
MLI	48.145	95.600	26.954	7.293	66.563	244.555
MHI	28.237	63.101	28.722	12.519	122.334	254.923
HI	28.410	99.455	50.955	40.609	673.048	892.477
<b>Total</b>	<b>212.003</b>	<b>384.562</b>	<b>141.007</b>	<b>74.108</b>	<b>924.065</b>	<b>1.735.745</b>

The market rent sector is small compared to the social housing sector. Low income household are most strongly represented in the cheapest segments of the social sector (SRQ and SRT). Almost 20% of the market rent sector is occupied by low income households, while in the model it is not possible to move to the market rent sector if one has a low income. It can be argued that low income households entered the market rent sector in a better economic situation, when private landlords were willing to take more risk. Negative income development could be another reason. Also a shortage of social housing can be a cause of low income households moving to another sectors than the social sector. The home ownership sector is by far the largest sector in the North Wing of the Randstad; this sector is dominated by high income households. Start values of other variables are taken from an uncertainty range. These ranges are given in Table 6.

TABLE 6: DIFFERENT START VALUES BY SECTOR

Variable/Sector	SRQ	SRT	SRL	MR	HO
Friction	1-1,5%	1-1,5%	1-1,5%	1-1,5%	1-1,5%
Transaction Rate	20-30	20-30	20-30	10-20	10-20
Buy-success	15-25% * factor dependent on income of household				n.a.

<b>New Houses</b>	20.000-30.000 houses/year
-------------------	---------------------------

The friction percentage determines the amount of supply at the start of the simulation. Supply is equal to  $1/(1-\text{Friction Percentage sector}) * \text{total households sector} - \text{total households sector}$ . For example, the friction percentage of HO sector =1%, the supply amounts to  $(1/0,99)*924.065-924065 = 9334$  houses. The transaction rates are chosen in such a way that the amount of supply stays realistic. When the transaction rates are high, the supply is allocated quickly to households which results in a drop of supply from 1,5% to less than 0,5% in 2 years. The start values of household demands are shown in Table 7. These are also specified to income and sector.

TABLE 7: DEMANDS SPECIFIED TO INCOME GROUPS AND SECTOR

Income/ Sector	SRQ	SRT	SRL	MR	HO	Total
<b>LI</b>	8.240	24.269	15.061	0	12.650	60.220
<b>MLI</b>	4.538	17.217	6.946	0	10.641	39.342
<b>MHI</b>	3.519	5.694	7.268	3.437	23.902	43.820
<b>HI</b>	5.363	8.166	10.819	9.722	68.725	102.795
<b>Total</b>	21.660	55.346	40.094	13.159	115.918	246.177
<b>Perc of Stock</b>	10,2%	14,4%	28,4%	17,8%	12,5%	14,2%
<b>Perc of Stock ( European Directive)</b>	6,0%	10,7%	15,6%	71,7%	12,5%	14,2%

In 2009, it was still possible for high income households to move to the social housing sector. The European Directive prohibit these housing moves. Therefore, each run an uncertain percentage of the MHI and HI demand to the social rental sector is added to the demands to the market rent sector. When this percentage amounts to 100%, the demand/total households by sector is as displayed in the last row of Table 7. This delivers a high pressure on the market rent sector. By starter substitution also the home ownership market receives extra demand of MHI and HI incomes.

## **6. Model Validation**

Validation of models is impossible because all models are wrong (Sterman, 2000). However, validation is still needed to build up confidence in a model. Furthermore, a model is made to answer a research question. It is important to show the limitations of the model, to prevent misuse of the model by the client and to enable the client to improve the model when needed (Sterman, 2000). Several tests are available for validation, which can be divided in three groups: direct structure tests, structure-oriented behaviour tests and behaviour patterns tests (Barlas, 1996). As consequence of the nature of the research question and the policy changes, the model is more an accountancy model than a dynamic model. Therefore, only direct structure tests and structure oriented behaviour tests will be applied to the model. The next two sections discuss the results of these validation tests. These validation steps are executed iteratively during the model building process.

### **6.1 Direct Structure Tests**

Direct structure tests are tests without using model output. This step focuses on parameter values and the equations. Subsequently parameter values, equations and dimensions are discussed. Last, the relevance of the parameters are discussed, whether enough parameters are present in the model to answer the research question.

#### **6.1.1 Parameter Values**

Values are checked during the model building process. In total more than 2500 parameters are present in the model, mainly demand variables. Parameter values and causal relationships (equations) should be compared with existing knowledge of the system. Input variables concerning propensities to move, sector occupancies, and demographic variables originate from WoON 2009 and CBS. These data sources are existing knowledge of the system.

Furthermore some variables of the model, like transition rate of sectors, friction emptiness, disappointment rate, current buy success, percentage switching starters, percentage switching demand (due to the European Directive), net housing stock added a year, are modelled using an uncertainty range. All uncertainty ranges are given in Appendix C.

#### **6.1.2 Equations**

Testing extreme conditions within equations is used to determine the validity of the equations. The model consists of a number of important equations which are copied many times. Extreme conditions for these equations are researched and displayed in Appendix D. Also the structure of these equations are explained in this appendix.

Possible effects of policy changes are reasoned using theory (chapter 2). Their quantitative effects are modelled as an uncertainty range. It is assumed that the exact effect is somewhere in this range. The same is done for causal relations in the model, like the effect of supply/demand rates on transaction rates or on starter substitution. It is not possible to forecast the real effect, because this depends on several other variables and behaviours. Within the time limits for the project it was not possible to study all causal relationships and exact values of variables. An uncertainty range can contain the values of different experts or researches; the model then supports both visions at the same time. The downside of an uncertainty range is that it is not possible to do exact statements about model results. The uncertainty ranges of the effects are given in Appendix C.

### **6.1.3 Parameter Dimensions**

The model uses one main unit, 'house', which means at the same time a household and a house. It is assumed that a household occupies maximum one house at a time. The unit of most of the stocks is 'house', and their inflow and outflow are measured in houses/month. The smallest time unit in the model is measured in months (the transaction rate). Delays and other time units are per year. Verification of dimensions is automatically executed by the software tool, however it is still important to check dimensions because both dimensions could be wrong, or the modeller can use a trick to get around differences in dimensions. This once done to translate growth percentages to indices. This does not influence the model behaviour and is an isolated part of the model.

### **6.1.4. Relevance of Parameters**

The model contains all relevant parameters needed to answer the research question of this master thesis. It is possible to isolate housing sectors and to isolate income groups. By different household types it is also possible to specify the effects of policy changes to specific groups. However, other parameters are needed to extend the model for broader research questions.

## **6.2 Structure Oriented Behaviour Tests**

The second group of validation tests uses model output. Several extreme situations are evaluated, the results are shown in Appendix E. The model reacts as expected on extreme values. A sensitivity analysis is also a structure oriented behaviour test. In this research a number of parameters are uncertainty ranges. So, the sensitivity analysis is already present in the model itself. This results (as described in chapter 8) in an uncertainty bandwidth around an average. Because of the robustness of the performance indicators (described in chapter 7) no special results arose during the analyses.

## **6.3. Conclusion Validation**

Several tests were performed and parameters and equations were checked. During the model building process several mistakes were restored, during the final check presented here no striking mistakes became visible. Validation should always be performed in the perspective of the model objective. The model concentrates on accumulations of behaviour and pays less attention to specific household moving behaviour. Within the current structure and objective of the model it was not possible to do extensive behaviour tests. When the model is extended to answer broader research questions, extra attention should be paid to the validation of specific system behaviour.

## 7. Uncertainty Analysis

This chapter consists of four sections. The first section identifies performance indicators which can be derived from the model variables. Three performance indicators will be identified and described in section 7.1. These indicators are used to compare the different scenarios. Section 7.2 explains the length of the simulation. Section 7.3 writes down the scenarios which are used in the analysis. The last step is to execute the analysis, which is divided in dynamics and static analysis. The most important results of these analysis are described in section 7.4.

### 7.1 Performance Indicators

Performance indicators should be chosen in such a way, that the following research question can be answered:

*What are possible effects of institutional, economic and demographic uncertainties in the Dutch Housing Market on the position of low income households in the social rental housing market in the North Wing of the Randstad?*

Because the coalition agreement emphasized that the social housing sector should focus on the low income households, this thesis will concentrate on the effects of uncertainties on the (relative) amount of low income households in the social housing sector. As Figure 23 indicates, the amount of low incomes households will be calculated as share of the total social housing stock and as share of all low incomes. To put the first indicator in perspective, the average income of the social housing stock is determined. Performance indicators can be specified to different segments of social housing. All performance indicators are briefly described next.

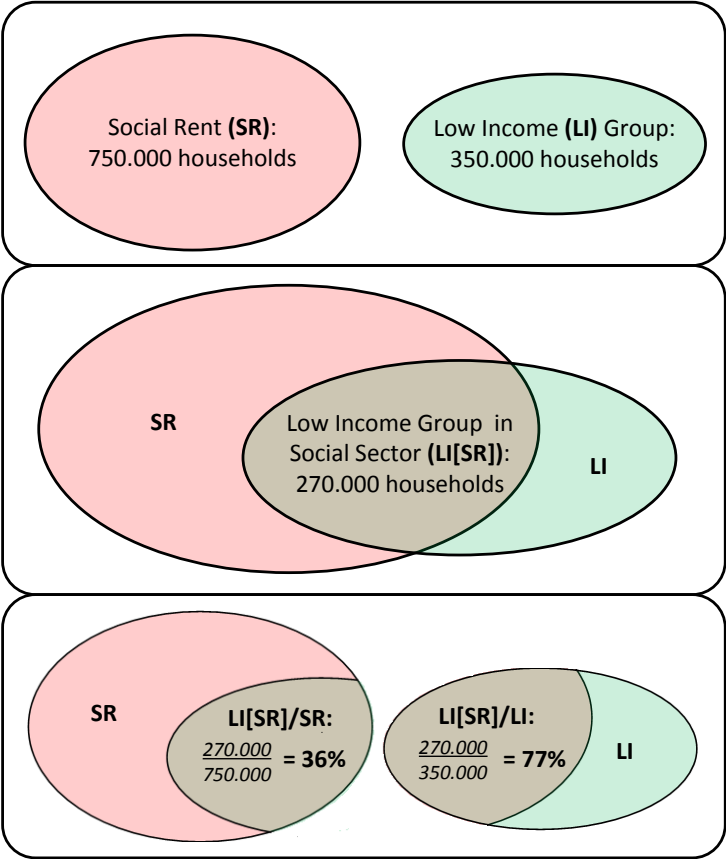


FIGURE 23: VISUALISATION OF PERFORMANCE INDICATORS

### **7.1.1. Presence of Target Group in the Social Housing Sector (% of Total Social Housing)**

At the moment, 36% of the social housing stock is occupied by low income households. This can be measured by dividing the number of low income households by the total amount of households in the social housing sector. This percentage gives also an indication about the amount of housing allowance which should be given to the low income households. This is also dependent on the height of the rent level; therefore it is important to evaluate the percentage for the segment below and above €550/month. This performance indicator is called **LI[SR]/SR** in the remaining of the report.

### **7.1.2 Average Income of Households in the Social Housing Sector**

It is also important to know something about the context of the previous performance indicator. Therefore, an 'average income' is computed of all households in the social sector. By giving LI 1 point, MLI 2 points, MHI 3 points and HI 4 points, an average can be computed. An example: 10 households are present in sector A: 4 LI, 4 MLI, 1 MHI and 1 HI. Another Sector, B, has the following distribution of 10 households: 4 LI, 1 MLI, 2 MHI and 3 HI. LI[SR]/SR is 40% for both A and B. However the average income of sector A amounts to  $(4*1+4*2+1*3+1*4)/10 = 1,9$ ; the average income of B amounts to  $(4*1+2*1+2*3+4*3)/10=2,4$ . Because the first performance indicator is split up in two segments, it is useful to do the same with this performance indicator.

### **7.1.3 Presence of Target Group in the Social Sector (% Total Low Income)**

The social sector is (among other reasons) meant to support low income households finding affordable housing. This percentage shows to what extent low income households are using this opportunity, or were able to use this opportunity. This is influenced by non-rational housing move behaviour and by the accessibility of the social housing sector for low incomes. In 2009, 78% of the low income households had a house in the social housing sector, while the social housing sector is more than 2 times bigger than the amount of low income households. This performance indicator is called **LI[SR]/LI** in the remaining of the report.

## **7.2 Simulation Time**

The model is run from 2011-2025. Input data of 2009 is most recent and used as starting point for 2011. No further reforms on the housing market are expected till the next Cabinet (2014). The length of the influences of the policy changes are different by run. Some effects will stay the entire simulation, for example the effect on the accessibility of the social housing sector for high incomes. Other effects are temporarily, for example the effect of higher harmonization effects on internal moving in the social housing sector. Two measurement points are chosen within the static analysis: January 2015 and January 2020, to explore the effects on the short and long term. The period 2011-2025 is used for the dynamic analysis.

## **7.3 Scenario Building**

The building blocks for scenario building are the uncertainty structures in the model. First it is important to run the model with only one active uncertainty structure, to determine the effect of the uncertainties on the performance indicators separately. This is done in round 1. Then, institutional measures are combined whereof the hypothesis is that they reinforce each other. Furthermore, some more variations of policy changes are explored, both separately and combined. 'EU [LI]' and '33k' are new designed policy changes. The content of these (and also all other) scenarios is described in Table 8.



TABLE 8: SCENARIOS

Round	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
1	0	+ Dem	+Eco	+EU	+Buy	+43k	+WWS
2	+43k/WWS	+All	EU [LI]	+43/33k	+43k/33k/WWS	+All (extra)	
<b>1.1 0</b>	No new policy changes are implemented. Initial propensities to move determine system behaviour.						
<b>1.2 Dem</b>	Demographic uncertainty is taken into account, no policy changes.						
<b>1.3 Eco</b>	Economic uncertainty is taken into account, no policy changes.						
<b>1.4 EU</b>	EU directive is implemented: SR only accessible for LI/MLI households						
<b>1.5 Buy</b>	Buy option: social sector shrinks by tenants which buy their house.						
<b>1.6 43k</b>	HI households are stimulated to leave the social sector by rent increase.						
<b>1.7 WWS</b>	Rent levels increase, social sector shrinks by harmonization effect.						
<b>2.1 43k/WWS</b>	Rent levels increase, social sector shrinks, by harmonization effect and by HI households which get rent increase.						
<b>2.2 All (1.1-1.7)</b>	Combined effect: social housing sector shrinks, accessibility only for LI/MLI. This scenario shows situation when all policy changes are implemented.						
<b>2.3 EU [LI]</b>	Extension of 1.4 EU. Segment 550- only accessible for LI households.						
<b>2.4 43k/33k</b>	Extension of 1.6 43k: Also MHI get rent increase.						
<b>2.5 43k/33k/WWS</b>	Rent levels increase, social sector shrinks, by harmonization effect and by HI /MHI households which get high rent increase.						
<b>2.6 All (1.1-1.7+2.3/2.4)</b>	2.2 All, including extensions of policy changes.						

## 7.4 Results

Not all results can be discussed; despite the emphasis on low income groups, the analysis still delivered 234 uncertainty ranges, expressed in 702 numbers (minimum, average, maximum) and 234 diagrams. The scenarios are compared using the minimum, average and maximum of uncertainty ranges. However, it is also important to have a notice about the behaviour which leads to the uncertainty ranges. This dynamic analysis is executed section 7.4.1, using one scenario as an example. The data of the uncertainty ranges (static analysis) is analyzed in section 7.4.2.

### 7.4.1 Results of Dynamic Analysis

Scenario 2.2 (All) is used to analyse the dynamic development of the performance indicators over time. This scenario is chosen because all uncertainty structures are present in this scenario. The housing market is an inert system: the total effect of policy changes can be spread over several years or decades. Figure 24 shows the uncertainty range of performance indicator LI[SR]/LI for the period 2011-2025. The red graph displays the run with the highest percentage (maximum), the yellow graph displays the run with the lowest percentage (minimum). Other graphs show percentiles: for example, the green line (95% percentile) indicates that 95% of all runs scored below this line. By filling the space between the 95% percentile and 90% percentile, a green surface is created which shows the values of the runs between 95% and 90% (Figure 25). The width of this surface gives an indication about the spread of the runs in this interval.

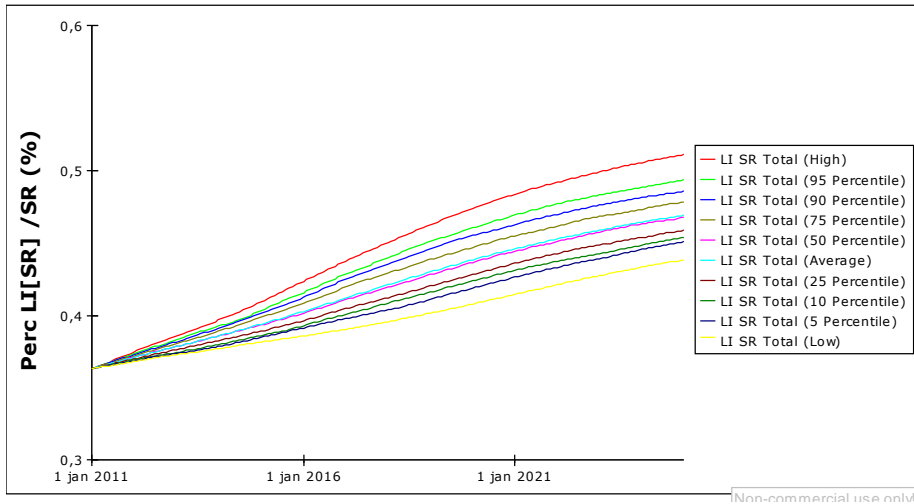


FIGURE 24: LI[SR]/SR (GRAPHS)

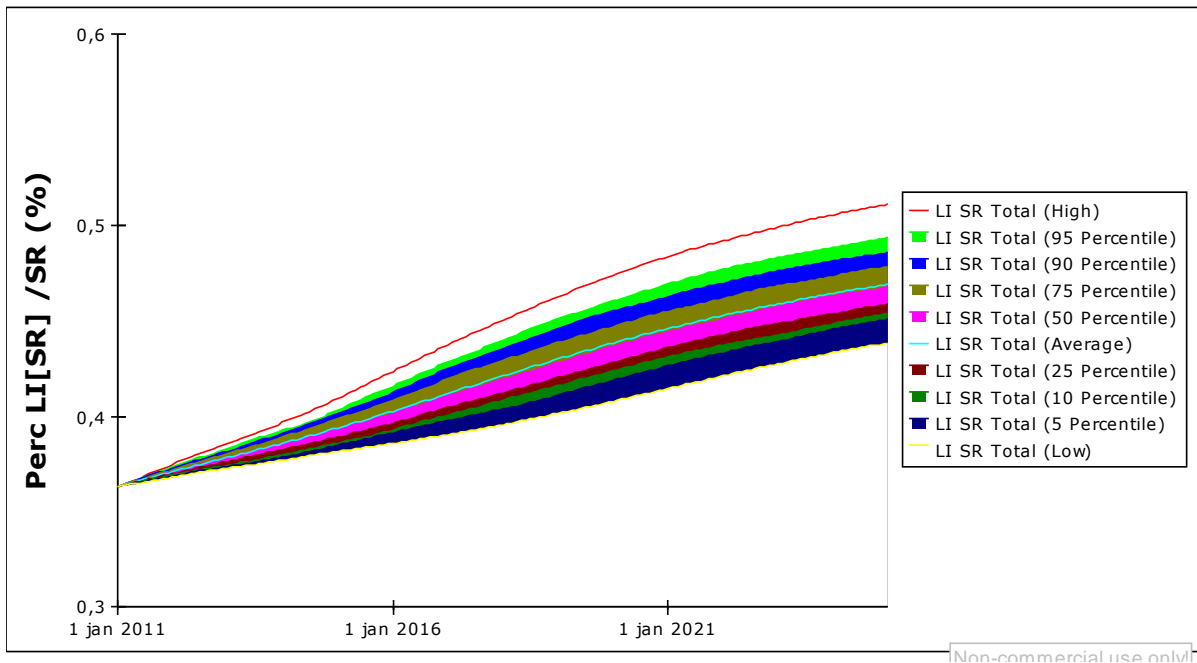


FIGURE 25: LI[SR]/SR (SURFACES)

The European Directive regulates the type of households flowing into the social housing sector. The social sector becomes more accessible for LI households by excluding the MHI and HI households. This policy change is a typical example of a policy change whose effects take some years/decades to fully evolve, because this policy change is only active after a mutation of a dwelling. The number of mutations should increase when the rent increases for HI households, which forces HI households to move to another sector. All policy changes combined result in a steady increase of LI[SR]/SR in high segment housing, while the increase in the low segment declines (Figure 26). This is caused by the occupancy of social housing by MLI households. Social housing is for them also almost the only accessible housing market.

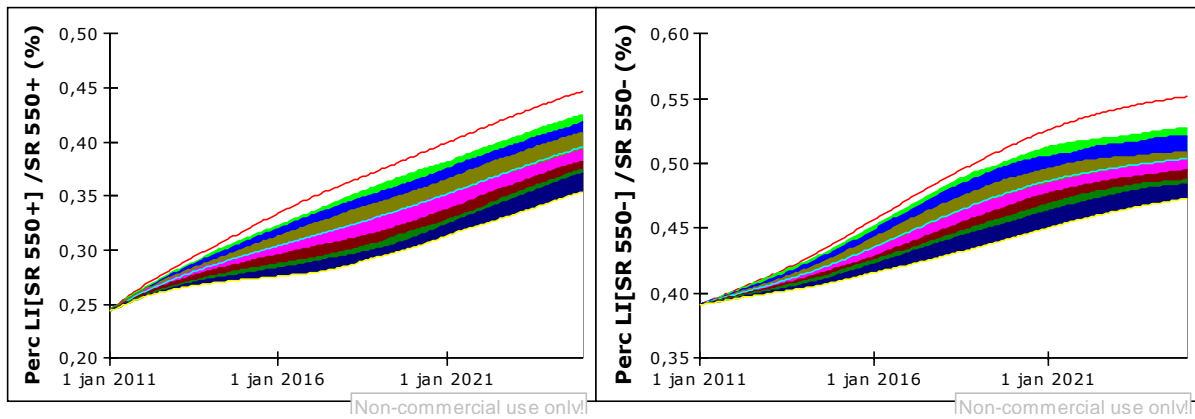


FIGURE 26: LI[SR]/SR: SPECIFIED TO HIGH SEGEMENT (€550+/MONTH, LEFT) AND LOW SEGMENT (€550-/MONTH, RIGHT)

These graphs are also influenced by the changing size of the different segments in the social housing stock. This is indicated by the results of performance indicator LI[SR]/[LI] (Figure 27).

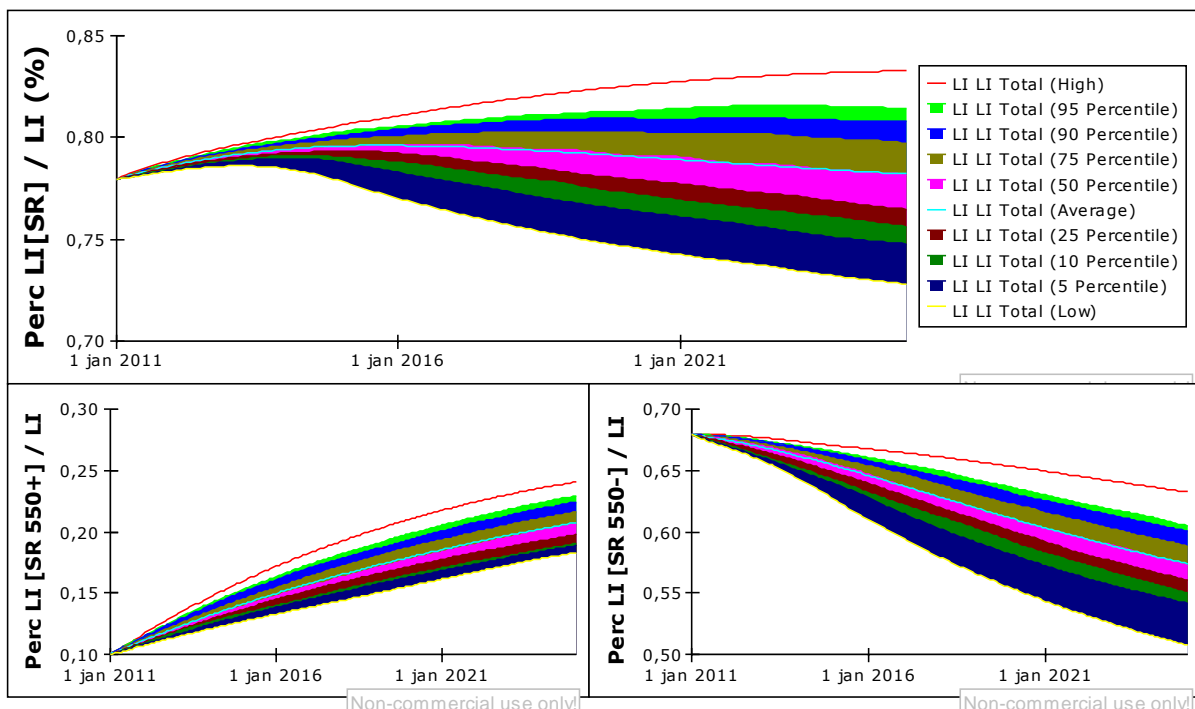


FIGURE 27: LI[SR]/LI (ABOVE), SPECIFIED TO HIGH SEGMENT (LEFT) AND LOW SEGMENT (RIGHT)

Although LI[SR]/SR increases in all segments of social housing, LI[SR]/LI does not change equally. This is caused by the policy changes 'buy-option' and 'WWS points'. As already is argued these policy changes result in a smaller social sector. Slowly, the dwellings move one LI segment up by harmonization effects and rent increases. Especially the lowest segment of social housing is sensible for these developments by lack of new social dwellings in the lowest segment. All higher segments have an inflow of dwellings of a lower segment. This is stressed by the two small diagrams of Figure 27. Summation of the different segments in the social sector delivers the stable behaviour showed by the upper diagram of Figure 27.

These figures give an indication of the position of low income households in the housing market. The average income of the social sector is computed to formulate some statements about the other income groups in the housing sector. The average income is displayed in Figure 28.

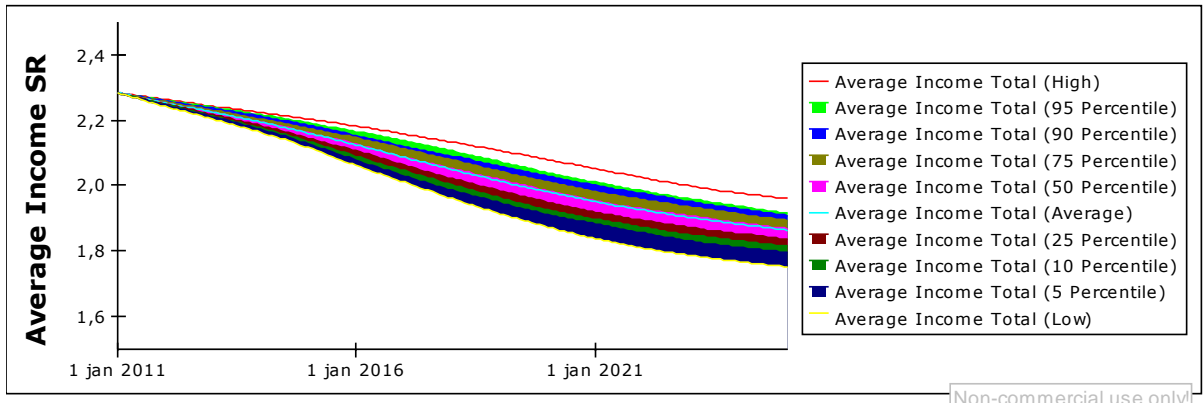


FIGURE 28: AVERAGE INCOME SOCIAL SECTOR

All segments display a steady decrease of the average income. This is mainly caused by HI households which move to other sectors (by the rent increase) and the inflow of LI and MLI households.

All uncertainty ranges become larger over time: the uncertainty range of 2012 is smaller than the uncertainty range of 2020. This is caused by the slow response of the housing market on the policy changes. Also values of for example demographic development become more uncertain when the simulation is further into the future.

#### 7.4.2 Results of Static Analysis

For each run the lowest, average and highest scores are taken from the uncertainty ranges for 3 performance indicators (LI[SR]/SR, LI[SR]/LI, Average Income), 3 segments (550+, 550-, Total) and two dates (1-1-2015, 1-1-2020). All scores are shown in Appendix F. Each uncertainty range is a summary of the results of 250 runs. The position of the average between the highest and the lowest value indicates the spread of runs over the uncertainty range.

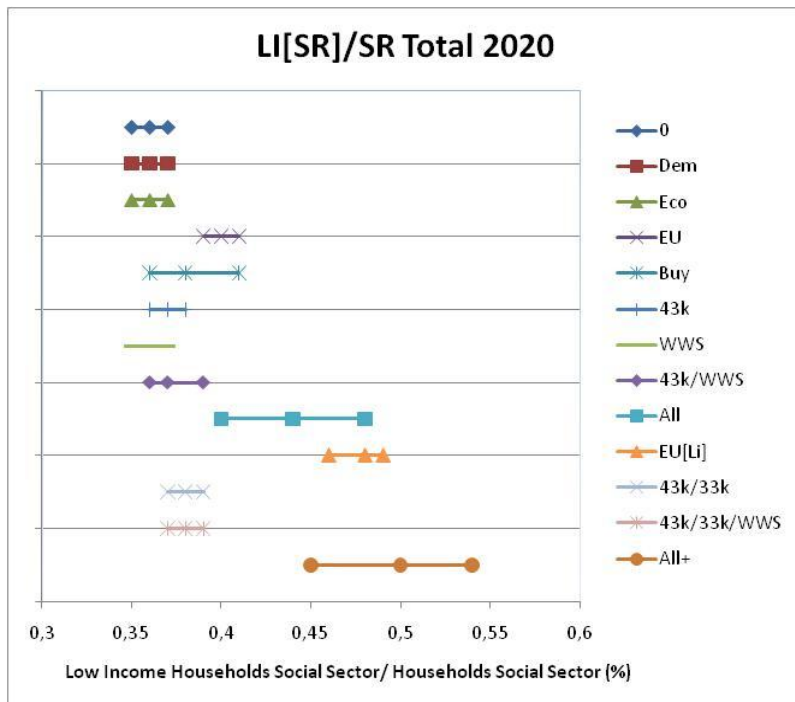


FIGURE 29: SHARE OF LOW INCOME HOUSEHOLDS IN SOCIAL HOUSING SECTOR

LI[SR]/SR is the first performance indicator examined; the uncertainty ranges for LI[SR]/SR in 2020 are shown in Figure 29. Demographic nor economic uncertainty heavily influences on this performance indicator. Demographic developments are not fully crystallized after the simulation time (9 years). Effects of economic uncertainty are reduced because of the nature of the performance indicator. These effects could have more effect on specific demands and supplies. From the separate institutional uncertainty structures, the European Directive and the buy-option have the highest value for LI[SR]/SR, however the uncertainty range of the buy-option is larger. Adding 25 WWS points seems to have no effect on this performance indicator. Higher scores are realized when this measure is combined with the '€43.000' rule. This behaviour is caused by the harmonization effect: rent levels go to a higher segment due to this effect. HI households which rent initially in low segment move to the high segment. Simultaneously the total amount of social housing stock decreases because of rents which transcend the liberalization limit. An important characteristic of this combination is that LI[SR]/SR in high segment (rent >€550/month) decreases and in low segment (rent <€550/month) increases. An attractive scenario, because the government has in this scenario lower expenses on housing allowance.

The two extensions of existing policy changes reinforce the effect of the original policy changes. EU [LI], which forbids access to the lowest segment of the social rent sector for MLI households seems to be very effective. Downsides of this measure cannot be showed by this performance indicators, however are present: the housing supply for households which 'fall between two stools', is decreased, which can have problematic effects for the housing of these households.

LI[SR]/SR can be placed in the context by showing the average income of all households in the social housing sector. These are given in Figure 30 on the next page.

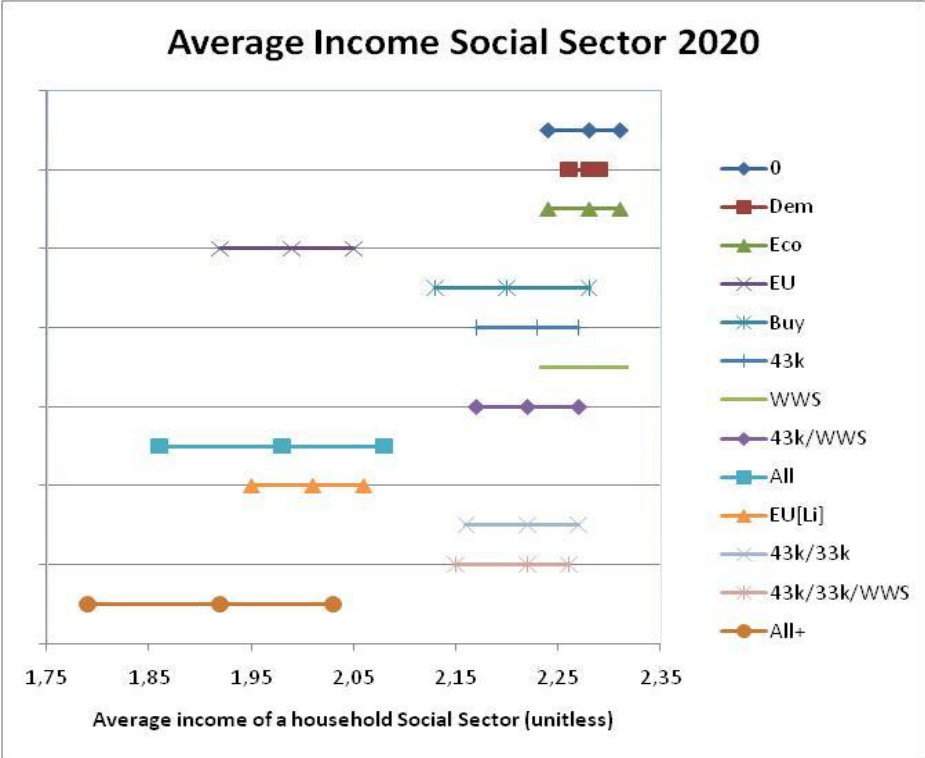


FIGURE 30: AVERAGE INCOME OF HOUSEHOLDS IN THE SOCIAL HOUSING SECTOR

The scenarios including the influence of the European Directive score positively (the lower the average income, the better). These policy changes are at the same time rigorous, by closing the door for a lot of households. Other measures give households the possibility to react and to make their own decisions. Looking in detail to the average incomes for high and low segment gives the same result for the combination of adding WWS points and higher rents for (middle) high incomes. The results of 2015 are the same except smaller uncertainty ranges and smaller differences. The trend for these performance indicators does not change from 2015-2020.

To complete the picture of the low income households in the social housing sector, it is necessary to examine LI[SR]/LI. Lower average income and positive scores for LI[SR]/SR are good results. However LI[SR]/LI is important because this performance indicator shows the accessibility of the social housing sector for low income groups, and to what extent these households make use of all opportunities provided by the government. Figure 31 gives the percentages for 2020.

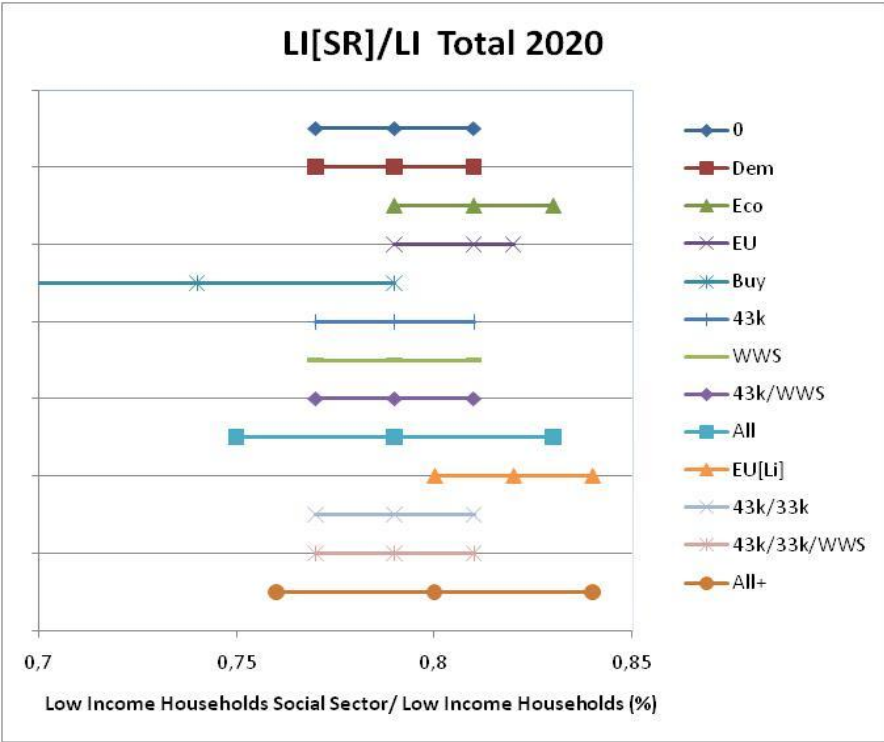


FIGURE 31: PERCENTAGE OF LOW INCOME HOUSEHOLDS IN SOCIAL HOUSING SECTOR OF TOTAL LOW INCOME HOUSEHOLDS

None of all uncertainty ranges of the scenarios is able to avoid overlap with the uncertainty range of the 0-scenario. Despite the positive results on the first two performance indicators no policy change or combination of policy changes is able to distinguish from ‘doing nothing’ for this performance indicator. This is caused by the shrinking social housing sector by the buy-option and by rent levels transcending the liberalisation limit. Another reason could be that low income households do not want to make use of the social housing sector. The social housing sector is more than two times bigger than the amount of low income households at the start of the simulation. So keeping the same percentage with a smaller social housing stock results in a more efficient allocation of social housing, which is already expressed by the first two performance indicators. However, this does not automatically increase the accessibility of the social housing sector for low income households.

## 8. Conclusions

The model building process was initiated to answer the research question. The model has a number of limitations because of the underlying objective of the model. However, the model has a lot of potential and is able to deal with other questions as well. Extra structures can be added to the model to make it more valuable. The limitations and opportunities of the model are discussed after answering the research question.

### 8.1 Answering the Research Question

In chapter 1, the following research question was formulated:

*What are possible effects of policy changes concerning the Dutch housing market on the position of low income households in the social rental housing market in the North Wing of the Randstad?*

To answer this question, a System Dynamics model is made, containing several uncertainty structures. This model is used to explore the possible effects of separate and combined uncertainty structures. Four policy changes are proposed which should make the social sector more exclusive for lower income households. The European Directive imposes housing move behaviour, while the other three policy changes stimulate certain housing move behaviour. The effects of the social sector are translated to three performance indicators: fraction low income households in the social sector of all households in the social sector ( $LI[SR]/SR$ ), fraction low income households in the social sector of all low income households ( $LI[SR]/LI$ ) and the average income in the social housing sector.

The dynamic analysis showed that the transition of the current social sector composition to a social sector more focused on lower income households is supported by the policy changes.  $LI[SR]/SR$  increases, while  $LI[SR]/LI$  decreases. The diagrams indicated that the transition takes some time, because the Dutch housing market is an inert market. In any case the increase of  $LI[SR]/SR$  is still significant in 2025, however the speed of the transition decreases over time. Because the policy changes also decrease the size of the social sector,  $LI[SR]/LI$  does not change heavily over time. Other households than LI households leave the social sector, while the amount of LI households in the social sector is stable. These other income groups increase the demand for housing in the home ownership and market rent sector. These effects are not taken into account in this research, but are relevant for further research.

The more elaborated static analysis showed that  $LI[SR]/SR$  and  $LI[SR]/LI$  are not heavily influenced by demographic and economic uncertainty. Demographic uncertainties do not penetrate the robustness of the performance indicators when these uncertainties are not combined with changes in propensities to move of specific household types. Economic uncertainty affects the amount of demand and the number of housing moves, but has a limited effect on the distribution of income groups in the social housing stock. Further research is needed to determine the effects of both economic and demographic uncertainty. Suggestions are given in section 9.3.

Adding WWS points and increasing the rent for (middle) high income groups have together a double effect:  $LI[SR]/SR$  decreases in the high segment of social housing (rent > €550/month) and increases in the low segment of social housing (rent <€550/month). The average income in the high segment increases while the average income in the low segment decreases. This is efficient for the government because this delivers lower expenses (lower housing allowances). The overall effect on

the performance indicators of these measures are small compared to effects of the implementation of the European Directive. Rigorous measures focused on the inflow of households in the social housing sectors seems to be most efficient. Other measures try to influence housing move behaviour, while the European Directive imposes this behaviour. These kind of aspects of policy changes are outside the scope of this research, however important when the overall performance of policy changes is assessed.

The uncertainty range of the 0 scenario of LI[SR]/LI overlaps with all the uncertainty ranges of the other scenarios. The allocation becomes more efficient, but simultaneously the social housing sector shrinks. So, the accessibility of the social housing sector for low income households does not increase spectacular. The social housing sector consists relatively of more low income households, but this does not automatically result in absolute more low income households in the social housing sector.

## 8.2 Recommendations

The four policy changes decrease the size of the social housing and focus the social housing sector on the target group, lower income households. The effects are not immediately noticeable, it takes some time till the effects on the performance indicators becomes significant, however the effect continues steadily. So, it is not possible to couple short-term objectives to this policies; effects of the policy changes take two or more government terms.

Several issues should be taken into account: First, the policies do not improve the situation for low income households in the social housing sector. Instead, the allocation of housing in the social housing sector becomes more efficient, having the same amount of low income households in a smaller housing stock. Second, it is questionable whether the market sectors (home ownership and rent) are affordable for the households which are denied access to the social housing market. This is the reserve of the coin: decreasing the amount of social housing leads to an increasing group of households searching for affordable housing in the market sectors. Whether the housing market is able to take up these households is beyond the scope of this research, however an important question which should be answered by the government. Last, the European Directive imposes behaviour while other policy changes stimulate behaviour. The communication concerning implementation of this directive towards housing associations needs therefore extra attention.

## 8.3 Limitations of the model

Next, some limitations of the model are listed subsequently. The model is a sub model of a larger housing market model. The income groups are chosen for the social housing sector. This results in a highest income group having a gross annual income higher than €43.000, while this is almost the lowest income group which flows into the home ownership sector.

Only the influences of the policy changes in the social housing sector are modelled. Other government regulation is assumed to be embedded in the model. When these regulations have to be assessed, another structure has to be added to the model. The policy changes which are examined are static, i.e. influencing inflows and outflows, but do not influence the model structure. This pushes the model more towards an accountancy model instead of a dynamic model.

Another limitation is that housing movement behaviour in the housing market is translated to housing move percentages. There is no underlying structure containing feedback loop of housing move motives. The starting point of the model is based on propensities to move adapted from WoON



2009, which are used in the whole simulation. Changes of housing motives are not modelled (besides the effects of uncertainties).

Fourth, the model only shows the effects of uncertainties on allocation of households across the sectors. It is not possible to formulate a policy advice based on the model about issues like costs, practicability and feasibility of measurements; these can only be reasoned.

Last, the assumptions needed to simplify the model result in some differences with reality. For example a household can only have propensities to move to one sector at a time. Housing move chains are not present in the model because the model uses aggregates. Due to these kind of assumptions it is not possible to formulate exact statements about the development of special groups of the housing market.

## 8.4 Opportunities of the model

Besides the mentioned limitations, the model has still a lot of potential on other areas. Right now only the effects of current policy changes in the social housing sector are assessed, however it is also possible to examine other policies. Some examples and proposals to take advantage of these opportunities follow subsequently.

In this research the position of LI households is emphasized, however it is also possible to examine the position of the other income groups or the position of several household types, or a combination between those, for example singles having a middle high income. Effect on and changes in actor behaviour can be modelled specified to income group, household type and sector. The effects of policy changes are in the current model general of nature, however it is possible to couple research results about the effects of policy changes to the model.

Another performance indicator can be added to the existing three, namely the ratio social housing stock/Low income households. This gives a more complete picture to the share of low income households in the social housing sector of the total of low income households. The initial value amounts to 2,16: currently, the amount of low income households is more than two times smaller than the amount of social housing stock.

‘Huur op Maat’ is a type of renting whereby the rent of a house depends on the income of the household. This will have an effect on the housing movement behaviour of the several income groups. The model contains right now already four income groups. These can be used to model the effects of ‘Huur op Maat’ on their propensities to move. This can be supported by an extra questionnaire among households in the social housing stock about their opinion of ‘Huur op Maat’.

The model simulates the effects for the North Wing of the Randstad. It is also possible to simulate the same policy effects for other areas, for example a low- and high-demand housing markets. Then it is possible to examine the policy changes for two different type of housing markets, which can be used to make some statements about the efficiency of the policy changes on the overall Dutch housing market. It is also possible to implement data from previous WoON researches, or from a future WoON research (WoON2012).

Last, this model can be coupled to a model of the home ownership sector. This model contains flows from social and market rent sector to the home ownership sector. These flows could be specified to income groups (for example €40.000-€50.000, €50.000-€60.000 and so on). The details gained by this specification can in turn be used to improve the current social housing market model.

## 9. Reflection: Project Proposal versus Thesis

In this section I want to refer to the original project proposal and compare the original plan with the final result. Differences are caused by the process between proposal and final research report. Therefore, process elements are used to explain differences and similarities between the research question and the final outcomes presented by the proposal and the report.

The research question in the proposal was as follows:

*What kinds of behaviour patterns could the rental housing market in the Randstad produce, given the uncertainty about the reactions of housing associations and households on the implementation of the EU decision, and are the intended policies of the new Cabinet effective and robust in this range of future scenario's?*

Finally, the research question became:

*What are possible effects of institutional, economic and demographic uncertainties in the Dutch Housing Market on the position of low income households in the social rental housing market in the North Wing of the Randstad?*

The first difference is the geographical delineation. This is done to avoid working with meaningless averages. It was proposed during a meeting with the employee of the Ministry of Internal affairs. The North Wing of the Randstad is supposed to be an important region in the future, so worthwhile to research.

A second and big difference are the performance indicators used to measure the state of the housing market. In the proposal 'behaviour patterns' were suggested to examine, while finally uncertainty ranges are used to compare scenarios. This is caused by the nature of the model: instead of a very dynamic model, rather an accountancy model is made. The behaviour in the model is more or less robust, because of the non-dynamic nature of the policy changes.

A similarity between both questions is the presence of three types of uncertainties, which are also present as uncertainty structures in the model. Instead of one large uncertainty analysis, several uncertainty analyses are made for different scenarios.

The first intention was to perform an ESDMA (Exploratory System Dynamics Modelling and Analysis) study. This was cancelled because of unavailability of software to do this analysis. Afterwards, the type of model made was not suitable for an ESDMA study. It was also a result of combining the two worlds of the supervisors. The first supervisor emphasized reality and concrete results, while the second supervisor concentrated on uncertainty patterns, which is less concrete. In my opinion this was not a negative process development, because I learnt to apply elements of both worlds and to combine these in one project. The result of this synthesis is written down in this report.

## Bibliography

- BARLAS, Y. 1996. Formal aspects of model validity and validation in system dynamics. *System Dynamics Review*, 12, 183-210.
- BOUMEESTER, H. J. F. M. & LAMAIN, C. 2010. Eigen Huis Marktindicator, 2e kwartaal 2010. Delft: TUDelft, OTB.
- BROWN, L. A. & MOORE, E. G. 1970. The intra-urban migration process. A perspective. *Geografiska Annaler*, 52, 1-13.
- CDA & VVD 2010. Vrijheid en verantwoordelijkheid, Concept Regeerakkoord VVD-CDA. Den Haag.
- CENTRAAL PLANBUREAU 1999. "De Grondmarkt: een gebrekkige markt en een onvolmaakte overheid"., Den Haag.
- CLARK, W. A. V. & DIELEMAN, F. M. 1996. Households and Housing, choice and outcomes in the housing market. . *Center for Urban Policy Reserach* [Online].
- COMMISSIE HEROVERWEGINGEN 2010. Brede heroverwegingen, hoofdstuk 4: Wonen.
- CPB 2010. Hervorming van het Nederlandse woonbeleid. Den Haag: CPB.
- CSED 2010. Naar een integrale hervorming van de woningmarkt. SER.
- DAALEN, C., THISSEN, W. A. H., PRUYT, E. & PHAFF, H. W. G. 2007. *Continuous Systems Modelling, System Dynamics*, Delft, Faculty of Technology, Policy and Management.
- DONNER, J. P. H. 2011. Circulaire Huurprijsbeleid voor de periode 1 juli 2011 tot en met 30 juni 2012. In: RELATIONS, M. O. I. A. A. K. (ed.). Den Haag.
- ELSINGA, M., HAFFNER, M. & VAN DER HEIJDEN, H. 2008. Threats to the Dutch Unitary Rental Market. *International Journal of Housing Policy*, 8, 21-37.
- ELSINGA, M. & WASSENBERG, F. 2007. Social Housing in the Netherlands. In: WHITEHEAD, C. & SCANLON, K. (eds.) *Social Housing in Europe*. London: London School of Economics and Political Science.
- ESKINASI, M., ROUWETTE, E. & VENNIX, J. 2009. Simulating urban transformation in Haaglanden, the Netherlands. *System Dynamics Review*, 25, 182-206.
- FORRESTER, J. W. 1969. *Urban Dynamics*, Cambridge MA, Productivity Press.
- FORRESTER, J. W. 1980. Information Sources for Modeling the National Economy *Journal of the American Statistical Association*, 75.
- FORRESTER, J. W. 1989. The Beginning of System Dynamics. System Dynamics Group, Sloan School, Massachusetts Institute of Technology.
- FRANCKE, M. 2010. *RE: How bloated is the Dutch housing market? (Summary of inaugural lecture)*.

- GROOT, E. A. D., HAASNOOT, R. & KEUR, M. 2004. *Motoriek van de economie: hoe kan het bedrijfsleven inspelen op economische golfbewegingen?*, Den Haag, Stichting Maatschappij en Onderneming.
- HAFFNER, M. E. A. & BOUMEESTER, H. J. F. M. 2010. The affordability of housing in the Netherlands: An increasing income gap between renting and owning? *Housing Studies*, 25, 799-820.
- HUISMAN, F. 2009. *Fighting Neighbourhood Deterioration. Exploring problems and policies for a Den Haag Zuid-West case study from a systems perspective*. TU Delft.
- IMF. 2011. Kingdom of the Netherlands—The Netherlands 2011 Article IV Consultation: Preliminary Conclusions.
- KONINKLIJKE VERENIGING VOOR DE STAATHUISSHOUDKUNDE 2008. *Agenda voor de Woningmarkt*. Amsterdam.
- LEMMERT, R., POPPER, S. & BANKES, S. 2003. Shaping the next one hundred years: New methods for quantitative, long-term policy analysis. Santa Monica: The RAND Pardee Center.
- MCKAY, M. D., BECKMAN, R. J. & CONOVER, W. J. 1979. Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code. *American Statistical Association*, 21, 239-245.
- MULDER, C. H. 1996. Housing choice. Assumptions and approaches. *Journal of Housing and the Built Environment*, 11, 209-232.
- MULDER, C. H. & HOOIMEIJER, P. 1999. Residential relocations in the life course. In: WISSEN, L. J. G. & DYKSTRA, P. A. (eds.) *Residential relocations in the life course*. New York: Kluwer Academic/Plenum Publishers.
- OORT, F. V., DE GRAAFF, T., RENES, G. & THISSEN, M. 2008. Economische dynamiek en de Randstedelijke woningmarkt. *Pre-adviezen*.
- PLANBUREAU VOOR DE LEEFOMGEVING 2008. *Verhuiscensuren en verhuisgedrag in Nederland. Een landsdekkend onderzoek*.
- PRIEMUS, H. 1984. *Verhuistheorieën en de verdeling van de woningvoorraad*. Delft.
- PRIEMUS, H. 2006. European policy and national housing systems. *Journal of Housing and the Built Environment*, 21, 271-280.
- PRIEMUS, H. 2010a. The credit crunch: Impacts on the housing market and policy responses in the Netherlands. *Journal of Housing and the Built Environment*, 25, 95-116.
- PRIEMUS, H. 2010b. Housing finance reform in the making: The case of the Netherlands. *Housing Studies*, 25, 755-764.
- PRUYT, E. 2010. *Using Small Models for Big Issues: Exploratory System Dynamics Modelling and Analysis for Insightful Crisis Management*.

- PRUYT, E. & HAMARAT, C. 2010a. The Concerted Run on the DSB Bank: An Exploratory System Dynamics Approach. Delft: Delft University of Technology.
- PRUYT, E. & HAMARAT, C. 2010b. The Influenza A (H1N1)v Pandemic: An Exploratory System Dynamics Approach.
- ROSSI, P. H. 1955. *Why families move: A study in the social psychology of urban residential mobility.*, Illinois, Glencoe, Free Press.
- STERMAN, J. D. 2000. Truth and beauty: validation and model testing. *Business Dynamics: systems thinking and modeling for a complex world.*
- VARGA, K. 2010. *Aandachtswijken. Een kwantitatief onderzoek.*, TU Delft.
- VROM, M. V. 2006. Ruimte geven, bescherming bieden. Een visie op de woningmarkt. Den Haag.
- VROMRAAD 2007. Tijd voor keuzes. Perspectief op een woningmarkt in balans. Den Haag: VROMRAAD.

## Appendix A: Characteristics COROP Regions Randstad

	<b>Respondents</b>	<b>Percentage Home Ownership Sector</b>	<b>Percentage Rent Sector</b>
<b>Utrecht</b>	4054	0,59	0,41
<b>Groot-Amsterdam</b>	4555	0,37	0,63
<b>Flevoland</b>	2039	0,65	0,35
<i>Zaanstreek</i>	638	0,49	0,51
<i>IJmond</i>	343	0,55	0,45
<i>Agglomeratie Haarlem</i>	5307	0,56	0,44
<i>Agglomeratie Leiden en Bollenstreek</i>	2089	0,59	0,41
<i>Het Gooi en Vechtstreek</i>	427	0,59	0,41
Alkmaar en omgeving	449	0,67	0,33
Kop van Noord-Holland	609	0,67	0,33

The table above shows the COROP regions which could belong to the North Wing based on their location. The basis of the North Wing of the Randstad consists of 'Groot-Amsterdam, Almere (Flevoland) and Utrecht. Other regions are surrounding regions of this basis. From these surrounding regions the *cursive regions* are also included because of the ratio home ownership/rent market. The assumption is that these regions attract households which want to leave Groot-Amsterdam or households which cannot find a house in Groot-Amsterdam.

## Appendix B: Details about Household development

### Marriages

There are three marriage options:

1. Both singles have already a house, so one single leaves his/her house. In this case, the new income class is assumed to be as shown in Table 9.
2. No one has a house, then the household is a starter (T2).
3. One single has already a house. New income is the same as in case 1.

The difference between case 1 and 3 is represented by adding a 'marry efficiency factor'. This factor expresses the percentage of singles who have already a house when they marry. The minimum value of this percentage is 50%, because then all marriages are as in case 3.

TABLE 9: REALLOCATION AFTER MARRIAGE

Type of Household	New Income
LI	50% LI, 50% MLI
MLI	MHI
MHI	HI
HI	HI

### Divorces

If a household does not consist of dual earners, the remaining household stays in the same income class, the other goes to LI. If they were dual earners, a decision table determines the reallocation of income groups.

TABLE 10: REALLOCATION OF INCOME CLASSES AFTER DIVORCE

Type of Household	Dual Earners		Single Earner	
	Staying	Moving	Staying	Moving
LI	LI	LI	LI	LI
MLI	LI	LI	MLI	LI
MHI	MLI	MLI	MHI	LI
HI	MHI	MLI	HI	LI

### Starters

Starters are households entering the housing market. They could be single or a pair. Their move on the housing market is labelled as 'urgent'. Pure starters are accompanied by just divorced households which became single. These starters are from the North Wing of the Randstad but also from outside the North Wing of the Randstad. Data of starters from 2006-2008 is used to determine the amount of starters by sector. This is done because information about income and household composition of future starters is not available. This method has downsides. Changes of characteristics of starters between the starting moment and 2008 are perceived as characteristics at the starting point. A starter (single) of 2006 which married in 2007 is in the model perceived as a starting pair. The numbers are halved to translate them to yearly percentages.

### Aging

After 35/40/45 years, a household will become that old that they can be called seniors: T1/T2/T3 → T4/T5. There is no movement from T3 to T2: It is assumed that when all kids are gone, the parents are more or less senior.

## Appendix C: Uncertainty Ranges

Name	Uncertainty Range	Unit
<b>Economic Uncertainty</b>		
Amplitude Short Wave Cycle	1,5-2	%
Amplitude Changes	-0,25-0,25	%
Period Short Wave Cycle	7-12	yr
Period Changes	-0,75-0,75	yr
Starting Point Short Wave	0-1	
Amplitude Long Wave Cycle	1,5-2	%
Period Long Wave Cycle	45-60	yr
Starting Point Long Wave (on sinus function)	0,2-0,3	
Delay Type (Interest, Inflation Housing Price, Loans) as reaction on Economy	1-6	Integer
Type of S Shape (Acceptance, Affordability, Huko, New Building, Housing move propensities, Transaction rate)	0,5-1	
Trend Economic Growth	1,5-2,5	%
<b>Demographic Uncertainty</b>		
Strength Effect (Death, Births, Rest home, TPeriod, Divorces, Marriages, Concentration on North Wing, Transaction).	0,5-1,5	
Trend Direction (Death, Births, Rest home, TPeriod, Divorces, Marriages, Concentration on North Wing).	-1-1	Integer
Marriage Efficiency	70-90	%
<b>Institutional Uncertainty</b>		
Buy Success Rental House (LI, MLI, MHI, HI)	(0,7;0,8;0,9,1)*(15-25)	%
Buy Success Rental House (LI, MLI, MHI, HI)	(0,7;0,8;0,9,1)*(15-25)	%
Effect European Directive on Switch behaviour of MHI and HI from social to market rent.	50-100	%
Effect Right to Buy	15-40	%
Effect extra WWS points (LI, MLI, MHI, HI) on intern demand Social Rent Sector	(1/0,85/0,9/0,95)-1	%
Logarithmic or Exponential (function influence ratio on starters)	0 - 1	integer
Disappointment Rate	2,5-4	Yr
Effect WWS on Harmonization Effect	5-15	%
Effect EU (MLI, MHI, HI)	50-100	%
Increase Max rent Level by WWS	10-20	%
Max Buy Success	50-100	%
Price Increase MHI	2,5-3,5	%
<b>Housing Market Uncertainty</b>		
Substitution Delay	0-1	Yr
Substitution Percentage	5-50	%
Transaction Rate (SR, MR, HO, Starters)	(20-30,10-20, 10-20, 30-40)	%
New Houses added to the housing stock	20.000-30.000	house



## Appendix D: Equation Analysis and Extreme Conditions

The following equations are tested: inflow housing stock, ratio supply demand housing stock, substitution and a random in and outflow of a demand stock. The uncertainty structures are not covered during these extreme condition tests. These consist mainly of graph functions, which are checked, but do not contain many variables.

### Inflow housing stock

The equation of the inflow of a housing stock is as follows:

$$HO\_Rel\_DemandPerc * Total\_Net\_Inflow + SRL\_Stock\_to\_HO + SRQ\_Stock\_to\_HO + SRT\_Stock\_to\_HO$$

*HO\_Rel\_DemandPerc* is 'Demand to HO/Total Demand'

*Total\_Net\_Inflow* is the yearly amount of houses added to the housing stock in the North Wing of the Randstad

*SR\*\_Stock\_to\_HO* refers to tenants which buy their house

Extreme condition: When the demand to home ownership housing drops to zero, *HO\_Rel\_DemandPerc* becomes 0%, which means that no newly built houses are added.

### Supply Housing Stock

MIN(3;

{'Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[LI])/ARRSUM(HO\_Demand);'

Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[LI])/ARRSUM(HO\_Demand)+ 'Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[MHI])/ARRSUM(HO\_Demand)-HO\_Demand[LI]);

'Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[LI])/ARRSUM(HO\_Demand)+'Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[MHI])/ARRSUM(HO\_Demand)-HO\_Demand[LI]+'Effect on Affordability'\*(HO\_Supply\*HO\_Aff\_T14[MHI])/HO\_Demand[MHI]+HO\_Demand[HI]);

(HO\_Supply\*HO\_Aff\_T14[LI])/ARRSUM(HO\_Demand)+(HO\_Supply\*HO\_Aff\_T14[MHI])/ARRSUM(HO\_Demand)-HO\_Demand[LI]+(HO\_Supply\*HO\_Aff\_T14[MHI])/HO\_Demand[MHI]+HO\_Demand[HI]+(HO\_Supply\*HO\_Aff\_T14[HI])/HO\_Demand[HI])

It is a long formula, but in principle simple to understand. The model uses arrays, so this formula shows the number of affordable housing for households with a **low income** (blue), **middle low income** (green), **middle high income** (orange) and **high income** (purple).

It is assumed that all households are able to buy houses which are affordable for low income households. The supply/demand ratio for low income households is equal to the number of affordable houses divided by the total demand. Summarized: # Affordable [LI]/Demand[all]. The ratio of middle low incomes is the ratio of LI plus the number of affordable houses for middle low incomes divided by all demand, excluding demand of LI because they cannot afford these houses. Summarized: #Affordable [LI]/Demand[all]+ #Affordable [MHI]/Demand[MHI+HI]. So, the supply demand ratio for middle high incomes is: Ratio [LI]+Ratio[MHI]+ #Affordable [MHI]/Demand[MHI+HI]. The supply demand ratio for high incomes is subsequently Ratio [LI]+Ratio[MHI]+ Ratio[MHI]+ #Affordable [HI]/Demand[HI].

An extreme condition could be that 0% of the housing is affordable for low income. This means that their supply/demand ratio amounts also 0, which results in zero transactions

### Substitution

Switch\_Starters\_Sub\*{DELAYINF(GRAPH(HO\_RatioT14[LI]/SRQ\_Ratio[LI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRQ[LI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[LI]/SRT\_Ratio[LI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRT[LI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[LI]/SRL\_Ratio[LI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRL[LI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[LI]/MR\_Ratio[LI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_MR[LI]\*Sub\_Perc);Sub\_delay;3;0<<houses/yr>>);

DELAYINF(GRAPH(HO\_RatioT14[MLI]/SRQ\_Ratio[MLI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRQ[MLI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MLI]/SRT\_Ratio[MLI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRT[MLI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MLI]/SRL\_Ratio[MLI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRL[MLI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MLI]/MR\_Ratio[MLI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_MR[MLI]\*Sub\_Perc);Sub\_delay;3;0<<houses/yr>>);

DELAYINF(GRAPH(HO\_RatioT14[MHI]/SRQ\_Ratio[MHI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRQ[MHI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MHI]/SRT\_Ratio[MHI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRT[MHI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MHI]/SRL\_Ratio[MHI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRL[MHI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[MHI]/MR\_Ratio[MHI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_MR[MHI]\*Sub\_Perc);Sub\_delay;3;0<<houses/yr>>);

DELAYINF(GRAPH(HO\_RatioT14[HI]/SRQ\_Ratio[HI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRQ[HI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[HI]/SRT\_Ratio[HI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRT[HI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[HI]/SRL\_Ratio[HI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_SRL[HI]\*Sub\_Perc)+

GRAPH(HO\_RatioT14[HI]/MR\_Ratio[HI];1;1;{GraphP1;GraphP2;GraphP3;GraphP4;GraphP5;GraphP6;GraphP7//Min:0;Max:1//}\*ST\_T2\_Dem\_MR[HI]\*Sub\_Perc);Sub\_delay;3;0<<houses/yr>>}}

Again, the colors represent the four type of incomes. For each income, 4 equations are present. In this case, the supply/demand ratio of 'Home Ownership Household Type 1 and Type 4' is compared with the supply demand ratio's of the remaining 4 sectors. A graph function and several uncertainty ranges determine which percentage of the demand of the other sectors goes to demand to Home Ownership.

### **Inflow Demand**

Substitution is one way to increase demand, the following equation shows the standard way how demand increases.

$$SRL\_T3\_Huko\_Lux * MR\_Acc * (SRL\_T3 - SRL\_T3\_Dem) * SRL\_T3\_Tend * SRL\_T3\_HuMR\_Lux$$

This formula shows the inflow of demand of households (T3, a pair with children) in the highest segment of the social sector to the market rent sector. It is a luxurious housing move, because these households have no urgency (contrary to starters and just divorced households) to move.

*SRL\_T3\_Tend* is the percentage which want to move of the total number of households. This percentage is multiplied by total number of households (SRL\_T3) minus the households which are already in a demand stock (represented by SRL\_T3\_Dem).

*SRL\_T3\_Huko\_Lux* is the percentage which want to rent when they move.

*SRL\_T3\_HuMR\_Lux* is the percentage within above percentage which want to move to the market rent sector. For scenarios including a EU directive, this percentage is for HI and MHI households always 100%, because access to the social sector is denied.

*MR\_Acc* is the accessibility of the market rent sector. When access is denied by financial of institutional borders for a special income group, MR\_Acc is 0. This means that no demand of these type of income groups can flow into the demand stock of MR.

### **Outflow Demand**

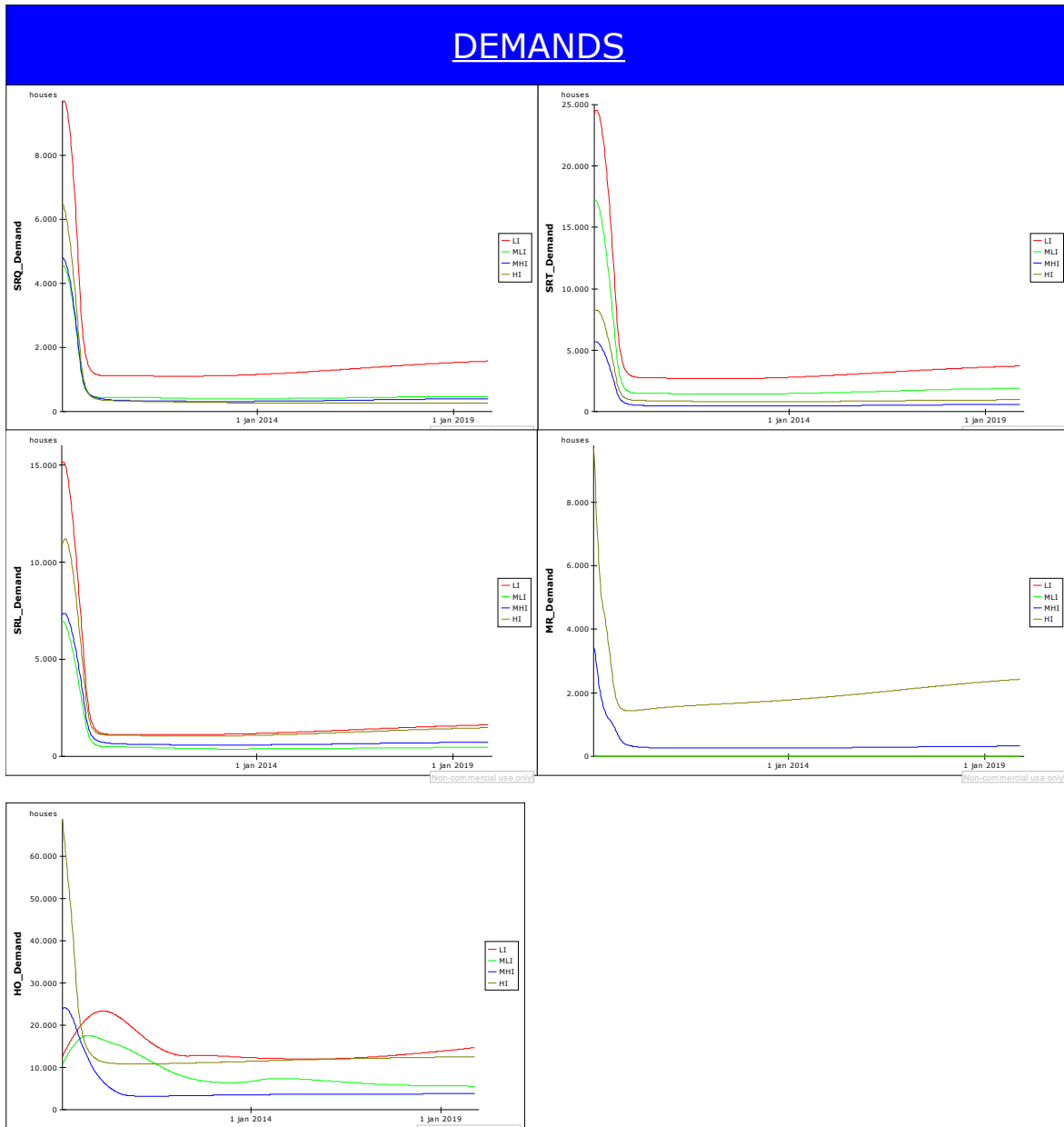
The number of successful housing moves is determined by the following equation:

$$SRL\_T3\_Dem\_MR * MR\_Ratio * MR\_Transaction\_Rate$$

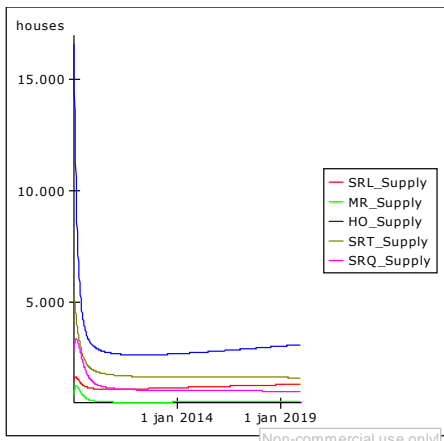
*SRL\_T3\_Dem\_MR* is the total demand of SRL\_T3 to MR. *MR\_Ratio* is supply/demand. *SRL\_T3\_Dem* is a part of the total demand to MR. It is assumed that the more demand from a specific group, the more successful housing moves occur in this group, ceteris paribus. *MR\_Transaction\_Rate* is the percentage of the total supply which is transacted each month. This cannot be 100% due to housing move delays. When one of these variables becomes zero, no successful housing moves occur.

## Appendix E: Extreme Conditions (Output)

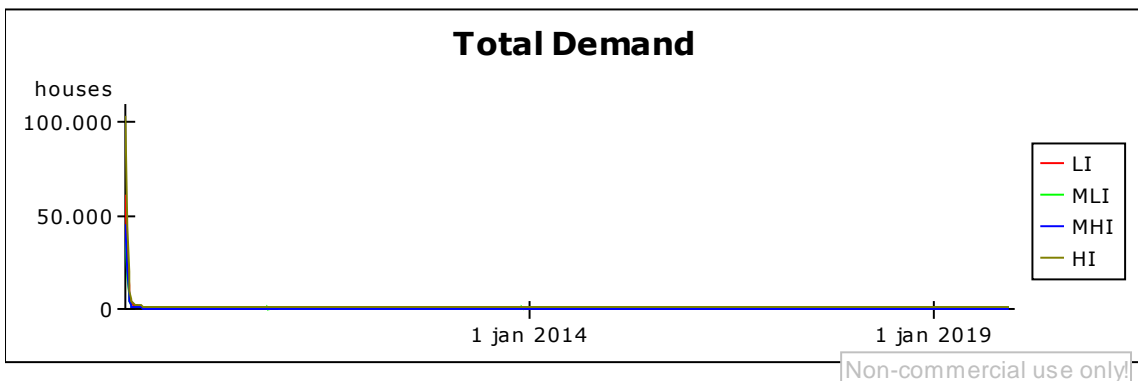
Extreme condition: Extreme amount of supply. All demand rates drop. Demands do not become zero, because there is always a friction emptiness. The demand of low incomes for the home ownership sector (red line, left below) increases because of the limited affordability (less than 1 %) of the home ownership sector.



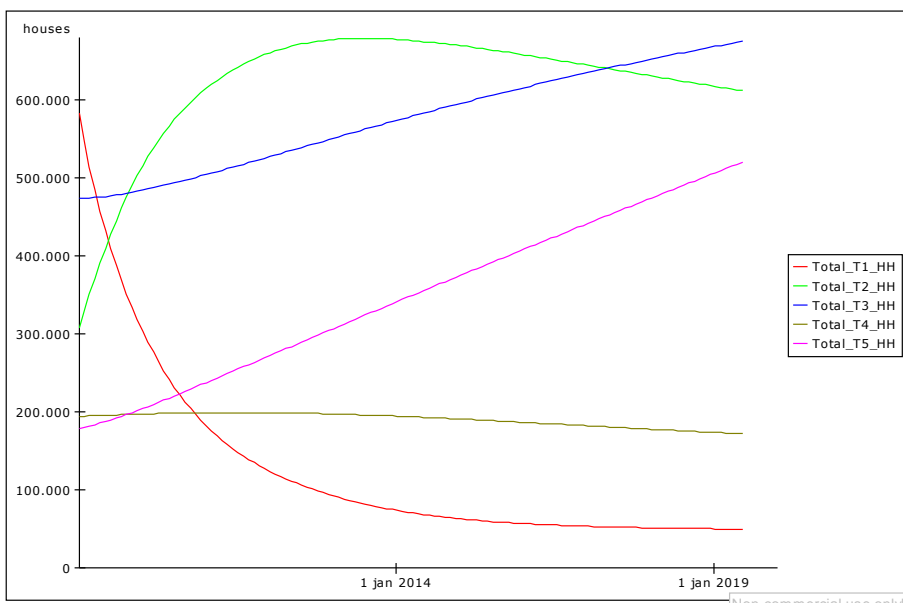
Extreme condition: 100% Transaction rates. The supply is expected to drop. The supply does not drop to 0, because the transaction rate is by month and the simulation step is 5 days.



Extreme condition: Disappointment rate is five days. All demands are expected to approach zero.



Extreme condition (demographic): Everyone Marries. Expected result: Less Singles. Red line is number of Singles. This amount drops, however not becomes 0. This is because of many starters are single and the marriage percentage is by year, so it is delayed compared to the simulation time step.



## Appendix F: Results

The figures below show the average, middle and highest value of 250 runs of 13 scenarios (description in paragraph 7.2) for three performance indicators (Average Income, Percentage Low Income of Social Sector, Percentage Low Income of total low income), three segments (Rent below €550/month, Rent above €550/month, All rents till €650), 2 moments (January 2015, January 2020).



