Master thesis

Financing and investment options of
homeowners dealing with property maintenance:
Foundation damage case in The Netherlands

In partial fulfillment of the requirements for the degree of
Master of Science
in Real Estate Management and Development

VERSION FOR KENWIB WEBSITE

A.A. (Anika) Cristini

Eindhoven University of Technology
Faculty of Architecture, Building and Planning

Graduation committee:
Prof. dr. ir. W.F. Schaefer *Eindhoven University of Technology*
Dr. ir. B. Glumac *Eindhoven University of Technology*
Ir. JM

Eindhoven, June 18th 2014

Technische Universiteit
Eindhoven
University of Technology

Aknowledgments

This thesis is the result of my graduation project, which concludes the master program Real Estate Management and Development at Eindhoven University of Technology. This research was conducted with the support of the department of Construction Management and Engineering and -. It was a very interesting topic and I enjoyed exploring and working on it.

During this project I had the pleasure to work with inspiring people and I especially enjoyed the interactions with the experts from the university, - , and other organizations. I want to thank them for their time and input for this research. In particular I want to thank my supervisors, the accomplished results were never possible without their help. Wim Schaefer, Brano Glumac and JM, thank you for your time, supervision and extensive knowledge.

I also want to thank my family and friends, *my solid foundation*. Thank you for your support and needed distraction during my graduation period. I would like to thank Sarike for designing the cover page of this thesis. Also I would like to thank Rianne and her family, for being my home in The Netherlands. Special thanks goes to my mother for her trust and positive motivation throughout my study. And Joost, thank you so much for your constructive comments, support and love.

Anika Cristini

Management summary

Homeownership has lot of benefits but due to the financial crisis since 2007 the focus is already moved towards the risks and responsibilities associated with homeownership. With foundation damage the security of a solid foundation falls apart which has a huge impact on the lives of the homeowners. About 400.000 households may have to deal with foundation damage, and if they want to stop the cracking and sinking of their home and protect the value, they have to accept the damage and repair the foundation. For many households the repair costs are already difficult to fund, and the current situation of general value decrease in the housing market and increasing requirements for funding make the problem worse. In the meantime, the foundation repair activities lack and cause impoverishment of the neighbourhoods. This research focuses on the financing of foundation repair and the main research question is formulated as: *How could financial institutions steer the reconstruction of distressed properties in a declining housing market?*

Within this research data from -, Kadaster and TNO is used to obtain a sample with financial information of homeowners in buildings at risk. All assumptions in the calculation models are based on literature and/or are validated by several field experts.

Financial situation of homeowners
To determine the financial situation of the households the entailed risks of an extra loan are considered, assuming that all homeowners in risk buildings need a loan for the foundation repair costs. To get this extra loan a homeowner has to meet Loan-to-Value (LTV) and Loan-to-Income (LTI) requirements. Four categories of households are set:

- Meet Loan-to-Value and Loan-to-Income requirements (category 1);
- Meet Loan-to-Income but not Loan-to-Value requirements (category 2);
- Meet Loan-to-Value but not Loan-to-Income requirements (category 3);
- Do not meet both requirements (category 4).

The households are distributed over the four categories as follows: -% in category 1, -% in category 2, -% in category 3 and -% in category 4. High LTI and LTV percentages are predictors for problematic categories, while a high income and value of the property, also correlated with high mortgages, are at the contrary predictors for less problematic households.

Scenarios to improve the household situation
To minimize the impact of foundation damage, all households must be able to provide the necessary maintenance to their property. Different variables (e.g. type of mortgage, price foundation repair, LTI and LTV norm, inflation on property value) influence the household situation and the distribution of the households over the four categories. By active steering on these variables the amount of households that cannot get a loan for foundation repair can be minimized.

Simulation results show that especially by decreasing the repair costs, extend the LTV norms and with special financial low interest arrangements the amount of households in category 1 increases rapidly. Households with problems with the LTI are the hardest to help out of a problematic category.

At this moment only households in category 1 can get a loan. Expanding the norms to make a loan possible for category 2 as well ensures for the mortgage lender the value of the collateral. Special attention is required for the LTI risks for the mortgage lender: the average LTI percentage increases when more loans are provided to customers Also the National Mortgage Guarantee norms can provide extra risks for the mortgage lender. -% of the total households are no more covered by this guarantee if they get a loan for foundation repair.

Best investment decision for homeowners

When a homeowner is confronted with foundation damage, there are several options on how to deal with this problem. This research focuses on the following options:

- Do nothing;
- Repair the foundation (and isolate the basement floor);
- Repair the foundation and extent the dwelling with a basement;
- Repair the foundation and install a ground source heat pump.

To determine the best investment option for homeowners, a decision support tool is developed that can be used by financial institutions. A System Dynamics model is developed to simulate the four investment options on four specific households (one household of each category). The results show that when households have enough lending capacity, the best investment decision is to repair and extend the property with a basement. Combining the repair activities with value increasing adjustments ensures a better investment and ensures the value of the collateral. For households that cannot afford this extra investment it is recommended to repair the foundation anyway instead of doing nothing.

Practical recommendations

The foundation damage problem requires a collective approach from different stakeholders. The required approach has to focus on a two-side prevention. On the long term, not yet damaged wooden piles have to be protected and groundwater levels need to be monitored to prevent, where possible, new cases of foundation damage. On the short term, there must be measures and regulations on how to deal with the existing damage. On the one side, homeowners with a property with damage have to be informed and helped through the process. Repair activities have to become more lean and upscaling could reduce the repair costs. This would have a significant impact on the amount of households that can afford the repair costs. On the other side, also new homebuyers have to be informed about, and protected from buying a house with possible damage.

If the foundation is not repaired the value of the property decreases and the LTV risk is not a risk for the homeowner solely. If there is no repair of the foundation damage the negative equity risk could also impact the mortgage lender. For the households that do not meet the LTI requirements, the special loans with guarantee of the municipalities need to be expanded on national level.

Table of contents

1. Introduction 1
2. Homeownership and market situation 3
2.1 The Dutch housing market 3
2.2 Homeownership and housing prices 3
2.3 Mortgage market 4
2.4 Mortgage risks 4
2.4.1 Credit risk 4
2.4.2 Negative equity risk 5
2.5 Impact of the credit crisis 5
3. Property maintenance and foundation damage 7
3.1 Property maintenance and property value 7
3.2 Foundation damage case 8
3.2.1 Wooden pile foundation 8
3.2.2 Shallow foundations 9
3.3 Causes of foundation damage 9
3.4 Effects of foundation damage 10
3.5 Consequences for the homeowner 10
3.6 Policy 11
4. Research Methods 13
4.1 Problem statement 13
4.2 Research question 13
4.3 Research boundaries 14
4.4 Research perspective 14
4.5 Research objectives 14
4.6 Research approach 15
4.7 Methods 16
4.7.1 Statistical analysis 16
4.7.2 MS Excel Visual Basic for Applications 16
4.7.3 System Dynamics 16
4.8 Validation 17
5. Financial situation of homeowners 19
5.1 Buildings at risk 19
5.1.1 Areas of risk 19
5.1.2 Building year 19
5.1.3 Considerations 20
5.2 Financial situation 20
5.3 Data 21
5.4 Descriptive Statistical Analysis 22
5.4.1 General characteristics of the sample 22
5.4.2 Foundation repair costs 23
5.4.3 Impact foundation damage on value of the property 23
5.4.4 Extent of the problem 24
5.4.3 Characteristics of the households in the categories 26
5.4.4 Factor Analysis and Determinant Analysis 27
5.5 Conclusions 31

6. Scenarios to improve the household situation 33
6.1 Model development 33
6.2 Base simulation 34
6.3 Main results 35
6.3.1 Variables 35
6.3.2 Impact of variables 36
6.4 Financial institutions' policy and risks 39
6.4.1 Policy 39
6.4.2 Risks for financial institutions 40
6.4.3 Consequences on National Mortgage Guarantee 42
6.5 Conclusions 43
7. Best investment decision for homeowners 45
7.1 Options for households 45
7.2 System Dynamics model description 46
7.2.1 Causal Loop 46
7.2.2. (Stock and flow) Model description 47
7.2.3 User interface 51
7.3 Case studies 52
7.3.1 Case study description 52
7.3.2 Data input 52
7.3.3 Results of simulations 54
7.4 Monte Carlo simulation 60
7.5 Conclusions 62
8. Conclusions 63
8.1 Answers research sub-questions 63
8.2 Practical recommendations 64
8.2.1 General recommendations 64
8.2.2 Recommendations for financial institutions 65
8.2.3 Recommendations for government 66
8.3 Discussion 66
8.4 Further research 67
References 68
Interviewees 70

1. Introduction

The right for adequate housing is protected in the Universal Declaration of Human Right. Housing is one of the underlining determinants of health. Besides the physiological factor, housing contributes to the psychological and social aspects of health (Thiele, 2002). We spend the most time of our life at home and the house is the base of all our activities. A house is a prerequisite for personal development and growth. The policy document *People Wishes Live* (in Dutch: *Mensen Wensen Wonen*) of the Dutch VROM Ministry (2001) denotes the value of homeownership. Homeownership contributes to more living comfort, satisfied people, social involvement and stable neighbourhoods. An own house is associated with freedom and independence, safety and security (Elsinga & Hoekstra, 2004).

Half of the homeowners experience property maintenance as the main disadvantage of homeownership (Elsinga & Hoekstra, 2004) and due to the financial crisis the focus is already moved towards the risks and responsibilities associated with homeownership (Van Middelkoop, 2011). With foundation damage the security of a solid foundation falls apart, metaphorically and literally. This problem has a huge impact on the lives of the homeowners and if they want to stop the cracking and sinking of their home they have to accept the damage and repair the foundation.

This research focuses on the foundation damage problem in The Netherlands. It provides knowledge and tools for possible solutions to limit the consequences of foundation damage due to financing restrictions.

The thesis is organized as follows.

Chapter 2 and 3 focus on the context: homeownership and property maintenance. The foundation damage problem in The Netherlands is here discussed in detail. In chapter 4 the research approach and the methodology are described. Chapter 5 offers the first results from the analysis. The size of the financing problem is here estimated, as well as the financial situation of homeowners dealing with foundation damage. Chapter 6 examines possible scenarios to make financing foundation repair possible for more households. Chapter 7 investigates the options of homeowners dealing with foundation damage and the best investment option is determined with the developed decision support tool and case studies. The conclusions of this research are reported in chapter 8, including recommendations and suggestions for further research.

2. Homeownership and market situation

The residential housing market represents about one third of the total world capital. Due to the size of this market it has consequently a significant impact on the overall economy (Hill, 2013). This chapter is the first part of the context of this research, which focuses on the residential housing market and in particular on homeownership and the mortgage market.

2.1 The Dutch housing market

The residential market is characterized by the rental and the owner-occupied sector. In The Netherlands both sectors have similar levels of government support. In 2012 the owner occupied housing sector comprises 59% of the total housing stock of 7.140.800 dwelling (CBS, 2013). The rate of homeownership in The Netherlands is relatively low compared with other European countries, but had a big grow the last years: in 1980 the proportion of homeownership was only 42% of the total housing stock (Priemus & Dieleman, 2002; Norris & Winston, 2012).

The share of commercially rented houses in The Netherlands is minimal and the social rented sector is the largest of all European countries. Almost all dwellings in the social sector are owned by housing associations (Elsinga & Hoekstra, 2004; Norris & Winston, 2011).

2.2 Homeownership and housing prices

An own house is for a household usually the largest investment within their life. The property is not only the place where the household lives, but it also determines their wealth. The changes in the housing price are important fields of study due to the impact and, at the same time, the dependence of the housing market on the economy. Changes in housing prices have a direct impact on households, and consequently on the economy. As well, house price development is at macro level the result of the disequilibrium between supply and demand, which is influenced by economic factors like income and interest rates (De Vries & Boelhouwer, 2005; Eurostat, 2013; Hill, 2013).

At micro level the value of a house depends on its quality and characteristics, as well as on the characteristics of the neighborhood and the other nearby houses. Houses are expensive and vulnerable investments. They need maintenance to protect their value. Each house has unique characteristics that have to meet the market demand also on the long-term to be able to resell the house. Most households have to finance their house with a mortgage, a *"collateralized debt contracts that transfer homeownership to the mortgage lender […] if the homeowners defaults",* as defined by Campbell *et al*. (2009).

Because housing prices reflect the state of the economy and because of the high involvement of financing, is understanding of the housing market and housing prices required. Mortgage lenders have to estimate the value of the houses in their portfolio to oversee their risks and determine their policy to avoid the impact of the fast changing market (Jansen *et al*., 2008; Hill, 2011)

2.3 Mortgage market

The amount of owner-occupiers with a mortgage debt is in The Netherlands, after Denmark, the highest in Europe, with 44% of the total housing stock (Priemus & Dieleman, 2002). Most households have to finance their house with a mortgage: in 2007, 89,5% of the owner-occupied houses was mortgaged and only 10,5% was mortgage free (Norris & Winston, 2012).

With the increase of the owner occupied rate, also the mortgage debt in The Netherlands increased rapidly. High levels of mortgage debt characterize the owner-occupied sector: the total mortgage debt in the country in 2007 was 600 million euro and equal to 60% of the total value of the owner occupied sector (Wieringa & Van Der Geest, 2008; Norris & Winston, 2012).

Due to the tax deductibility and the retirement regulations, the Dutch mortgage debt is one of the highest in the world related to the GDP, the income of the homeowner and the value of the house. The lending capacity of a household is determined by the height of the mortgage compared to the value of house, the Loan-to-Value, and by the income, the Loan-to-Income (Brosens, 2009).

Banks are traditional mortgage lenders; Rabobank is market leader with a market share over 25%, followed by ING and ABN Amro (Wieringa & Van Der Geest, 2008). The most common mortgage in The Netherlands is the interest-only variant and homeowners do not redeem (part of) their debt over the years. This makes homeowners vulnerable for the value change of their property. Due to new tighter funding requirements, new interest-only mortgages are no more provided, but the existing ones still cover over half of the total amount of mortgages (De Nederlandsche Bank, 2011).

2.4 Mortgage risks

Getting a mortgage comes with certain risks, because of the amount of money borrowed and the long time it takes to pay it back. A mortgage includes taking risks for both the homeowners and for the mortgage lender. The two main risks for the homeowners are the credit risk and the risk of negative equity. The risk of the mortgage lender derives from the homeowner risks: if homeowners cannot pay the monthly costs or repay the negative equity, this results in the consumer credit risk for the mortgage lender (Brosens, 2009). In the next paragraphs the risks of the homeowners are described in more detail.

2.4.1 Credit risk

The credit risk refers to the risk the homeowner will not be able to pay the mortgage payments due to changes in the households' financial situation, like income decrease or expenses increase. We can indicate this risk with the Loan-to-Income (LTI) percentage, a finance measure that compares an individual mortgage to the maximum allowed mortgage based on the income. The LTI percentage represents the ratio of the consumer's income that goes toward paying the mortgage and the maximum allowable based on Nibud Standards (maximum 100%). Sometimes it is also indicated as the ratio of the loan and the annual

income: 4,5 is the conventional rule of thumb for the maximum allowed. The Nibud is the Dutch national institute for budget information (Dutch: Nationaal Instituut voor Budgetvoorlichting) and each year it sets the new standards of income criteria for granting mortgages. Banks and mortgage lenders need to comply to the code of conduct for mortgage financing (Dutch: Gedragscode Hypothecaire Financiering, GHF) where is established that they needs to follow the Nibud norms (Brosens, 2009; Van Middelkoop, 2011; Van Hoek & Koning, 2012).

For zero-energy houses the maximum lending capacity based on the LTI ratio, can be exceeded with a maximum of 13.500 euro. This is possible for households with an annual income starting from 29.000 euro. This extra lending capacity is possible because the household has no energy costs (Dijsselbloem, 2013).

2.4.2 Negative equity risk

Negative equity is the term used to describe the financial situation of a homeowner when the value of the property is lower than the outstanding amount of the mortgage. The Loan-to-Value (LTV) is the ratio of the mortgage and the value of the property. A LTV higher than 100% means the household has a negative equity. The maximum LTV percentage allowed is 104% in 2014 (including 2% of capital transfer tax). Between 2013 and 2018 the government is lowering the maximum LTV percentage gradually to 100%. This means that since 2018 it will be no more possible to get a mortgage higher than the value of the house (Brosens, 2009; Van Middelkoop, 2011).

In municipalities with local guarantees for required housing improvements, it is since 2014 possible to exceed the maximum LTV norm (Dijsselbloem, 2013). Financial arrangements are made possible whit guarantee of the municipalities through a special financial arrangement (Dutch: Stimuleringslening) of the Stimulation Fund Public Housing (Dutch: Stimuleringsfonds Volkshuisvesting) (KCAF, 2014).

For mortgages up to 265.000 euro, this risk could be covered by the National Mortgage Guarantee (Dutch: De Nationale Hypotheekgarantie, NHG). With the NHG the government guarantees the negative equity risk of the household. Under certain circumstances and conditions, the negative equity can be cancelled (Van Hoek & Koning, 2012).

2.5 Impact of the credit crisis

The housing market is characterized by short periods of fast growth in housing prices followed by a quick decline. Considering a longer time period there can be stated that the housing prices increases with an average percentage that corresponds with the inflation (Van Ewijk & Teulings, 2009). Since the early nineties housing prices increased rapidly due to low interest rates, tax deducibility of mortgage interest, shortage of high quality dwellings and increase of the incomes. In the period between 1996-2001 housing prices increased about 10% each year (Brosens, 2009). De Vries and Boelhouwer (2005) state: *"House prices can be explained by demand oriented variables speculative effect: when prices continue to increase consumers speculate on further rises and act swiftly".*

As a consequence of the credit crisis, since 2008 in The Netherlands the housing prices are decreasing rapidly and the number of housing transactions are reduced by 50%. At the end of 2012 the value of over 800.000 mortgaged houses was lower than the mortgage and thus 25% of all homeowners had a negative equity (CBS, 2013; Lupi & Van Dijken, 2013). The average negative equity for homeowners is 5.000 euro but for 200.000 households the negative value is more than 30.000 euro. Especially recently moved, young households have to deal with this problem; they generally financed their home with an interest-only mortgage and they bought the house at the peak pricing while now the value of their property decreased (Schilder & Conijn, 2012).

Risks connected to mortgages were also present before the crisis, but the crisis has increased these risks. Homeowners only sow houses as a save investment because of the continuous increase in value since 1985. The risks of negative equity became real at the moment that homeowners want to sell the house and they remain with a debt as a result of a negative surplus value (Ras *et al*., 2010; Schilder & Conijn, 2012).

Since the credit crisis the requirements and regulations to get a mortgage are tightened and the maximum lending capacity based on both income and value of the house is limited. This limits the lending capacity for especially lower incomes and starters. Before the code of conduct for mortgage financing (GHF) of 2011, it was possible for mortgage lenders to deviate from the norms (Van Hoek & Koning, 2012).

Since mid-2013 preliminary indicators show a slow recovery of the housing market. Especially the decline of housing prices is slowing down. Although the Dutch level of unemployment is still increasing and average income is declining (Rabobank, 2013).

3. Property maintenance and foundation damage

Problems concerning the own property can keep households up at night. Foundation damage in particular has an overall impact on the homeowner's life because of the high repair costs and long during repair activities. *"Every problem in my world now falls between the stony quotation marks of a crumbling foundation"* (Shilkoff, 2013). This chapter is the second and last part of the context of this research. It focuses on property maintenance and on the foundation damage problem in The Netherlands.

3.1 Property maintenance and property value

The value of a property is in literature defined as the sum of the value of the building and the value of the ground. The value of the building is determined by the new construction value corrected with depreciation (Van de Minne and Franck, 2012). Depreciation is defined by Clapp and Giaccotto (1998) as *''the decline in value with respect to age because of increased maintenance costs and decreased usefulness''*. According to the research and literature study of Wilhelmsson (2008) depreciation can be caused by physical deterioration, functional and external obsolescence. The main difference between these causes is that obsolescence may not occur while physical deterioration is a factor will always occur as consequence of passing of the years. Another important difference is that physical deterioration can be prevented or restored while the effects of obsolescence cannot be eliminated, except for functional obsolescence that is accompanied by high investment costs. An extra aspect that has impact on the price of the property is the *vintage* effect. This can have positive or negative impact. Also the building year and the effect of the characteristics of the building of that specific period can have impact on the price (Van de Minne & Franck, 2012).

Several international studies on depreciation focus on the impact of the level of maintenance applied. The depreciation rate can be lowered with property maintenance. The results of the research of Knight and Sirmans (1996) show that the depreciation rates are significantly lower for a maintained property than for a property that is not maintained.

Homeowners can thus chose to invest in the repair, maintenance or improvement of their property to minimize the impact of depreciation on the value of the house. Lack of property maintenance has also a negative impact on the image, quality of life and safety in a neighbourhood. In The Netherlands the duty of maintaining each ones property is captured in the Housing Act (Dutch: Woningwet*)*. The requirements for a dwelling on safety, health and usability are captured in the Building Regulations (Dutch: Bouwbesluit) (Lupi, 2013).

In 2000 the last national research on the maintenance level of the Dutch housing stock shows that the average repair costs for owner-occupied dwellings is about 3.000 euro. Especially the 750.000 one-family and pre-war dwellings require a high average investment of 6.109 euro. For over 90.000 of these homeowners the repair cost will rise to 23.000 euro. The main costs for homeowners are estimated for the repair of the garage and storage

rooms, window frames, roof, ceiling, façade and installations (Meijer and Thomsen, 2006). At this moment the private housing market, especially the cheaper dwellings, have not only to deal with residual debt and bad sellable property problems. A significant problem is poor maintenance: it is estimated that in 2013 there are about 50.000 owner-occupied dwellings with bad maintenance and over 500.000 with a low maintenance level. A bad level of maintenance is defined as a required investment for recovery of the dwelling of 25% or more of the new construction value and a low maintenance level for an investment of 10% to 24% of the value (Lupi, 2013).

Property maintenance is an important factor in order to maintain the value of the property, but homeowners can also invest in measures to improve the value of the house. Adding square meters is an improvement that in many cases can increase the value of a dwelling significantly, especially in urban areas where square meters are rare and expensive. Sustainable interventions to the dwelling have also a positive impact on the value. Energy labels are increasingly important aspects in the valuation of properties. A dwelling with low energy costs is more attractive than one with high costs.

3.2 Foundation damage case

Large-scale property maintenance problems in The Netherlands are related to foundation damage. In The Netherlands 750.000 buildings on wooden foundation piles have a risk towards foundation damage. It concerns buildings built between 1890-1945 in areas with weak subsoil, in the Western part of The Netherlands and the areas along the rivers. The forecast for foundation damage in 2001 with perceived consequences before 2050, was 100.000 damaged houses with total costs of 5 billion euros. Research institute Deltares made in 2012 an accurate estimation of the total financial impact of wooden piles foundation damage. If every building at risk needs to be repaired the financial impact will reach the fictitious maximum of 40 billion euro's. Homeowners bear the risk of the maintenance of the property, but this will also impact financial institutions because the value of the collateral decreases (Deltares, 2012).

The amount of houses with foundation damage is growing faster than the recovered ones (VROM, 2005). Also buildings without wooden foundation piles in these areas and built between 1890-1945 show cracking and sinking. About 300.000 houses on shallow foundation have a risk for foundation issues. Now the estimation of houses with foundation damage has increased to 200.000 spread over 150 municipalities e.g. Zaanstad, Dordrecht, Haarlem, Rotterdam, Schiedam and Gouda (KCAF, 2012; Klaassen & Van Overeem, 2012). In the next 10 years at least 400.000 households may have to deal with foundation problems (KCAF, 2012; CURNET/SBR, 2012).

3.2.1 Wooden pile foundation

Sand soils in The Netherlands have a high bearing capacity. In the peat and clay areas in the period till 1945 the buildings were founded on wooden piles to transfer the weight of the construction thought the weak peat into the deeper stable sand layer (SEV, 2009).

Still 12,5 million wooden piles are estimated to be in use in the peat- and clay areas to support buildings. Wooden foundation piles were implemented since the industrialization period till the end of the Second World War when concrete piles replaced them. The different local soil conditions and features of the building above require different pile foundations. The piles differ in length and diameter in different cities. In Rotterdam the average length is 14,5 meter with a diameter of 25 cm while in Zaandam the length of the piles is 7 meter and a diameter of 11 cm. The stems differ in the timber species. Short piles used to be pine and longer piles used to be imported spruce or fir stems. The quality of the wood, defined by the growth rate, origin and process of harvesting, is the most important factor in the variety in degree of conservation of the pile (Klaassen & Creemers, 2012; Klaassen & Van Overeem, 2012; Klaassen, 2008).

Wood will decompose by biological processes in nature, but in a wet and anoxic environment this process can be stopped or at least slowed down. In fact, from archeological discoveries it is known that wood can be conserved for over thousands of years, and so also wooden foundation piles can resist over hundreds of years. Despite of the propitious soil for wood preservation in the Western part of the Netherland, wooden pile foundations are rotting due to different causes (see paragraph 3.3 *Causes of foundation damage*) (Huisman *et al*., 2008; Klaassen & Creemers, 2012; Klaassen & Van Overeem, 2012).

3.2.2 Shallow foundations

Buildings on shallow foundation have to be located on sand soils. When build on weak clay- and peat subsoil, the building sinks with waterlogging problems as a consequence. Ground vibrations caused by speed bumps accelerate this process. In cities like Rotterdam and Dordrecht different foundations with and without foundation piles are implemented. The buildings without foundation piles are sinking and settling although the ones standing on piles (Klaassen & Creemers, 2012).

3.3 Causes of foundation damage

There are actually four major causes of damaged foundations (VROM, 2005):

- Wood decay due to low groundwater level (Dutch: *paalrot*);
- Wood decay under water (Dutch: *palenpest*);
- Negative skin friction;
- Design- and execution errors.

Wood decay due to low groundwater

Wood-degrading fungi are active when pile heads are not positioned below the lowest expected groundwater height. The combination of oxygen supply and humidity creates the optimal environment for the growth of wood-rotting fungi. With a high concentration of oxygen white- and brown rot fungi are active, while at low oxygen levels softrot fungi are active.

There are different causes for low groundwater levels. Most are the consequence of an insufficient water management by local governments, like leak sewer, incorrectly adjusted

storm drains, groundwater abstraction, construction sites lowering groundwater level. Other causes for low groundwater levels can be related to climate changes (Huisman *et al*., 2008; KCAF, 2012).

Wood decay under water

From recent studies of the last decades it is observed that wood degradation can also occur when the full wooden pile is located under ground water level. Erosion bacteria cause, with a low decay velocity, degradation of the wooden piles under waterlogged conditions and without oxygen supply (Huisman *et al*., 2008; Klaassen & Creemers, 2012; Klaassen & Van Overeem, 2012).

Negative skin friction

Negative skin friction is the phenomenon that occurs when ground layers, due to subsidence, stick to the piles and push them down trough the bearing soil. Before the Second World War the effect of negative skin friction was not taken into account in the construction calculations (Klaassen & Creemers, 2012).

Design- and execution errors

Design and execution mistakes include all mistakes caused by a lack of knowledge about foundations, like the use of shallow foundation on weak subsoil. Other examples are: use of too short piles, incorrectly drive of piles into the ground, insufficient quality of wooden piles, overload of the foundation (KCAF, 2012; VROM, 2005).

3.4 Effects of foundation damage

The foundation is essential for the stability of a building and when it is damaged it has impact on the whole building. Bacterial degradation usually causes urgent problems while the lack of bearing capacity of the subsoil or the effects of subsidence by shallow founded buildings are gradual processes (SEV, 2009). Visible signals of foundation damage are unequal settlements, cracks in the walls, clamping doors and windows. Typical for shallow foundations is that due to subsidence the dwellings are confronted with rising water. The damage to a building can be categorized in architectural damage, constructive damage and risk for collapse (CURNET/CBR, 2012).

Municipalities concern about both social and market impact of foundation damage on the neighbourhoods. The negative effects of distressed properties are discussed in multiple studies. If foundation damage is not repaired it will have a negative impact on the livability, image and attractiveness of a neighbourhood. The market effect of foundation damage contributes to further price decrease in a neighbourhood that will affect the value of all houses in the surrounding (Campbell *et al*., 2009; Johnson *et al*., 2013; Schuitemaker & Wassenberg, 2013).

3.5 Consequences for the homeowner

Homeowners are responsible for the maintenance of their house and consequently for the maintenance of the foundation of their house (VROM, 2005).

To establish the condition of a building, foundation inspections can be done by specialized organizations to gain an estimation of the actual quality of the foundation and a forecasting for the next 25 years (Klaassen & Van Overeem, 2012). The costs for this inspection are about 3.000 euro. When the damage is detected and established, in the most case interventions to limit the damage are not enough and the owner of the property should proceed with the repair of the foundation. But foundation repair is a serious intervention and there are different aspects that slow down or even obstruct this process. It requires high investments, lot of time and causes great nuisance.

The costs to repair the foundations are very high, but do not have any added value for the house. The average repair costs are between € 600 and € 1.200 euro per square meter (VNG, 2009) with significant differences between the regions. The repair cost for an average dwelling are € 45.000 in Zaanstad, € 60.000 in Dordrecht and € 70.000 in Rotterdam, but can increase far over the € 100.000 for large buildings or due to high damage to the building envelope (KCAF, 2012).

In addition to the social and financial aspects of foundation damage, the repair activities have to take place for the whole building block. This means that all households in the building block have to participate. This usually results in a long and laborious process (CURNET/SBR, 2012).

3.6 Policy

Foundation damage is a complex problem with different aspects: financial, social, political, legal, structural, etc. Consequently different stakeholders are involved. In all interviews emerged that the different stakeholders are reluctant to be active involved in this problem to not become the problem owner.

During the last years directives for foundation inspections and repair were determined and the F3o organization (Independent organization for foundation research) was founded to guard and improve the quality of all construction activities concerning wooden pile foundation.

In the last few years the awareness of the need to work together is emerging. Congresses, brainstorming and other activities are organized to bring the stakeholders together, but the responsibilities and commitment of each are still unclear.

From a legal point of view, the homeowner is responsible for the state of the foundation and the municipalities or the mortgage lender can summon the homeowner to point at the duty of maintenance.

A national clear policy is missing and only a few municipalities are active involved in this problem. The policy of these municipalities in particular aimed at monitoring and protecting the quality of the housing stock. Different local governments, like Dordrecht, Rotterdam and Zaanstad, have investigated the condition of the foundations in their municipality. Due to samples, they made an estimation of the buildings with risk for foundation damage and the degree of degradation. The results are public but not always even accurate for each dwelling

because there can be differences in the degradation of pile foundations among buildings in the same street. Further, these municipalities are involved in the information and communication to the homeowners, they grant subsidies or guarantee low interest loans.

4. Research Methods

4.1 Problem statement

Large-scale property maintenance problems in The Netherlands are mainly caused by foundation damage. Around 750,000 buildings on wooden piles have a risk for foundation damage (Deltares, 2012) and in the next twenty years 400,000 homeowners may have to deal with unexpectedly required high foundation recovery costs (KCAF, 2012; CURNET/SBR, 2012). At the same time 89,5% of the owner occupied houses in The Netherlands are mortgaged houses and for 25% of the mortgaged houses the value of the mortgage is already higher than the actual value of the property (CBS, 2013). Due to high costs of foundation damage the value of the house decreases rapidly and without intervention homeowners see deteriorate their property. In the long-term municipalities can declare the dwelling uninhabitable and the residents are forced to move.

Costs for foundation damage increase the housing costs of the homeowners. For many households repair costs were already difficult to fund, and the current situation of general value decrease in the housing market and increasing requirements for funding make the problem worse. In the meantime, the lack of foundation repair activities cause impoverishment of the neighbourhoods (KCAF, 2012).

There is limited information and awareness about foundation damage, while it has a big impact on homeowners and financial institutions. Thereby, there is limited knowledge about the financial consequences for homeowners and for financial institutions how to steer their customers and how to limit future risks for them and their organization.

The research problem is stated as:
From now and in the coming decades there will be homeowners who have to deal with unexpectedly required high foundation recovery costs. Homeowners face a difficult investment choice for the reconstruction of their distressed property limited by the declining housing market and the their own financial possibilities.

4.2 Research question

The main research question is formulated as follows:
How could financial institutions steer the reconstruction of distressed properties in a declining housing market?

The problems that go along with foundation damage are various and there are many possible solutions. In this research we focus only on a part of this problem.

The sub-questions are formulated as follows:

1. *What is the financial situation of homeowners dealing with foundation damage?*
2. *How could financial institutions (and other stakeholders) minimize the impact for the customer and their own organization?*

3. *What will be the best investment decision for homeowners with a mortgage dealing with foundation damage?*

4.3 Research boundaries

This research focuses on present homeowners with a mortgage in The Netherlands. New homebuyers are excluded from this research. The possible foundation risks are nowadays known, so these unexpected costs can be foreseen in advance and in case of established damage new homebuyers can easier get a loan to repair the foundation of the house they want to buy. For them this repair contributes to increase the value of the house, while for existing homeowners this repair is needed to maintain the value of the house. This premise implicit a need of controlled property transactions and awareness of the new homebuyers regarding the state of the foundation.

This research only takes into account that homeowners lack the foundation repair due to problems to get a loan. Other reasons why homeowners do not repair the foundation are not considered in this research. This has no influence on the settlement of the dwelling or on the financial consequences for the homeowner.

4.4 Research perspective

Subject of this research are primary homeowners with a mortgage. They have to make the investment decision and they are the one who primary have to deal with the financial consequences of foundation damage and the value decrease of their house.

This research looks at the problem from the perspective of the financial institutions. They are ones of the stakeholders that could contribute to make foundation repair possible for homeowners. At the same time, financial institutions could also have to deal with the problems when homeowners cannot fulfill their financial obligations. The loan restrictions meant to protect customers and banks can in the case of foundation damage lead to high financial losses for both of them.

4.5 Research objectives

The purpose of this research is to advise financial institutions on how to steer their customers dealing with foundation damage. The results from the analysis are used to support in the decision-making of the owners and financial institutions.

To accomplish this purpose this research focuses on:

(1.) The estimation of the extent of the problem, thus how many homeowners in The Netherlands cannot dispose of financing for foundation repair and what is the financial situation of homeowners dealing with foundation damage;

(2.) Get insight in the factors that determine the financial situation of homeowners to allow financial- or other institutions to estimate how they can meet the need of their customers/homeowners;

(3.) The development of a model to gain insight in the consequences of the different choices of the homeowners. The investment choices of homeowners dealing with foundation damage can be:
- Do nothing;
- Repair the foundation (and isolate the basement floor);
- Repair the foundation and extent the dwelling with a basement;
- Repair the foundation and install a ground source heat pump.

4.6 Research approach

This research is a problem-solving project undertaken to minimize the impact of the problem. The goal of this research is to contribute to change the current situation and follows the classic problem-solving *regulative cycle* of Van Strien from 1997 (Van Aken *et al*., 2009). In this research we will focus on the first three steps of the regulative cycle, problem identification, diagnosis and design. This is the so-called *design* part. A *design* is defined by Van Aken *et al*. (2009) as *"a model of an entity to be realized, as an instruction for the next step in the creation process".*

The steps and methodologies applied during this research are schematically shown in the research framework in figure 4.1. The methods are further explained in paragraph 4.7.

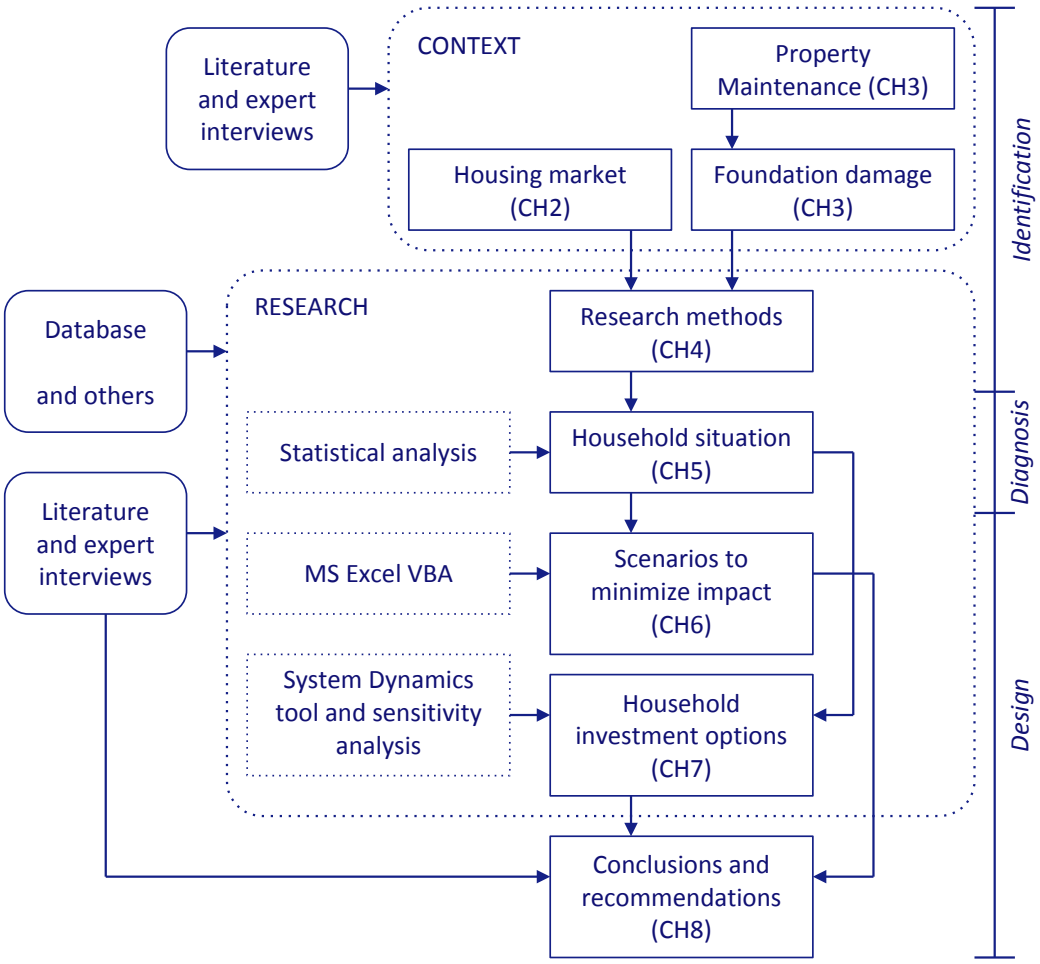

Figure 4.1 Research framework

4.7 Methods

In this research different methods are used to answer the research sub-questions. All analyses are based on data from - and public datasets, and supported by information and data from literature and expert interviews. The different methods used are described below.

4.7.1 Statistical analysis

To answer the first research question the data is analyzed with support of software package IBM SPSS Statistics. First, the general descriptive statistics are given and next the more extensive statistical analysis Factor Analysis (FA) and Discriminant Analysis (DA) are used. Both methods produce a coordinate system with axes in a two dimensional space. FA is used to reduce the dimensionality of a data set. From a set of existing variables new artificial variables (factors) are created that account for most of the variance in the observed variables. The factors re-determine the location of the original data on the x-y axis. DA provides a class-separability and draws a decision region between the given classes.

4.7.2 MS Excel Visual Basic for Applications

To answer the second research question, MS Excel Visual Basic for Applications (VBA) is used as supporting tool.

MS Excel VBA is the name for the programming language of MS Excel. It is especially used to automate repetitive tasks and works by running macros. With VBA a macro is made to standardize and ultimate the data processing in MS Excel, used to analyze and present the data. With input boxes the user can control the input variables and process different simulations with the same macro.

4.7.3 System Dynamics

To answer the third and last research question, the System Dynamics (SD) research methodology is used to develop a model with the software package Vensim PLE Plus.

SD is a methodology for analyzing systems and their change over time. Stock and flows are the two central concepts of SD. The stock and flow conventional representation is based on the hydraulic metaphor introduced by Forrenster in 1961.

Stocks are accumulations, *bathtubs of water.* Stock changes by action of the flows and the flows represent changes, *the flow of water into and out the bathtubs.* In mathematics, *t*he stocks integrate their flows:

$$\text{Stock}(t) = \int [\text{inflow}(s) - \text{Outflow}(s)]\, ds + \text{stock}(t_0)$$

The net flow into the stock is the rate of change of the stock. *The water in the bathtub at any time is the accumulation of the water flowing in through the tab less the water flowing out through the drain*.

SD models are used to improve the understanding of the system and stocks are the basis for decision-making (Ford, 2010; Sterman, 2000).

Different aspects of the households are combined in a System Dynamics based model. The sensitivity analysis, Monte Carlo Analysis (MCA), is used to eliminate the uncertainty related to the assumptions for the different options. The different data used in the model comes from literature study and interviews with experts.

4.8 Validation

The input and structure of the models are discussed and validated with field experts from - and other organizations, as well as by experts from Eindhoven University of Technology.

5. Financial situation of homeowners

In the last years an increasing attention for the foundation problem is seen within literature. Foundation repair is a big intervention with high financial costs and has a significant impact on the household finances. If a household cannot repair the foundation, the property will continue to loose value and in the long-time, due to safety issues, the household will be forced to leave the property when it is declared unfit for habitation. Little is known about the financial situation of households and how many households cannot afford the costs of this intervention.

This paragraph provides an answer on the first research question: *"What is the financial situation of homeowners dealing with foundation damage"*. Firstly, to estimate the extent of the problem, the aspects *risk buildings* and *financial situation* are discussed, followed by a description of the used data. Then the results of the statistical analysis are reported.

5.1 Buildings at risk

In The Netherlands there are around 750.000 buildings on wooden piles and 300.000 on shallow foundation that have a risk for foundation issues. The buildings at risk include 400.000 private houses that at this moment face, or in the short time will face, this problem. Considering that 90% of the households in The Netherlands have a mortgage, we can conclude that this problem involves about 360.000 households. Since there are in total 7.569.000 households in The Netherlands (CBS, 2013) this means that 5% of the Dutch households could have a problem with the financing of foundation damage.

To identify the buildings at risk two aspects have to be determined: the area and the building year. In this research, when risk buildings are mentioned, it covers the buildings that satisfy these features as described below.

5.1.1 Areas of risk

Foundation problems concern buildings on wooden foundation piles and buildings on shallow foundation in the weak subsoil areas. Sand soils in The Netherlands have a high bearing capacity, but in the loam and clay areas buildings have to be founded on piles to transfer the weight of the construction trough the weak peat into the deeper stable sand layer (SEV, 2009). On the loam and clay subsoil, buildings incorrectly founded on shallow foundation have not sufficient foundation support and as a consequence of subsidence risk to need a new foundation on piles. Clay- and loam soils are located in the Western part and river areas of the country. For a geographic overview of the risk-areas see appendix 1.

5.1.2 Building year

The other important aspect to identify buildings at risk is the year of construction. Wooden piles were used till the end of World War II, before the introduction of concrete piles. 21% of the actual private housing supply is built before 1945. In the literature there are some

discrepancies in the determination of the exact risk period. The Knowledge Center Foundation Problems (KCAF) refers to buildings built between 1890-1960 as risk buildings (KCAF, 2012). Klaassen (2013) explores the foundations of historic buildings older than 300 years, but set the start of the large use of wooden piles for buildings around 1875, during the industrialization period. According to the Deltares research (2012), this research considers as risk dwellings the ones built between 1890-1945 to not overestimate the problem.

5.1.3 Considerations

In the Deltares research (2012) there is a subdivision in low risk and high-risk areas, based on subsidence forecasting. Due to the lack of data within this thesis the only division possible is based on the subsoil type, resulting in only two risk levels for the different zip-code areas: risk and no risk.

Literature and interviews reveal the expectation that all the risk buildings between now and 10-25 years will have to deal with this problem. However, the last 5 years some buildings are already repaired but there is not a recorded amount of repaired buildings on national level. It is very hard to make statements about which buildings in the future will of will not have foundation damage. At this moment, there are lots of examples of similar buildings within the same street with and without damage. Also there are examples of differences in damage between piles under the same building. This research considers a worse case scenario and takes all the risk buildings into account because there is no telling about what will happen. Also there is no data about the houses or recently bought with knowledge of the damage.

5.2 Financial situation

To determine the financial situation of the households the entailed risks of an extra loan are considered, assuming that all homeowners in risk buildings need a loan for the foundation repair costs. To get this extra loan a homeowner has to meet Loan-to-Value and Loan-to-Income requirements.

Four categories of households are set:

- Meet Loan-to-Value and Loan-to-Income requirements (category 1);
- Meet Loan-to-Income but not Loan-to-Value requirements (category 2);
- Meet Loan-to-Value but not Loan-to-Income requirements (category 3);
- Do not meet both requirements (category 4).

The actual financing options for households, summarized in table 5.1, are determined by the requirements the households meet. These requirements are strictly determined to protect homeowners for excessive mortgages, but in the case of foundation damage they limit the amount of households that can get a loan.

Table 5.1 Financing options for households by category.

		Loan-to-Value	
		Yes	No
Loan-to-Income	Yes	*(1) Financing*	*(2) Problem*
	No	*(3) Customized loan*	*(4) Problem*

For households in category 1 that meet both requirements there is no problem to get a loan. They have enough lending capacity based on their income and the value of the house.

Households in category 2 do not meet the Loan-to-Value requirement. The income offers enough lending capacity for an extra loan but the value of the collateral does not offer enough guarantees for the mortgage lender. In general these households will not get an extra loan, but considering that foundation repair is a required intervention to protect the value of the property, mortgage lenders will tend to arrange a custom loan with the household. However, at the moment, there are no official financial arrangements for the households in this category.

For households in category 3 there is a financial arrangement of the Stimulation Fund Public Housing (Dutch: Stimuleringsfonds Volkshuisvesting) to get a loan for foundation repair. This arrangement is only available with incentives from the municipality. At this moment, only 5 municipalities (Bunschoten, Dordrecht, Rotterdam, Schiedam and Weesp) provide this incentive. For the households in this category all the other municipalities there are no financial arrangements.

Households in category 4 have the biggest problem to get a loan. They have no lending capacity based on the income and on the value of the house.

5.3 Data

This research uses data from -, Kadaster and TNO to obtain a sample with financial information of homeowners in buildings at risk.

The database of the - available for this research contains mainly transactions of the last 5 years. From this database all homeowners (with a mortgage at -) in the risk areas and with a building built between 1890-1945 are filtered. To identify the risk areas on 4-digit zip code level, the TNO surface map of 2010 is combined (in ArcGIS software) with the zip-code map of The Netherlands. For the 40 different types of subsoil, according to different literature (Erwich & Vliegen, 2001; Deltares, 2012; KCAF, 2012) is defined if they are *risk* or *no risk*. The result is a list of zip codes of the risk areas. For the houses mortgaged by - in these areas (matching the BAG-ID, unique property-number), the database of the - is completed with information of the year of construction and size of the house from the public database Bag Extract of Kadaster. The result is a sample of homeowners in buildings at risk, with the information shown in table 5.2.

Table 5.2: Information of homeowners

Homeowners information
Initial exposure amount
Outstanding amount (in 2013)
Savings for mortgage payback (in 2013)
Initial household income
Date income is checked
Initial Loan-to-Income percentage
Initial Loan-to-Income class
Age (in 2013)
Age class
NHG Indicator
Market value property (in 2013)
Type of property
Location
Size of the house
Year of construction

To protect this highly confidential information, in the database all personal details that can be related to a particular household are omitted, like: name, address, customer number, bank account, BAG-ID, etc.

With the already known information of the households, new data is calculated, as the indexed income, Loan-to-Income percentage and Loan-to-Value percentage. For the use in SPSS the data is recoded. Data smoothing is necessary to eliminate incomplete and unlikely data. An overview of the data preparation is reported in appendix 2. This results in a sample of 12.180 households.

5.4 Descriptive Statistical Analysis

In this paragraph the results of the descriptive statistics are described, to establish the size and characteristics of the households in risk building. First the general situation in the sample is explained, then, the amount of households with a problem to get a loan is estimated and divided into the four categories as described in the previous paragraph 5.1.2. At the end the characteristics of the households in the four categories are discussed.

5.4.1 General characteristics of the sample

5.4.2 Foundation repair costs

Foundation repair costs depends on different aspects, like required length, the amount of piles and the weight of the house. Especially the depth of the piles is decisive for the estimation of the costs. A custom calculation and examination of a building is necessary to estimate the costs for repair. However the costs for foundation are very different so it is not possible to estimate the repair costs with only the available information in the dataset: the total size of the house, the type of property and the location.

Although the costs for foundation repair depends on several aspects, the below values are used for calculation purposes. They are based on literature and validated by foundation repair experts from KCAF and Pudelko.

- 60.000 euro for houses;
- 15.000 euro for apartments;
- 35.000 euro for houses in the *Zaanstreek* (in the sample: Oostzaan, Koog aan de zaan, Zaandijk, Zaandam, Westzaan, Krommenie, Assendelft, West-Knollendam, Wormer, Jisp, Wormerveer).

5.4.3 Impact foundation damage on value of the property

The value of a property depends on many variables. The state of the foundation is obvious a depreciation factor, but there is no research about the direct impact of foundation damage on the value of the property. Literature provides many methods for analysis of depreciation rate of the housing price and the level of maintenance, commonly used for example to measure the impact of the crisis or changes in neighborhood attractiveness.

In order to determine the impact of foundation damage on the value of a house, this research was attempted to apply the Hedonic Price Index method. The Hedonic model expresses the price of a property as the function of different characteristics (De Vries *et al*., 2009). With the Hedonic Price is tried to determine the impact of foundation damage but the lack of data prevents the use of these method. Firstly, the information about the property is deficient. According to Minne & Francke (2012) to quantify the impact of physical deterioration should also be taken into account the level of maintenance, functional and external obsolescence and the value of ground. Secondly there is no information about the state of the foundation of the properties in the sample. With the Audit Risk Method is tried

to offset this lack by filtering the properties that most likely have with foundation damage, but the huge dataset and no guarantee that there are households in the set with foundation damage that already depreciated the value of the property, also prevents the use of this method.

The shortage of information about the properties in the dataset and in particular about the condition of the foundation, led to the use of a qualitative method to determine the impact of foundation damage on the value of the property, based on literature and interviews.

Literature focuses especially on the difficulty to sell properties with foundation damage. Important information from literature is that repaired properties have no extra value compared with properties that have no damage: foundation repair does not provide any value increase, but is just an intervention to preserve the value of the property. Also is there is no damage, the value of the property decreases further due to damage to the structure.

Short phone interviews with 14 real estate brokers in Dordrecht and Zaandam gave a general impression of the complexity of the problem. The complete list of brokers can be found in appendix 4.

The opinions and experiences are very different. Some brokers have no experience with this problem or had the last years only one property for sale with damage. Others had more experience and had very different cases. Some properties for sale had much more problems than only foundation damage and had to be completely renovated. In these cases it is very difficult to determine the impact of the foundation damage separately from the impact of the other damage. About the other sold properties with established foundation damage and no other maintenance deficiency, the brokers agree that the repair costs can one-on-one be subtracted from the valued price of the property without damage. Most buyers are discouraged for the purchase of houses that have foundation damage, but in practice this not always means that the properties are unsellable. Especially, traditional houses with characteristic elements are sold with foundation damage without problems. Also properties that not require repairing the foundation immediately, are seen by buyers as interest investment due to the actual low prices and the extra time they have to save money for the repair in the future.

In this research we assume that the impact of foundation damage on the value of the property is the same as the expected repair costs. For the additional damage to the structure the decrease is estimated as 3% of the value each year. Above results are extensively discussed and validated in the interviews with KCAF and Woonkoers Makelaardij, Dordrecht.

5.4.4 Extent of the problem

In this research the amount of households with problems to get a loan for foundation damage is estimated with the assumption they need a full loan for the repair costs. Private savings are not taken into account. The households are divided into the four categories described in paragraph 5.1.2. The household distribution of the sample over the four

categories is showed in table 5.3 and figure 5.1. The largest category is category 2. People meet the Loan-to-Income but not the Loan-to-Value variables.

Table 5.3 Household distribution in categories in sample

Household category	Frequency	Percent
1. Meet LTI and LTV	-	-
2. Meet LTI and not LTV	-	-
3. Meet LTV and not LTI	-	-
4. Do not meet LTV and LTI	-	-
Total	-	-

Figure 5.1 Pie chart distribution of the households over the four categories within the sample

Table 5.4 shows the minimum and maximum amount of households in the four different categories for the total population, with a confidence interval of 95%. The total population concerns 360.000 homeowners with a mortgage in buildings at risk.

-

-

Table 5.4 Household distribution in The Netherlands, confidence interval 95%

Category	Minimum [percent]	Maximum [percent]	Minimum household [amount]	Maximum household [amount]
1. Meet LTI and LTV	-	-	-	-
2. Meet LTI and not LTV	-	-	-	-
3. Meet LTV and not LTI	-	-	-	-
4. Do not meet LTV and LTI	-	-	-	-

-

The distribution of the households and the average shortage is given in table 5.5.

Table 5.5 Percentage households and mean shortage

Shortage (€)	Percentage households	Mean shortage (€)
No Shortage *	-	-
0 - 10.000	-	-
10.000 - 20.000	-	-
20.000 - 30.000	-	-
30.000 - 60.000	-	-
> 60.000	-	-
Overall	100%	-

** Households with no shortage are in category 1: meet both the Loan-to-Income and Loan-to-Value requirements. The other households are distributed over the remaining 3 categories.*
*** The categories are not distributed equally. For a shortage smaller than half of the costs, it is interesting to know the level of shortage in more detail. For shortages larger than half of the costs this is not relevant.*

5.4.3 Characteristics of the households in the categories

For a better understanding of the differences between the households in the four categories in this paragraph are given the average values of different characteristics of the groups. These are based on the data derived from the database. The results are shown in table 5.6. There are clearly some similarities in some values between the categories that meet the LTI requirements (1 and 2) and between the categories that meet the LTV requirements (1 and 3).
-
-
-
-

Table 5.6 Characteristics of the households

	Category 1 Meet both requirements	**Category 2** Meet only LTI requirements	**Category 3** Meet only LTV requirements	**Category 4** Do not meet both requirements
Mortgage				
Exposure amount				
Outstanding amount				
Interest-only mortgage				
Redemption mortgage				
Average shortage for extra loan				
Income				
Mean Income				
Low-income households				
Middle-income households				
High-income households				
House value				
Mean value of the house				
Negative equity (without extra loan)				
Age				
Average age				
Most frequent age-class				
Loan-to-Income				
0-25%				
25-50%				
50-75%				
75-100%				
100-125%				
>125%				
Loan-to-Value				
0-25%				
25-50%				
50-75%				
75-100%				
100-125%				
>125%				
HNG				
Households with NHG				

5.4.4 Factor Analysis and Determinant Analysis

In this paragraph we use FA and DA to determine the household situation (category 1 to 4) due to the characteristics of the household. In table 5.7 are showed the variables used for the household characteristics. For the mortgage, income and value of the house the common logarithm (Log10*(x)*) is used for normal distribution.

Table 5.7 Variables for household characteristics

Variable (x_i)
x_1 Mortgage (LOG10)
x_2 Income (LOG10)
x_3 Value of the house (LOG10)
x_4 Age
x_5 Loan-to-Income percentage
x_6 Loan-to-Value percentage

Before conducting the FA the correlation between the variables is established. The correlation analysis shows a significant correlation between almost all variables (confidence interval 99%). The only exception is that there is no correlation between the Loan-to-Income percentage and the value of the house. For the correlation matrix see appendix 5. Due to the correlation, the components from the FA can be used as predictor variables.

With the FA from the six variables (x_i) six principal components are calculated. The two components with the highest eigenvalue are extracted, with a Kaiser norm. Table "Total Variance Explained" in appendix 6 shows the variance explained by each component and the cumulative variance. The two remaining factors explain 74% of the total variance.

The factors are rotated with the varimax method. Table 5.8 shows the factor rotated coefficient matrix. The coefficients (a_{ij}) in the matrix show the loadings of each variable on the two factors (F_1 and F_2).

Table 5.8 Rotated Factor loads coefficient matrix

	Factor loading	
	1	2
LG10Mortgage	0,861	0,461
LG10Income	0,923	0,059
LG10Value	0,867	-0,362
Loan-to-Income	-0,028	0,512
Loan-to-Value	0,143	0,928
Age	0,180	-0,788

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

In figure 5.2 for each variable (x_i) the loading on component 1 is plotted in the vertical dimension (x-axis) and the loading on factor 2 is plotted in the horizontal dimension (y-axis). The variables Loan-to-Income, Loan-to-Value and age load heavily on factor 1. This factor indicates the scale and size in the model. The income variable loads on factor 2. The mortgage and value variables load on both factors, but especially on factor 2. This factor indicates the lending capacity of the household.

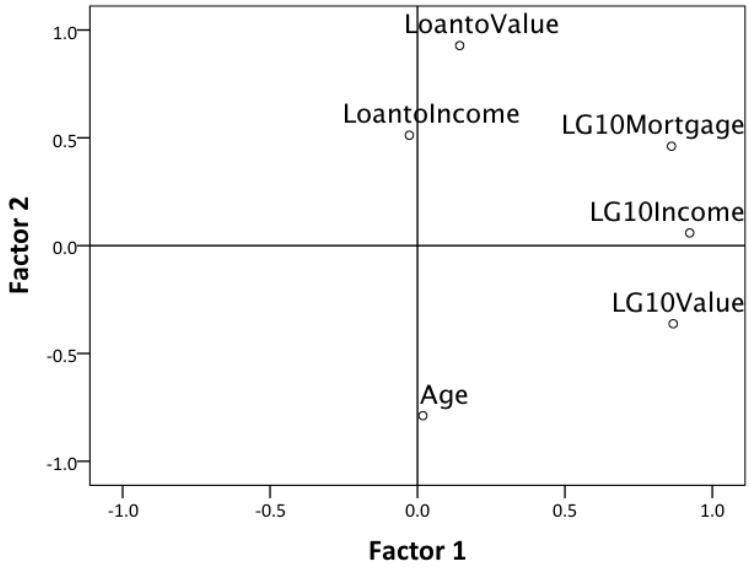

Figure 5.2 Factor plot of variables (loadings)

The FA allows defining each variable (x_i) with the two factors F_1 and F_2. The plot of F_1 and F_2 for all households is shown in figure 5.3.

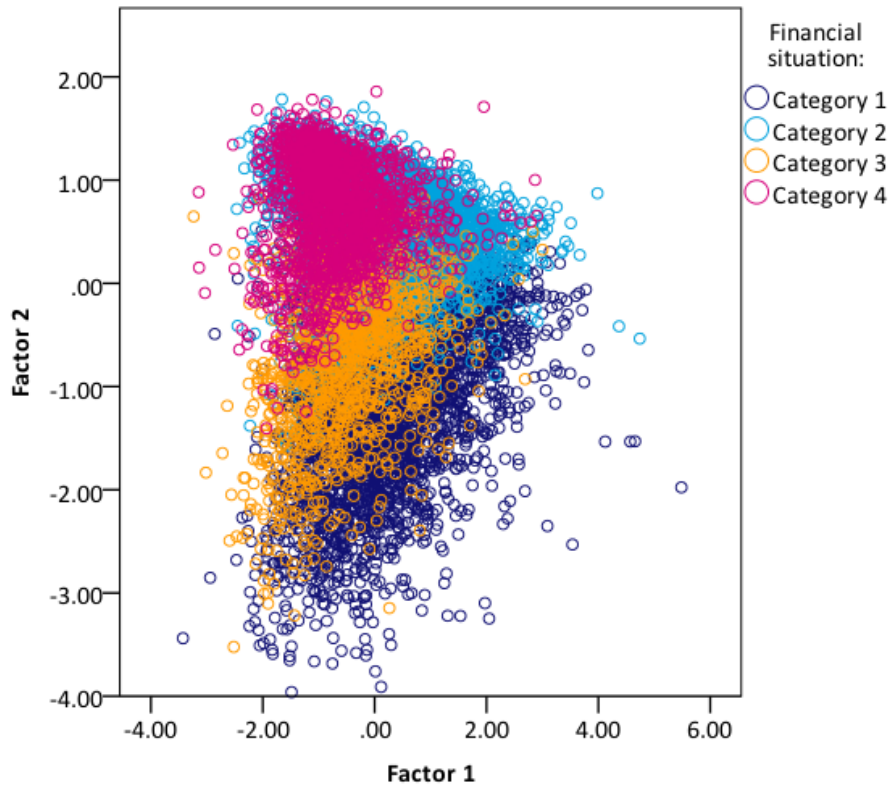

Figure 5.3 Data plot factor 1 and factor 2

In the scatter plot the different household categories are marked in different colors. Factor 2, especially loaded by the Loan-to-Value, Loan-to-Income and age, determines the major difference in classes: the higher factor 2 the more problematic the household situation is. Household category is behind category 3 and 4, and tends to the right, the same as category 1. Factor 1, especially loaded by the income, mortgage and value of the property, determines the difference in income situation based on the income lending capacity.

The DA provides the decision region to determine the financial situation of the household between the four categories. Only the most important results are discussed, the total output of the DA is in appendix 7.

Table 5.9 shows the function coefficient matrix. The number of discriminant dimensions is the number of categories (4) minus 1. However, one dimensions has a small eigenvalue so only two discriminant functions are used, which together explain 99,4% of the variance. The coefficients of the variables Loan-to-Income and age are extremely low in the two residual functions. These variables define especially function 3, the one that is eliminated.

Table 5.9 Canonical Discriminant Function Coefficients

	Function	
	D_1	D_2
LG10 Value	3,641	- 0,632
LG10 Income	- 0,078	1,264
LG10 Mortgage	- 4,808	- 3,484
Loan-to-Value	9,525	0,003
Loan-to-Income	- 0,013	0,082
Age	- 0,004	0,009
(Constant)	- 0,787	9,983

The constant values indicate the intersection point of the two discriminant axes. The intersection of the discriminant axes is given by the constant and corresponds with point (-0,787; 9,983). The unstandardized coefficients are used to create the two discriminant functions, which are:

D_1 = - 0,787 + (3,641)LG10 Value + (- 0,078)LG10 Income + (-4,808)LG10 Mortgage + (9,525)Loan-to-Value + (- 0,013)Loan-to-Income + (- 0,004)Age

D_2 = 9,983 + (-0,632)LG10 Value + (-1,264)LG10 Income + (- 3,484)LG10 Mortgage + (0,003)Loan-to-Value + (0,082)Loan-to-Income + (0,009)Age

Discriminant function 1 is especially determinate by the variables Loan-to-Value, value and mortgage, while discriminant function 1 by income and mortgage. Households that score positive on D_1 do not meet the Loan-to-Value requirements, and households that score positive on D_2 do not meet the Loan-to-Income requirements. This can also be seen in figure 5.4. The data is plot on the discriminant dimension. The plot shows that households that not meet the requirements based on the value of the property are on the right part of the graph and households that not meet the income requirement on the upper side of the graph.

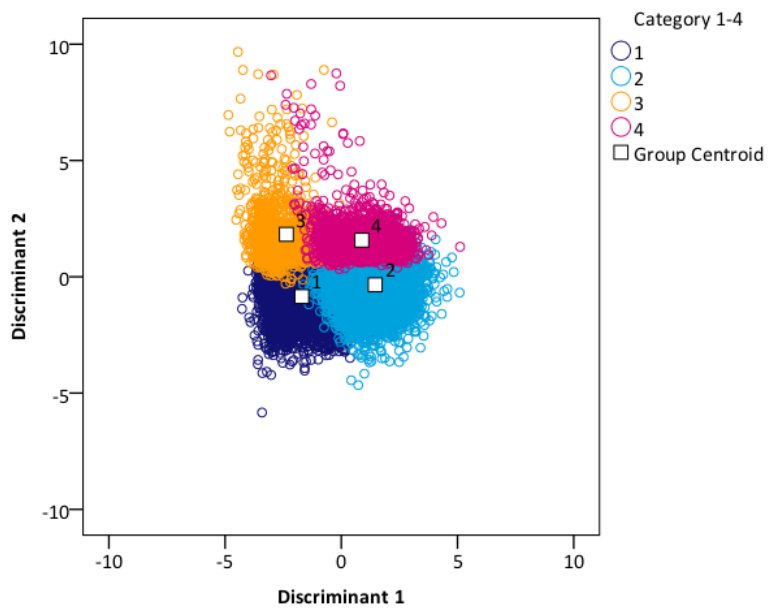

Figure 5.4 Canonical Discriminant Functions

There is a small overlap between the groups, but the model gives a very good estimation of the predicted household situation: 85,5% of the grouped cases is correctly classified by the model (see table Classification Results, in the appendix). The relative location of the boundaries of the four categories on the x-y axis is shown in the territorial map in the appendix.

5.5 Conclusions

The financial situation of the homeowners depends on the lending capacity based on the LTI and LTV requirements. Based on these two requirements the households are divided into four categories, assuming that all homeowners in risk buildings need a loan to finance the foundation repair costs. Only -% of the households can get a loan for foundation repair based on the actual norms. The used database includes variation, which can be explained primarily by two factors. High LTI and LTV percentages identify problematic households. A high income and value of the property, also correlated with high mortgages, are at the contrary predictors for less problematic households. Classification in the four categories is possible with two discriminant functions and is accurate for 85,5%.

6. Scenarios to improve the household situation

The previous chapter divided the households in four categories based on their financial situation and lending capacity and described the characteristics of each category. The aim of this chapter is to identify variables that have a significant impact on the household distribution over the four categories. By active steering on these variables different stakeholders can make a loan for foundation repair possible for more households.

This chapter provides an answer on the second research question: *"How could mortgage lenders (and other stakeholders) minimize the impact of foundation damage on the households and their own organization? "*. To minimize the impact of foundation damage, all households must be able to provide the necessary maintenance to their property. In this chapter first, the change in the distribution of the households is simulated within a scenario based on actual norms and expectations, then, by changing these conditions. At the end of the chapter the risks of different policies for financial institutions are estimated.

6.1 Model development

To simulate different scenarios a model is created using MS Excel VBA. The model calculates for each year the household distribution over the four categories, based on changing variables. The model is based on a double loop: the first sets the household category for each household in the sample, the second for each year. The time horizon of the model is 15 years, with 2013 as t_0 and t_x from 2014 to 2028. The model calculates for each year the income increase, the development of the value of the property and the repayment rate of the mortgage. It establishes the household distribution over the four categories each year. The simulations are based on the data from the - database. The input data and the script are given in appendix 8 and 9.

The model compares a base scenario, based on actual norms and expectations, and a scenario with custom variables. The simulation in VBA starts up with input boxes for the values of the different variables. The input boxes are shown in appendix 10. Changes from the base scenario can be set for different variables at the same time.

The output in MS Excel shows the percentage of households in the four categories in each year in a time horizon of 15 years. The impact of the variation of the variable is shown as the percentage of the increase or decrease of households per category between the simulation and the basis scenario in each year. A percentage of 2% means that the amount of households in the corresponding group with the specified change in variable is increased with 2% compared to the base scenario. An example is shown in appendix 11.

6.2 Base simulation

The base simulation is based on actual household information (repayment), norms (LTI and LTV) and expectations (inflation on property and foundation repair costs). The values are given in table 6.1.

Table 6.1 Variables base simulation

Basis simulation variables	
Inflation on property value	2,10%
Foundation repair costs (euro) apartments/Zaanstreek/other	15.000-35.000-60.000
Loan-to-Value norm	104% (2014), 103% (2015), 102% (2016), 101% (2017), 100% (from 2018)
Loan-to-Income norm	100%
Repayment	Y/N

The inflation on property is based on the actual inflation: 2,1%. The housing market is characterized by periods of fast growth in housing prices followed by quick decline. The long-term rates of appreciation stay constant and in line with the average inflation rate (Van Ewijk and Teulings, 2009). All simulations assume an income increase indexed with the variables in table 6.2.

Table 6.2 Constants for calculation of income at t_x

Inflation and raise of income households <40	6%
Inflation on income other households	2%
One-time income decrease after age 65	35%

The results of the base simulation show the changes over time in the household distribution over the four categories, due to income increase or decrease, increase in the value of the property and mortgage repayment. The households distribution is showed in figure 6.1.

Figure 6.1 Base simulation household distribution

This simulation reveals a positive forecast for the household distribution. The amount of households in category 1 increases significantly in 15 years, from -% to -% of the total households. Especially the amount of households in category 2 decreases significantly, as well category 4. In five years this category decreases from -% to -% of the total households. The small group of households that still remains in this last category consists of households that already have a high-risk mortgage. For this households foundation damage is an unfortunate external cause that increases further their risks and decreased their financial situations.

6.3 Main results

This paragraph first describes the variables subject to change, then for each household category the main results of the different simulation are compared.

6.3.1 Variables

This research analyzes the impact on the household distribution of the following variables:

- Repayment mortgage;
- Repair costs;
- Loan-to-Income norm;
- Loan-to-Value norm;
- Interest-only and low interest loan;
- Market situation.

Below each variable is described in more detail.

Repayment mortgage

The lending capacity of the household increases over time due to repayment. By changing the mortgage from interest-only to a mortgage with redemption, the amount of homeowners that can get an extra loan increases. For the homeowners with mortgages with repayment only a partial annuity mortgage is simulated to not overestimate the lending capacity of the households. Also in the change of type of mortgage, only partially the mortgage changes from interest-only into annuity. A mortgage with a total annuity repayment can otherwise have a to high impact on the household, due to the increase of the monthly cost.

Repair costs

The repair costs for foundation damage are high. Research and new repair technologies can lower the prices significantly. Also due to the increase of the scale of the problem, organizations can optimize the repair processes. Lowering the costs for foundation repair increase the amount of households that can afford the repair.

Loan-to-Income norm

The Nibud determines the LTI norm and the mortgage lender cannot deviate from this percentage because a higher LTI norm would directly increase the risks for a household. Through a small tolerance some outliners can still be helped.

Loan-to-Value norm
A high LTV percentage is especially a high risk when a property has to be sold. To protect the value of the collateral and thus give a loan for foundation repair, mortgage lenders and households could accept a higher maximum LTV percentage.

Interest-only and low interest mortgage for the repair costs
This is one possible financial arrangement for financing foundation repair: a redemption free loan with only 2% interest. For the household it amounts a monthly payment of 50,- euro to repair the foundation. It is a high-risk loan for the mortgage lender, so this should be provided only if a household has no other possibility to get a loan. Similar financial arrangements are at this moment made possible whit guarantee of the municipalities through the Stimulation Fund Public Housing.

Market situation
The market situation is a variable that cannot be controlled, but has an impact on the increasing or decreasing value of the property. Since the crisis the values of the properties are decreasing, but since the first quarter of 2014 the housing market is recovering. This variable must provide insight in the impact of the situation of the housing market on the problem of financing foundation repair.

6.3.2 Impact of variables

This paragraph report the results of the different simulations compared for each household category. In each simulation only one variation at time is applied to determine the impact of the individual variables. Table 6.3 shows an overview of the variations simulated.

Table 6.3 Variations in variables for different simulations

Variations	
Type of mortgage	All mortgage with repayment
Price foundation repair	-10%, -20%, -30%, -40%, -50%
LTI norm	101%, 102%
LTV norm	105%, 110%, 115%, 120%
Inflation on property value a year	-5%, -2%, 0%, +5%
Interest only and low interest loan	Interest 2%

The variations of these variables are based on possible actions or scenarios. At this moment there are not yet the conditions to implement all these changes.

For each category the impact of the variations of the variables are compared with the basis scenario. Only the overview of the household distribution is shown below. The results of the individual simulations are in appendix 12.

For the variables with more than one variation, only one is used in the comparison between the variables. The simulations compared with the basis scenario are: all household have a mortgage with redemption, foundation repair price -30%, LTI norm 102%, LTV norm 120%, property value increase 5% a year, interest-only loan. The households move over time from category 4 to category 3 and 2, and from category 3 and 2 to category 1.

Category 1

Figure 6.2 shows the amount of households in category 1 in the different simulations. All options reveal a growth of the category over time. In 15 years all options are close to each other with about -% of all households in category 1.

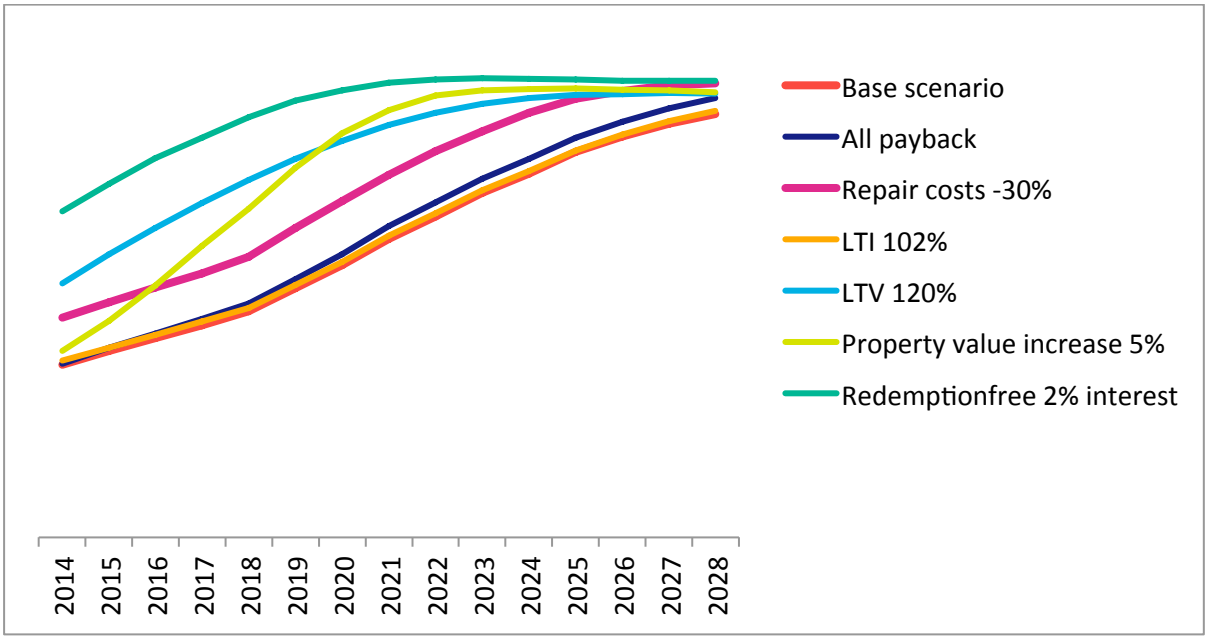

Figure 6.2 Percentage households in category 1 [percentages in this figure are omitted]

Increasing the LTI norms to 102% and changing the mortgage for all households to a partially repayment mortgage have only a limited impact. The decrease of the repair costs with 30% and a LTV norm of 120% have both a significant impact confronted with the base scenario. A property value increase of 5% has also a significant impact on the amount of households in this category; it shows that a rising housing market and housing prices will positive influence the household distribution especially on the long-term. Nevertheless, this is a variable that cannot be influenced. The low interest loan almost doubles the amount of households in category 1 compared with the base scenario.

Category 2

The amount of households in category 2 in each year is the result of the inflow of households from category 4 and the outflow of the households to category 1. Figure 6.3 shows the amount of households in this category in the different simulations. In all results the amount of households in category 2 significantly decreases to - and - percent. The variables that influence the percentage of the household in category 2 are almost the same as in category 1.

The LTI norm and partially repayment mortgage of all households have only a limited impact on the outflow of the households in this category. The decrease of prices with 30% has a significant impact on the distribution, followed by the LTV norm and the low interest loan. The increase of the value of the properties has a significant impact on the long time.

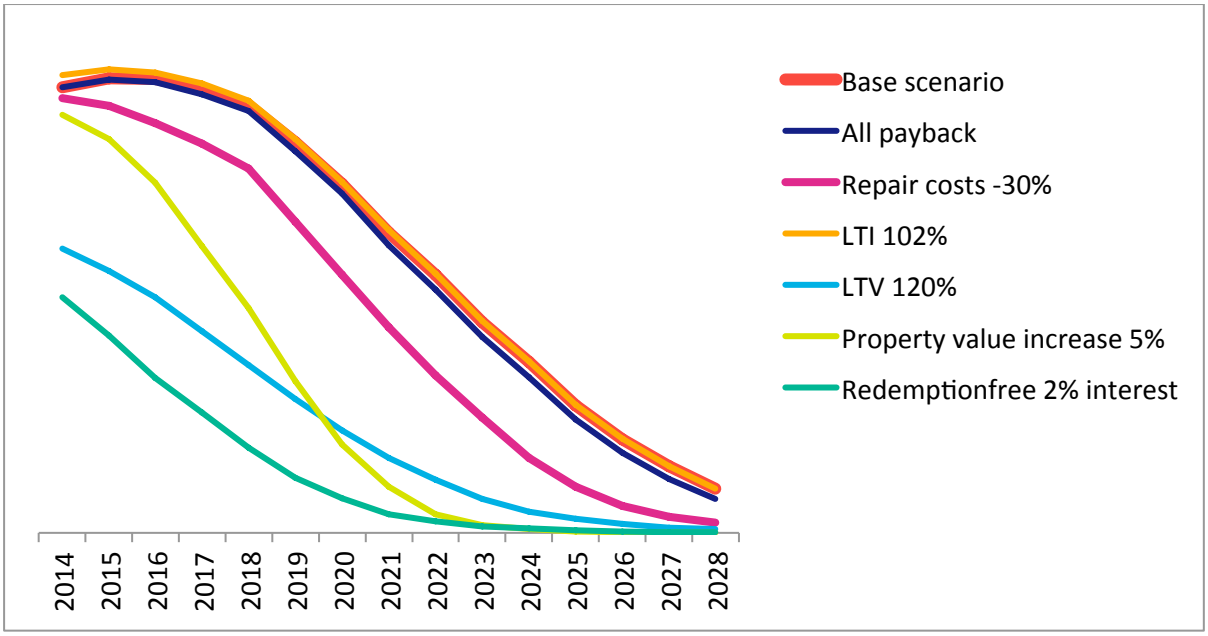

Figure 6.3 Percentage households in category 2 [percentages in this figure are omitted]

Category 3

The variables have different impact on the percentage of the households in category 3 and are the result of the changes in category 2 and 4. The amount of households in category 3 is almost constant and there is a balance between the inflow from households from category 4 and the outflow to category 1. This means it is very hard to help people out of this category. The percentage of household in category 3 is shown in figure 6.4. In all simulations the percentage over the 15 years is between -% and -% of the total households.

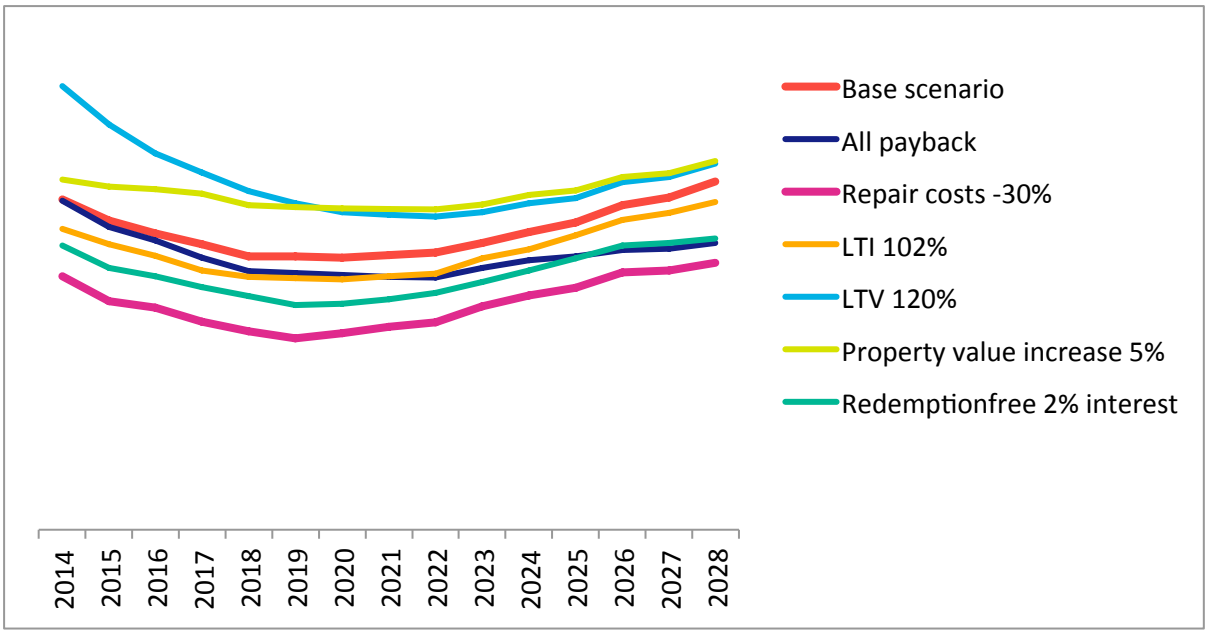

Figure 6.4 Percentage households in category 3 [percentages in this figure are omitted]

Category 4

Figure 6.5 shows the amount of households in category 4 in the different simulations. All options reveal a rapidly decrease of the amount of households in this category over time.

Within seven years all options are close to each other with less than -% of all households in category 4.

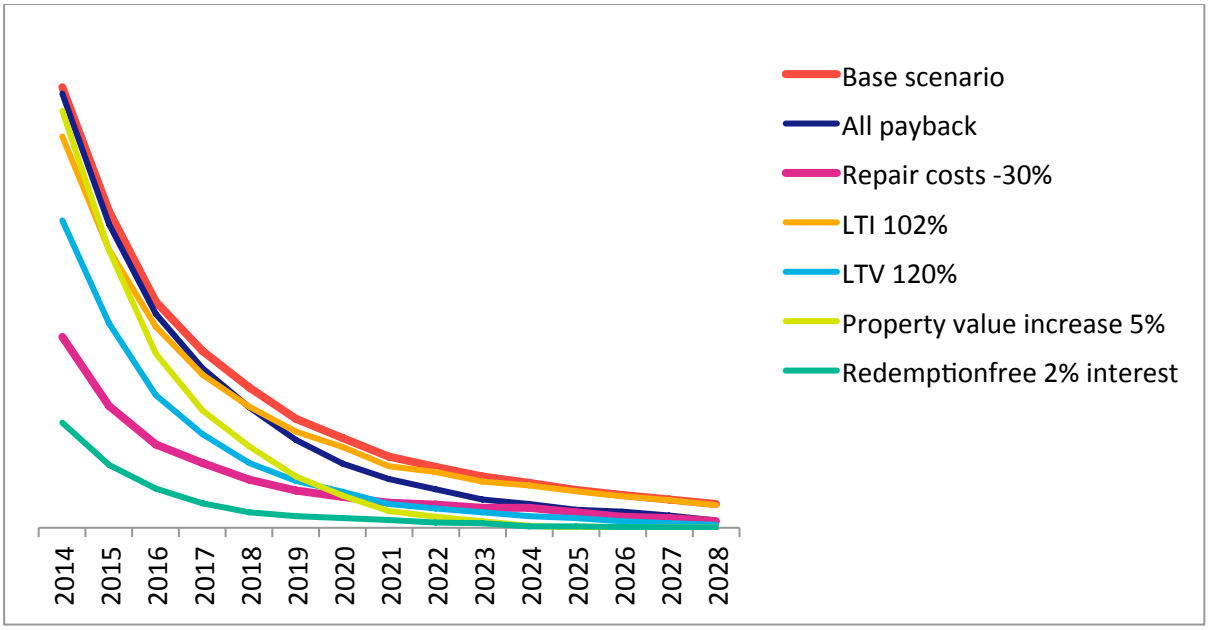

Figure 6.5 Percentage households in category 4 [percentages in this figure are omitted]

The change in LTV norm, price decrease and low interest loans have the highest impact on the outflow of households from category 4, especially on the short-term. The impact of the other variables is very close to the base scenario.

6.4 Financial institutions' policy and risks

In this paragraph the different possible bank policies are analyzed to investigate the bank's risks and how this could be minimized.

6.4.1 Policy

At this moment only households in category 1 can get a loan. Some options for extending the policy for granting loans are here explored, with the aim to make an extra loan possible for as many households as possible, still concerning a safe range.

The options here analyzed are based on the previous analysis. The base simulation shows that in the first years most households are in category 2. As discussed in chapter 5.2, households in category 2 have enough lending capacity based on their income to afford an extra loan but there are no financial arrangements to get a loan for them, because of the Loan-to-Value norm. If households and mortgage lenders would get the possibility to financing a loan also for category 2 and thus accept a Loan-to-Value higher that 104%, already in the first year, almost -% of the households will not have a problem to get an extra loan. Figure 6.2 and 6.3 already showed that broaden the LTI and LTV norms can increase the households in situation 1 and 2.

Figure 6.6 shows that a LTI norm of 102% and a LTV norm of 120% increase the amount of households in situation 1 with -% in the first year. Almost -% of al households in the first year will be in category 1 or 2 with extended norms.

Figure 6.6 Household distribution custom simulation: LTV 120% and LTI 102%

The analyzed options for financial institutions are:

- Give a loan only to category 1 (this is the actual situation);
- Give a loan to category 1 and 2;
- Give a loan to category 1, expand the LTI and LTV norm for classification of the household categories respectively to 102% and 120%;
- Give a loan to category 1 and 2, and expand the LTI and LTV norm for classification of the household categories respectively to 102% and 120%.

These options are compared with two extreme situations:

- No household in the sample will have foundation damage;
- All households get a loan for foundation repair.

6.4.2 Risks for financial institutions

To evaluate the risk of the different policies for the mortgage lenders, this paragraph focuses on the development over t_x of the average LTI and LTV percentages in the sample. The results are based on the worse case scenario that all households have established foundation damage at t_0 (2013) and also the extra loan was given at t_0 to the households. The extra loan is an annuity loan with a repayment time of 30 years.

Figure 6.7 shows the change in the average LTI percentage for the different possible bank policies.

Figure 6.7 Average Loan-to-Income percentage

Clearly in all cases the average LTI percentage decreases over the years: incomes are supposed to increase (the only decrease is at age 65) and the exposure amount is supposed to decrease due to repayment of the extra loan and for the majority of the households of the mortgage. When all households got a loan at t_0 the average LTI percentage is consequently the highest and in the situation that there is no damage, the average LTI percentage is the lowest. The figure shows clearly that when more people get a loan, the average LTI percentage is consequently higher. The difference between the policies for category 1 and 2 with and without extended norms is very small. There is only a small group that due to the extended norms goes from category 3 to category 1.

Figure 6.8 shows the average LTV for the different possible bank policies.

Figure 6.8 Average Loan-to-Value percentage

In the calculation for the average LTV for properties that are not repaired are taken into account first the value decrease due to foundation damage (the same as the expected price for repair) at t_0 and then also the decrease over the years due to deterioration of the property (3% of the value a year).

The value decrease of the non-repaired properties also has an impact on how fast the average LTV percentage decreases. For both options with a loan for category 1 and 2, the average LTV decreases slower than the option with no damage. The option 'all households get a loan' decreases faster due to the fact that the extra loan is fully repayment, while the mortgages are interest only, or only partially repayment.

Also the difference between the average LTV percentage for the two policies that allow a loan to category 1 and 2 is very small. The overall LTV percentage for this option is significantly higher than the actual average LTV without damage, but extremely lower than the policy based on the actual norms that grants an extra loan only to category 1.

6.4.3 Consequences on National Mortgage Guarantee

The NHG limits the negative equity risk for the homeowners, and consequently for the mortgage lender. The NHG norms are very strict. The maximum outstanding amount covered by the NHG is € 265.000. If the outstanding amount, including the extra loan for foundation repair, exceeds the maximum allowed the household is no more covered by this guarantee. For the mortgage lender, giving these households an extra loan, implicit taking over the risks that were covered by the NHG.

Figure 6.9 shows for each year the amount of households with NNG that with an extra loan for the foundation repair costs exceed the maximum outstanding mortgage allowed by this guarantee.

Figure 6.9 Percentage households with and without NHG

-% of the total households have a NHG mortgage. Because of the extra loan, the amount of households that still are covered by the NHG decrease with -% in the first year. This implicit that in the case that all households needs a loan in the first year, the mortgage lender takes over the risks of -% of the total households if they give them the loan for foundation repair.

6.5 Conclusions

To minimize the impact of foundation damage, all households must be able to provide the necessary maintenance to their property. The variables that influence the household situation are especially the repair costs, LTV percentage and low interest loans. Households with problems with the LTI are the hardest to help out of a problematic category. The options for financial institutions to extend the lending norms are analyzed and could make a loan possible for significantly more households. Expanding the norms to make a loan possible for more households ensures for the mortgage lender the value of the collateral. Special attention is required for the LTI risks for the mortgage lender: the average LTI percentage increases when more loans are provided to customers. Also the NHG norms are very strictly and can provide extra risks for the mortgage lender.

7. Best investment decision for homeowners

Households in a difficult situation to get an extra loan for foundation repair (category 2, 3 and 4) do not meet the Loan-to-Income and/or the Loan-to-Value requirements. The aim of this chapter is to contribute to solving the households' problem of financing foundation repair by investigating the impact of foundation damage on the household situation and the consequences of different investment options. This chapter answers the third research question: *"What will be the best investment decision for homeowners dealing with foundation damage?"*. This objective is pursued by developing a decision support tool that can be used by financial institutions.

7.1 Options for households

When a homeowner is confronted with foundation damage, there are several options on how to deal with this problem. This research focuses on the following options:

1. Do nothing;
2. Repair the foundation (and isolate the basement floor);
3. Repair the foundation and extent the dwelling with a basement;
4. Repair the foundation and install a ground source heat pump.

Below each option is discussed in more detail.

A household can decide to not repair the foundation, as long the municipality or the mortgage lender do not summon the household to repair it denoting the duty of maintenance of the property. The value of the property decreases due to the foundation damage and consequently continues decreasing over the years because of damage to the structure. In this research is assumed a decrease rate of 3% each year.

Repair the foundation is the required investment to maintain the value and prevent the collapse of the property. During the repair activities almost the total ground floor is removed, and this is why foundation repair is combined with by the construction of a new and better-insolated floor. This results in small energy savings.

The repair activities can also be combined with extension of the property. Because a lot of ground is already removed to extract the foundation piles, the costs for the construction of a basement are reduced. Due to the extra square meters the value of the property increases. In this research is assumed an increase in value per square meter of the half of the actual square meter value of the property.

Also for a heat pump, combining the installation with the repair activities reduce the costs for the installation of the vertical pipes of the system. A heat pump uses the ground as source to heat and cool the property, reducing energy consumption what returns in energy savings for the households. Also the investment for the heat pump is reflected in value increase of the property.

In this research selling the property is considerated as an exit decision: it is not included within the model because a household can choose to sell the property in each option at any time in the model. The situation of the household at the selling moment is in any case visible in the model.

7.2 System Dynamics model description

This paragraph focuses on the development of the decision support tool to evaluate the best investment decision for households. The time horizon of the System Dynamics model is 30 years, from 2013 to 2043.

7.2.1 Causal Loop

The lending capacity, related to the maximum LTI and LTV requirements, is established to protect the households and the financial risks for the mortgage lender. Households with foundation damage are in the situation that due to interventions to their home, they protect the value of the property and their risks, but the interventions implies an extra financial investment that increases their risks. Figure 7.1 shows this main idea in the form of a simple causal loop diagram.

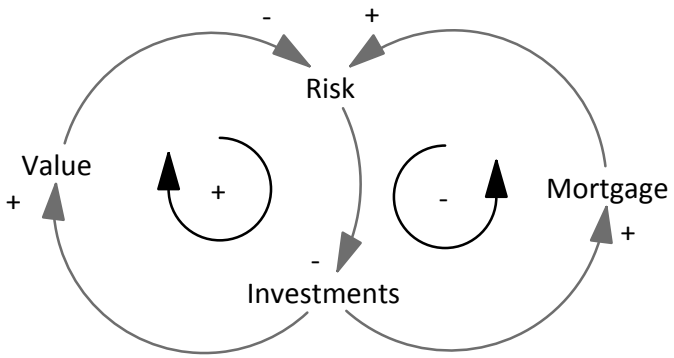

Figure 7.1 Causal loop diagram basis concept

These aspects and the investment options are combined in a complete causal loop diagram, showed in figure 7.2.

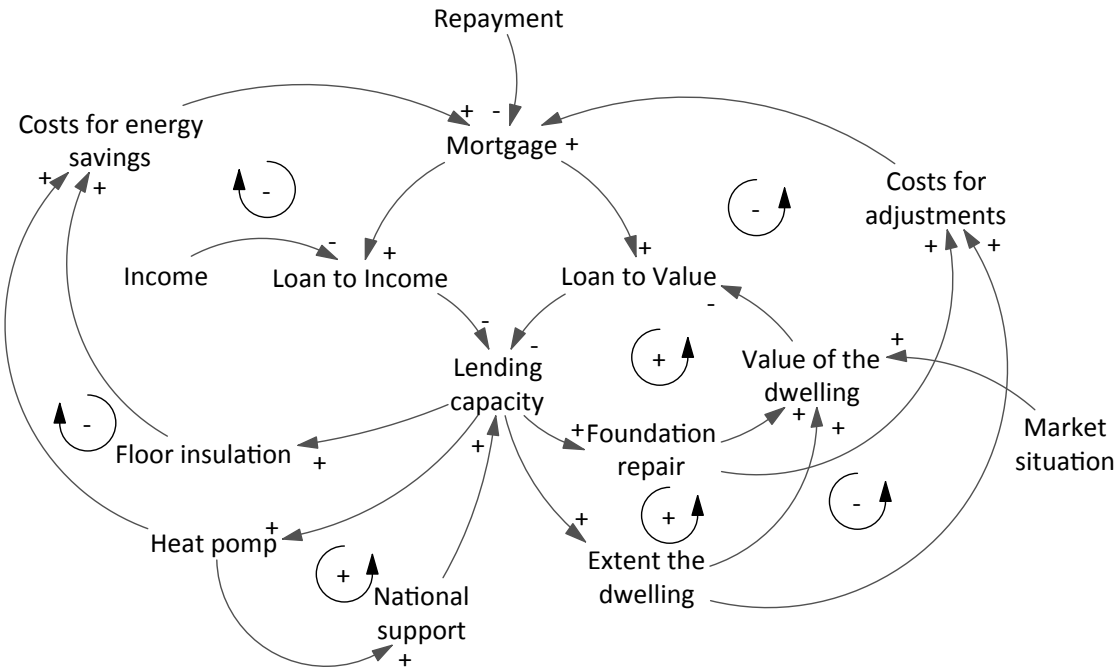

Figure 7.2 Causal loop diagram household situation and investment options

The causal loop in figure 7.2 shows different sub-systems. The aim of the model is to investigate the development of the different aspects and the impact on the household situation. The different investment options of the household (foundation repair with floor insulation, extent the dwelling and heat pump) require extra costs and have direct impact on the high of the mortgage. The mortgage, the value of the property and the income of the household determine the lending capacity of the household.

7.2.2. (Stock and flow) Model description

The System Dynamics model is divided into four sub-systems: *outstanding amount*, *household situation*, *annual expenditures* and *equity minus expenditures*. Each sub-system is described below. Appendix 13 gives an overview of all used variables in the calculation model and appendix 14 of the formulas used by the model.

Outstanding amount

The starting point of the model is the total outstanding amount, defined by the sum of the mortgage and the extra loan(s).

The calculation of the yearly annuity and the repayment rate are based on the monthly annuity. The formula for the monthly interest rate is based on the annual mortgage interest rate of 5%.

Monthly interest = ((1 + 5%)^ 1/12) - 1
*Monthly annuity = (monthly interest/1 – ((1+monthly interest)^ -period)))*mortgage*

For every loan a single calculation stock and flow model is made. Figure 7.3 shows the model for the mortgage. The total period of the mortgage is 30 years. The outstanding amount of the mortgage depends on the type of mortgage. For an interest-only mortgage the outstanding amount remains the same over the years. For mortgages with repayment, in the

calculation only a part of the outstanding amount is redeemed over the years to not overestimate the repayment rate of the household. Namely, in the last years, a combination of repayment and interest-only mortgages was the most common mortgage.

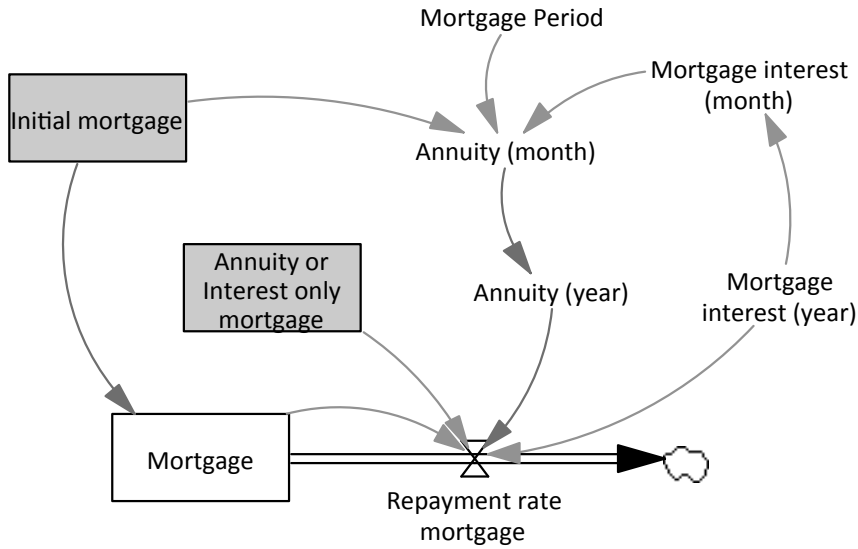

Figure 7.3 Mortgage sub-system; determines the mortgage repayment and the outstanding amount

The same calculation is used for the extra loans. These sub-systems are in appendix 15. The extra loans are all fully repaid with an annuity loan. For households that choose to get an extra loan to repair the foundation the repayment calculation is based on annuity loan and a repayment period of 30 years.

Households that choose to extent the property with a basement have, besides the loan for foundation repair, also a loan for the construction of the basement. The size of the basement used within the calculation model is 35% of the total squared meter of the building. The costs of the basement are the squared meters of the basement multiplied by 700 euro. The repayment period for the loan is 30 years.

For households that choose the option of installing a heat pump, the loan for repair the foundation is extended with the purchase and installation costs for the heat pump. In the calculation model the costs used are 15.000 euro. Some municipalities grant subsidies for heat pumps. The repayment period of the loan is 15 years.

Households situation

This sub-system calculates the situation of the household based on the lending capacity. The outstanding amount is the basis to determine the household situation. The two parts of this sub-model are the value of the property used to determine the Loan-to-Value and the income of the households used to determine the Loan-to-Income.

The value of the property is determined by the initial value of the property and the changes due to the market situation. The basement or the heat pump also increases the value of the property. The value of the property decreases when the foundation is not repaired. The first impact of the damage on the value is equal to the repair costs, then every year the value continues to decrease due to damage to the structure.

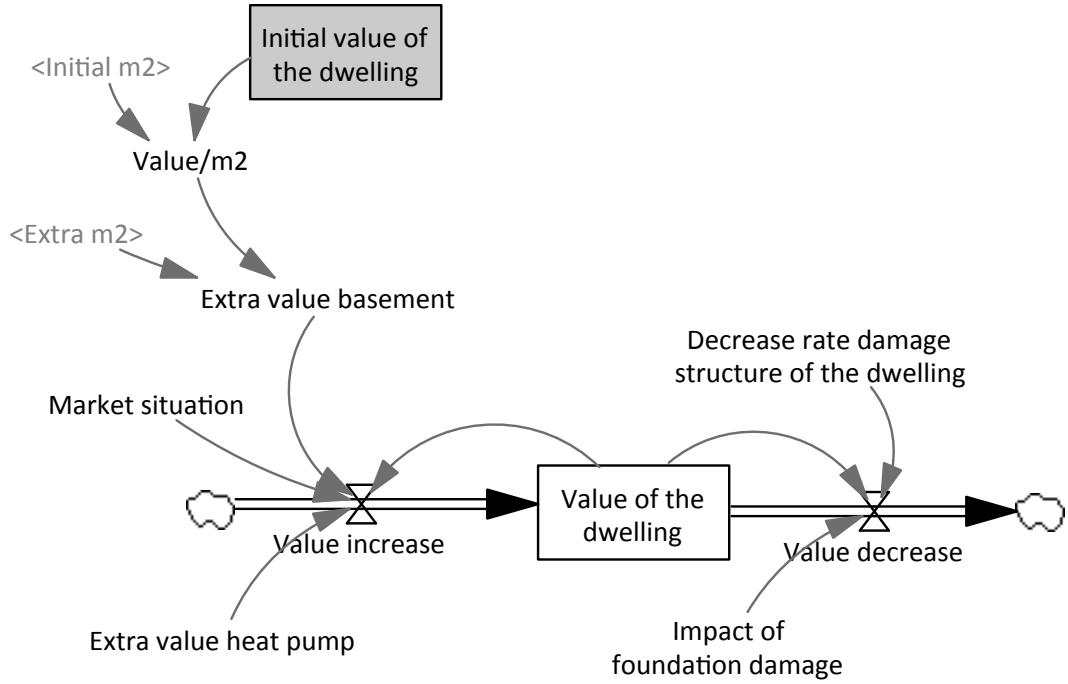

Figure 7.4 Value of the property

The income is determined by the initial income and the income growth, based on the age of the homeowner (see table 6.2).

The outstanding amount, the value of the property and the income of the household determine the LTI and LTV, that are used to establish the household situation. For each year is defined to which category the household belongs. Figure 7.5 shows the part of the model for the determination of the household situation based on the difference between the LTI and LTV and the norms.

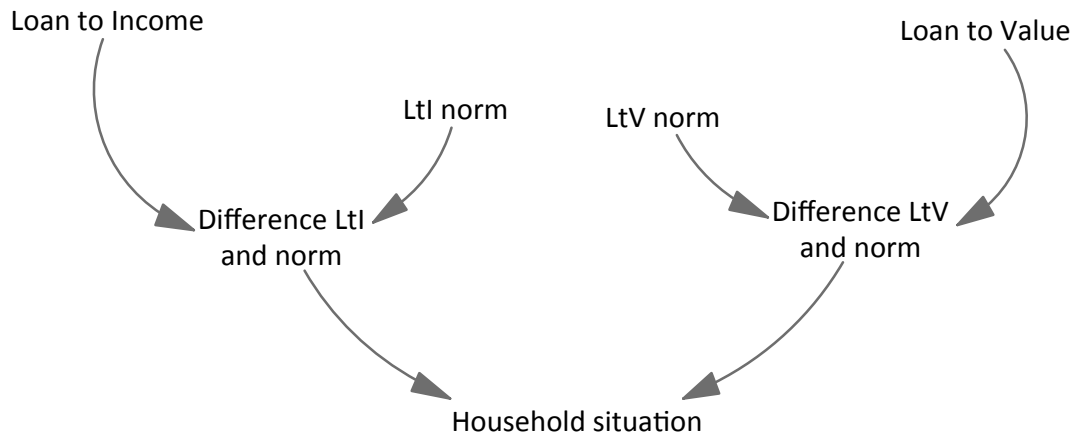

Figure 7.5 Household situation

The household situation allowes to identify how risky the investment option is for the household and consequently for the mortgage lender. The total overview of the submodel household situation is in appendix 16.

Annual expenditures

The annual housing expenditures are the sum of the annual expenditures for energy, gas and annuity, as shown in figure 7.6. The cumulative housing costs are calculated by the mathematical integral of the inflow.

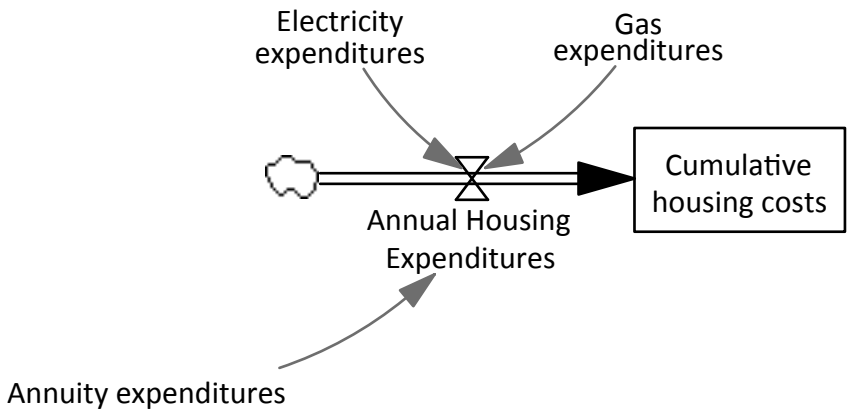

Figure 7.6 Housing costs

The annuity expenditures are the sum of the annual costs for mortgage and extra loans (repayment and interest). To calculate the electricity and gas expenditures the annual use of electricity and gas is multiplied by the electricity and gas costs. The use of electricity and gas is adjusted with the energy savings, which differs for the different options. Price inflation rates for electricity and gas are taken into account within the model. Figure 7.7 shows the calculation model for the electricity expenditures.

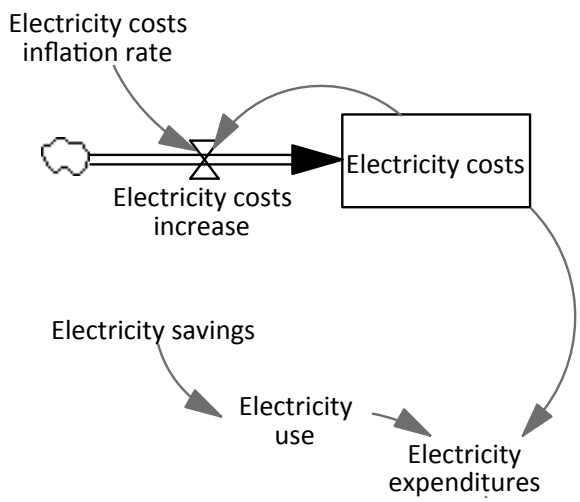

Figure 7.7 Electricity expenditures

The total overview of the submodel annual expenditures is shown in appendix 17.

Equity minus expenditures

The last part of the model calculates the difference between the equity and the expenditures of the household, to identify what each investment actually cost, including the energy savings over time and the accumulated equity. This is, with the household category, the main criteria for decision-making. The sub-system is shown in figure 7.8.

The Net Present Value (NPV) of the housing expenditures represents the sum of the discounted cash flows for the different expenditures. The NPV of the equity represents the discounted value of the property each year minus the outstanding amount. The NPV enables comparing the value of the equity and the expenditures over time. A higher value for the difference between the equity and the cumulative expenditures, indicates a better investment choice.

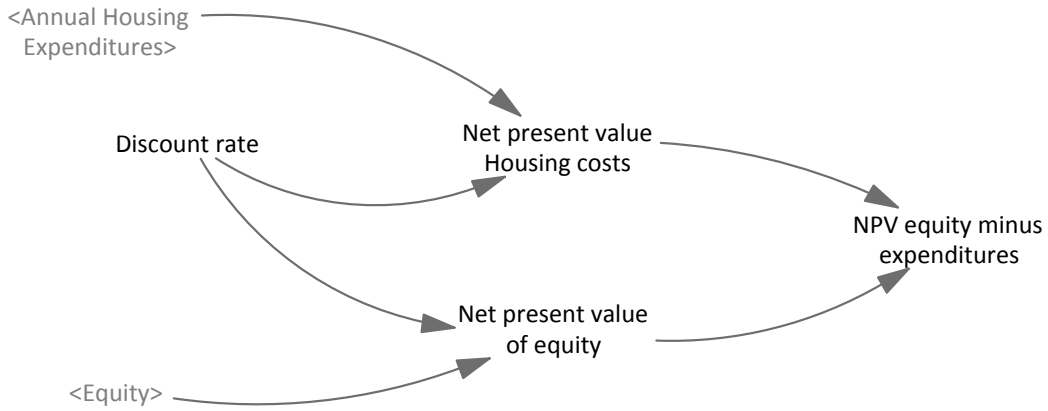

Figure 7.8 Sub-system; NPV equity minus expenditures

7.2.3 User interface

To simulate the situation of a specific household the model provides an input- and output window that guide the user in the use of the model. Step by step is explained how to run the simulations. An overview of the input- and output window is reported in appendix 18.

The available information of the household can be entered before starting the simulation.
The nine input variables the model uses as input for the calculations are:

- Initial mortgage
- Type of mortgage
- Initial income
- Initial value of the property
- Initial Loan-to-Income percentage
- Initial m2
- Initial age
- Subsidies heat pump (depending on municipality policy)
- Expected foundation repair costs

In the output window the four investment options of the household can be simulated and compared. The output variables are:

- Outstanding amount
- Value of the property
- Equity
- NPV equity minus expenditures
- Household situation (category and LTI-LTV percentage)

The model can also be used by households, but it is built on the limited information available by the mortgage lender. The model uses average values for electricity and gas use, and estimates the possible size of the basement. Households do not have to use the estimations. For the use by homeowners the model has to be extended so that more values can be specified as input variables.

7.3 Case studies

7.3.1 Case study description

The designed system dynamics model is applied on four specific households in the database. Because the situation for each household is unique, the four different investment options are simulated for one household of each category. The aim is to find the best investment option for each household.

Each of the four households is selected from one of the four different categories and is considered representative for the group. This means that the income, age, outstanding amount and value of the house of these households most closely match with the group average.

Without foundation damage these households have a secure financial situation and do not have a risky mortgage. The LTI percentage is lower than 100% and the LTV percentage is lower than 104%.

7.3.2 Data input

The input variables that differ for the four households are shown in table 7.1. The households have for three variables the same input: they have a mortgage with repayment, are in municipalities without subsidies for the purchase of a heat pump and the expected repair costs are 60.000 euro.

Table 7.1 Input variables case studies

	Income t_0 (Euro)	**Mortgage t_0 (Euro)**	**Total square meters (m^2)**	**Value of the house t_0 (Euro)**	**LTI (%)**	**Age (years)**
Category 1						
Category 2						
Category 3						
Category 4						

Table 7.2 shows the initial energy prices, initial annual use of energy and the economic variables used in the simulations. These variables are the same for all simulations and are based on statistics obtained from Nibud, Statistics Netherlands (CBS) and interviews with - experts.

The model simulates for all household that the damage is detected in 2014. To not overestimate the impact of the value increase due to the market situation on the short-time, only 1% increase of the value of the property is used, instead of the inflation rate of 2,1%. The values for energy use are based on the average use of the households in The Netherlands.

Table 7.2 Variables for all simulations

Variable	Value	Units
Mortgage interest	5	Percentage/year
Interest on foundation repair loan	5	Percent
Interest basement loan	5	Percent
Interest heat pump loan	2	Percent
Market situation	1	Percent
Foundation repair year	2014	Year
Mortgage period	360	Months
Period loan foundation repair	360	Months
Period loan basement	360	Months
Period loan heat pump	180	Months
Gas use	1440	m^3/year
Gas price	0.8	Euro/m^3 (incl. tax, e.a.)
Gas price rate	6	Percentage/year
Electricity use	3340	kWh/year
Electricity price	0.2	Euro/kWh (incl. tax, e.a.)
Electricity price rate	3	Percentage/year
Discount rate	5	Percent
Loan-to-Income norm	100	Percent
Loan-to-Value norm	104	Percent

The variables that differ between the four investment options are shown in table 7.3. These values are based on literature and interviews with experts from - and KCAF.

Table 7.3 Variables for the four investment options

	1. Do nothing	**2. Repair foundation with floor insulation**	**3. Repair (same as option 2) and basement**	**4. Repair (same as option 2) and heat pump**
Foundation repair costs	-	€ 60.000	€ 60.000	€ 60.000
Construction basement costs	-	-	700 €/m^2	-
Heat pump costs	-	-	-	€ 15.000
Decrease rate due to damage to the structure	3% a year	-	-	-
Decrease due to impact foundation damage	€ 60.000	-	-	-
Increase value due to basement	-	-	0.5*value/m^2	-
Increase value due to heat pump	-	-	-	€ 15.000
Extra m2	-	-	0.35 *init.m^2	-
Electricity savings	-	-	-	-30%
Gas savings	-	15%	15%	100%

7.3.3 Results of simulations

This paragraph discusses the most important simulation results for the four investment options for the four households. The results of the simulations of the household in category 1 are extensive described, while for the other three households only the results are discussed that significantly differ from the ones of the first household. The remaining results can be found in appendix 19.

Household category 1

Figure 7.9 shows the outstanding amount in the four different options. In option 1 the outstanding amount is only the mortgage. The other options include the mortgage and the corresponding extra loans. The extra loans are in 30 years completely redeemed, the only outstanding amount at the end of the model is a part of the initial mortgage.

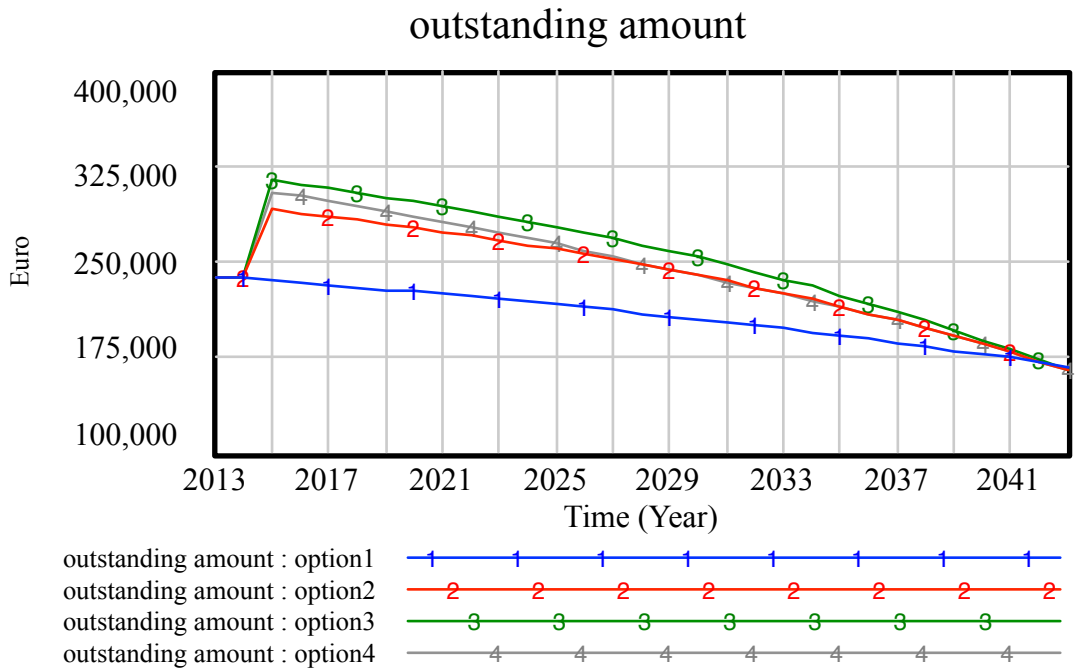

Figure 7.9 Outstanding amount

The annual housing expenditures are shown in figure 7.10. The annual expenditures include the monthly payments for the mortgage and the extra loans and the annual costs for electricity and gas. Option 1, do nothing, has almost for the whole simulation period the lowest annual expenditures, while option 3, extent with basement, has the highest costs. The increase of the annual housing expenditures is for option 4 the less, due to the energy savings: in about 10 years the annual costs reaches the costs of option 2, only repair the foundation.

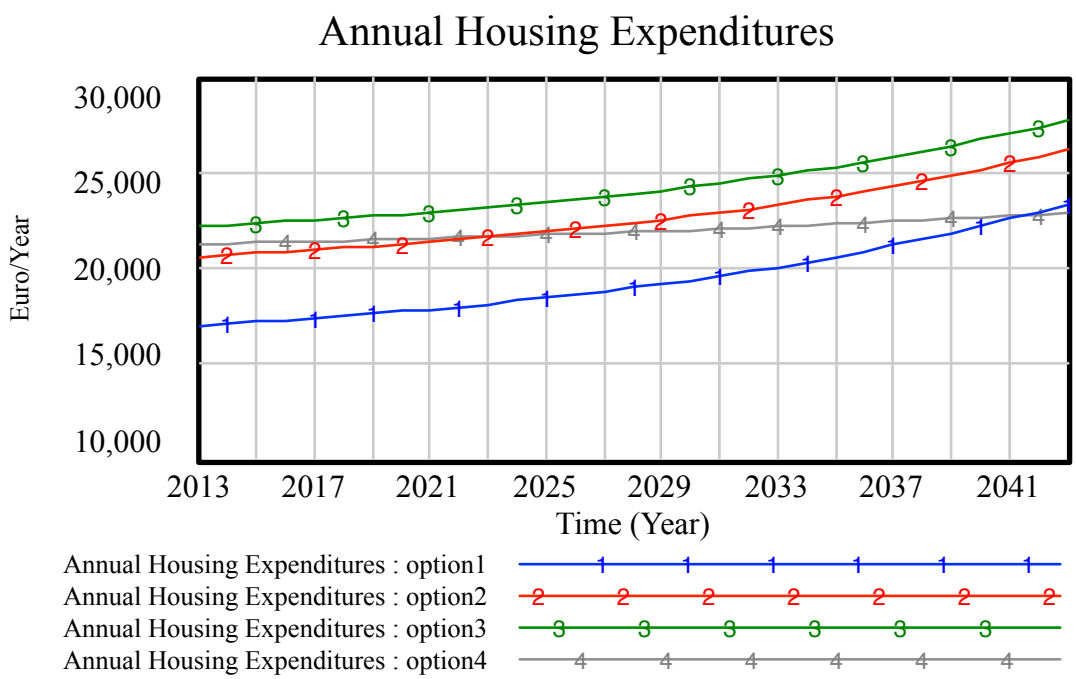

Figure 7.10 Annual housing expenditures

Figure 7.11 shows that repairing the foundation is an investment to maintain the value of the property. Option 2, 3 and 4 show that more investments in the property correspond to a higher property value. Especially interesting is the development of the value for option 1. When the damage is identified, it has direct effect on the value of the property. Then, the value decreases continuously over the years and consequently also the gap with the other options increases.

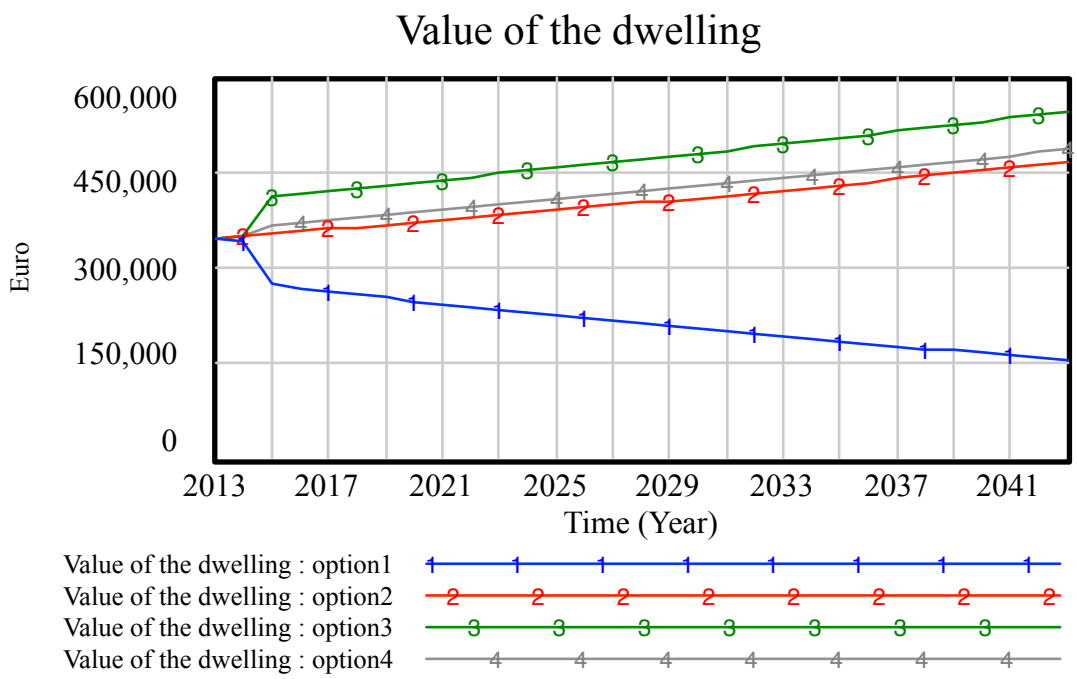

Figure 7.11 Value of the dwelling

The home equity graph in figure 7.12 shows the difference between the value of the property and the outstanding amount. If the household choses to do nothing, in 8 years the

home equity results negative. The highest home equity results for option 3, followed by option 2 and 4, that are close to each other.

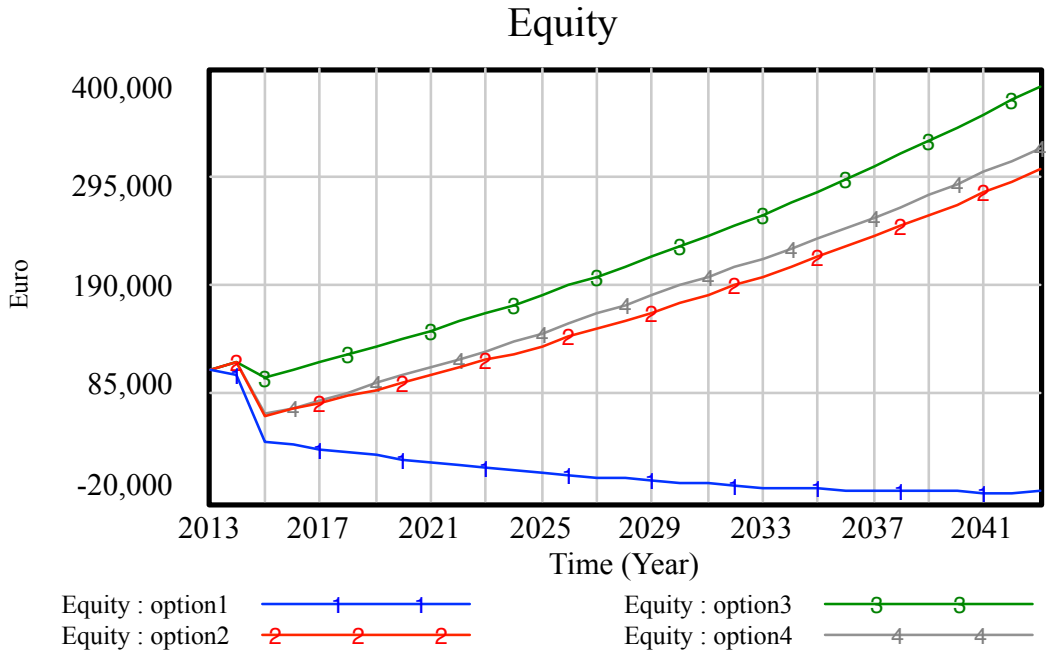

Figure 7.12 Home equity

Figure 7.13 shows the NPV of the equity minus the expenditures. In this graph is thus represented the NPV of the cumulative expenditures for housing and the accumulated equity each year. The figure shows that the values for all options are very close to each other. Option 1 has the lowest score, especially considering that usually properties with foundation damage in a few years are declared unfit for habitation. The homeowners had to provide new housing. The model does not take into account in the calculation of the expenditures in option 1 these extra costs. This would further decrease the values in this graph for option 1.

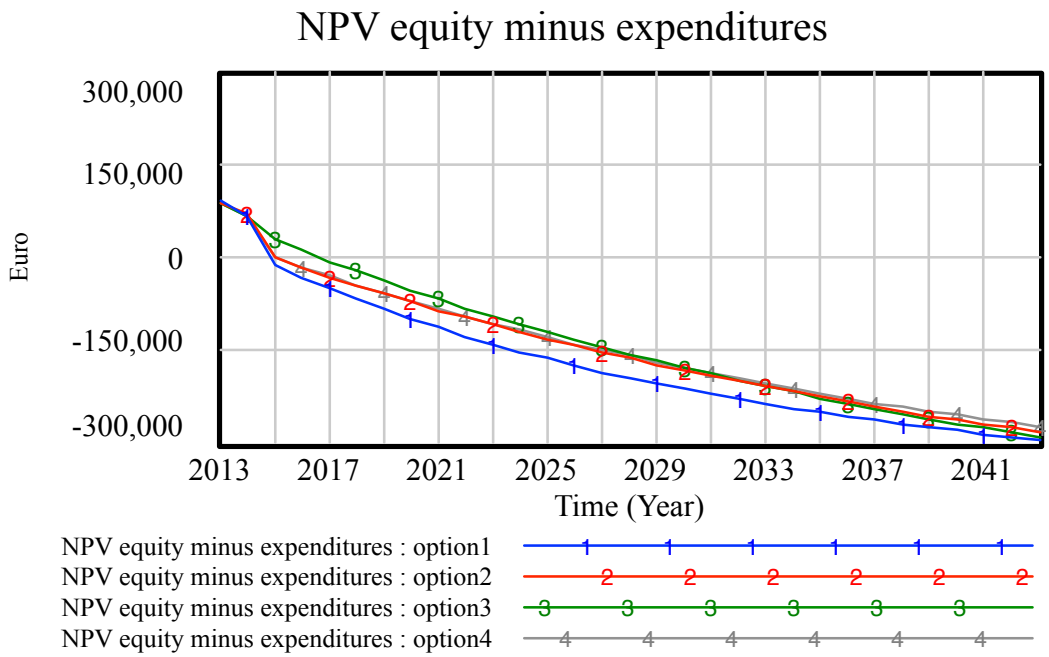

Figure 7.13 Equity minus expenditures

Figure 7.14 and 7.15 shows respectively the LTI and LTV percentage.

In figure 7.14 the impact of the extra loan on the LTI percentage in show. In 2032 the impact of the decrease in loan due to retirement on the LTI percentage is visible. The LTI is almost the same for option 2 and 4, because of the shorter repayment period of the loan for the heat pump.

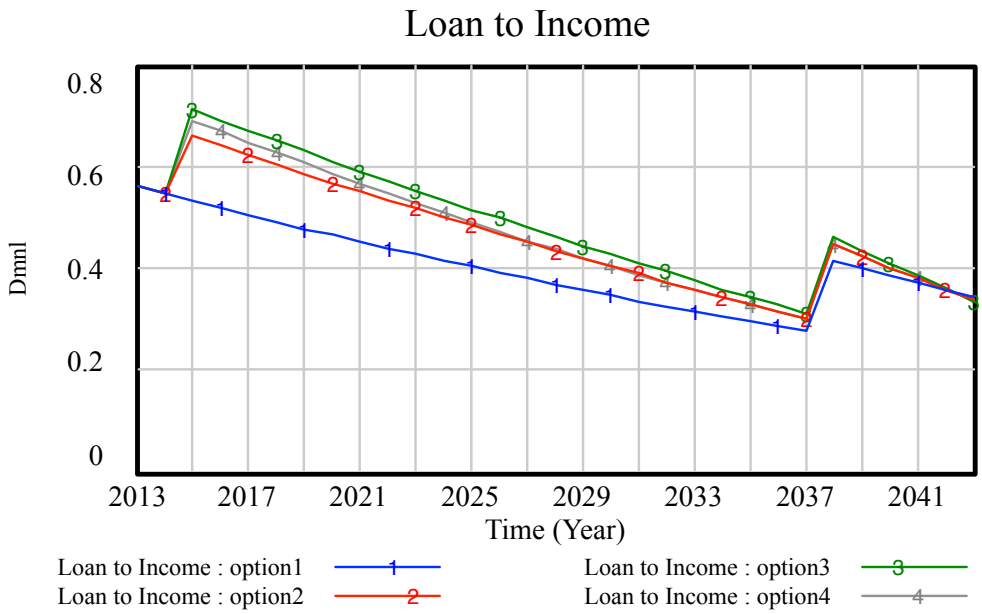

Figure 7.14 Loan-to-Income percentage

In figure 7.15 the impact of foundation damage on the value of the property is clearly visible, and is related to the risks for the homeowners and mortgage lender. Option 3 has a lower LTV, but option 2, 3 and 4 are all close to each other.

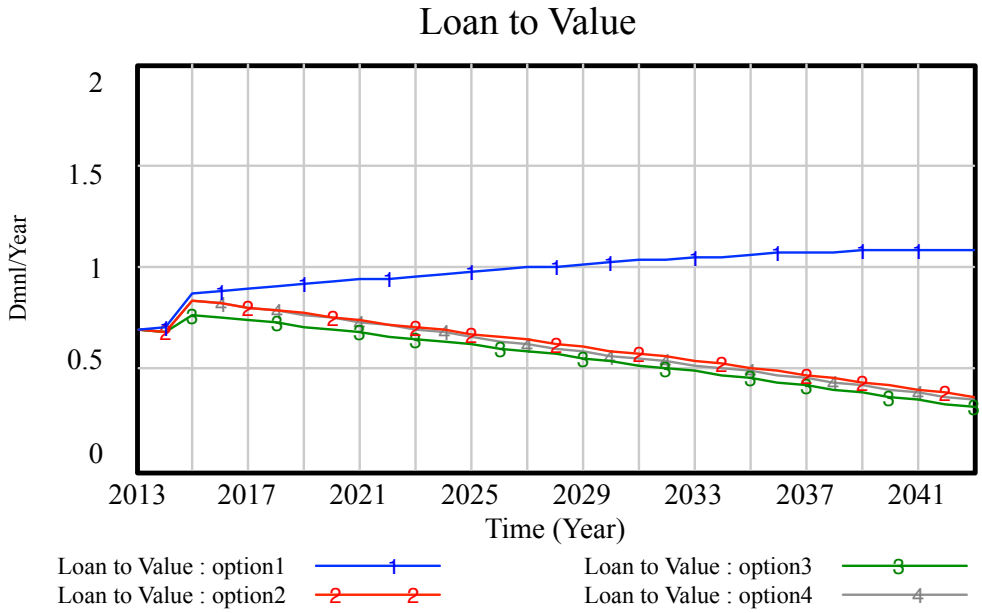

Figure 7.15 Loan-to-Value percentage

The household situation is shown in figure 7.16. This household has enough lending capacity for all investment options. When the household choses to not repair the foundation, at the end of the period the outstanding amount will be higher than the value of the property.

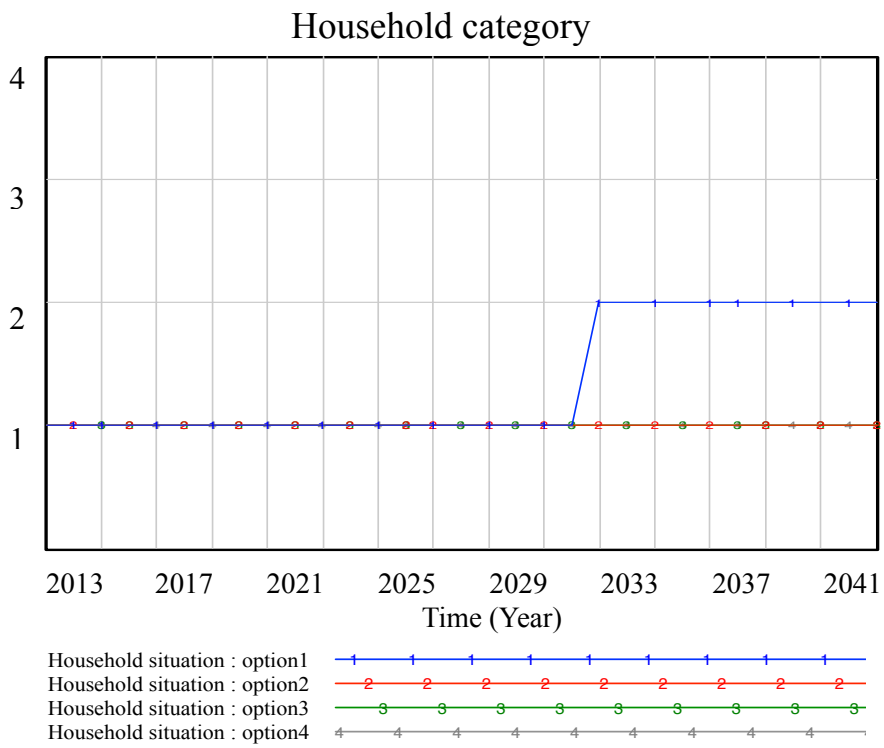

Figure 7.16 Household situation; household category 1

Household category 2

The results from the simulation for the household in category 2 are almost the same as the simulations for the household in category 1. The results are in appendix 19. The only exception is the household situation, shown in figure 7.17.

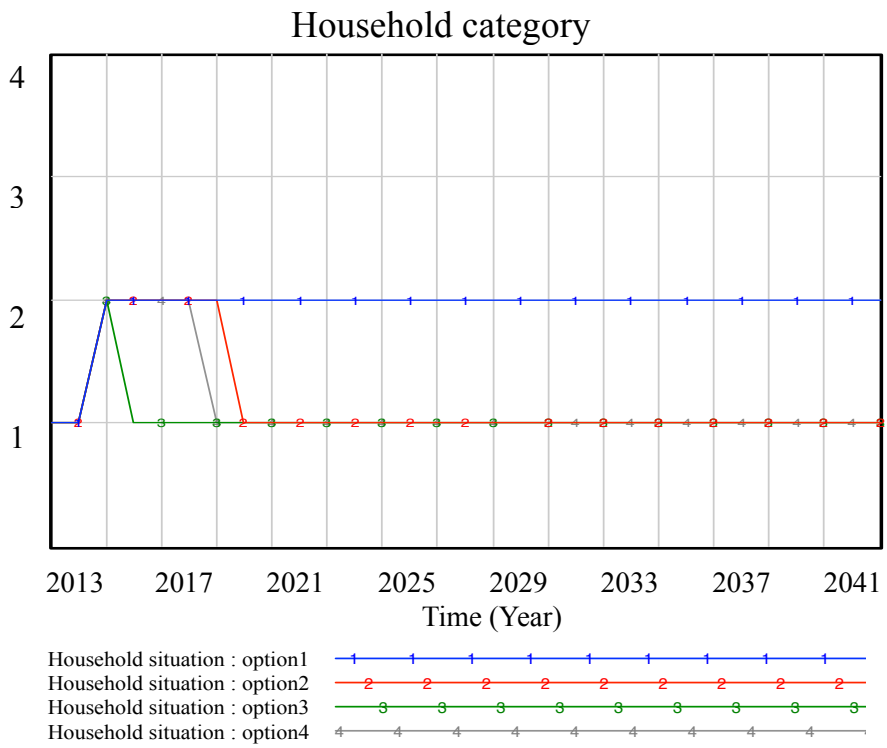

Figure 7.17 Household situation; household category 2

For option 1, 2 and 4 the household is in category 2: meets the Loan-to-Income requirements but not the Loan-to-Value requirements. Doing nothing, option 1, results in value decrease and holds the household in category 2 during the whole simulation period and implicit a negative equity risk. Because of the value added by the heat pump, the household situation will return to category 1 after three years, one year before the option only repair the foundation. Option 3 has for this household an interesting situation; by the additional value of the basement, the household is back in category 1 in only one year.

Household category 3

Also the results from the simulations for the household in category 3, are almost the same as for the household in category 1. The household situation in the four options is reported in figure 7.18.

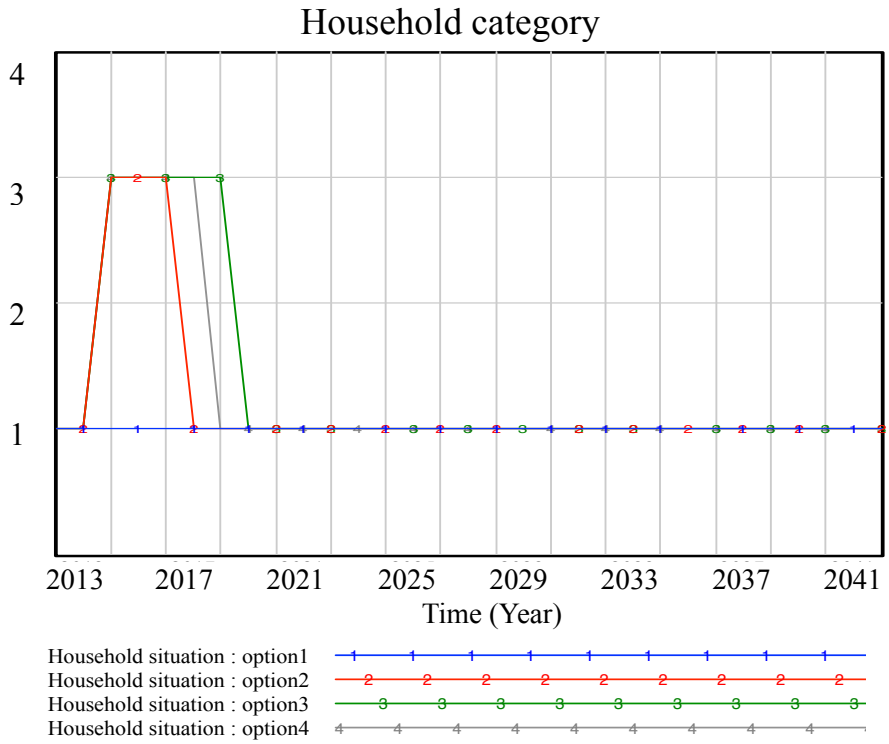

Figure 7.18 Household situation; household category 3

For this household the situation is determined by the size of the investment: higher costs implicit a longer period in category 3. Option 1 will not bring the household in a risky situation based on the LTI and LTV requirements. This household, choosing the option do nothing, stays for the total period in category 1. However the LTV percentage for option 1 is increasing instead of decreasing like for the other options, but remains under the 100% norm.

Household category 4

At last, also the results from the simulations for the household in category 4, are almost the same as for the household in category 1. The household situation in the four options is reported in figure 7.19.

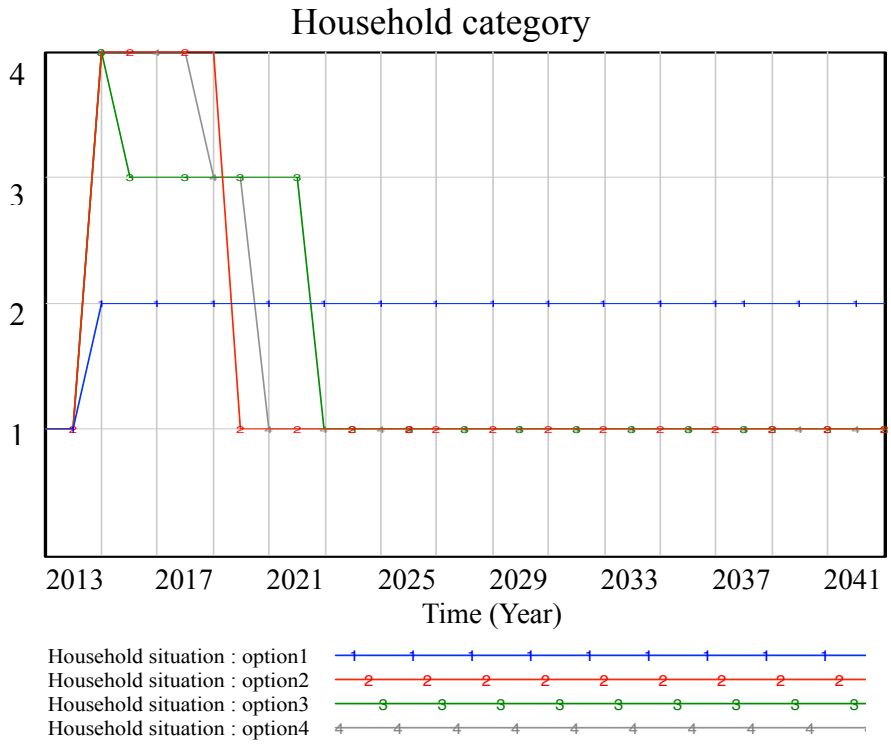

Figure 7.19 Household situation; household category 4

Option 1, do nothing, implicit for the household a lost of value that takes the household to category 2 in the first year. Also for this household the situation is further determined by the high of the investment and struggles especially with the LTI requirements. Within option 2 and 4 the household does not meet both LTI and LTV requirements, while option 3 takes the household to category 3.

7.4 Monte Carlo simulation

The Monte Carlo Analysis (MCA) is used to test the outcomes of the simulation of the NPV of the equity minus the expenditures, because the results of the analysis in chapter 7.3 are very close to each other. The simulation is implemented on the household in category 1. The MCA is used to eliminate the uncertainty related to the assumptions for the different options and tests if the conclusions deducted form the model will change when these uncertainties are incorporated. Uncertainties taken into account concern the impact of the foundation damage or are related to the impact of the investments. The MCA calculates the model by substituting these values with different values in the given range. The range of parameters is shown in table 7.4. By the use of MCA in Vensim PLE plus these combinations were automatically and randomly selected.

Table 7.4 Parameter range and distribution input MCA

Parameter	Range	Distribution
Foundation repair costs	48.000-72.000 euro	Random triangular (peak 60.000)
Basement costs	700-400 euro/m^2	Random triangular (peak 700)
Heat pump cost	13.500-16.500 euro	Random triangular (peak 15.000)
Decrease rate due to damage	1%-3%	Random uniform
Increase value due to basement	0.5-1.5 /m^2	Random triangular (peak 0.5)
Electricity increase due to HP	25%-35%	Random triangular (peak 30%)
Gas savings due to floor insulation	10%-20%	Random triangular (peak 15%)

The results of the MCA in year 10 are shown in table 7.5 and in figure 7.17. The graphs are in appendix 20.

Table 7.5 Results MCA of equity minus expenditures in year 10

	option 1	option 2	option 3	option 4
Maximum	-93.194,00	-88.441,00	-52.513,50	-85.702,60
+ 50%	-115.980,00	-96.396,60	-72.887,30	-94.331,70
Median	-133.373,00	-100.005,00	-80.262,00	-98.030,40
- 50%	-144.292,00	-103.511,00	-87.309,10	-101.437,00
Minimum	-160.442,00	-111.505,00	-107.144,00	-109.364,00

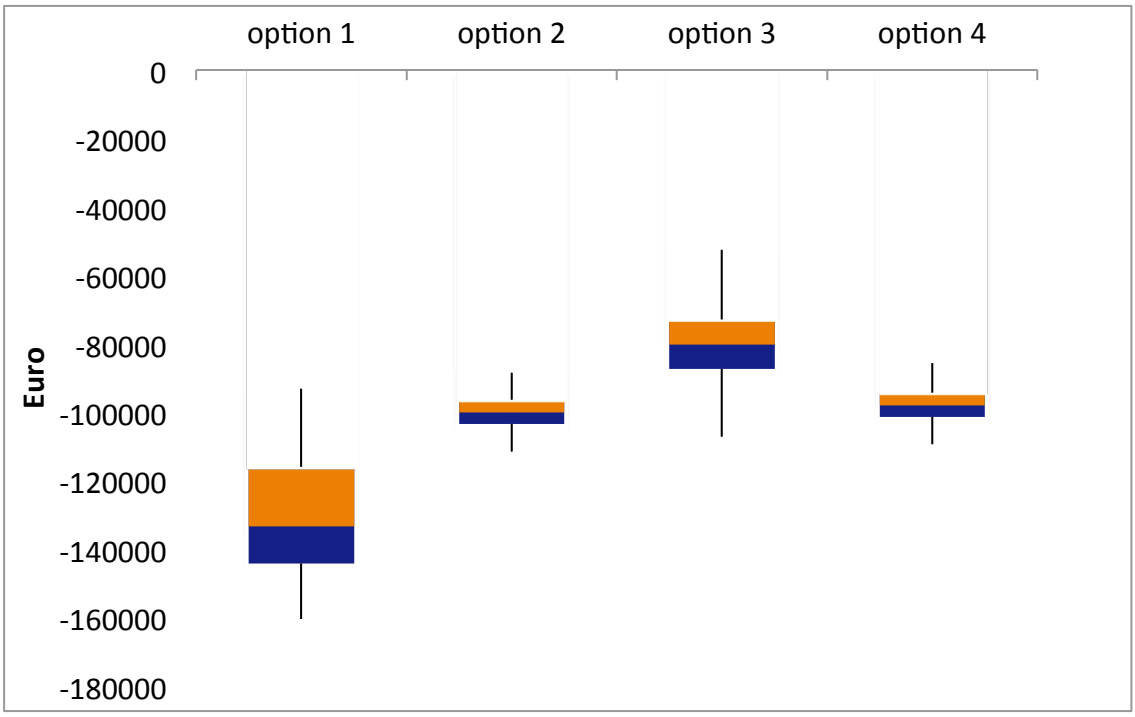

Figure 7.20 Boxplot results MCA of Equity minus expenditures

The results show that most results of the four options differ significantly. Option 1 is the choice with the most costs compared with the expenditures, and also the option with the most uncertainty. Option 3 results as the best option. Option 2 and 4 are still very close to each other.

7.5 Conclusions

In this research four options for households dealing with foundation damage are analyzed and compared. To determine the best investment option for homeowners, a decision support tool is developed with the SD method. Whit the model the situation of four different households is simulated and a MCA is used to eliminate the uncertainty related to the assumptions for the different options. The best investment decision can be identified considering different aspects of the household situation and the difference between the annual housing expenditures and the accumulated equity over the years. The results show that when households have enough lending capacity, the best investment decision is to repair and extend the property with a basement. Combining the repair activities with value increasing adjustments ensures a better investment and ensures the value of the collateral. For households that cannot afford this extra investment it is recommended to repair the foundation anyway instead of doing nothing.

8. Conclusions

This research focuses on the research problem stated in chapter 4: *From now and in the coming decades there will be homeowners who have to deal with unexpectedly required high foundation recovery costs. Homeowners face a difficult investment choice for the reconstruction of their distressed property limited by the declining housing market and the their own financial possibilities.*

This chapter describes the conclusions of the research. First, the three research sub-questions are answered. The answer on the main research question follows in the practical recommendations paragraph. Then the results and the models are discussed, based on experts' feedback, including the conditions and limitations of this research. The chapter ends with some suggestions for further research.

8.1 Answers research sub-questions

The first research question is: "*What is the financial situation of homeowners dealing with foundation damage?".* Households have to meet requirements based on their income (Loan-to-Income, LTI) and on the value of the property (Loan-to-Value, LTV) to get an extra loan to repair the foundation. The households are divided into four categories.

Category	Minimum [percent]
1. Meet LTI and LTV requirements	-%
2. Meet LTI and not LTV requirements	-%
3. Meet LTV and not LTI requirements	-%
4. Do not meet LTV and LTI requirements	-%

Only -% of the used sample meets both requirements. High LTI and LTV percentage identifies problematic households. A high income and value of the property, also correlated with high mortgages, are at the contrary predictors for less problematic households. However, the results of the analysis also show that the situations of most households are similar to each other.

The second research question is: *"How could financial institutions and other stakeholders minimize the impact for homeowners and their own organization?".* Due to income increase, repayment and increase of the value of the property, over time most homeowners create extra lending capacity and can afford the loan for foundation repair. But when foundation repair is necessary, it cannot be postponed. Several actions can be undertaken to improve the situation of homeowners. Extending the LTI and LTV norms and low interest loans increases the amount of homeowners that can afford the extra loan. Also increasing housing prices and the decrease of the repair costs increase significantly the amount of households that can afford the repair costs. Especially, homeowners that do not meet the LTI requirements are the hardest to help out their critical situation. At this moment only households in category 1 can get a loan. Expanding the norms to make a loan possible for category 2 as well ensures for the mortgage lender the value of the collateral. Special

attention is required for the LTI risks for the mortgage lender: the average LTI percentage increases when more loans are provided to customers Also the National Mortgage Guarantee norms can provide extra risks for the mortgage lender.

The third research question is: *"What will be the best investment decision for homeowners with a mortgage dealing with foundation damage?".* Households dealing with foundation damage have different investment choices. In this research four different options are compared: (1.) do nothing, (2.) repair the foundation, (3.) repair and build a basement and (4.) repair and install a heat pump. The best investment decision can be identified considering different aspects of the household situation and the difference between the annual housing expenditures and the accumulated equity over the years. Using the net present value, the cash flows can be compared and the options of the homeowner can be evaluated. With a System Dynamics model the situation of four different types of households is simulated. The main conclusion is that repair is better than doing nothing, and when homeowners have enough lending capacity, value improving measurements combined with foundation repair are recommended.

8.2 Practical recommendations

In this paragraph the main research question is answered: *"How could financial institutions steer the reconstruction of distressed properties in a declining housing market?".* The main question implicitly asks for recommendations for financial institutions on how to deal with this problem. In this research emerges the need of a collective approach between different stakeholders. For this reason, first, the general recommendations are given before discussing the recommendations for financial institutions. At the end the implications that concern the government in particular are discussed.

8.2.1 General recommendations

As mentioned, the foundation damage problem requires a collective approach by different stakeholders. Government, municipalities, financial institutions, contractors, homeowners' organizations, brokers, water governance, housing associations, and others, have to work together to approach the problem from different sides but with a common policy. All stakeholders have to take action.

The required approach has to focus on a two-side prevention. On the long term, wooden piles that are not damaged yet have to be protected and groundwater levels need to be monitored to prevent, where possible, new cases of foundation damage. On the short term there must be set up measures and regulations on how to deal with the existing damage. On the one side, homeowners with a property with damage needs to be informed and helped through the process. On the other side, new homebuyers need to be informed about and protected from buying a house with possible damage. This means that there must be created awareness about the problem and new homebuyers have to be alert when they buy a new house in an area at risk. The purchase contract could include a clause about the state of the foundation to protect new homebuyers.

Contractors have to be prepared for the expected large demand for foundation repair in the coming next years. Only a small number of houses are yet repaired. The repair activities have to become more lean and upscaling could reduce the repair costs. The decrease of the repair costs has a significant impact on the amount of households that can afford a loan. Investments in research and new technologies are necessary to speed up this process.

For households in a very critical situation there must be developed new options, such as insurance for foundation damage, or an emergency fund. Especially to make the repair possible for a building block even if there are some households that cannot afford the loan.

The importance of knowledge and information about the problem is getting more and more important. The KCAF already fulfills an important role informing homeowners dealing with foundation damage. Although, currently lot of information from inspections (private and from local municipalities) are not centrally available (for public use). Also the information about the already repaired properties and the properties with established damage are not centrally archived. This problem requires the availability of these information.

Homeowners have to be aware of the risks of homeownership and they have to take their responsibility and action.

8.2.2 Recommendations for financial institutions

One of the results of this research is that over time a lot of the homeowners could afford the extra loan. This implicits the need to secure that no new customers eventually could get in a new problematic situation. Focusing on the existing customers, financial arrangements with tax incentives for savings can be developed and stimulated for households with established foundation damage.

The LTV risk is not a risk for the homeowner solely. If there is no repair of the foundation damage the negative equity risk could also impact the mortgage lender. Making a loan possible for all households that meet the Loan-to-Income norm, even if they do not meet the LTV norm, has a huge impact on the extent of the financing problem. If a homeowner is forced to leave the property because it is unsafe, the financial risks of double housing costs or an extreme high negative equity are high. This risk for the homeowner and consequently for the mortgage lender, can be limited by accepting higher LTV norms to protect the collateral. Financial institutions can help households that are slightly over the norm by extending the LTI norm. Large deviations from the norm can be too risky for the homeowner, because the costs for the mortgage and the loan will be too high for the income of the household. A good alternative could be a national guarantee for households without enough income.

Mortgage lenders must pay special attention to mortgages guaranteed by NHG. They should not take over the risks from the NHG.

8.2.3 Recommendations for government

The government is in the central position to bring all stakeholders together and create a common policy for the prevention of new damage and the approach for new damage cases. Especially to manage the municipalities, at this moment they have total different policies. Important is that all municipalities in risk areas are involved in this problem. They have to investigate and monitor the situation of the housing stock and prevent new problems. They also should inform and advise homeowners, and help within the process of bringing them together for repair activities that have to be taken for the whole building block. Stimulate repair activities and make it easier helping with construction permits.

Strict supervisions and regulation for new mortgages is necessary to protect new homebuyers from too high or risky mortgages. But on the other side, the government also has to create more flexibility for the financial institutions to deviate from the LTI and LTV requirements for foundation repair loans. This really helps households dealing with foundation damage.

Loans for households that do not meet the LTI norm are currently only available with guarantee of the municipalities. At this moment only 5 municipalities facilitate this loan. There is a need for an overall financial arrangement for all households in this category on national level.

It is inevitable that there will be some problematic cases of homeowners that cannot afford the repair costs. Homeowners left over with a high negative equity, or in the worst-case, foreclosure or debt restructuring programs. The government should organize appropriate help for these households.

The government can monitor and where possible manage the groundwater levels to prevent new damage.

8.3 Discussion

It is very difficult to make a prediction about the amount of homeowners that will have to deal with foundation damage. This thesis estimates the worse case scenario and takes into account all possible households dealing with foundation damage. Recently, the amount of properties that are affected by this problem is called into question. Not all dwellings with foundation damage have the same priority to repair.

This research did not discuss the required collective aspect of the repair activities. At this moment lots of repair activities stuck because some households in the building block cannot afford the repair costs. In this research the focus is on making a loan possible for most households. This minimizes the scenario that one household blocks the repair activities for the entire building block. Of course it is inevitable the there will be some extreme problematic cases of homeowners and also for this group there must be developed an approach.

Experts from KCAF and - validate the models and their results. The results give an accurate reflection of the experience from the field and provide new insights, useful for a possible problem approach and decision support.

8.4 Further research

Due to the complexity of the foundation damage problem, lots of research and developments are required. With regard to lending problems three ideas for further research are here proposed:

- Elaborate specific financing arrangements for homeowners that have not enough lending capacity based on their income.

- Elaborate the structure of an emergency fund, guarantee or insurance for foundation damage.

- Identify the impact of the social damage if properties are not repaired, including the costs when neighbourhoods impoverish, value of properties decreases and households are led into debt restructuring programs.

References

- Brosens, T., 2009. Hypotheekrisico's voor huiseigenaren. *Economische Statistische Berichten,* 94(4570), pp.614-617.
- Campbell, J.Y., Giglio, S. & Pathak, P., 2009. *Forced sales and house prices.* Cambridge: National bureau of economic research.
- Clapp, J.M., Giaccotto, C., 1998. Residential hedonic models: a rational expectations approach to age effect. *Journal of Urban Economics,* 44, 415–437.
- CURNET/SBR, 2012. *Handboek funderingsherstel*. Rotterdam, The Netherlands.
- De Nederlandsche Bank, 2011. *Overzicht Financiële Stabiliteit in Nederland*. Spring 2011, number 3. Nederlandse Verd, eniging van Banken, Gedragscode Hypothecaire Financieringen.
- Deltares, 2012. *Schades door watertekorten en -overschotten in stedelijk gebied*. The Netherlands.
- De Vries, P. & Boelhouwer, P., 2005. Local price house developments and housing supply. *Property Management,* 23(2), pp.80-96.
- Dijsselbloem, J.R..V.A., 2013. *Wijziging van de regeling hypothecair krediet.* Kamerbrief FM/2013/1930 M.
- Elsinga, M. & Hoekstra, J., 2004. *Op eigen kracht. Eigenwoningbezit in Nederland.* Delft: OTB.
- Erwich, B. & Vliegen, M., 2001. Klei en veen. *Index,* 3, pp.22-23.
- Eurostat, 2013. Handbook of residential property prices indices. Luxembourg: Publications office of the European Union.
- Ford, A., 2010. Modeling the environment. Washington: Island press.
- Hill, R., 2011. *Hedonic price indexes for housing.* OECD Publishing.
- Hill, R., 2013. Hedonic price indexes for residential housing: a survey, evaluation and taxonomy. *Journal of economic surveys*, 27 (5), pp.879-914.
- Huisman, D.J., Manders, M.R., Kretschmar, E.I., Klaassen, R.K.W.M. & Lamersdorf, N, 2008. Burial conditions and wood degradation at archaeological sites in The Netherlands. *International Biodeterioration & Biodegradation*, 61, pp.33–44.
- Jansen, S.J.T, De Vries, P., Coolen, H.C.C.H., Lamain, C.J.M. & Boelhouwer, P.J., 2008. Developing a house price index for The Netherlands: a practical application of weighted repeat sales. *Journal of real estate finance and economics*, 37, pp.163-186.
- Johnson, M.P., Solak, S., Drew, R.B. & Keisler, J., 2013. Property value impacts foreclosed housing acquisitions under uncertainty. *Socio-economic planning sciences*, pp.1-17.
- Kennis Centrum Aanpak funderingsproblematiek (KCAF), 2012. *Kapstok refundering.* Dordrecht, The Netherlands.
- Kennis Centrum Aanpak funderingsproblematiek (KCAF), 2014. *Financiering van funderingsherstel.* Dordrecht, The Netherlands.
- Klaassen, R.K.W.M. & Creemers, J.G.M., 2012. Wooden foundation piles and its underestimated relevance for cultural heritage. *Journal of Cultural Heritage*, 13, pp.123-128.
- Klaassen, R.K.W.M. & Van Overeem, B.S., 2012. Factors that influence the speed of bacterial wood degradation. *Journal of Cultural Heritage*, 13, pp.129–134.
- Klaassen, R.K.W.M., 2008. Bacterial decay in wooden foundation piles—Patterns and

causes: A study of historical pile foundations in The Netherlands. *International Biodeterioration & Biodegradation*, 61, pp.45–60.
- Knight, J.R. & Sirmans, C.F., 1996. Depreciation, Maintenance, and Housing Prices. *Journal of housing economics,* 5, pp. 369–389.
- Lupi, T., 2013. *Problemen aan onderkant particuliere woningmarkt in beeld*. Den Haag: Platform 31.
- Lupi, T. & Van Dijken, K., 2013. *Financiële risico's van woningeigenaren in krimpregio's.* Den Haag: Platform 31.
- Meijer, F. & Thomsen, A., 2006. *Kwaliteit van de particuliere woningmarkt*. Gouda: Habiforum.
- Norris, M. & Winston, N., 2012. Home-ownership, housing regimes and income inequalities in Western Europe. *International Journal of Social Welfare*, 21, pp.127–138.
- Priemus, H. & Dieleman, F., 2002. Social housing policy in the European Union: past, present and perspectives. *Urban Studies,* 39 (2), pp.191-200.
- Rabobank, 2013. *Dutch housing market quarterly.* September 2013. Economic research department.
- Ras, M., Ooms, I. & Eggink, E., 2010. *Kopers in de knel?* Sociaal en Cultureel Planbureau, Den Haag.
- Schilder, F. & Conijn, E., 2012. *Restschuld in Nederland: omvang en consequenties*. Amsterdam School of Education.
- Schuitemaker, A. & Wassenberg, F., 2013. Nieuwe oplossingen voor slechte wningkwaliteit. Den Haag: Platform31.
- SEV, 2009. *Manifest voor funderingsherstel*. The Netherlands.
- Shilkoff, M. 2013. Living in a metaphor. Available at: http://life.nationalpost.com [Accessed May 12, 2014].
- Statistics Netherlands (CBS), 2013. Statline. Available at: http://statline.cbs.nl/StatWeb/?LA=nl [Accessed November 5, 2013].
- Sterman, J.D., 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* New York: Irwin/McGraw-Hill.
- Thiele, B., 2002. A human right for adequate housing: a tool for promoting and protecting individual and community health. American Journal of public health, 92 (5), pp. 712-715.
- Van Aken, J.E., Berends, H, & Van Der Bij, H. (2009). *Problem solving in organizations*. Cambridge: University Press.
- Van de Minne, A. & Franck, M., 2012. De waardebepaling van grond en opstal. *Real Estate Research Quarterly*, pp. 14-23.
- Van Ewijk, C. & Teulings, C., 2009. *De grote recessie*. Amsterdam: Balans.
- Van Hoek, T. & Koning, M., 2012. *Situatie op de Nederlandse hypotheekmarkt. Gevolgen voor de woningmarkt.* Amsterdam: EIB.
- Van Middelkoop, M., 2011. Hypotheken: individuele en regionale risicofactoren. *Tijdschrift voor de volkshuisvesting*, 1, pp.16-21.
- Vereniging van Nederlandse Gemeenten (VNG), 2009. *Het herkennen en aanpakken van eventuele funderingsproblemen bij koop of verkoop van een woning*. The Netherlands.
- Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM), 2005. *Mijn huis verzakt… Wat nu? Verslag van het vierde seminar over funderingsaanpak*. Rotterdam, The Netherlands.
- Wieringa, G. & Van Der Geest, T., 2008. *De Nederlandse hypotheekmarkt.* Deventer:

Kluwer.
- Wilhelmsson, M., 2008. House price depreciation rates and level of maintenance. *Journal of Housing Economics*, 17, pp.88–101.

Interviewees

Appendix

Appendix 1: Loam- and peat subsoil in The Netherlands
Appendix 2: Data preparation
Appendix 3: Situation in the sample
Appendix 4: List of real estate agencies
Appendix 5: Correlation matrix
Appendix 6: Principal Component Analysis SPSS output
Appendix 7: Discriminant Analysis SPSS output
Appendix 8: Input data VBA
Appendix 9: Script VBA simulation custom variables
Appendix 10: Input boxes MS Excel VBA
Appendix 11: Output MS Excel VBA
Appendix 12: Results simulations
Appendix 13: Parameters used in SD model
Appendix 14: Formulas
Appendix 15: Sub model Outstanding amount
Appendix 16: Sub model Households situation
Appendix 17: Sub model Annual expenditures
Appendix 18: User interface, input and output window
Appendix 19: Results SD simulations households category 2, 3 and 4
Appendix 20: Results Monte Carlo Analysis for household category 1
Appendix 21: English summary
Appendix 22: Dutch summary