Adequate Social Housing

Using system dynamics modelling to develop a policy strategy that increases the number of adequate rental properties in the Dutch social housing sector

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Preface

In front of you lies the master thesis ”Adequate Social Housing: Using system dynamics modelling to develop a policy strategy that increases the number of adequate rental properties in the Dutch social housing sector.” This master’s thesis was created to meet the graduation requirements of the Engineering and Policy Analysis (EPA) program at the Delft University of Technology. Throughout the months of February through October 2022, I was engaged with this master thesis project.

In this report, research on the challenges regarding the availability of adequate rental properties in the Netherlands’ current social housing sector is reported. Given that the system under study is a complex dynamic system containing uncertainties, this research provides more insight into, among other things, the most influential components of the Dutch social housing system and how they interact with one another over time. Additionally, through the use of a policy analysis, insights into the potential behaviour that the investigated system might exhibit in the future as a result of the implementation of particular policies were attained. Consequently, all the insights gained from the various analyses carried out in this study will be presented in the conclusion. These insights can provide Dutch policymakers with the necessary knowledge to efficiently assist social housing associations to meet the rising demand for adequate rental properties in the social sector.

The process of creating this research report over the past few months has been enlightening. I had the opportunity to acquire new knowledge regarding a variety of topics during this process, including the social housing system in the Netherlands. In addition, I have enjoyed applying and expanding the varied knowledge and skills I have learned in the past five years while pursuing both my bachelor’s and master’s degrees at the Delft University of Technology. The biggest personal fulfilment for me came from honing my modelling skills while creating my own system dynamics model of the studied social housing system.

Without the assistance of the different members of my graduating committee who assisted me during the execution of this investigation, this project would not have been possible. In light of this, I would like to take this opportunity to express my sincere gratitude to Dr. Ir. C. (Els) van Daalen, Dr. H.J.F.M. (Harry) Boumeester, and Dr. M. (Martijn) Eskinasi for always being eager to share their knowledge and years of experience with me as well as for being open to my queries throughout this research. Subsequently, I would like to express my deepest gratitude to Dr. Ir. W.L. (Willem) Auping, Prof. Dr. Ir. J.H. (Jan) Kwakkel, and Ir. S.R.M. (Stefan) Salome for their assistance in creating and combining the system dynamics model with the EMA Workbench.

Furthermore, I want to express my appreciation to all my loved ones for being such an wonderful support system. First and foremost, I want to express my gratitude to my family for their unwavering love and support they have shown me throughout my entire life. I also want to express my appreciation to my childhood friends from Curaçao and the ones I’ve made since moving to the Netherlands for their support during my academic endeavours. Without you, this journey would not have been possible.

As a final note of gratitude, I would like to wish you a pleasant reading experience. I hope you find this study interesting and that it might provide you with more insight into the challenges the Dutch social housing sector is currently facing.

Hillary Isenia Bustamante
The Hague, October 2022

Summary

Despite the fact that everyone has the right to adequate housing, this fundamental human right has become a critical manner in several European Union (EU) nations, especially in the Netherlands (OHCHR, 2009; Rosenfeld, 2015; European Parliament, 2020). Despite being the largest social sector in Europe, accounting for approximately 30% of the Dutch housing market, recent research suggests that housing associations are unable to properly handle their social responsibilities in the current environment in the Netherlands (Penders, 2020). First of all, recent changes in the housing market demonstrate that the demand for social housing has not only expanded but also diversified its target audience (Madsen & Ghekière, 2021). Recent studies indicate that aside from the poor and vulnerable, also the elderly, young adults (starters), and middle-income families, along with vulnerable and special groups are becoming increasingly interested in this housing aid (OECD, 2020; Madsen & Ghekière, 2021).

In order to meet the rising social housing demand, housing associations are expected to construct more than 25,000 new social houses each year until 2035, with the number of dwellings that must become more sustainable gradually increasing from 25,000 to over 60,000 (Penders, 2020; Madsen & Ghekière, 2021). According to Penders (2020), approximately €116 billion is required for all investments up to and including 2035, however, around €30 billion in social tasks (nearly 25% of the total amount) will not be accomplished since housing associations' expenditures (interest, taxes, maintenance, and management) are rising faster than their income, namely rentals. In the Netherlands, the creation and management of social housing is the responsibility of social housing associations. However, the different actions that these housing associations can take in order to fulfil their social obligations depend mainly on the housing policies that the Dutch policymakers implement.

As a result, it has recently come to light that a significant portion of the social housing stock in the Netherlands is unfit for habitation. One in five of all social rental dwellings in the Netherlands, which is estimated to be home to 312,500 households, are expected to be energy-poor, according to recent studies (P. Mulder et al., 2021; Aw, 2021). In addition, according to current Autoriteit woningcorporaties (Aw) data, the housing associations themselves provided about 80,000 social rental houses in (very) poor conditions (De Regt & Bunskoek, 2021).

Given that the Dutch social housing is currently struggling to meet its social obligations due to a paradox of rising demand and constrained financial means. More legislative actions will be required to alleviate the current housing crisis through the social housing market. Therefore, this study aims to answer the following research question:

What policy strategy could Dutch policymakers put in place to assist social housing providers to ensure that there are enough adequate rental properties available to meet the rising housing demand?

In this study, this research question will be answered by means of a simulation modelling approach. It was decided to investigate the underlying mechanisms in the social sector in the Haaglanden urban region by conducting various analyses (including uncertainty analysis and policy analysis) using the system dynamics (SD) simulation model, the Dutch Social Housing Model, which was created during the execution of this study. Contrary to the conventional SD approach, this study is accomplished by combining the SD approach with the Exploratory Modeling and Analysis (EMA) methodology – which employs computer experiments to support decision-making under uncertainties. Given the dynamic complexity and deep uncertainty linked to the researched system, this method was performed to draw valid conclusions regarding the Dutch social housing market under deep uncertainty (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021; Kwakkel & Pruyt, 2015).

First of all, the results show that up to and including 2050 there will be a housing shortage in both the social housing market (hereinafter referred to as SGEI) and the housing market for middle-low-income households (hereinafter referred to as Non SGEI) in the Haaglanden urban region. In particular, the shortage of SGEI homes will remain at around 60,000 homes from now until 2050, while the shortage of Non SGEI homes will continue to rise to about 20,000 homes. This can be explained by the difficult financial situation of the social housing associations, which cannot meet their social obligations.

Despite the anticipated gradual increase in the social housing associations' financial sources, this study shows that these corporations will only have enough financial resources to invest in the social housing market. Due to this, it is expected that the housing quality of SGEI houses will improve, while that of the Non SGEI houses is expected to deteriorate. The reason being, that if the housing association has sufficient financial resources for a particular house (in this case the SGEI houses), it can ensure that the homes in question can undergo maintenance, which improves the housing quality.

Given that the main purpose of this study is to identify policies that will enhance the system behaviour of the social housing market, it was decided to examine the following social housing regulations: Increase Average Rent, More Subsidy for Social Housing, More Planning Capacity for Social Housing, Lower Interest Rate, and Eliminate Landlord Levy. This is due to the fact that the policies Increase Average Rent, More Subsidy for Social Housing, and Eliminate Landlord Levy all improve the cash flow of social housing associations, with Eliminate Landlord Levy lowering the expenditures while the other two policies increase the income of the social housing associations. The expectation is that improved income flow will put social housing businesses in a stronger financial position, allowing them to make more investments to address the housing shortage and quality. Furthermore, More Planning Capacity for Social Housing guarantees more land at the disposal of housing associations compared to the current situation for the construction of new social housing to ensure that the growing housing demand will be met by the housing supply.

It is advised to use a combination of these policies to address the issues with the social housing system because no single of these policies can effectively address both the housing scarcity and the poor housing quality of both housing markets. Based on the results, it can be concluded that the combination of the following policies should be used in Dutch social housing: (1) More Planning Capacity for Social Housing, (2) More Subsidy for Social Housing, and (3) Eliminate Landlord Levy.

First of all, More Planning Capacity for Social Housing ensures that more building land will be made available to housing associations to build social housing, thereby reducing the housing shortage and simultaneously improving the housing quality of SGEI houses. Through this policy, more building land will be made available to housing associations to build social housing, thereby increasing the construction of new SGEI Houses. A faster increase in the housing supply compared to the housing demand will ultimately cause the shortage of SGEI houses to decrease. An increase in new construction will cause a reduction in the quality of SGEI Houses, as newly constructed homes have a condition score of 1 which will pull the average housing condition score down. It should be highlighted that this policy intervention only works best for social housing. Due to the major construction of SGEI houses caused by this policy, the housing associations will need to take a lot of new loans in order to finance this housing development. The financial situation of these firms will worsen since their debt will increase faster than their own equity (due to the gap between housing demand and supply produced by building). Furthermore, the lack of and poor quality of Non SGEI homes was unaffected by this reduction in financial resources; no investments were made in the Non SGEI housing market because housing associations were already unable to do so financially in the base case.

More Subsidy for Social Housing and Eliminate Landlord Levy, on the other hand, promote housing associations' financial resources, enabling investment in new home construction and maintenance of existing homes, thereby reducing housing shortages while improving housing quality. It should be noted that these policy interventions work best for homes owned by middle-low-income households. In general, both policies offer an increase in the financial sources of housing associations to such an extent that these corporations will now have enough financial resources to invest in the Non SGEI houses market also. Since the discrepancy between housing supply and demand in this industry will reduce as a result of a faster increase in housing supply relative to housing demand, this will ultimately result in a decrease in the shortage of Non SGEI houses. On the one hand, since newly built homes have a condition score of 1, increasing the investment in the building of new Non SGEI homes will result in an improvement in the quality Non SGEI houses. On the other hand, increasing the investment in the maintenance of Non SGEI homes will ultimately lead to an improvement in the quality of Non SGEI Houses because the conditions of the properties will be improved during the maintenance process.

It should be noted that the policy Eliminate Landlord Levy has a medium to a high positive impact on all the KPIs studied in this research, while More subsidy for Social Housing has the most influence on the financial condition of the companies and consequently the Non SGEI housing sector, given that these policy interventions had resulted in the largest increase in the associations' financial resources compared to the base case. This is because this policy guarantees that housing associations will have more income. If the expenses of these associations remain the same, a higher income will guarantee that the housing associations will turn a profit as their income exceed their expenses. With the help of this profit, the loans made will be repaid, which will increase the financial resources of the association as the debt capital decreases faster than the total capital. This also explains why the shortage of SGEI houses is more positively impacted by this policy than the quality of SGEI houses, despite the policy having a less favourable effect on these KPIs.

It is advised to ascertain the value of the most influential uncertain parameters prior to the selection of the policy strategy because the majority of the KPIs, with the exception of the housing shortage for middle-low income households, are behaviorally sensitive to the uncertain parameters investigated in this study. Moreover, it is challenging to assess the robustness of the investigated policies because of the significant overlap between the findings of the several policies reviewed by the robustness study. The efficiency and robustness of the various policies mentioned in this study and their combination should therefore be thoroughly examined using the data that have been gathered of the most influential uncertain parameters. This information allows for the most precise mapping of the researched system's behaviour during the application of the policy interventions. Policymakers are then able to decide on a course of action that is supported by empirical facts as a result. Ultimately, it is recommended that the other actors also be included in the policymaker's selection procedure, as they may have differing opinions about the different policy candidates. The many perspectives that the actors involved have regarding the social housing system must therefore be thoroughly researched.

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1
Introduction

Adequate housing, also known as decent and affordable housing, is a fundamental human right that was acknowledged for the first time in 1948 when the United Nations General Assembly adopted the Universal Declaration of Human Rights (OHCHR, 2009; Rosenfeld, 2015; European Parliament, 2020). However, in many European Union (EU) nations, adequate housing has become a critical concern. To begin with, there are not enough affordable homes available in most EU countries to meet the increasing demand (Pittini et al., 2015; Madsen & Ghekière, 2021). On top of that, housing has recently risen to the top of Europeans' spending priorities, given the fact that a large number of EU households have to spend on average over 40% of their disposable income on housing (Rosenfeld, 2015; Pittini et al., 2015, 2017). Housing prices incremented by a total of 26% between 2010 and 2020, while rents increased by 14% (Housing in Europe, n.d.). This is due to said high housing costs and the fact that their growth exceeds the income in most EU nations, resulting in 156 million people on the verge of poverty in Europe when housing costs are factored in (Rosenfeld, 2015; Pittini et al., 2017, 2019).

Subsequently, the number of homeless persons in Europe has increased substantially in recent years (Pittini et al., 2015; European Parliament, 2020). Current studies estimate that over 700,000 individuals experienced sleepless nights in Europe every night in 2020, representing a 70% increase in homelessness over the last ten years (European Parliament, 2020; Madsen & Ghekière, 2021). To make matters worse, the Coronavirus Disease 2019 (COVID-19) pandemic has demonstrated that having access to adequate housing can literally signify the difference between life and death. Recent studies suggest that individuals might suffer from a variety of ailments and illnesses, as well as stress and social and economic isolation, as a result of poor living conditions (Madsen & Ghekière, 2021). The study of Brandily et al. (2020) observed that the pandemic had a twice-as-large impact on excess mortality in the poorest French municipalities and that the COVID-19 death rate positively correlated with the share of overcrowded housing units on the municipal level. Furthermore, 31% of adults in England experienced mental or physical health difficulties as a result of a lack of space in their home or its condition during the lockdown, according to recent research performed by the National Housing Federation (NHF, 2020). As a result of the ongoing COVID-19 pandemic, long-standing housing issues such as accessibility, quality, and affordability have become even more acute.

Current governments have rekindled their interest in social housing as a means of meeting the increased demand for adequate housing in EU countries, thereby addressing long-standing issues in the current housing market (Madsen & Ghekière, 2021). Although the definition, size, scope, target population, and type of provider of social housing vary significantly by country, social housing remains an important part of the housing systems that are designed to meet the needs of those who cannot compete in the market, afford to be homeowners, or rent decent housing in the private market (Whitehead & Scanlon, 2007; Rosenfeld, 2015; OECD, 2020). First of all, recent changes in the housing market demonstrate that the demand for social housing has not only expanded (England currently has 1.1 million social households and is expected to reach 2 million next year) but also diversified its target audience (Madsen & Ghekière, 2021). Recent studies indicate that aside from the poor and vulnerable, also the elderly, young adults (starters), middle-income families, along with vulnerable and special groups are becoming increasingly interested in this housing aid (OECD, 2020; Madsen & Ghekière, 2021).

Moreover, investing in social housing development can result in larger economic advantages throughout the supply chain. Eurofound concluded that inadequate housing costs the EU economy roughly €194 billion per year in direct and indirect expenditures such as healthcare and missed productivity respectively (Pittini et al., 2017).

Likewise, building these residences would result in savings in welfare spending by relocating families receiving housing benefits from private rented housing to social rental housing (Chaloner et al., 2019). This is anticipated to prevent the emergence of a vicious feedback cycle between the granting of housing benefits and the increase in prices (Madsen & Ghekière, 2021). Furthermore, OECD (2020) suggests that housing investment has the potential to provide a long-term, inclusive, and environmentally friendly economic stimulus. This is due to the large fiscal volume, high employment intensity, and long-term focus of most social housing projects, as well as its incentive to expedite the development of environmentally sustainable building techniques, given that this sector accounts for nearly 30% of the global energy-related CO_2 emissions (IEA, 2020; OECD, 2020).

In the meanwhile, the COVID-19 pandemic has given governments the opportunity to better understand the characteristics and needs of disadvantaged households and the homeless. Given the scarcity of housing, it is becoming increasingly vital to guarantee the quality of the current stock. In normal circumstances, prior to the pandemic, it was estimated that European social housing providers spent approximately €23 billion per year on refurbishment and upkeep of existing housing stock, accounting for more than 40% of their total expenditure (Housing Europe, 2020). These characteristics can be utilized to help tailor the existing and future social housing response to the demands of their target audience (OECD, 2020). More outside space, access to green spaces and balconies to prevent overcrowding and noise pollution, not to mention energy-neutral homes to save money on energy are just a few of the most recent needs listed in Madsen & Ghekière (2021).

However, the social housing industry is currently confronted with a trade-off between growing demand and limited resources. In several EU nations, housing cooperatives have been hampered by rising land and construction prices on the one hand and tightened banking requirements on the other (Madsen & Ghekière, 2021). For instance, the basic price of ”iron - steel reinforcing bars” grew by nearly 110% in Italy, more than 70% in France and Germany, and nearly 64% in Spain, according to the European Steel Review (Bauer, 2021). Moreover, the European Construction Industry Federation (FIEC, 2021) argues that the Basel III agreement – set of measures designed to improve bank regulation, supervision, and risk management – will make it more difficult for customers to engage in construction projects. It will additionally hamper the companies' day-to-day operations, culminating in the loss of 440,000 employees in the industry. As a result, home-buying programs are now out of reach for many low- to middle-income families, in particular younger families (Madsen & Ghekière, 2021). Furthermore, the FIEC claims that these restrictions jeopardize the construction sector's contribution to economic recovery and endanger the potential impact of European recovery programs (Bauer, 2021).

Addressing these interlinked difficulties would require policy action across a wide variety of sectors (OECD, 2021). Given that social housing and the extent to which it interacts with national economic structures, welfare regimes, social trends, and policy aims differ substantially across EU countries, it was decided that the focus of this study would be on the social housing system in the Netherlands (Gibb, 2002; Scanlon et al., 2015; Rosenfeld, 2015; OECD, 2020). The reason being that the Netherlands has the largest social sector in Europe, accounting for approximately 30% of the Dutch housing market (Pittini et al., 2017, 2019; Madsen & Ghekière, 2021). Despite the magnitude of its social housing system, the Netherlands has experienced one of the largest increases in land and home prices in recent years among EU countries, due to a recent shift in the social housing framework, severe housing scarcity and owner-occupied home finance is becoming increasingly affordable in the country (OECD, 2020; Wisse, 2021). As reported by Eurostat (2021), the Netherlands has the EU's highest average purchase price per hectare of arable land, which was €69,632 in 2019. House prices in the EU rose 9.2% on average in the third quarter of 2021 compared to the previous year, with the Netherlands posting one of the highest increases at 16.8% (Swagerman, 2022a).

1.1. Knowledge Gap

Given that the housing shortage in the Netherlands is expected to considerably increase until 2024, the Ministry of Binnenlandse Zaken en Koninkrijksrelaties (BZK, 2021c) estimates that 900,000 new houses will be needed to meet the housing demand over the next ten years. According to a recent study, approximately 87,000 new homes will be required each year until 2035 to bridge the housing shortfall, of which 27,000 should be developed by social housing providers (Madsen & Ghekière, 2021). Furthermore, it has recently come to light that a significant portion of the social housing stock in the Netherlands is unfit for habitation. One in five of all social rental dwellings in the Netherlands, which is estimated to be home to 312,500 households, are expected to be energy-poor, according to recent studies (P. Mulder et al., 2021; Aw, 2021). In addition, according to current Autoriteit woningcorporaties (Aw) data that the housing associations themselves provided, about 80,000 social rental houses in (very) poor conditions (De Regt & Bunskoek, 2021).

In light of this, as well as the fact that the COVID-19 pandemic demonstrated how having access to adequate housing can actually mean the difference between life and death, the Ministry of BZK has taken a number of steps to make it feasible to provide enough high-quality, affordable housing in a welcoming environment for those who need it. First of all, the Ministry of BZK is particularly interested in accelerating the completion of large-scale housing projects by providing financial assistance to municipalities, among other things. Aedes (the Dutch federation of social housing companies) and VNG (the Dutch Municipalities' Association) have also reached administrative agreements with the Ministry of BZK to expedite the development of 150,000 social rental dwellings (BZK, 2021a). However, Aedes anticipated the completion of around 20,000 new social properties in 2020, implying that the social housing objective has been missed in the year 2020 (Madsen & Ghekière, 2021). Madsen & Ghekière (2021) also anticipates that this will continue to be the case during the ensuing years. Aedes emphasizes that the housing organizations in the Netherlands lack the resources necessary to meet the rising demands, notably those for appropriate maintenance and new housing development (De Regt & Bunskoek, 2021). Due to the elevated household growth forecast of 848,000 families from 2021 to 2034, representing a 10.5% increase, the Netherlands' shortage of adequate social housing would only get worse if the current situation is not resolved (Gopal et al., 2021).

However, among other things, it is very important to take into account the ambiguities surrounding this difficult situation when looking into potential solutions during the execution of this research. This is because numerous studies have demonstrated that the provision of adequate housing in the social housing sector through decision-making is a wicked problem (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021). Wicked problems are "ill-defined, ambiguous, and associated with strong moral, political, and professional dilemmas," in contrast to so-called "tame problems" that can be successfully dealt with using conventional linear, analytical procedures (Le Roux et al., 2011; Jonsson et al., 2021). A few characteristics of wicked problems are elusiveness, subjectivity, uniqueness, and complexity, all of which apply to the planning of adequate housing development in this sector (Adams, 2011; Le Roux et al., 2011).

First of all, elusiveness can be seen in the ambiguity surrounding this issue's true origin – whether it stems from a lack of available land, slow rates of production, rising home prices, or a combination of these three factors (Adams, 2011). Moreover, it is clear how inherently subjective any characterization of the issue is from examining the various legislative "solutions" put up by those who believe that land has either environmental or economic worth (Adams, 2011; Le Roux et al., 2011). The method used to address the problem will depend on the choice of explanation for the issue (e.g., politics, economics, education, etc.), as a wicked problem is thought to be the symptom of another wicked problem (Le Roux et al., 2011).

Despite the fact that many nations struggle with the housing issue, each nation ultimately has its own special circumstances (e.g., due to historical considerations, politics, financial or geographic considerations) that shape the nature of its housing challenge in a distinctive way (Le Roux et al., 2011). Even within a single nation, this can vary. Even though there may be a considerable national consensus on the subject of new housing development, regional variations in market dynamics, among other things, make it challenging to predict planning outcomes and guarantee the novelty of each new situation where the issue is raised (Adams, 2011). Finally, the societal-environmental planning issues and difficulties that are currently being faced, such as public housing laws, are characterised by complicated relationships, comprising a web of factors that affect one another in a complex manner (Adams, 2011; Jonsson et al., 2021).

As a result, the primary goal of the present study is to investigate possible measures that policymakers in the Netherlands may use to help increase the number of adequate rental houses in light of uncertain external circumstances. Therefore, this study aims to answer the following research question:

What policy strategy could Dutch policymakers put in place to assist social housing providers to ensure that there are enough adequate rental properties available to meet the rising housing demand?

In view of the stated aim of this research, the following sub-questions have been formulated:

1. *What does the existing Dutch social housing market look like?*
   In order to increase the production of adequate rental housing in the Netherlands, first, a thorough understanding of the current situation in which the housing associations function is required. This allows for a high-level system overview of the most influential aspects of the Dutch social sector.
2. *How may the existing Dutch social housing evolve in the absence of government intervention?*
   Subsequently, utilizing the insights gained in the Dutch social housing sector, an overview of how the main system may develop through time will be provided, allowing for the dynamics between the main indicators in the Dutch social housing system to be identified.

3. *What are the relative impacts of policies on the existing Dutch social housing over time?*
It is critical to acquire insight into the long-term effects of the examined policy on the social housing market to provide Dutch policymakers with an effective policy strategy. As a result, an overview of the policy effect on the key performance indicators of the Dutch social housing system will be presented at the end, which will serve as the foundation for the policy recommendation.

1.2. Approach

The social housing market is prone to experience crises just like any other sector. According to Elsinga et al. (2016), the global financial crisis in 2008 significantly worsened the housing scarcity while simultaneously driving down the WOZ value of properties on the social housing market, which resulted in a decline in the market value of these homes. It is essential for the policymakers' decision-making process to anticipate the housing market in order to avert these crises and meet their responsibility to ensure that every citizen of the nation has a safe place to live as much as feasible. However, this housing market is particularly difficult to forecast due to dynamic complexity and deep uncertainty that continue to alter the behaviour of the Dutch social housing market (Ali et al., 2020; J. Sterman, 2002).

In order to assist Dutch policymakers in making well-informed decisions, several mathematical models that forecast the future and calculate the various implications of policy changes pertaining to the housing market have been developed over the years (Van Dijk et al., 2016; Groot et al., 2020). Espino & Bellotindos (2020) establish that system dynamics (SD) models, as opposed to mathematical models, are more adaptable in anticipating complex occurrences, making them more suitable for outlining the complexity of the Dutch social housing market (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021).

In recent years, several studies have used the system dynamics approach to evaluate the Dutch housing market in light of its characteristics. Examples of studies that have applied this methodology to the evaluation of policy in relation to Dutch social housing include investigations of De Groen (2011); Yucel & Pruyt (2011); Eskinasi et al. (2012). Despite this, no SD model was found that primarily focused on the social housing market in the Netherlands, so that the adequacy of the social housing stock can be mapped. Because of this, the social housing model put forth here will attempt to conceptualize the idea of adequate housing and identify the policies that enable the availability of enough adequate housing in the Dutch social housing sector.

The creation and management of social housing are the responsibility of social housing associations. However, the different actions that these housing associations can take in order to fulfil their social obligations depend mainly on the housing policies that the Dutch policymakers implement. In order to gain new insights into how the Dutch policymakers can assist these organizations in achieving their responsibilities, it was decided that this SD model will be mostly centred on the perspective of the housing association.

Contrary to what has been typically done in this field, this is accomplished by combining the SD technique with the Exploratory Modeling and Analysis (EMA) methodology. The study by Kwakkel & Pruyt (2015) makes the case and provides evidence for the use of SD modelling in conjunction with EMA to address important societal challenges, similar to the lack of adequate housing in the social housing sector, as this phenomenon is characterized by dynamic complexity and deep uncertainty (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021).

1.3. Structure

The following chapter, 2 Problem Identification, delves deeper into the Netherlands' social housing system and presents the sector's most noteworthy findings. Subsequently, the implemented approach of the present study can be found in chapter 3 Research Methodology. Moreover, chapter 4 Dutch Social Housing Model provides a description of the simulation model that was created in this study in order to answer its primary research question. Additionally, the outcomes of the various analyses that were conducted in this study are presented in chapter 5 Model Outcomes. The conclusion and academic discussion related to the social housing system investigated in this study are finally covered in chapter 6 Conclusion & Discussion.

2 Problem Identification

As indicated in the Introduction, social housing in the EU differs by country (Whitehead & Scanlon, 2007; Rosenfeld, 2015; OECD, 2020). The study by Gruis (2019) shows that even within the EU countries significant variations in social housing can be observed within the EU countries. Over the years, numerous classifications have been employed to better comprehend the similarities and differences among the social housing sectors. Nevertheless, today's leading theories in comparative housing research use typologies to categorize countries (Hoekstra, 2010). CECODHAS (2007) suggests that the EU countries' social housing diversity can be generally categorised using the following characteristics: a) size of the sector, measured by the proportion of social rental housing in the total housing stock, b) forms of "governance" (ranging from public companies to cooperatives and non-profit organizations), c) forms of social property rights, such as rental housing, affordable ownership and shared ownership, and d) housing policy framework within which these actors operate. It can be observed that the allocation criteria of the housing policy framework have been regularly used in recent years to depict the social housing sectors in EU (CECODHAS, 2007; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020). The EU social housing model is categorized as follows based on these criteria:

1. **Universalistic model**: A universalistic model regards housing as a primary public obligation, with the goal of providing decent quality housing at a reasonable price to the entire population (CECODHAS, 2007; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020). In the study of Kemeny (1995), this model is also known as a unitary rental market (Elsinga et al., 2008).
2. **Targeted model**: Targeted models suggest that the market allocates housing resources to individuals with the goal of meeting only the surplus housing demand that the market is unable to meet. A distinction is made between ***generalist*** (also referred to as the dual rental market (Elsinga et al., 2008)), and ***residual*** types within this approach. Targeted models can be ***generalist***, if housing is distributed based on the income level, and ***residual***, if housing is assigned based on a household's vulnerability (CECODHAS, 2007; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020).

In the Netherlands, an EU nation that has traditionally followed a universalistic approach, social housing is considered a public obligation provided through non-profit organizations (CECODHAS, 2007; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020). Since the target level and the size of the EU's social housing sectors are inversely related (i.e. the more targeted the housing model, the smaller the social sector), it's no wonder that countries such as the Netherlands have the biggest share of social housing stock in their housing systems, over 40% at the turn of the century (Van Kempen & Priemus, 2002; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020). However, a recent European Commission (EC) ruling on state aid requiring a clearer definition of social housing allocation advised the Netherlands to pursue a more generalist targeted approach (OECD, 2020). As a result, social housing providers in the Netherlands are now focusing on households with yearly incomes of less than €40,765 for single-person homes and €45,014 for multi-person households (OECD, 2020; Rijksoverheid, 2022). OECD (2020) claims that despite the new income limitations, more than half of the Dutch population is still eligible for social housing.

In order to acquire a better understanding of the transition from universalist to targeted social housing, a historical overview of the Dutch social sector will be presented first (section 2.1). Subsequently, section 2.2 provides insight into the challenges the Dutch social housing market is currently encountering.

2.1. Historical Overview

The first social corporations in the Netherlands emerged around 1850, with the majority of them being organized by wealthy residents, businessmen, churches, and later social organisations such as labour unions (Van Leuvensteijn & Shestalova, 2006; R. De Jong, 2013). These corporations aimed to build basic residences for the workers independent from the government (Hakfoort et al., 2002; Van Leuvensteijn & Shestalova, 2006; R. De Jong, 2013). However, the Nationaal Archief (n.d.) contends that a million people lived in deplorable conditions in the Netherlands around 1900. Due to the terrible condition of these homes, especially in large cities, the government opted to become more active in decontamination, designing laws, and utilities (such as gas, water, light, and urban planning), rather than relying on private initiatives to develop housing (Nationaal Archief, n.d.). With the passage of the first Housing Act in 1901, the government and housing organizations became jointly responsible for assuring the provision of adequate, affordable housing in the Netherlands (R. De Jong, 2013). This law permitted the government to grant subsidies and government loans to housing organizations and municipal housing associations in order to eradicate slums and replace them with new structures (Hakfoort et al., 2002; R. De Jong, 2013; Musterd, 2014). However, R. De Jong (2013) states that only the housing organizations that use their resources purely for the benefit of social housing and do not distribute profits to third parties were eligible for these subsidies under this statute. The annual government contribution to housing groups grew substantially once the 1901 Housing Act went into effect, from approximately €25,000 in 1915 to around €450,000 in 1922 (Hakfoort et al., 2002).

Housing associations progressively grew in number and importance over the first half of the 20^{th} century, but after WWII, they became the most influential actors in the Dutch housing market (Hakfoort et al., 2002; R. De Jong, 2013; Musterd, 2014). Following this war, the government was forced to play a significantly larger role than before due to a combination of reconstruction, rapid population expansion, and a severe shortage of building materials and cash (R. De Jong, 2013). Housing corporations proved to be an effective vehicle for addressing the massive housing difficulties of the time (Hakfoort et al., 2002; R. De Jong, 2013; Musterd, 2014). This was exacerbated by the government's centralized approach, which had set itself the goal of alleviating the quantitative housing problem by the use of object subsidies – subsidies for the construction of dwellings for the social rental market – as early as the postwar period (Hakfoort et al., 2002; Musterd, 2014). Because housing associations were a large receiver of these subsidies, their percentage of the total housing stock increased considerably (Van Kempen & Priemus, 2002; Hakfoort et al., 2002; R. De Jong, 2013). Between 1945 and 1990, the percentage of property owned by housing associations expanded from 10% to 40% of the overall housing stock, accounting for more than 90% of the rental segment (Musterd, 2014). Hence, the growing share of the social housing association was predominantly at the expense of the private rental sector (Hakfoort et al., 2002). R. De Jong (2013) discovered that the housing industry was related to government economic policies without significantly modifying the model, based on the following basic tendencies in social rental housing throughout time:

- As soon as the major issues was resolved and the economy improved, the subsidies were reduced, a private initiative was allowed to thrive once again, and the use of the housing corporations was called into question.
- When the economy slowed down again, and the housing scarcity persisted – as it did at the end of the 1970s – the government turned to the housing association sector for anti-cyclical investment.
- When housing shortages were no longer a major issue in times of crisis – as they were in the 1920s and 2013 – the housing association industry was severely harmed.
- Ultimately, restrictive rental rules and money skimming reduced the investment power of housing organizations, just as they did in the 1930s.

Meanwhile, Elsinga & Lind (2013) described the shifts in financial support for social housing in the decades after WWII as an attempt to revert to a less government-controlled and more market-oriented housing system. As part of the so-called 'grossing and balancing operation', the housing associations were financially privatized in 1995 under the *Balansverkorting Geldelijke Steun Volkshuisvesting* Act (VROM, 1995; Van Leuvensteijn & Shestalova, 2006; Elsinga & Lind, 2013). As a result of this legislation and the fact that the final object subsidy program was discontinued in 1997, housing associations became more or less financially self-sufficient (Van Leuvensteijn & Shestalova, 2006; Elsinga & Lind, 2013). The reason being that housing corporations were forced to work as a revolving fund (where rents and housing sales earnings are used to develop new dwellings), while securing loan guarantees for social housing from government-supported Guarantee Funds (Van Leuvensteijn & Shestalova, 2006; Elsinga & Lind, 2013; Financieren in Netwerken, n.d.).

As a result, the housing association as we know it today arose – a private, non-profit organization linked to a public task through specialized legislation, regulations, subsidies, and finance (Hakfoort et al., 2002; Van Leuvensteijn & Shestalova, 2006; R. De Jong, 2013; Elsinga & Lind, 2013). Even though the social rental sector was sufficiently developed and financially stable, the research of Elsinga et al. (2008) had reservations about the Dutch universalistic concept's long-term viability. In particular, this study discovered the following three threats to the universalist model in the Netherlands:

1. **The EU's rental sector policy, and in particular its competition policy**; the competition between non-profit and profit housing associations was not on an equal footing due to unequal government support (e.g., only non-profit associations have easy access to lower-cost financing), what conflicts with the EU's competition policy in the rental sector and may result in a targeted framework (Elsinga et al., 2008; Elsinga & Lind, 2013).
2. **The model's lack of support**; concerns regarding the functioning and efficiency of housing associations have emerged, raising doubts about, among other things, the housing association's position between market and state, which may result in a change in framework (Elsinga et al., 2008; Elsinga & Lind, 2013).
3. **The competition from the owner-occupied sector**; because homeownership in the Netherlands has been encouraged in a variety of ways (e.g., mortgage interest is 100% tax-deductible) and the owner-occupied sector in this nation is generally more appealing to higher-income groups, social rented housing is expected to become property for lower-income groups, and thus a targeted sector (Elsinga et al., 2008).

According to OECD (2020), the Netherlands' transition from a universalist to a targeted approach was primary aided by the EU's competition policy. This EU policy aims to level the playing field for market activities, including social housing, and to prevent state aid from distorting competition for commercial services offered on the market (Elsinga et al., 2008). The European Commission (EC) discovered in 2009 that there were no standards governing housing services for non-disadvantaged tenants, as well as the fact that the viability of the Dutch social housing sector required government support, such as loan guarantees, cheap land prices, and low-interest rates (Elsinga et al., 2008; Eskinasi et al., 2012; Elsinga & Lind, 2013; Van Gent & Hochstenbach, 2020). Because this aid prevented profit and non-profit associations from competing on an equal footing, the EC determined that state aid may only be used for social purposes (Elsinga et al., 2008; Elsinga & Lind, 2013).

As a result, in January 2012, a new scheme – the interim Services of General Economic Interest (SGEI) plan – was launched to carry out the committee's judgment (Elsinga et al., 2008). This Act was aimed at social housing, which is defined as residences with a monthly rent less than the liberalization limit of €664.66 at the time, which has since been increased to €763.47 per month (Elsinga et al., 2008; Rijksoverheid, 2021).[1] A notable outcome of this policy was the adoption of income requirements, which required 90% of the social stock of housing associations to be allocated to households with an annual income of up to €34,000 at the time (which was raised to €45,014 in the meantime), and the remaining 10% to be allocated to those in urgent need of a home (Elsinga & Lind, 2013; Van Gent & Hochstenbach, 2020; Rijksoverheid, 2022). Given that the allocation of social housing has been based on income since this policy's inception, it can be inferred that the Netherlands has a generalist targeted social housing policy (CECODHAS, 2007; Braga & Palvarini, 2013; Rosenfeld, 2015; OECD, 2020). Furthermore, this policy assures that if a housing association does not achieve these 90% requirements, it will not be eligible for a loan guarantee for the construction of its social dwellings (Elsinga et al., 2008). Prior to this legislation's enactment, there were no such allocation requirements, as only 75% of all social rental housing was assigned to low-income households and vulnerable target groups (Van Gent & Hochstenbach, 2020).

Simultaneously, the central government was under pressure to get its finances in order, therefore the landlord levy was established in 2012 and first imposed in 2013 (Lijzenga et al., 2020). This agreement stipulates that landlords who rent out more than 10 dwellings must contribute an annual levy to the housing allowance. Furthermore, tenants in social housing with a household income of more than €43,000 will be allowed an annual maximum rent rise of 5% plus the inflation rate (rather than just the inflation rate) in order to finance the landlord levy and displace households who might afford to buy a home (Lijzenga et al., 2020; Van Gent & Hochstenbach, 2020). The substantial rent rise has led to a rapid increase in the number of tenants who are unable to afford their rent, resulting in a considerable increase in housing benefit expenditure, in particular more than €420 million annually (Woonbond, 2017).

[1]The liberalization limit decides whether a house is designated as social rental housing or as free-market housing. If the rent is less than this threshold, it is classified as social housing, and the household would be eligible for housing benefit (InfoNu, 2020).

As a result, from 2014 onwards, the landlord levy was expected to generate €0.76 billion in yearly revenue, but it has already climbed to €1.7 billion, with housing associations covering nearly 95% of the cost (Lijzenga et al., 2020). Woonbond (2017) noticed a decrease in new construction and refurbishment of social rental housing, while the sale of social housing increased and the price of more rental housing rose over the liberalization limit, in order to ensure that rentals for social housing remained affordable. Due to these unwelcome stimuli, the number of taxable rental properties in the private rental sector has plummeted from 315,000 to 200,000 residences in just three years (Woonbond, 2017).

As a result of the revised maximum income criterion for social rental homes, middle-income households are effectively prohibited from this tenure (Eskinasi et al., 2012; Van Gent & Hochstenbach, 2020; Madsen & Ghekière, 2021). According to Van Gent & Hochstenbach (2020), the continued labour market flexibility, the rapid rise in house prices since 2013, and the introduction of stricter mortgage criteria have made it increasingly difficult for middle-income households to buy a home. Resulting in a significant increase in the number of middle-income families who lack access to social housing and owner-occupied housing in the Netherlands.

Following the implementation of the 2012 SGEI plan, Elsinga & Lind (2013) noticed a variance in target demographics across the various social housing corporations in the Netherlands. Housing the low-income households and more target groups became a significant business for some housing associations while housing the lower middle incomes remained a core business for others who sought methods to accommodate this group in ways that were compatible with the new policy (Eskinasi et al., 2012; Elsinga & Lind, 2013). Raising the rent of vacant houses over the social rent level so that they are no longer SGEI and can be allocated to households earning more than the income limit is one such technique (Elsinga & Lind, 2013).

Political leaders and developers' preferred approach is so-called middle-income housing, with monthly rates ranging from €720 to €1,000 in 2019 (Van Gent & Hochstenbach, 2020). Since nearly one-third of all middle-income households cannot afford rent above €720 per month, and private developers struggle to build middle-income dwellings in high-demand (urban) areas, the 2015 Housing Act made it harder for housing associations to provide this type of housing (Eskinasi et al., 2012; Van Gent & Hochstenbach, 2020). The 2015 Housing Act granted the national government a key policy tool known as 'appropriate allocation', which mandates housing associations to ensure that all low-income households are assigned to rental housing at a government-determined acceptable rent level (Schilder & Scherpenisse, 2018).

According to recent research, there are approximately 700,000 households in the Netherlands who are not eligible for social housing and cannot afford private-sector rent; however, there are only about 400,000 rental units in the country that fall into this category, leaving hundreds of thousands of middle-income households stranded (Madsen & Ghekière, 2021). Moreover, the 2015 Housing Act has several limitations (see Table 2.1 for further details), leading to its examination in 2019, adjustment in 2020, and becoming effective on January 1^{st}, 2022, as the 2022 Housing Act (Aedes, n.d.; BZK, 2021b).

Table 2.1: Shortcomings of the 2015 Housing Act.

Bottlenecks		Citation
Excessive administrative fees	Housing associations would incur administrative expenditures of €90 million as a result of the 2015 Housing Act, which is more than three times greater than before. According to the research of Bex et al. (2017), modifications to the law might save at least €28 million per year.	Bex et al. (2017)
Local restriction	The local social task appears to be higher than the leeway in both the design and enforcement of the 2015 Housing Act. The basic parameters of this Act are just too limited, and there is far too little room for deviation (locally). Or there is the chance, but navigating the tangle of legal texts, far-reaching statutes, ministerial directives, and orders in Council is tough.	Commissie-Van Bochove (2018)
Cheap skewed renters	Lower-income households are limited in their access to the social sector, but appropriateness is not checked while someone is already living in social housing. Because the housing association is not authorized to terminate the contract, households with an income that is higher than the primary target group for social rental housing (cheap skewed renters) can continue to live in their social housing. As a result, a significant number of social dwellings are unavailable to lower-income households.	Schilder & Scherpenisse (2018)
Reinforced segregation	As a result of the 2015 Housing Act, social tenants earn less on average, contributing to rising poverty concentrations in districts and blocks with high social housing. Poverty concentrations can be harmful to children's development, stigmatize residents, and obstruct employment and educational possibilities. Furthermore, poverty concentrations are frequently regarded as socially and administratively undesirable, as they result in increased expenses for social services and maintenance.	Hochstenbach & Van Gent (2018)

2.2. Social Housing Progression

A recent study by Groenemeijer (2022) indicates that the Netherlands is currently experiencing a housing shortage of approximately 314,700 properties (3.9% of the housing supply), as a result of the country's rapid population growth since February 2021. This indicates that there has been an increase of 35,400 houses in the Dutch housing deficit since the corona year 2021 when the shortfall of 279,300 dwellings (3.5%) was estimated (Groenemeijer, 2022). Research conducted by Capital Value in collaboration with ABF Research predicts that the housing shortage will worsen over the next few years, reaching 316,000 units in 2024, due to the rapid increase in the number of (one-person) households in the Netherlands (Capital Value, 2022). One-person households in this nation are projected to grow by 262,000 (+8%) to 3,410,000 in 2027, making up 69% of the country's entire expansion in households (Capital Value, 2022). Additionally, this analysis indicates that Greater Amsterdam (6.7% in 2022), Delft and Westland (6.5% in 2022), and Flevoland (5.5% in 2022) will see the greatest shortages in the country.

Given the severity of the housing scarcity, the national government has set a goal for itself to reduce the housing shortfall to 2% by 2035, or earlier if possible (Capital Value, 2022; Groenemeijer, 2022). In order to absorb the national housing shortage in 2031 (which Primos predicts will be 2.5% of the housing stock in that year) and bring it down to the desired proportion of 2%, it will be necessary to construct an additional 42,800 homes on top of the planned housing construction of 868,100 new buildings (Gopal et al., 2021; Groenemeijer, 2022). As a result, the government and market players hope to construct 1 million additional houses over the following ten years, giving them a total planned capacity of more than 1,044,000 units (Groenemeijer, 2021; Capital Value, 2022). Out of the roughly 1 million predetermined dwellings for which information is available, Groenemeijer (2022) suggests that 429,900 (42%) are categorized as rental properties, 400,300 (40%) as owner-occupied homes, and 180,600 (18%) are still unclassified as either rentals or owner-occupied homes. Subsequently, of the approximately 1 million expected residences for which price segment information has been provided, 49% are in the affordable category, 24% are in the expensive category, and 28% are in the unclassified price group (Groenemeijer, 2022). The study by Groenemeijer (2022) suggests that regulated rentals, mid-range rentals, cheap owner-occupied homes, and mid-range owner-occupied homes are all regarded as housing options that fall under the affordable category.

Despite these anticipated changes, Capital Value (2022) forecasts that over the next five years, more than 1.3 million households will look for a home on average, with 46% of the yearly household seekers opting for rental properties and the remaining 54% for owner-occupied homes. Of the potential tenants, 75% are looking for regulated rental properties, while 25% are looking for liberalized rentals (Capital Value, 2022). This is due to the fact that the regulated rental market, where annual demand exceeds supply by 64,000 dwellings, exhibits the biggest disparities between supply and demand today (Capital Value, 2022). Subsequently, the current liberalized rental market also has a significant gap, with annual demand surpassing supply by 16,000 properties (Capital Value, 2022).

2.2.1. Origin of Social Housing Scarcity

Since 2018, housing associations have been the largest group of landlords in the social rental sector, with over 2.1 million social rental homes, 92% of which are under the liberalization limit of €752.33 per month in 2021 (BZK, 2021c). However, recent research conducted jointly by Aedes (the Dutch federation of social housing companies) and three ministries, including BZK, suggests that housing associations are unable to properly handle their social responsibilities in the current environment in the Netherlands (Penders, 2020). First of all, housing associations are expected to construct more than 25,000 new social houses each year until 2035, with the number of dwellings that must become more sustainable gradually increasing from 25,000 to over 60,000 (Penders, 2020; Madsen & Ghekière, 2021). According to Penders (2020), approximately €116 billion is required for all investments up to and including 2035, however, around €30 billion in social tasks (nearly 25% of the total amount) will not be accomplished since housing associations' expenditures (interest, taxes, maintenance, and management) are rising faster than their income, namely rentals. Subsequently, because the demand for social housing far outnumbers the supply, waiting times have gotten longer in recent years. In at least a quarter of Dutch municipalities, one would have to wait more than seven years on average to secure social accommodation (Kraniotis & De Jong, 2021). Several recent studies believe that the landlord levy's rise over time is mostly to blame for the current housing associations' financial difficulties and that it should be repealed Aedes (2020); Lijzenga et al. (2020). However, the study of Briene et al. (2019) on tax reductions in the period 2012-2016 found no significant positive relationship between the degree of intensity of the tax reduction and the investment ratio of housing associations in new housing construction, despite the fact that approximately 77% of housing associations used it and received on average €1.5 billion in tax reductions.

Furthermore, Capital Value (2022) anticipates that it will be very challenging to supply acceptable, inexpensive rental housing in the upcoming years, in part because of the sharp increase in construction costs and the high land costs (which together comprise the foundation costs of social housing corporations). The average foundation cost of a social house in the previous year was €187,000 (Van Dalen & Van Eijs, 2021). Aedes examines the foundation costs per m^2 of living space in order to appropriately compare the various dwelling styles that are present in Dutch social housing. The foundation cost per m^2 grew by 13% from €2,256 in 2019 to €2,560 in 2020 (Van Dalen & Van Eijs, 2021).

According to Van Dalen & Van Eijs (2021), the main cause of this rise in foundation costs is an increase in construction prices, which rose by as much as 18% in a span of a year. First and foremost, the COVID-19 pandemic is mostly to blame for the recent steep increase in construction costs for new homes. The supply of construction materials was affected by the temporary shutdown of production by numerous producers of (raw materials for) building materials that took place in 2020. Additionally, the demand for building materials – especially steel and wood – has increased significantly over the past years due to a rebound in construction across the globe, including in the Netherlands. This has ensured that the most significant price increases in this country are around steel (>50% for e.g. tubes), wood (softwood 50%, hardwood 25%-35%, and sheet material 6%- 60%), and rubber- and plastic-based products (±50% for e.g. PVC pipes), as reported by Rats et al. (2021).

Furthermore, the study of Rats et al. (2021) also demonstrates that construction costs have grown further as a result of the quality enhancements brought about by gas-free and Nearly Zero-Energy Buildings (NZEB) constructions. Recent publications support the findings of the Bouwend Nederland (association of infrastructure and construction firms) survey among its participants, showing that gas-free construction has led to a significant increase in construction prices of at least 10% in the Netherlands, while the NZEB standards will increase the price of single-family new construction homes by 11.5% – 16.0% (Aedes, 2021; Rats et al., 2021).

Another factor that contributes to the current Dutch home industry's surge in foundation costs is high land expenses. In particular, land costs increased by 3% last year, bringing the average land costs to €22,861 per social house (Van Dalen & Van Eijs, 2021). As a result of the location, the suitability of the property, and the leasing market, the free agricultural land market is characterized by rising prices (Silvis & Voskuilen, 2020). However, the research of Silvis & Voskuilen (2020) indicates that in addition to the considerations already discussed, the three key factors impacting current land prices are the decline in interest rates, the restricted supply, and the expansion of agriculture. First of all, the low-interest rate increases the price of land since it makes it more affordable. Due to the low-interest rate, more money may be spent on land if costs stay the same, which increases the price of land (Silvis & Voskuilen, 2020).

Subsequently, the limited amount of agricultural land is another element that contributes to the price rise of agricultural land. For starters, the market for free agricultural land is quite small. Only 1.5% – 2% of the entire area is really covered by the annual free market transactions that determine the price of agricultural land since farmland trades are almost exclusively made inside families rather than on the open market (Kadaster, 2020; Silvis & Voskuilen, 2020). Due to the decline in supply that was already constrained (1.8 million hectares of land were under cultivation in 2019, down from nearly 2 million in 2000), prices have increased recently (Silvis & Voskuilen, 2020).

Finally, the expansion of agriculture will also be responsible for land price growth. When compared to smaller businesses with limited land at their disposal, larger ones often produce more money with the same amount of work and expenses. This implies that huge corporations can, if necessary, transform some of the potential earnings from extra land into the bid price, which in turn raises the price of agricultural land (Silvis & Voskuilen, 2020).

2.2.2. Adequate Housing

As previously mentioned, adequate housing is a basic human right that is covered by, among other places, Article 11 of the International Covenant on Economic, Social, and Cultural Rights and 31 of the European Social Charter (OHCHR, 2009; Rosenfeld, 2015; PILP, 2021). Subsequently, the Dutch Constitution contains a provision for the right to housing in Article 22 paragraph 2, which among other things states that the Dutch government is required to provide housing for everyone (PDC, 2018; Vlemminx & Passchier, n.d.; Nederlandse Grondrechten, n.d.). When defining the right to housing, international and European treaties place a strong emphasis on the necessity of both quantity (enough housing) and quality (housing must be "adequate"); given that housing is more than just a place to lay your head (PILP, 2021).

As a result, the Dutch government has obligations with respect to the right to decent housing. According to College voor de Rechten van de Mens (2018), these obligations relate to the accessibility, acceptability, quality, and availability of housing. For further information on these characteristics of adequate housing, consult Table 2.2. The right to adequate housing also includes safeguards against threats, intimidation, and other forms of retaliation, according to the UN Committee (Amnesty International, 2019). In order to encompass all of the aforementioned factors, this study's definition of the right to adequate housing uses the following depiction: '[t]he right of every woman, man, youth and child to gain and sustain a safe and secure home and community in which to live in peace and dignity' (Rolnik, 2018, p. 180). To assesses the appropriateness of existing homes in the Netherlands, several techniques are currently utilized. The following techniques – Residential Satisfaction, and Condition Measurement – will be more thoroughly explained below to ensure a better grasp of these various methods.

Table 2.2: Characteristics of adequate housing (College voor de Rechten van de Mens, 2018).

Housing Characteristics	Description
Accessibility	In this context, accessibility refers to the provision of the facilities, services, resources, and infrastructure in Dutch houses that are necessary to ensure a safe, secure, and comfortable way of life.
Acceptability	Acceptability in this context indicates the extent to which the Dutch dwellings are taking cultural identity into consideration.
Quality	In this instance, the physical safety and health of people are what constitutes the quality of housing. A house must first provide protection from dampness, cold, heat, rain, and wind, on the other hand. Additionally, access to jobs, healthcare, educational opportunities, and other social amenities must be included.
Availability	Hereby, availability includes both financial and physical availability. Housing, for instance, is improper if it fails to address the unique requirements of vulnerable populations like the elderly, children, and those with disabilities. Housing availability is intimately related to financial accessibility in the form of affordability, particularly for populations who are already vulnerable.

Residential Satisfaction

The adequacy of the various homes in the Dutch stock is first and foremost evaluated by residential satisfaction. Residential satisfaction can be characterized as the perception of the discrepancy between residents' expectations and reality regarding their homes (Campbell et al., 1976; Amérigo & Aragones, 1997). Through this, the researchers hope to identify the elements, both those of the individual and the home environment, that affect how satisfied a person is with their residence (Adriaanse, 2007). It is believed that variables including tenure status, the longevity of residence, physical aspects of the home and neighbourhood, social ties, and socio-demographic characteristics of people influence satisfaction levels (Adriaanse, 2007; Huang & Du, 2015).

However, research has demonstrated that it is challenging to empirically measure residential satisfaction. According to Amérigo & Aragones (1997), there are two distinct issues with this approach: first, the social desirability brought on by direct inquiries of the form ”To what extent are you satisfied with...?” in addition to the challenge of identifying ”objective” measures of residential satisfaction. As a result, a new direction within this approach was initiated where multi-dimensional scaling, consisting of physical and psycho-social aspects, was taken into account in order to develop a general model of residential satisfaction that places user goals at the centre of the evaluation (Amérigo & Aragones, 1997; Adriaanse, 2007). Calculating the difference between the perceived and ideal living environments is particularly used to determine the level of residential satisfaction, with a smaller difference indicating greater satisfaction than a larger difference (Amérigo & Aragones, 1997).

For decades, Statistics Netherlands (a Dutch governmental institution that gathers statistical information about the Netherlands) and the Ministry of Binnenlandse Zaken en Koninkrijksrelaties (BZK) have used the *WoonOnderzoek Nederland* (WoON), a relatively large, lengthy national survey that is carried out every three years among nearly 47 000 Dutch citizens that implement this approach, to assess, among other things, residential satisfaction (Stuart-Fox et al., 2022; Swagerman, 2022b). According to the WoON 2021, 87% of all households in the Netherlands reported being content with their residences in 2021 (Stuart-Fox et al., 2022). Despite a slight improvement from the last survey in 2018 (+1%), satisfaction is still lower than it was in 2009, when residential satisfaction stood at 90% (Kullberg & Ras, 2020; Stuart-Fox et al., 2022; Swagerman, 2022b). Given that residential satisfaction among tenants in both the social and private renting sector is equivalent to 72%, tenants clearly have less residential satisfaction than owner-occupants, who report a satisfaction rate of 95% (Stuart-Fox et al., 2022).

Stuart-Fox et al. (2022) asserts that this is primarily a result of home maintenance: 88% of owner-occupiers believe their property is well-maintained, as opposed to 60% of renters in both the housing association and private rental sectors.

Additionally, the proportion of inhabitants who believe their home is too tiny is higher among tenants, whereas the proportion who believe their home is too large is higher among owner-occupiers (Stuart-Fox et al., 2022). Subsequently, there is substantial variation in levels of residential satisfaction between the municipalities in the Netherlands. Residents of very urban municipalities report the lowest levels of residential satisfaction in the WoOn 2021, while those of non-urban cities report the greatest levels. This is because owner-occupied and private rental prices are significantly higher in large cities than in smaller, less urban municipalities, and there are typically long waiting lists for social housing in large cities. As a result, residents of urban towns might have to settle for a home that they are (somewhat) less happy with sooner (Stuart-Fox et al., 2022). In contrast to Rijssen-Holten in Overijssel, which has the shortest registration term in the Netherlands with an average waiting time of 8 months, Amsterdam, the country's largest city, has a waiting period of approximately 14 years (NOS op3, 2021a,b; De Telegraaf, 2021).

Condition Measurement

Furthermore, there are a number of methods that are also used in the Netherlands to evaluate the adequacy of the current housing stock that place a greater emphasis on the physical condition of the homes in comparison to residential satisfaction. The approaches that measure the home's energetic state, such as the Nearly Zero Energy Buildings (NZEB)[2] for new construction and the energy label[3] for existing properties, together with the condition measurement serve as a few examples of these methods (Van Plateringen, 2013; BZK, 2020; NEN, n.d.).

The condition measurement is an approach used in the Netherlands to evaluate the adequacy of the current housing stock, which applies more attention to the physical condition of the housing stock. The Kwalitatieve Woning Registratie (KWR) first introduced the condition measurement in the Netherlands in the late 1970s to better understand the construction and housing quality of the Dutch housing stock (Dankert, 2018; PIT Beheer, n.d.). Over the years that followed, this assessment was improved upon, and it was implemented as an independent standardization of maintenance for all types of buildings in the Netherlands starting in 1985 (PIT Beheer, n.d.). This assessment is now known as the NEN 2767 standard. An independent inspector makes an inventory of the information about the studied object's construction parts during the condition measurement and information about any flaws in the construction part is examined and recorded. Using the NEN 2767 standard, the inspector assesses the gravity, scope, and intensity of the identified flaws before determining the condition score (NEN, n.d.; De Regt & Bunskoek, 2021). According to NEN (n.d.), a condition score is an objective value stated on a six-point scale (1 to 6, with 1 serving as the highest score and, consequently, the best level in terms of building condition) that represents the technical condition of a building component (see table 2.3).

Table 2.3: Condition scores description (Piaia et al., 2021, p. 902).

Condition Score	Description	Condition State
1	*Very good condition*	Occasional minor defects
2	*Good condition*	Occasional signs of ageing
3	*Reasonable condition*	Localised visible ageing, components functionality not at risk
4	*Borderline condition*	Component functionality occasionally at risk
5	*Bad condition*	Ageing condition is irreversible
6	*Very bad condition*	Technical state for replacement/ demolition

[2]The concept of NZEB can be described as a "very high energy performing building with a very low quantity of energy required covered to a very large proportion by energy from on-site or nearby renewable sources" (Cirami et al., 2017). The Netherlands' new building rules, known as NZEB, only computes the energy consumption related to buildings, such as heating, cooling, hot water, and auxiliary energy for pumps and ventilators (Lente-Akkoord 1.0, n.d.).

[3]The building's classification (from G to A++++, with A++++ serving as the highest class and, consequently, the best level in terms of energy), floor space, type, and standard energy consumption – expressed in gas, electricity, heat, and total primary energy consumption – are all listed on the energy label, officially known as the energy performance certificate (Van Plateringen, 2013; Majcen, 2016; NVM, n.d.; BZK, 2022). Each energy label also contains a list of target values – improvements that could be made to the roof, floors, and windows to increase energy efficiency in the house – such as installing double glazing or roof insulation (NVM, n.d.; BZK, 2022).

Table 2.4: Defect parameters description (Dankert, 2018; NEN, n.d.; PIT Beheer, n.d.).

Defect Parameters	Attribute		Description
Severity	Minor Defect		No influence on the functionality
	Serious Defect		Loss of quality without directly affecting functionality
	Earnest Defect		Direct reduction in functionality
Extent	Extent 1	<2%	The defect is incidental
	Extent 2	2% to 10%	The defect is local
	Extent 3	10% to 30%	The defect occurs regularly
	Extent 4	30% to 70%	The defect is significant
	Extent 5	≥ 70%	The defect is common
Intensity	Intensity 1	Low (initial stage)	The defect is barely noticeable
	Intensity 2	Intermediate (advanced stage)	The defect is clearly noticeable
	Intensity 3	High (final stage)	De defect is very clearly noticeable

By using the following three factors, the defects[4] of the studied building are quantified: (1) *severity*, which can be further classified into Minor, Serious, and Earnest defects; (2) *extent*, where the extent of the defect is calculated as a percentage; and (3) *intensity*, which denotes the defect's stage (consult Table 2.4). As a result, a condition score for the relevant building component can be determined using these three criteria, as illustrated in Table 2.5. With the help of the condition score for this relevant construction component, the conditions score for the higher levels of abstraction element and eventually the examined building can be aggregated (Dankert, 2018; NEN, n.d.; PIT Beheer, n.d.). Recent studies show the NEN 2767's applicability because this methodology, which standardizes the classification of defects to objectively and uniformly measure the physical quality of construction components/ buildings, is the core of condition assessment to gain knowledge of the maintenance condition of construction components/ buildings, to be used as a basis for determining maintenance costs and prioritizing repairs, and to enable better management and control of the building stock (Kuijper & Bezemer, 2016; Di Giulio et al., 2020; Piaia et al., 2021). Housing associations can compare the condition of their dwellings and identify the upkeep requirements and potential dangers of the investigated real estate objects (Dankert, 2018).

Table 2.5: Overview of condition score per defect parameter combination (Den Broek, 2015).

			Extent				
		Intensity	1) Incidental <2%	2) Local 2% to 10%	3) Regular 10% to 30%	4) Significant 30% to 70%	5) Common ≥ 70%
Severity	*Earnest*	1) Initial	1	1	2	3	4
		2) Intermediate	1	2	3	4	4
		3) Final	2	3	4	5	6
	Serious	1) Initial	1	1	1	2	3
		2) Intermediate	1	1	2	3	4
		3) Final	1	2	3	4	5
	Minor	1) Initial	1	1	1	1	2
		2) Intermediate	1	1	1	2	3
		3) Final	1	1	2	3	4

Recent data from the Aw, provided by the housing associations themselves, was examined by the research editors of RTL Nieuws and revealed that one in every 25 (± 80 000) social rental properties for which a so-called condition score is known is in moderate to very bad condition, i.e. from the condition score 4 onward (De Regt & Bunskoek, 2021). According to inspector Roel Warring, a home with a condition score of 4 or higher would soon (within 3 years) need significant maintenance (De Regt & Bunskoek, 2021). Inspectors advise housing associations to aim for a condition score of 2 (the ideal score) and avoid properties from falling into the condition score of 4 (De Regt & Bunskoek, 2021).

More than 80 housing organizations around the nation appear to find this to be effective, although this is undoubtedly not the case for all housing associations. As an illustration, nearly half (49%) of the residences owned by the Woonstad Rotterdam fell into condition scores 4 to 6(moderate to very poor). Additionally, a sizeable portion of the property (44%) at Woningbedrijf Velsen and ProWonen falls into these categories (De Regt & Bunskoek, 2021). According to Woonstad Rotterdam, the numbers the corporation itself submitted to the Aw paint an inaccurate picture of the current state of maintenance because, in their view, the condition score only rises when all the planned work is completed, which does not occur simultaneously (De Regt & Bunskoek, 2021).

[4] A defect is defined by NEN 2767 as a condition of a material or construction part in which there is a degradation or loss of performance (NEN, n.d.).

Even though three-quarters of the current social housing stock in the Netherlands is at least 30 years old (given the fact that the vast majority of the social dwellings were built before 1990), the experts who spoke with RTL Nieuws said, ”The fact that they are older is no excuse.” (De Regt & Bunskoek, 2021; Aw, 2021). Poor conditions, such as leaks, crumbling window frames, mouldy walls and ceilings, impassable balconies, or other hazards, might endanger people's safety or drastically lower their quality of life. In the social housing industry, deferred maintenance affects 36% of tenants who rent from housing associations. Aedes claims that the areas near Rotterdam and The Hague in particular have a much larger share of deferred maintenance (De Regt & Bunskoek, 2021).

2.2.3. Policy

The Dutch government has established a number of regulations to control this market ever since the first Housing Act was passed in 1901, which divided responsibility for the Dutch social housing market between the government and housing organizations (R. De Jong, 2013). Table 2.6 provides a summary of the most significant regulations the government enacted in the social housing industry over the past century.

Table 2.6: Overview of the key policies that affect social housing.

Policies	Explanation
Rent Regulation	The policymakers use this method in order to ensure that the maximum reasonable rent for rental houses in the regulated market sector is established and the maximum yearly rent rise for these residences is also established (CPB, 2010).
Grants and Guarantees	Up until the middle of the 1990s, the government gave housing associations financial aid to build social housing. Since the federal government and local governments serve as their guarantors, the government currently provides housing associations with financial resources, such as the opportunity to borrow money at comparatively low-interest rates (CPB, 2010).
Housing Benefit	The housing benefit is designed for families whose rent is excessively high in relation to their income (CPB, 2010). Given that housing associations receive 99% of their income from the monthly rent that residents pay, policymakers employ this strategy to ensure that these associations can stay afloat (Aedes, 2018).
Spatial Planning Policy	The policymakers specify systematically how space is used and set up via the spatial planning policy. The availability of land for housing is determined by this policy, which has a big effect on property prices that influence the rent (CPB, 2010). This applies to zoning plans, in which the municipal council decides, among other things, the use and building possibilities for social rental housing (VROM, 2006).
Building Decree	All buildings, including residences, must at least conform to the building regulations set forth in the Building Decree with regard to safety, health, the usability of construction projects, and the environment. The aforementioned laws impact building costs and, consequently, property prices that influence the rent (CPB, 2010).
Landlord Levy	Landlords of social housing, including housing associations, must pay a tax on the market value of their social housing under the landlord levy, which was instituted in 2013 with the goal of balancing the state's budget (Woonbond, 2017). The aforementioned tax ensures the current housing associations' financial difficulties (Aedes, 2020).

According to Aw, home maintenance will continue to be crucial in the coming years (Aw, 2021; IenW, 2022). The COVID-19 pandemic has shown that access to adequate housing can actually mean the difference between life and death, which is one of the reasons why proper housing has become a crucial issue in the Dutch housing market. According to Madsen & Ghekière (2021), people who live in substandard conditions may experience a range of diseases, stress, and social and economic isolation. The research by Van Beuningen (2018) revealed that life satisfaction is positively correlated with one's level of happiness with one's house. At the present rate of new building, purchase, demolition, and sale, it would theoretically take 130 years to replace the entire housing stock, which is insufficient to maintain a good quality of life (Aw, 2021). The Ministry of BZK has taken a variety of actions to make it attainable to provide enough high-quality, affordable housing in a friendly environment for individuals who need it. First off, the Ministry of BZK is particularly interested in accelerating the completion of major housing projects by, among other things, offering financial support to municipalities (BZK, 2021a). Subsequently, the Ministry of BZK believes that the removal of the landlord tax will provide housing associations with adequate financial resources to resume their role in the social housing sector (De Jonge, 2022). However, Aedes emphasizes that there aren't enough resources to fulfil the increasing demands that the housing associations in the Netherlands must meet, including proper maintenance, and new construction (De Regt & Bunskoek, 2021). This is supported by the study of Briene et al. (2019) on tax reductions found no significant positive causal relation between the degree of intensity of tax reduction and the investment ratio of housing associations in new housing construction. As a result, the main objective of this study is to analyze potential (robust) policies that Dutch policymakers may adopt to aid in ensuring that there are enough adequate rental homes to meet the household growth forecast of 848,000 families from 2021 to 2034, representing a 10.5% increase (Gopal et al., 2021).

3
Research Methodology

There are a number of factors that can have an impact on the Dutch social housing market. This social sector is particularly impacted by supply and demand since homes become more expensive when demand is high and supply is limited, just like the housing market in general (Ali et al., 2020). However, demand and supply are delayed since housing development might take months or even years to complete, depending on the magnitude of the project. Recent research demonstrates that the availability of land and building supplies, along with the financial position of the social housing providers, have an impact on the housing construction in this market.

On the one hand, Penders (2020) reveals that approximately €116 billion is required for all investments in the social housing market up to and including 2035, however, around €30 billion in social tasks (nearly 25% of the total amount) will not be accomplished since housing associations' expenditures (interest, taxes, maintenance, and management) are rising faster than their income. On the other hand, Capital Value (2022) and Van Dalen & Van Eijs (2021) anticipate that it will be extremely difficult to supply acceptable, inexpensive rental housing in the coming years, in part due to the sharp increase in construction costs (which rose by 18% in a year) and the high land costs (which increased by 3% last year, bringing the average land costs to €22,861 per social house).

Furthermore, social housing buildings are durable and are anticipated to last for many decades. A recent study by Aw, 2021 shows that three-quarters of the current housing stock in the Netherlands, where the majority of social housing was built before 1990, is at least 30 years old. Even if a social house is demolished, the land will continue to exist and increase in value since it might one day be utilized for, among other things, housing developments (Ali et al., 2020; Silvis & Voskuilen, 2020).

The social housing market is prone to experience crises just like any other sector. According to Elsinga et al. (2016), the global financial crisis in 2008 significantly worsened the housing scarcity while simultaneously driving down the WOZ value of properties on the social housing market, which resulted in a decline in the market value of these homes. It is essential for the policymakers' decision-making process to anticipate the housing market in order to avert these crises and meet their responsibility to ensure that every citizen of the nation has a safe place to live as much as feasible. However, this housing market is particularly difficult to forecast due to the interaction between the aforementioned components that continue to alter the behaviour of the Dutch social housing market (Ali et al., 2020).

In order to assist Dutch policymakers in making well-informed decisions, several quantitative and qualitative models that forecast the future and calculate the various implications of policy changes pertaining to the housing market have been developed over the years. The research conducted in conjunction with the Central Planning Bureau, the Social and Cultural Planning Bureau, and the Planning Bureau for the Living Environment, which is published as the *Kansrijk Woonbeleid 2020* under the series *Kansrijk Beleid*, is for example recent research that used the CPB model, a mathematical model, to forecast and understand the effects of various housing policies in order to support Dutch policymakers in their decision-making process (Groot et al., 2020).

Espino & Bellotindos (2020) establish that system dynamics (SD) models, as opposed to mathematical models, are more adaptable in anticipating complex occurrences, making them more suitable for outlining the complexity of the Dutch social housing market (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021). First, when considering causality (relationship between supply and demand), the SD approach is preferable to mathematical models as Espino & Bellotindos (2020) claims that the outcomes of these mathematical techniques (such as regression models) may be harmed if the correlation is taken into account as a cause.

Subsequently, the SD approach is preferred since it makes it easier to model and evaluate systems, as well as their associated behaviour and/or policy, over long time periods, given the desired parameters (Forrester et al., 1976; Espino & Bellotindos, 2020). Given that the scarcity of adequate housing in the social housing sector is characterized by dynamic complexity and deep uncertainty, it was decided to use the SD approach in conjunction with the Exploratory Modeling and Analysis (EMA) methodology to address this societal challenge (Adams, 2011; Le Roux et al., 2011; Jonsson et al., 2021; Kwakkel & Pruyt, 2015).

The research methodology will be detailed in this section in order to acquire a better understanding of the different techniques used in this study to answer the established research question, as well as its related sub-questions. Given that the system under investigation is characterized by dynamic complexity and deep uncertainty, it was established that the System Dynamics Modeling and Analysis (ESDMA) methodology is the most suitable for this research. As a result, the two techniques that makeup ESDMA, namely System Dynamics and Exploratory Modelling and Analysis, are discussed first. The data sources used to realize this study are then summarized in section 3.3. Finally, section 3.4 presents an outline of the research's methodology to conclude.

3.1. System Dynamics

System Dynamics (SD) is a computer-aided approach that, in the words of Wolstenholme (1989, p. 171), "describes, models, simulates, and analyzes dynamically complex issues and/or systems in terms of the processes, information, organizational boundaries, and strategies". This method was created by Jay W. Forrester at the end of the '50s and the start of the '60s because he believed that conventional problem-solving techniques did not adequately explain the strategic operations that take part in complex systems (Forrester, 1995). As a result, the primary goal of the SD approach is to identify and depict the elements of complexity – which include feedback processes, accumulation and dispersal of resources, time delays, and nonlinear and/or history-dependent behaviour – that determine the dynamics of a system (J. D. Sterman, 2001). Consequently, a causal theory to explain the behaviour of the studied system can be obtained by examining the relationship between system structure and time evolutionary behaviour using SD models. Additionally, the identified theory can be used as the basis for system-level interventions to change the resulting behaviour (Lane, 2000). This causal theory needs to describe how the system's internal structure gives rise to dynamic behaviour; in other words, it needs to be endogenous (G. P. Richardson, 2011).

Understanding the components of an SD model is required before this can be achievable. SD models are simplified representations of systems consisting of variables and connections between (some) of these variables represented in differential/integral equations (Pruyt, 2013). Stock-flow structures are used in SD models to visualize these equations (Forrester et al., 1976; J. D. Sterman, 2001; Pruyt et al., 2011; Pruyt, 2013). In these models, stocks (also known as *levels*) are integral equations that reflect components of the system where accumulation occurs (Forrester et al., 1976). A stock variable is actually the sum of its inflows minus its outflows over time, starting from its initial value (Pruyt, 2013). Therefore, flows (also known as *rates*) are the factors in an SD model that cause the stock's value to change over time. According to the SD method, a model's stock-flow structures are the origin of the varieties of behaviour that it, and thereby the system it represents, displays. Changes in the relative dominance of the different feedback loops in the system, each of which has non-linearities, delays, and accumulation or draining processes that fluctuate throughout time, are the cause of these dynamic behaviour (Lane, 2000; J. D. Sterman, 2001).

Several structured processes for model development have been put forward in the SD literature, with those of Wolstenholme (1989), Forrester & Albin (1997) and J. D. Sterman (2001) being some examples. Although there are differences in naming and determining which activities fall under which step, the SD modeling process broadly comprises the following five components: (1) formulating the problem to be addressed; (2) explaining the causal theory, or dynamic hypothesis, about the causes of the problem; (3) formulating a computer simulation model to test the causal theory; (4) testing the model to assess its fit for purpose; and (5) use the model for policy analysis to design and evaluate structural policies that address the problem (J. D. Sterman, 2001; Kwakkel & Pruyt, 2015). In order to fulfil the specified research goal using the SD methodology, in this research, the aforementioned defined steps will be denoted as follows; (1) problem identification, (2) model conceptualization, (3) model formulation, (4) model testing and (5) model use.

The housing market has been extensively modelled using the SD approach for many years. Perhaps the most well-known example is the Urban Dynamics model, where the first operational dynamics model of complex systems that examines the underlying interaction between the housing market, population and industries in an urban environment was introduced by Jay W. Forrester in 1969 (Forrester, 1970; Garn & Wilson, 1972; Sanders & Sanders, 2004). The structure of this model represents an ”urban area” and consists of three categories of industries — *new, mature, and young* — three categories of housing — *premium, worker, and underemployed* — and three categories of people — *managerial-professional, labor, and underemployed* (Forrester, 1970).

According to Eskinasi (2014), ”ageing processes” have a significant role in the Urban Dynamics model due to the fact that premium housing may filter down to becoming a worker or underemployed housing, and companies evolve from new enterprises through mature businesses into declining industries. Moreover, the ”urban area” in this SD model is shown as a social system that operates in an environment with which it interacts. People can move into and out of the ”urban area”, but the amount of people entering and leaving the ”urban area” depends on how attractive it is in comparison to its surroundings (this phenomenon also goes by the name relative attractiveness). According to changes in the environment-related factors, which are used as a benchmark in this model, attractiveness increases or decreases. Furthermore, the environment hereby is regarded as an infinite resource because it absorbs or supplies people depending on how appealing the ”urban area” is (Forrester, 1970; Sanders & Sanders, 2004).

Even though the Urban Dynamics model helped develop the methodology that is now known as system dynamics, various other models have since been created that address its criticisms and/or delve further into other knowledge gaps that aren’t addressed by this model (Sanders & Sanders, 2004; Eskinasi, 2014). A few examples of this include (1) studies that create a spatial version of Urban Dynamics to account for interactions between various residential areas in a city (Sanders & Sanders, 2004; Uchino et al., 2005), (2) studies that connect an urban transportation-planning model to a condensed version of Urban Dynamics (also known as URBAN1) in an effort to find a balance between accessibility and socioeconomic development (Kuroda & Tsaur, 1990; Swanson, 2003), and (3) studies that have used the Urban Dynamics model for policy evaluation (Jarzynka, 2006; J. Richardson & Elizabeth, 2010).

Table 3.1: Overview of published research on the Dutch housing market.

Study	Scope	Main Objective
De Groen (2011)	Northern Randstad	To investigate the consequences of the four policy alterations the Dutch government suggested in order to increase the market’s accessibility of social housing for low-income families until 2020.
De Groen et al. (2012)	Northern Randstad	To investigate the consequences of the four policy alterations the Dutch government suggested in order to increase the market’s accessibility of social housing for low-income families until 2020.
Eskinasi et al. (2011)	Netherlands	To provide insight into the interaction of the various sub-markets of the housing market (the market for housing services, the investment market and the housing construction market).
Eskinasi et al. (2012)	Haaglanden Region	To gain a deeper understanding of how green-field development and transformation affect the success ratio of the housing corporations – which is calculated by dividing the annual supply of social housing units by the total number of applicants for those units –, and to gain knowledge of the impact of suggested policy interventions on the housing market in this region.
Sanders & Sanders (2004)	Rotterdam	To gain knowledge of how urban areas change as a result of interactions between people, housing, and commercial buildings; while taking into account the connections between different residential zones in a city.
Van Nistelrooij (2009)	Netherlands	To simulate the relationship between the Dutch housing processes and the financial mortgage support.
Yucel & Pruyt (2011)	Netherlands	To draw attention to the importance of the current housing stock and the inertia it might cause during the energy transition process, and to examine the effectiveness of a number of potential policy measures that might be able to help to lessen this inertia and make significant headway in the residential energy transition.

Subsequently, additional studies have replicated Jay W. Forrester's methodology and used the SD approach to investigate the Dutch housing market. For an overview of the different studies that have been done on this topic, consult Table 3.1. Nevertheless, no SD model was discovered that was exclusively focused on the social housing market in the Netherlands so that the adequacy of the social housing stock can be mapped. The SD model proposed here will therefore make an effort to conceptualize the concept of adequate housing in an SD model to uncover policy strategies that enable the availability of enough adequate housing in the Dutch social housing sector. Given that social housing associations are responsible for the production and operation of social housing, this model will consequently mostly be centred on their point of view to gain insight into how policymakers can better help these organizations meet their obligations. Contrary to conventional practice, this is accomplished by combining the SD approach with the Exploratory Modelling and Analysis (EMA) methodology. Exploratory System Dynamics Modeling and Analysis (ESDMA) is the name given to the synthesis of these two approaches (Pruyt, 2010; Kwakkel & Pruyt, 2015). According to Kwakkel & Pruyt (2015), SD modelling can be used in conjunction with EMA to address significant societal challenges due to its dynamic complexity and deep uncertainty, much like the scarcity of adequate housing in the social housing sector (Adams, 2011; Jonsson et al., 2021).

3.2. Exploratory Modelling and Analysis

Exploratory Modeling and Analysis (EMA) is a research methodology that employs computer experiments to evaluate complex and deeply uncertain systems in order to support decision-making (Auping et al., 2012; Bankes et al., 2013; Kwakkel & Pruyt, 2015). EMA is based on the work of Steve Bankes, who first introduced this method as exploratory modelling at the start of the '90s to distinguish between the two main uses of computer models, consolidative and explorative modelling (Bankes, 1993). In contrast to consolidative modelling, which uses a model as a surrogate for the system in the real world to forecast the system's behaviour, explorative modelling employs a model as a hypothesis generator to reason about how the system will behave in the face of uncertainty (Bankes, 1993; Agusdinata, 2008; Kwakkel & Pruyt, 2015). By examining the results of multiple of these hypotheses through extending the assumptions of a systems model (when useful and resource-friendly), one can determine which statements about system behaviour are generally true (Bankes, 1993; Agusdinata, 2008). Each hypothesis serves as a single "mirror" through which the behaviour of the system can be examined, and in situations of deep uncertainty, numerous mirrors offer a more accurate "image" than a single mirror (Agusdinata, 2008). By employing computational experiments, EMA investigates the various hypotheses about the system (Auping et al., 2012; Bankes et al., 2013; Kwakkel & Pruyt, 2015). A computational experiment, according to Agusdinata (2008), can be characterized as a single computer run of a model using a single set of inputs.

An open exploration and focused search can be distinguished as the primary search strategies in EMA. Since open exploration attempts to produce a series of computational experiments that cover the space of plausible models, or uncertainty space for short, it can be used to systematically examine the uncertainty space. In contrast, the directed search uses optimization techniques – such as evolutionary algorithms and conjugate gradient methods – to uncover detailed information on the dynamics of certain regions within the entire uncertainty space (Kwakkel & Pruyt, 2015; Kwakkel, 2022). Additionally, directed search and open exploration can be complementary to one another (Kwakkel & Pruyt, 2015). As a result, EMA may be utilized for three different purposes: (1) investigating the impact of uncertainties, (2) conducting focused searches in specific regions of the uncertainty spaces; and (3) conducting extensive policy testing (Pruyt, 2010; Pruyt et al., 2011).

EMA will be used in this study to investigate the impact of the uncertainties in the Dutch social housing system that have an impact on the policy strategies that Dutch policymakers can implement to increase the number of available adequate homes in the social housing market. To attain this objective, which will be carried out in the Exploratory Modeling Workbench [5], several techniques that fall under the open exploration component of EMA are used in this study. In light of the fact that the EMA workbench conceptualizes the systems under investigation using the XLRM framework, where X stands for uncertainties, L for policy levers, R for the simulation model, and M for model results, multiple scenarios that consist of distinct uncertainty and policy combinations will be constructed utilizing this computational tool (Lempert, 2003). Each scenario is constructed by sampling one value from the bandwidth of each uncertain parameter studied, which is pre-specified by the researcher in the EMA Workbench. Latin Hypercube Sampling was chosen as the sampling technique in this analysis since it is the EMA Workbench's default sampling method and it systematically covers the whole uncertainty space of combined uncertain parameters across the number of replicates specified (McKay et al., 2000; Kwakkel, 2017).

[5] The Exploratory Modeling Workbench (EMA Workbench) is an open-source package in Python that combines data management, visualization, and analysis with multi-method simulation for exploratory modelling (Kwakkel, 2017).

3.3. Model Data

This research was conducted using a variety of sources. Forrester (1980) asserts that an SD model may incorporate a variety of data sorts, including written (articles, books), mental (from the modeller's or an expert's observation), and numerical data. All of these data sources were used in this study to build the Dutch Social Housing Model. A description of how these data sources were used in this study is presented below. Please consult Appendix A if more specific information on the data types employed in this research is needed.

On several characteristics of the Dutch housing market, including supply, production, and demand, there are numerous public sources available. The reason for this is that there are some organisations including Statistics Netherlands, Aedes, and ABF Research that specialize in gathering data on the (social) housing market in the Netherlands and making it available to the public. On its websites, the Dutch government has also made available a number of research studies that the government consults when making decisions regarding the housing market. The aforementioned written data source was primarily used to determine the model structure and set of assumptions surrounding the Dutch Social Housing Model. During project consultations, the mental data of my second supervisor and the external supervisor, who are both authorities in the Dutch social housing market, were gathered in order to fill in the remaining data gaps on the model structure and assumptions.

First of all, two data sources, namely Statistics Netherlands and *WoonOnderzoek Nederland* (WoON)[6] 2018, were used to retrieve the numerical data of the housing demand. First, the population factors that affect the population development in the studied area, such as the number of births, immigration, and deaths per year, were calculated using data from Statistics Netherlands. Additionally, the WoON 2018 was used to identify the household features that affect housing demand, including the number of individuals residing in the various household types.

Subsequently, a variety of data sources were employed to retrieve the numerical data on the housing supply. First of all, the publications of the ABF Research have been used to identify the planning capacity, i.e., the amount of land at the disposal of social housing associations for the construction of new social housing in a specific region. Subsequently, the number of social houses that must be in the model at the beginning of the model run in order for it to be consistent with the historical data was determined using Statistics Netherlands data. In the end, the WoON 2018 and the Autoriteit woningcorporaties[7] (Aw) was used to determine the characteristics of the social housing. In particular, the WoON 2018 was used to determine the age distribution of the social housing, while the Aw was used to determine the distribution of condition scores.

Ultimately, multiple data sources were employed to retrieve the numerical data on the social housing associations' financial situation. To begin with, a publication of the Aw has been used to define the solvency criteria for the SGEI (15%) and Non SGEI homes (40%). Secondly, by using Statistics Netherlands data, the historical WOZ value of social housing was identified. Finally, data from Aedes and ABF Research were used to identify the expenses social housing associations incurred when financing housing developments in the social sector.

3.4. Modelling Approach

In order to fulfil the specified research goal using the SD methodology, the aforementioned defined steps in the SD modelling procedure were divided in four different phases in this research. In general, all steps were performed in a separate phase of this research, with the exception of steps 3 and 4, which were carried out in the third phase of this research (see Figure 3.1). Throughout these stages, a variety of different methods were employed. Figure 3.1 depicts a high-level picture of how these techniques are applied to address the research questions in this study at the various phases of the research process.

To begin with, this study conducted various desk research. Since several definitions are used to express the concept of "adequate housing", desk research has been conducted first to clarify this key notion. Based on this definition, it can be determined which house properties, such as the housing price (€) and house size (m^2), should be included in the SD model. Desk research was also used in this study to gain more insights into the challenges that the Dutch social housing system is currently dealing with. Ultimately, the same method was utilized to identify the factors that have the most influence on the production of adequate housing in the social sector (alongside population growth and housing price), as well as how they interact (C. H. Mulder, 2009; A. De Jong et al., 2019).

[6] WoON is a relatively large, lengthy national survey that is carried out every three years among nearly 47,000 Dutch citizens that implement this approach, to assess, among other things, residential satisfaction (Stuart-Fox et al., 2022; Swagerman, 2022b).

[7] Aw is a regulating organization that makes sure social housing associations focus on their core task, which is to make sure that low-income households can live comfortably and inexpensively.

This information was compiled into a conceptual model, namely a causal loop diagram (CLD), to depict the fundamental causal mechanisms that are anticipated to emerge from the feedback structure (Binder et al., 2004). To determine the housing properties and demographic characteristics of the population, Aw and Statistics Netherlands sources, among other things, were utilized, respectively. Finally, the desk research was used to identify the numerous national policies that (would) have an impact on the social housing market, particularly those that affect the social housing production, in order to facilitate policy analysis (more explanation is provided below). This information was primarily gathered through policy research and reports.

The formalisation of a simulation model that follows the SD methodology was used as a subsequent step in this investigation. The CLD was combined with the data acquired on the factors of influence on the housing system to create the SD model, the Dutch Social Housing Model. Similarly to the CLD, the model was presented in Vensim, one of the most used SD software. Furthermore, the model has been put to the test to see if its usefulness is consistent with its intended purpose. This is accomplished, among other things, by performing a boundary adequacy test and sensitivity analysis.

Ultimately, during the model use phase of this research, different computational experiments were carried out. Since dealing with societal challenges, such as the social housing sector, is a crucial burden that will continue to be difficult for decision-makers, this project explored and evaluated uncertain dynamic issues and assess the robustness of the studied policy using the EMA Workbench (Pruyt et al., 2011; Le Roux et al., 2011; Auping, 2018; Jonsson et al., 2021). To begin with, this was accomplished by mapping the effect of the uncertain parameters on the model behaviour as a result of the uncertainty analysis. In order to map the robustness of the policy interventions, a policy analysis was subsequently undertaken in this study.

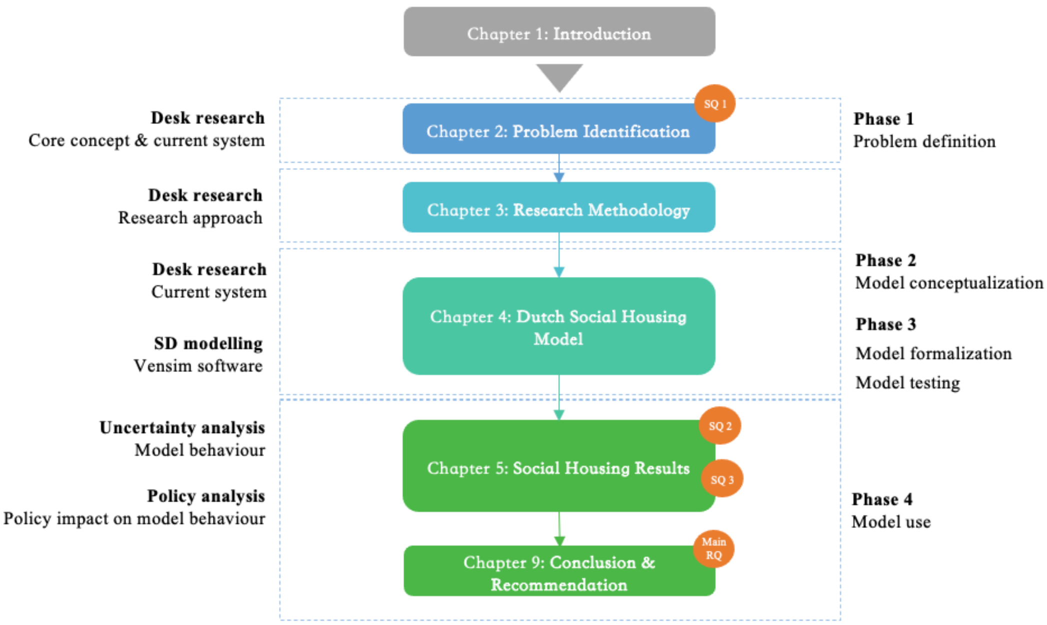

Figure 3.1: Research flow diagram of the Dutch social housing.

4

Dutch Social Housing Model

In this chapter, the developed SD model representing social housing in the Netherlands will be discussed. To begin with, this SD model will be described by means of the Model Conceptualization in section 4.1. Since this SD model is a general model that can be used in different parts of the Netherlands and/or even the Netherlands as a whole, in section 4.2 the urban region from which data has been used to quantify the model is described. Finally, the results of the various tests performed with the developed model are briefly presented in section 4.3, in order to check whether this model is fit for its purpose.

4.1. Model Conceptualization

This section of the report will explore the conceptualization model now that more knowledge has been collected about the Haaglanden social housing market. Model conceptualization is necessary to understand the complexity of the system being studied in order to convert it into the domain of system dynamics principles – including stock, flows and feedback loops (Randers, 1997). These insights have been attained through the years via a variety of techniques, such as the Stock-Flow Diagram (SFD), the Causal-Loop Diagram (CLD), and the Sub-System Diagram (SSD). Each of these methods for mapping the system's primary relationships has its own benefits and drawbacks. On the one hand, the main feedback mechanisms of the examined system can be described in depth using a CLD, but they appear obscurely or are completely unrecognizable due to the number of details in SFD. On the other hand, unlike the CLD, the SFD may pinpoint the critical accumulations (stocks) that characterize the system, the flows that affect them, and the influences on the flows (Lane, 2000; Martinez-Moyano & Richardson, 2013). Given these characteristics of the various diagrams and the fact that the CLD and the SFD complete each other's weaknesses, the system will be conceptualized in this study utilizing a combination of CLD and SFD (also known as a hybrid CLD-SFD). First of all, finding the model's objective is necessary to enable this. In essence, the purpose of this SD model is twofold:

1. *To comprehend the system of adequate social housing in the Netherlands.* Since no SD model has yet been used to map the adequacy of social housing in the Netherlands, a preliminary attempt will be made to map the system's influencing factors, their interactions, and the extent to which they have an impact on the system in the Netherlands using this model. In addition, this particular model's purpose is essential since, without the requisite knowledge of the system's dynamic complexity, no efficient policy strategy to increase the number of adequate social Housing can be developed.
2. *To find a policy strategy that would improve the underlying dynamics of the social housing market in relation to adequate housing in the Netherlands.* The reason for this is that there is a time constraint to reach an effective housing solution that will result in more adequate homes in the social market in the Netherlands, and ultimately in the Netherlands with the perceived insights; otherwise, the Netherlands' social housing shortage will only worsen due to the high household growth prediction of 10.5% in the upcoming years (Gopal et al., 2021).

In order to map the extent of the interactions within the system boundaries and identify solutions to limit the scarcity of social housing while maximizing the quality of provided housing, this dynamic system will be studied using three key performance indicators (KPIs), as shown in Table 4.1. Consult the hybrid CLD-SFD in Figure 4.1 to further understand how these KPIs relate to one another in the system under investigation. Based on this hybrid CLD-SFD, it can be observed how the following aspects of the social housing system are taken into account in the developed SD model: (1) housing demand based on the population of the Netherlands; (2) the development of the social housing stock, which depends on new construction, demolition, homes sold, along with ageing, degradation and maintenance of existing homes; and (3) financing of housing development in the social housing market of the Netherlands. As a result, three sub-models – the population sub-model, the housing market sub-model, and the financial sub-model – can be seen when the model's structure in Figure 4.1 is examined. The main structures of these sub-models and their underlying assumptions are described in the next portions of this section to help readers better comprehend the various characteristics of the three sub-models in this SD model.

Table 4.1: Overview of key performance indicators (KPIs).

KPI	Description
Solvency Ratio	Indicates the extent to which the financial ability of social housing providers will allow them to meet costs and achieve expansion and growth.
SGEI Houses Shortage *Non SGEI Houses Shortage*	Indicates the extent to which the supply of social housing does not satisfy the demand for housing by the citizens.
Average Condition Score of SGEI Houses *Average Condition Score of Non-SGEI Houses*	Describes the average quality development of the current social housing supply, with a lower condition score indicating greater quality.

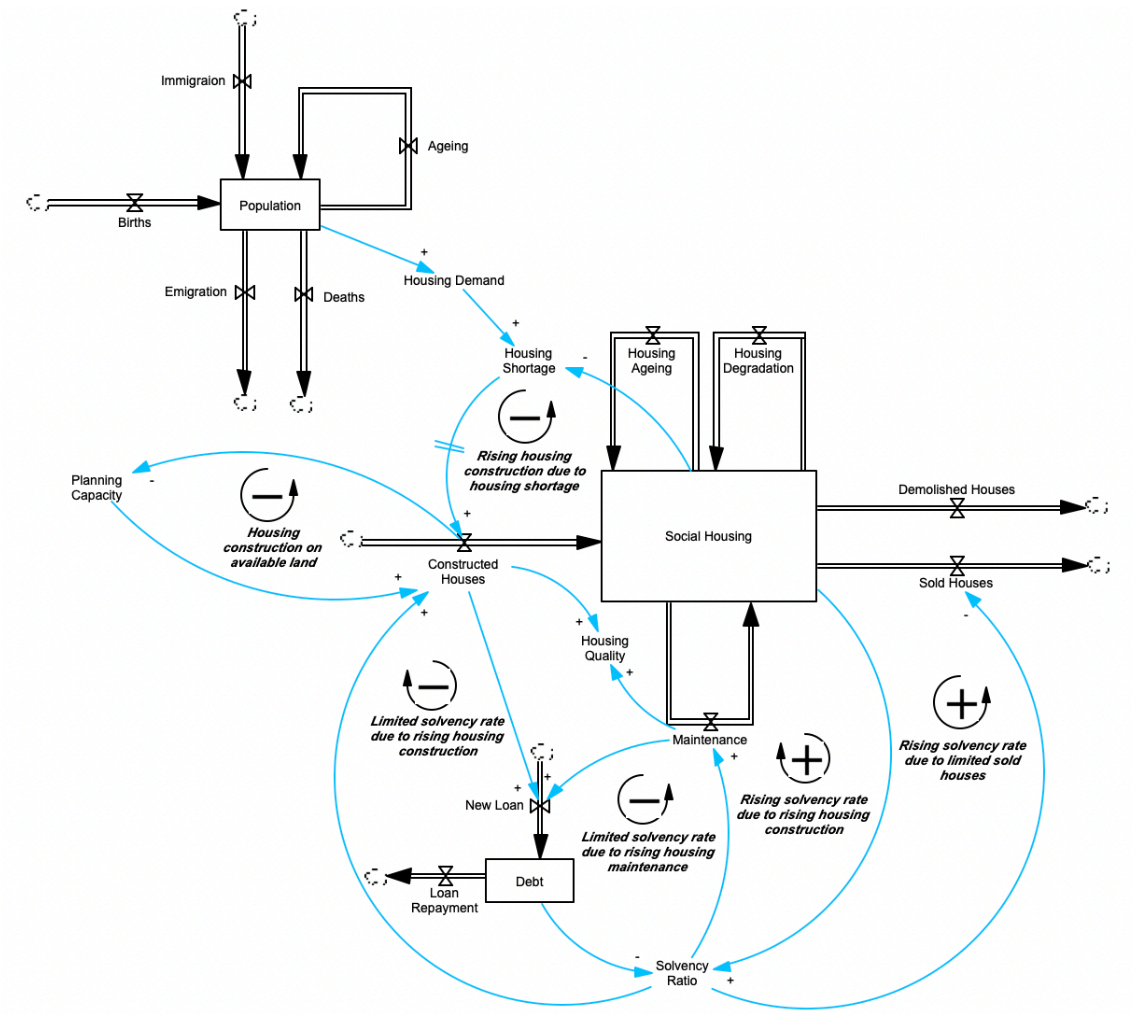

Figure 4.1: Hybrid CLD-SFD of the social housing model at a high aggregation level.

4.1.1. Developed Dutch Social Housing Model

To better understand the essential components of the three sub-models in this SD model, the main structures of these sub-models and their underlying assumptions are detailed below for each sub-model. Besides, the settings for the SD model are also listed in this section. For further information on the established model in this research, please refer to Appendix A.

Population Sub-model

In the population sub-model of this SD model, the household development over the years that takes place in the Netherlands is mapped. This is intended to ultimately determine the housing demand for the social housing sector in the Netherlands. In this research, the term housing demand is understood to mean the number of social houses that are needed to meet the housing needs of low- and middle-low-income households living in this region. As a result of the SGEI plan that was introduced in 2012, from that moment on, housing associations in the social sector must have 90% of the social stock of housing associations to be allocated to low-income households with an annual income of up to €34,000 per year at the time (which was raised to €45,014 per year in the meantime), and the remaining 10% to be allocated to those in urgent need of a home namely the middle-low income households (Elsinga & Lind, 2013; Van Gent & Hochstenbach, 2020; Rijksoverheid, 2022).

For this reason, the households in the Netherlands are divided by income, i.e. low-income, middle-low income and other income class, and only the households that are part of the low-income and the middle low-income class are used to identify the housing demand for social housing in the region in question (see Figure 4.4). Since the types of housing are different for each of these income classes, it has been decided to calculate the housing demand for low-income households separately from that for middle-low-income households. Moreover, it should also be noted that the social housing associations are not responsible for providing housing for the entire housing demand of middle-low-income households, which is in principle the task of the free housing sector. For this reason, the housing demand of middle-low-income households in this model only includes part of the total households that fall into this income category. This is determined by means of a fixed constant, namely ”Low Middle Household Share in Social Market”.

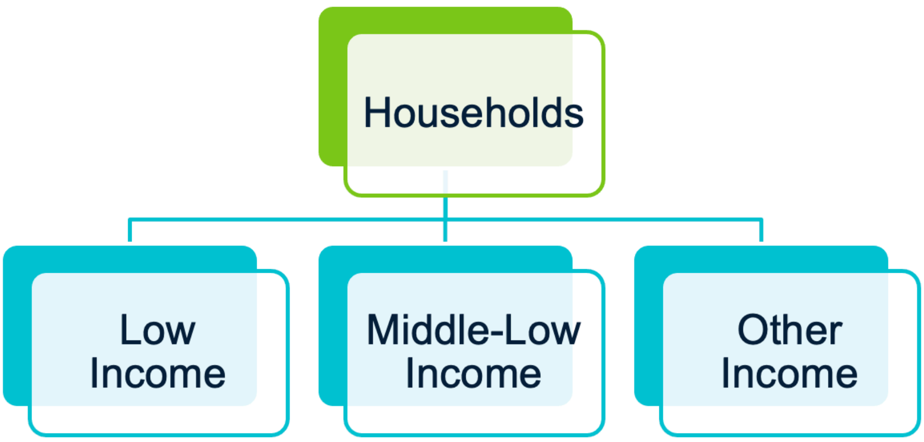

Figure 4.2: Representation of the households division in the Dutch Social Housing Model.

It can be established that the income class of the various residents in the Netherlands is not dependent on the age of the person. As a result, it can be observed that some young people in the Netherlands have a low income, but there are also young people who have a high income or are in between. However, it should be noted that a pattern can be seen throughout the Netherlands that mainly young adults and the elderly fall under low-income households. Therefore, it has been decided to divide the households between young adults, adults and the elderly. The number of households in each of these categories varies over time and does not remain constant. This is caused by various reasons, namely that a cohabiting couple separates and one of them moves to another residence or that children older than 18 leave their parents’ house to enter the housing market. Due to this household development, it was decided to identify the households by using an ageing chain of the population, in which the population is divided between children, young adults, adults, and the elderly (consult Table 4.3).

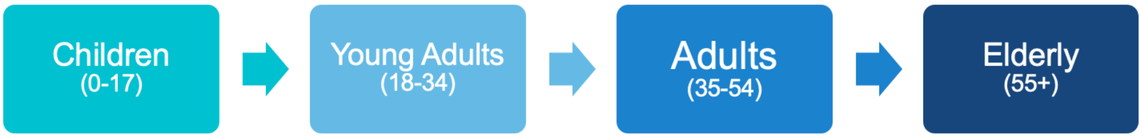

Figure 4.3: Representation of the population ageing chain in the Dutch Social Housing Model.

Based on this ageing chain, first children are born, then after 18 years, they move to the next population category, namely young adults, and so on until they become elders and reach the final category of elderly. In the meantime, each of these categories may also increase as different people of different ages immigrate to the Netherlands and decrease as the people living in this region may die or emigrate outside this region. Given that it is assumed in this research that every child in the Netherlands resides with their parents, all population categories except that of the children are used to determine the number of households in this model for each given time. To identify the total number of households that are in each of these population categories, the average household size, which differs per population category, was used. Subsequently, using the income distribution in the Netherlands, it was determined how many low- and middle-low-income households are located in each of these types of households. Ultimately, the total housing demand for each of these income classes is determined by summing the number of households with the same income class.

Housing Market Sub-model

In the population sub-model of this SD model, the housing development over the years that takes place in the Netherlands is mapped. Since the total housing development is addressed in this model so that it can easily be compared with the total housing demand in the Netherlands, the choice has been made in this model to combine the housing stock of the various housing associations that rent out social housing in the Netherlands together.

It should be noted that in the social housing sector there are different types of housing that can then be classified into different price classes. However, since in this study, we look at the homes intended for low-income households and households with a middle-low income, it has been decided to divide the homes into homes below the liberalization limit of €763.47 rent per month in 2022 and homes that exceed this threshold. In particular, dwellings below the liberalization threshold (hereinafter *SGEI Houses*) are intended for low-income households, and dwellings above the liberalization threshold (hereinafter *Non SGEI Houses*) are intended for medium-low income households. In this model, two aspects of these types of homes are monitored, namely their age and physical condition using the condition score. In this model the age of the houses is determined in intervals of 5, for example, there are houses that are younger than 5 years (namely new construction), houses that are between 5 and 10 years and so on up to the last category which depicts houses that are 80 years old and older. In this model, the age of the dwellings is used to indicate the differences in, among other things, the probability that the various dwellings are demolished. For example, older homes, in this model older than 70 years, are demolished more quickly than homes that are young. Even for the homes that are being sold, the age of the home plays a role.

It should be emphasized that a distinction has been made between the frequency in which SGEI Houses are sold compared to Non SGEI Houses. In this model, it is assumed that at SGEI Houses, the mature homes are the ones that are being sold, as they are old enough to repay their investment, but young enough to match the housing trend. Since the Non SGEI Houses are not the primary residence they are responsible for, they are more likely to sell homes that are not young any more than to invest in the maintenance of these homes. In addition, the condition score in this model was used to map the adequacy of the various built homes in this sector. The reason for this is that this is the most objective way that is used in the Netherlands to map the condition of a home. As explained before, the condition score is expressed on a 6-point scale, whereby the houses with the best conditions (namely the new construction) are indicated with a 1 and the houses with the worst condition, and therefore should be demolished, are indicated with a 6. In this model, it is assumed that it takes about 10 years to deteriorate the condition of the existing houses (in particular, the condition score of each house goes 1 point higher after about 10 years) if no maintenance takes place. Both of these two properties are represented in this model using subscripts, where ”AgeGroups” indicates the age categories and ”ConditionScore” the condition categories.

In addition to the developments in the various properties of the different homes, this sub-model also maps out the various processes that influence the amount of the housing stock itself. This includes the construction of new homes along with the maintenance, demolition and sale of existing homes (see Figure 4.1). First of all, before a new home can be built, it must first be planned. Since there are several delay steps between the planning and delivery of a built housing, the new construction delivered in this model is specified as a third order delay of the housing being planned. In this model, only homes for which there is enough planning capacity are available. This means that if the housing shortage exceeds the planning capacity of a specific housing, only the amount of housing for which capacity has been reserved will be built. Since the planning does not immediately respond to the housing shortage, but there is a delay in between, the planned housing in this model is specified as a first order delay of the minimum between the housing shortage and the planned capacity. In principle, the housing shortage is the difference between housing demand and housing supply. In the event that there is more housing supply than demand, the value of the housing shortage will be negative, indicating a housing surplus. The manner in which housing demand is defined in this model has already been shown in the population sub-model. The housing supply, on the other hand, is defined in this sub-model as the sum of the built homes and homes under construction for a specific type of home.

As a result, the housing supply for the SGEI Houses and the Non SGEI Houses is determined separately, so that a distinction can be made between the housing shortage for the social housing market and the market for middle-low-income households (see Figure 4.4). For many years now, the Dutch government has had a say in the planning capacity of new construction in the housing market. In particular, this property of the system has been mapped by modelling the distribution of housing in the different housing sectors. In particular, the stakeholders of the housing market nowadays have to ensure that 30% of every construction project must end up in the social housing sector. In this model, this dynamic is mapped out by a fixed percentage of the total capacity that becomes available for new construction. This then forms one of the inflows of the stock that maps out how much capacity is available for the homes in the social sector. This capacity can then increase when houses are demolished, as it is assumed in this model that all the land that is freed from the demolished houses is used to build new houses. Furthermore, this capacity decreases when new social housing is planned to eventually be built in a particular location.

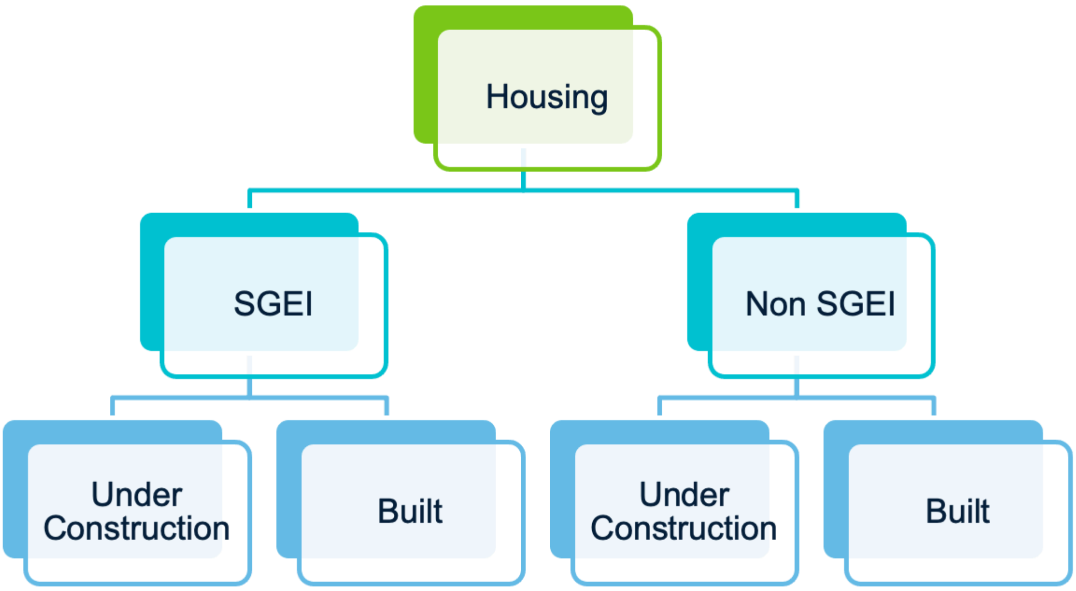

Figure 4.4: Representation of the housing division in the Dutch Social Housing Model.

Of the various processes that have been mentioned, the maintenance procedure together with the demolition and sale procedure as mentioned earlier depends on the properties of the homes. In this model, a distinction is made between minor and major maintenance (consult Figure 4.1). In this case, minor maintenance means, among other things, the outside painting, repairing the window frames and cleaning the gutters. On the other hand, major maintenance includes, among other things, the addition of extra insulation materials or the installation of a central heating system, together with changing the pipelines or the exterior of the houses. In this model, all homes with a condition score higher than 2 can undergo minor maintenance regardless of age. The reason for this is that it was assumed in this study that no matter how much maintenance goes into a home, it will never turn out as well as a new build as these homes have been used and have aged over time. In case of minor maintenance, the condition score will decrease by 1 point scale in this model. So if there is a house with a condition score of 3, it will have a condition score of 2 after a little maintenance. Moreover, only houses in relatively bad condition, namely a condition score of 4 or higher, can do major maintenance regardless of age. And unlike minor maintenance, in which the homes gradually improve, for major maintenance, a distribution has been used in which most homes that have undergone major maintenance end up with a condition score of 2.

The other homes are divided between the condition scores 3 and 4, with very few homes ending up in this last condition score. This has been done to indicate that even if major maintenance has taken place, certain homes, in this case, a fairly small portion of the houses that undergo maintenance, may not end up in a good condition making the distribution more realistic. In particular, only houses that are older than 70 years and have a condition score of 6 are demolished in this model. In addition to the differences in age between SGEI and Non SGEI Houses mentioned earlier, the houses must also be in good enough condition (namely a condition score lower than 6) in order to be sold to third parties. Furthermore, the interaction between the housing stock of the SGEI Houses and the Non SGEI Houses is also indicated using the liberalization procedure. In this procedure, the rent of the SGEI Houses is increased to such an extent that it exceeds the liberalization limit, whereby these houses become part of the Non SGEI houses. This is indicated in this model by removing these houses from the housing stock of the SGEI Houses and then putting them in the housing stock of the Non SGEI Houses using the ”Liberalized SGEI Houses” flow. In this model, it is assumed that only homes in a good condition, i.e. homes with a condition score lower than 4, can be liberalized.

Ultimately, it should be noted that solvency exerts a great deal of influence on the construction of new homes, together with the maintenance and sale of existing homes (see Figure 4.1). In the Netherlands, it has been found that there is a positive relationship between the solvency ratio of a housing corporation and new construction together with the maintenance of existing homes, while there is a negative relationship between the solvency ratio and the homes sold. Since the solvency ratio indicates the extent to which the financial ability of social housing providers will allow them to meet costs and achieve expansion and growth, an increase in the solvency of the housing corporation will ensure that they have more money to invest in new construction and maintenance, thereby promoting these two processes. On the other hand, if there is an increase in solvency, there will be a decline in the number of homes sold. The reason for this is that at that time there is no need to liquidate the homes since the corporation is doing well financially. Only when there is a decline in solvency and money is needed to ensure that housing associations will meet costs and achieve expansion and growth, will the sale of homes be promoted. In this model, much like in reality, different thresholds are used for the different types of homes. Principally, the SGEI Houses must exceed the 15% threshold to exert a positive/negative effect on new construction, maintenance and sold homes, while for the Non SGEI Houses a threshold of 40% must be exceeded (Van Nieuwamerongen & Van Kalsbeek, 2020).

Financial Sub-model

In the financial sub-model, the cash flow of housing associations in the Netherlands is mapped out (consult Figure 4.5). The reason for this is to map out the financial state of the housing associations while they invest in the housing stock by means of new construction and maintenance or they remove homes from the housing stock by means of demolition and sale. In order to map this out, the solvency ratio was mainly used. To find out the solvency ratio of the housing associations in this model, the use was made of the total capital and the loan capital. In general, the solvency ratio can be determined by dividing the shareholders' equity by the total capital of the organization. Since equity is the difference between the total capital and the debt, in this model the solvency is determined by dividing the difference between the total capital and the debt (equity) by the total capital. In this model, the total capital is determined by multiplying the number of houses built (SGEI Houses together with Non SGEI Houses) by the average WOZ value of social housing. The reason for this is that for a simplification of the system in this study it is assumed that the average market value of a home is the same as the average WOZ value per social house.

Moreover, in this model total debt is specified as an accumulation of all loans that the social housing associations have not yet repaid. Every time new homes are built and/or existing homes are maintained, new loans are connected. This is because this model assumes that all new construction and maintenance are financed by taking out new loans. Subsequently, new loans are also taken out if the housing corporation is in the red, namely if its expenses exceed its income. In this model, the sum of housing income (which is the sum of the rental income together with the income generated by the sale of homes), subsidy and new loans at a certain point in time are regarded as the income of the housing associations. While the expenses consist of housing expenses (which is the sum of the management costs together with the construction costs), taxes, interest payments, and loan payments. In particular, the loans are only repaid if the housing association had made a profit, namely if the income exceeds the expenditure.

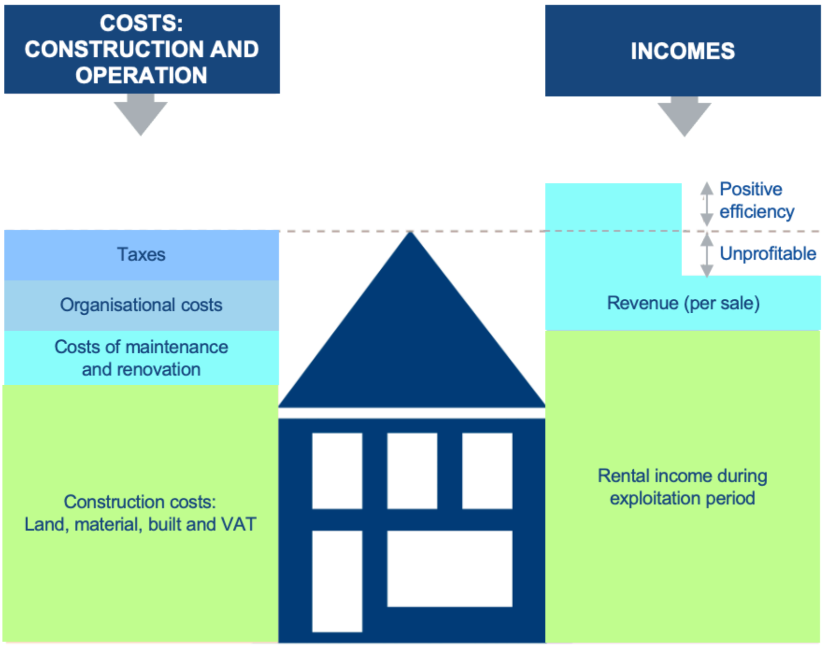

Figure 4.5: Representation of the social housing corporations' income and expenditure in the Dutch Social Housing Model.

Model Settings
The SD model developed in this study covers the time period from 2012 to 2050. Since 2050 is regularly cited as a reference point in the most popular projections utilized by Dutch governments about the Dutch social housing industry, 2050 has been chosen as the end time of the model. In order to ensure that the findings have a solid historical foundation, which necessitates an initial time of 10 years prior to the research's conduct, the year 2012 was selected. Additionally, the year 2012 was chosen because the majority of the historical data used to develop this model can be obtained up to and including the year 2012. Furthermore, the unit of time was set to a year because it allows for accurate modelling of the many processes that can affect the condition of social housing, including new construction development, deconstruction, maintenance, ageing, and degradation, which typically take months or even years to complete. Subsequently, 0.0078125 was chosen as the time step of this SD model. Because larger time steps resulted in significant changes in behaviour, which means that they were insufficiently tiny to accurately depict the system's behaviour over time. Since the model incorporates discrete functions, such as WITH LOOKUP, and IF THEN ELSE functions, the Euler integration approach is used. Ultimately, this SD model was implemented in the SD modelling software Vensim DSS version 9.2.4, because of the built-in functionalities that this software has to perform analyses, execute model testing and connect the model with external packages – including the EMA Workbench – to enable more advance analysis.

4.1.2. Assumptions
Several assumptions are established when developing the model in order to effectively represent the real system in the SD model. To verify the justifications for the judgments made, it is necessary to store the assumptions formed. The following assumptions were made for this project:

1. Assumptions regarding the population sub-model:
   (a) Every child born in this model resides with their parents.
   (b) The total households in this model are determined by taking the sum of the entire population excluding the children.
   (c) The number of households in this model increases due to immigration and children who are old enough to participate in the housing market (18+).
   (d) The number of households in this model decreases due to emigration from the region studied and mortality.
2. Assumptions regarding the housing market sub-model:
   (a) New construction can only take place in the event of a housing shortage.
   (b) With time, newly constructed homes age and their condition deteriorate.
   (c) Only "SGEI Houses" in a good condition (i.e. a condition score lower than 4) are eligible for liberalization.
   (d) Only constructed homes may be sold to outside buyers.
   (e) Only mature "SGEI Houses" can be sold to outside buyers
   (f) Non-SGEI houses are easier to sell than SGEI houses.
   (g) All the land that is freed from the demolished houses is used to build new houses.
   (h) "SGEI Houses" are where every low-income household resides.
   (i) Only a small percentage of low- and middle-income households reside in "Non SGEI Houses".
   (j) The plan capacity per year remains constant during the model run.
   (k) Only constructed homes with a condition score greater than 2 (3, 4, 5 and 6) are eligible for minimal maintenance.
   (l) Only constructed homes with a condition score higher than 3 (4, 5 and 6) are eligible for major maintenance.
   (m) Only constructed homes with a condition score of 6, which indicate wear and tear, are eligible for demolition.
   (n) No matter how much maintenance goes into a home, it will never turn out as well as a new build as these homes have been used and have aged over time.
   (o) It takes about 10 years to deteriorate the condition of the existing houses (i.e., the condition score of each house goes 1 point higher).
3. Assumptions regarding the financial sub-model:
   (a) All new construction and maintenance are financed by taking out new loans.
   (b) Solvency affects new construction, maintenance homes, owner-occupied homes and the rise in rents.
   (c) Loans are only reimbursed if a profit has been achieved (i.e., when income exceeds expenditure).
   (d) In the event that a loss is incurred (income is less than expenses), additional loans are taken out to cover the loss.
   (e) In this research, taxes include the company tax, landlord levy, and other levies.
   (f) The average market value of a home is the same as the average WOZ value per home.
   (g) Other levy is a fixed percentage of the balance, namely 5%.
   (h) Management and maintenance costs are a fixed percentage of the rent, namely 11%.
   (i) In this research, construction costs include demolition and foundation expenditures.
   (j) A predetermined percentage of the average construction costs is used to calculate the average maintenance costs, namely 40% for minor maintenance and 80% for major maintenance.

4.1.3. Included Policy

This section will look at the policies that have been included in this research since the purpose of this SD model is, among other things, to identify policies that will enhance the system behaviour of the social housing market in the Netherlands. The Dutch government has, as was previously described, implemented a variety of regulations to regulate this social housing market since the first Housing Act was passed in 1901 (R. De Jong, 2013). The government's most important social housing regulations from the previous century are compiled in Table 2.6 of section Policy. Only the policies *Rent Regulation*, *Grand and Guarantees*, *Spatial Planning Policy*, and *Landlord Levy* of the ones listed in Table 2.6 will be examined given the scope of this study.

This is due to the fact that the policies *Rent Regulation*, *Grand and Guarantees*, and *Landlord Levy* all influence the cash flow of social housing associations, with *Landlord Levy* having an effect on expenditures while the other two policies affect how much money the associations have in income. Furthermore, *Spatial Planning Policy* guarantees the amount of land at the disposal of housing associations for the construction of new social housing and the exploitation of their existing housing. Table 4.2 provides a summary of the policies examined in this study.

Table 4.2: Overview of the key policies that are analyzed in this study (a subset of Table 2.6).

Policies	Explanation
Rent Regulation	The policymakers use this method in order to ensure that the maximum reasonable rent for rental houses in the regulated market sector is established and the maximum yearly rent rise for these residences is also established (CPB, 2010).
Grants and Guarantees	Up until the middle of the 1990s, the government gave housing associations financial aid to build social housing. Since the federal government and local governments serve as their guarantors, the government currently provides housing associations with financial resources, such as the opportunity to borrow money at comparatively low-interest rates (CPB, 2010).
Spatial Planning Policy	The policymakers specify systematically how space is used and set up via the spatial planning policy. The availability of land for housing is determined by this policy, which has a big effect on property prices that influence the rent (CPB, 2010). This applies to zoning plans, in which the municipal council decides, among other things, the use and building possibilities for social rental housing (VROM, 2006).
Landlord Levy	Landlords of social housing, including housing associations, must pay a tax on the market value of their social housing under the landlord levy, which was instituted in 2013 with the goal of balancing the state's budget (Woonbond, 2017). The aforementioned tax ensures the current housing associations' financial difficulties (Aedes, 2020).

4.2. Model Quantification

As noted in the previous sections, the severity of the social housing problem varies by country, hence the focus of this study is on the EU country of the Netherlands (Gibb, 2002; Scanlon et al., 2015; Rosenfeld, 2015; OECD, 2020). Because recently the Autoriteit woningcorporaties (Aw, 2020) pointed out that the severity of the issue for social housing associations varies per municipality in the Netherlands, and the new Housing Act (2022) offers local governments more legislation flexibility, the Haaglanden urban region will be used to quantify the developed SD model in this study (Aw, 2020; BZK, 2021c). The reason being that the housing associations in the Haaglanden region experience the worst possible financial condition (Aw, 2020). In spite of having one of the lowest financial opportunities for further home investment, Haaglanden provides more dwellings to households receiving housing benefits than the majority of other Dutch regions (Aw, 2020). Furthermore, based on the 2021 Primos estimate, it is predicted that sections of this region will see the most population growth (16%), and hence the highest household formation (16%), until 2035 (Gopal et al., 2021). As a result, it can be concluded that the potential policy strategies identified in this study to improve the housing problems in the Haaglanden region are likely to be effective in the other regions in the Netherlands as well.

Table 4.3: Characteristics of the municipalities in the Haaglanden region (CBS, 2022).

Municipality	**Total Population** [Inhabitants]	**Household Size** [Inhabitants/Household]	**Total Housing Stock** [Houses]	**Rental Properties** [%]
Delft	104,572	1,8	52,130	62,3
's-Gravenhage	553,417	2,641	267,654	58,0
Leischendam-Voorburg	76,659	2,08	37,202	42,2
Midden-Delfland	19,484	2,4	8,052	26,4
Pijnacker-Nootdorp	56,572	2,57	22,203	28,5
Rijswijk	56,941	2,02	27,899	50,8
Wassenaar	27,115	2,22	12,262	43,0
Westland	112,448	2,37	46,369	31,3
Zoetermeer	125,767	2,2	56,668	45,1

The Haaglanden this urban region encompasses nine different municipalities: Den Haag, Delft, Pijnacker/ Nootdorp, Rijswijk, Voorburg/Leidschendam, Westland, and Zoetermeer (Schepers et al., 2021; Wikipedia, 2022). The properties of these municipalities differ from one another, as seen in Table 4.3. As an illustration, it can be observed that among the municipalities in this region, The Hague and Zoetermeer have the biggest populations and housing stock, whilst Delft has the largest rental sector. It should be noted that despite these differences no distinction has been made between the various municipalities that make up the Haaglanden urban region in the Dutch Social Housing Model. The reason for this is that multiple municipalities in the Netherlands, including the Haaglanden municipalities, have been forming a joint housing market region for years, whereby tenants for social housing can go anywhere in this region through the regional platform that connects the housing associations with the tenants called Woonnet Haaglanden (Gemeente Den Haag, 2017). Please consult Appendix A if more detailed information on how the various elements used in this research's model were quantified is needed.

4.3. Model Testing

This section of the report will critically assess whether the model developed in this study is appropriate for its intended use. According to Senge & Forrester (1980), the usefulness of a model is determined by how well it serves its intended purpose, which does not necessarily imply a high degree of similarity to the real world given that there is no method to demonstrate a model's correctness to depict reality. In this study, the modelling objective is to construct a representation of the Dutch social housing market so that policies that can have an impact on this system can be investigated. By putting the SD model through a number of validation tests, this section seeks to assess the SD model's fitness for its purpose. First of all, in order to assess the SD model's applicability in light of its structure, a boundary adequacy test was performed. In order to determine whether the SD model was correctly implemented in the Vensim software, the model's dimensional consistency, integration error, time step, and simulation length were subsequently mapped. Finally, the extreme condition test and sensitivity analysis were executed with the developed SD model in order to assess the model's behaviour. For a detailed description of each validation test carried out during this investigation, please refer to Appendix B.

Regarding the boundary adequacy test, it can be concluded that the level of aggregation used in the developed SD model is adequate for its purpose. Despite the fact that the merger of the housing associations and the various municipalities that make up the Haaglanden region has ensured that fundamental distinctions between these entities and their mutual interaction are not included in this model, this aggregation level has ensured that the social housing stock and demand in Haaglanden as a whole is calculated by the model which is what is required for developing housing policy. In addition, multiple studies on the subject have shown that there is only a slight difference between models that include these types of interactions within a region compared to those that leave these interactions out (Sanders & Sanders, 2004; Uchino et al., 2005; Eskinasi, 2014).

When examining the model's structure, three sub-models can be identified, namely the population sub-model, the housing market sub-model and the financial sub-model. Since the structure of this model also includes the dynamic interactions within and between the different sub-models, it can be observed that this model contains dynamic complexities of the actual social housing. Since the housing supply of this model has no endogenous impact on the population moving to the Haaglanden region, but migration to the region is rather determined by a constant, this test has revealed that important feedback loops between housing supply and demand are absent in this model. Chapter 5 takes the uncertainties associated with this limitation into account by performing an uncertainty and robustness analysis where this constant is varied.

To ensure that the model's parameters didn't have any conflicting dimensions, the dimensional consistency test was utilized. Fortunately, the Vensim simulation software has a built-in ”unit check” function. As a result, several unit tests were actively carried out during the model's development to make sure that the equations accurately reflected real-world notions. No unit errors were discovered once the test was completed, indicating that the dimensions of the model parameters are properly implemented in Vensim. Given that the model being employed is made up of a lot of discrete events, such as the ”Liberalized SGEI Houses”, which uses an IF THEN ELSE function together with a PULSE TRAIN function (see description in Appendix A), it was decided to use Euler as the integration method with a relatively small time step (0.0078125) to increase the model's accuracy. Given that the model behaviour does not significantly change for time step 0.0078125 or smaller, it can be concluded that this particular time step is suitable for the model in question. Ultimately, it can be concluded that the simulation period 2012-2050 generally provides an accurate portrayal of the system behaviour over time, since the model behaviour remains approximately the same as the simulation length is extended.

As previously mentioned, the extreme condition test was performed together with the sensitivity analysis to evaluate the model's behaviour. In particular, the extreme condition test was used to evaluate the behaviour of the model when the input parameters, regarding housing demand and supply, are set to extreme values. An extremely low and extremely high value was used to vary each of these characteristics. Last but not least, it was seen that the KPIs behaved as predicted under extreme conditions, indicating that there are currently no conditions that can overcome these two model properties.

Subsequently, using the sensitivity analysis areas of the model where the behaviour is more sensitive to inputs were identified. To begin with, this analysis made it evident that all KPIs are behaviorally and numerically sensitive to the constant Low Middle Household Share in Social Market which influences the housing demand of Non SGEI Houses. It should be noted that the Non SGEI Houses Shortage and Average Condition Score of Non SGEI Houses had the least behavioural change of these various KPIs, as the bandwidth of these KPIs is the narrowest. Despite this being the case, this analysis demonstrated that this constant will have the most impact on these KPIs because this constant controls the demand for Non SGEI homes in this model.

Additionally, all KPIs are numerically sensitive to the constants Average Shortage Reaction Time, Average Construction Time, Information Delay, Average WOZ Value Alteration Percentage, and Examination Time of Total House Shortage, while only the Solvency Ratio is numerically sensitive to constants Major Maintenance Cost Part and Minor Maintenance Cost Part. The latter is significant because it is based on this that maintenance costs are calculated, which in turn establishes how much money must be borrowed in foreign capital. Since the Solvency Ratio is calculated as the quotient of equity and total equity (the sum of equity and foreign capital), a rise in foreign equity will result in a decrease in the Solvency Ratio. Given that changes in the Solvency Ratio will have an indirect effect on the other KPIs and this was not the case, it can be assumed that the influence of this constant on the Solvency Ratio was limited.

Chapter 5 takes these behaviour and numerical sensitivities into account by varying these constants within realistic boundaries consisting of a wider bandwidth than the ±10% used in the sensitivity analysis during the execution of the uncertainty and robustness analysis. This makes it easier to map the uncertainties related to the model parameters for which the behaviour is more susceptible and understand their impact on the researched policies.

Lastly, based on the result of the various validation tests performed in this study it can be argued that the Dutch Social Housing Model has the right setup, structures, and behaviours to assess how the Dutch social housing system might develop over conceivable futures, given policy interventions. However, the model's function is restricted to qualitative rather than quantitative analysis; it can identify the kind of behaviours that policies cause and, in particular, the effects that uncertainties have on those behaviours, but it is unable to shed light on specific values. The reason for this is that the sensitivity analysis performed has revealed that the KPIs in the current model are numerically sensitive to many of the constants that are based on the researcher's educated assumptions.

5 Model Outcomes

In this part of the report, several analyses will be performed using the SD model introduced in the previous chapter (Developed Dutch Social Housing Model). First of all, the insights of the Base Case are presented in section 5.1, to ensure that the findings and insights derived from the analyses performed in this study can be better understood. To gain a better insight into the execution and purpose of these analyses, the Experimental Design in section 5.2 gives a summary of the conducted analyses in this research. Subsequently, the results of the uncertainty analysis and the policy analysis are presented in section 5.3 and 5.4, respectively.

5.1. Base Case

In this part of the results, the baseline scenario is explained by interpreting the behaviour of the KPIs when the model is simulated without interventions. These insights are necessary so that the effect of the interventions and/or tests can be better identified and analysed. The results of the base case can be seen in Figures 5.1 - 5.5.

Based on the behaviour of the KPIs during the base case, the current problems in the social housing market can be observed. First of all, Figures 5.1 and 5.2 show that up to and including 2050 there will be a housing shortage in the social housing market and the housing market for middle-low-income households. In general, the base case shows that the shortage of SGEI Houses will remain at around 60,000 houses from now until 2050, while the shortage of Non SGEI Houses will continue to increase until it exceeds 20,000 homes. This behaviour can be explained by the difficult financial situation of the social housing associations, which is expressed in the solvency ratio in this study.

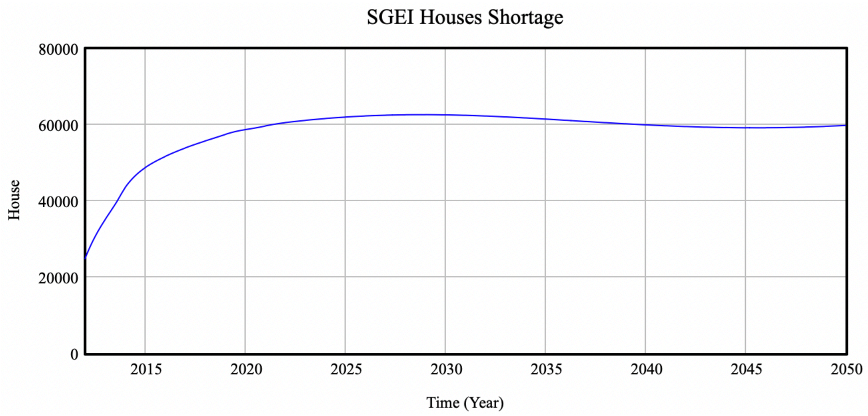

Figure 5.1: SGEI Houses shortage in Haaglanden.

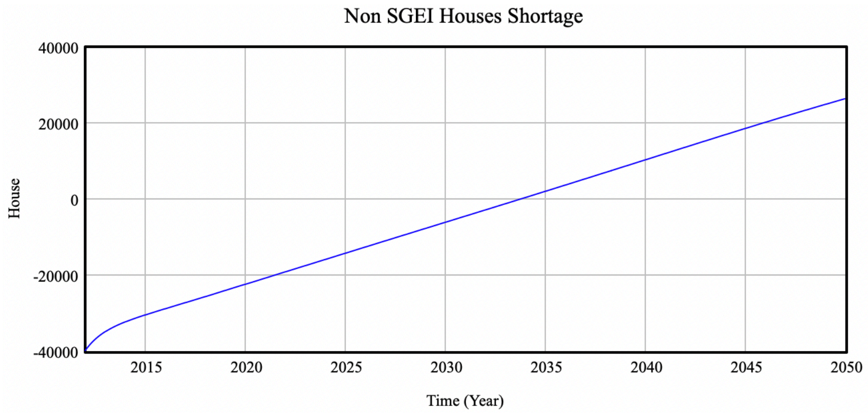

Figure 5.2: Non SGEI Houses shortage in Haaglanden.

In the Netherlands, it has been found that a solvency ratio above 15% is required to be able to build SGEI Houses, while this threshold is 40% for the Non SGEI Houses. By means of Figure 5.5 it can be seen that the solvency ratio increased from about 25% in the year 2022 to just over 30% in 2050. The reason for this is that the equity capital of the social housing associations is increasing faster than the debt capital. Due to the fact that properties become more expensive when demand is high and supply is limited, the value of social housing in this model and hence the equity is expected to increase in conjunction with the growing housing shortage of Non SGEI dwellings. In the coming years, it is anticipated that the social housing associations' expenditures, which are financed by taking out new loans, and thus the debt capital, will generally remain constant because they will only invest in the construction of a fixed number of SGEI homes due to its shortage remaining at around 60,000 homes after 2022. Additionally, beyond the year 2022, construction expenses in this model remain unchanged.

Since the solvency ratio is above 15%, all possible SGEI Houses for which enough land is available will be built. Since the housing supply of SGEI Houses is increasing at about the same rate as the housing demand, the shortage of SGEI Houses will reach a balance of around 60,000 homes. On the other hand, no new Non SGEI Houses are being built, as the housing associations do not have enough financial resources (the solvency ratio is lower than 40%) to be able to invest in these types of houses. Since the housing demand continues to increase, due to population growth, and the fact that the housing supply of Non SGEI Houses remains the same as no new Non SGEI Houses are built, the SGEI Houses shortage will continue to increase until 2050.

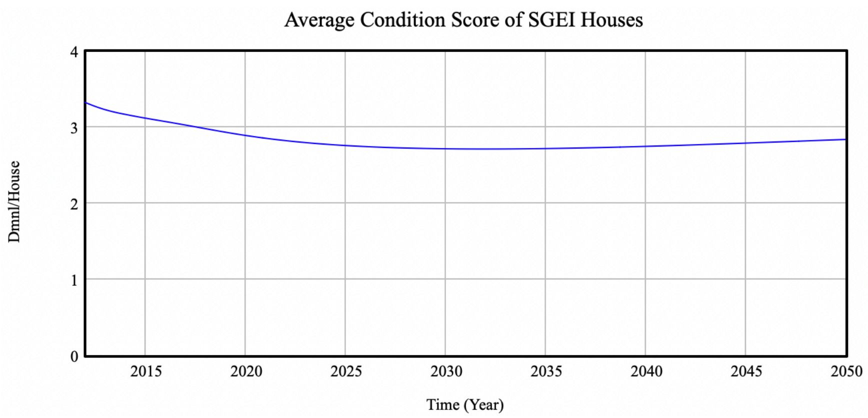

Figure 5.3: Average condition score of SGEI Houses in Haaglanden.

In addition, the financial resources of the housing associations also influence the maintenance of the SGEI and Non SGEI Homes, which is reflected in the behaviour of the average condition score of these homes in this study. In particular, the maintenance of the houses lowers the average condition score, as the conditions of the houses are improved through this procedure. As a result, investing in more maintenance of homes will lead to lower condition scores, as can be seen in Figure 5.3. If the initial value of the average condition score is compared with the value in the year 2050, a decrease in the average condition score of approximately 0.5 can be observed.

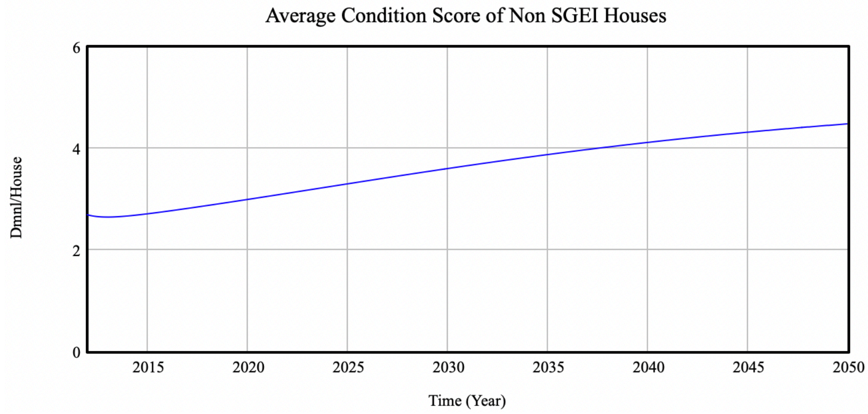

Figure 5.4: Average condition score of Non SGEI Houses in Haaglanden.

By means of these figures, it can be seen that there are enough financial resources up to and including the year 2050 to invest in the maintenance of SGEI Houses and not in Non SGEI Houses (since Figure 5.4 shows that the average condition score only increases during the model run). The reason for this is that the solvency ratio has exceeded the threshold of the SGEI Houses (15%) and not that of the Non SGEI Houses (40%), as a result of which these housing associations only have sufficient financial resources to invest in the SGEI Houses.

Besides this direct influence that the solvency ratio exerts on the condition of the homes, there is also an indirect influence via the new-build development. Since new-build homes have a condition score of 1 as they have just been built and are therefore in the best condition that the homes can contain, more new construction will lead to a lowering of the average condition score of the homes. For this reason, the direct influence that the solvency ratio exerts on the average condition score of the homes should be reinforced by the indirect influence that it exerts via the new construction. Based on Figures 5.1 and 5.3 it can be clearly seen this phenomenon occurs to a limited extent in the average condition scores of SGEI Houses. As a result, the ratio of homes with a condition score of 1 and the other scores remains limited in this housing market, even after the production of new homes. This is mainly seen from the 2040s onwards, as a relative decrease in the housing shortage of the SGEI Houses of a few hundred houses did not lead to a further decrease in the average condition score of these houses but an increase.

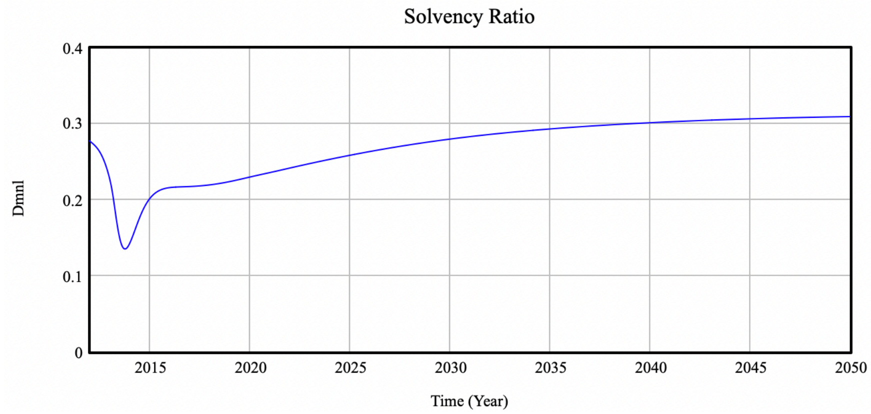

Figure 5.5: Solvency Ratio of the social housing providers in Haaglanden.

Moreover, around the year 2013, a very strong decrease in the solvency ratio of the housing associations can be seen in Figure 5.5. This behaviour can largely be explained by the fact that the housing demand grew faster compared to the housing supply in these times due to the sharp increase in construction costs after the global crisis in 2008, which led to a significant increase in the housing shortage while plummeting the WOZ value of the homes causing the value of the homes to reduce (Elsinga et al., 2016). In addition, the introduction of the landlord Levy, who became active in 2013, has also ensured that the housing associations had fewer financial resources to invest in new dwellings and/or maintenance of existing homes.

5.2. Experimental Design

The experiments that have been carried out using the Dutch Social Housing Model are outlined in this section of the chapter. Several experiments have been implemented in this study to gain insight into the system of adequate social housing together with the effect of policy interventions by examining the behaviour of the KPIs. These insights were attained in this study, through the application of an uncertainty and policy analysis. It was decided to conduct these analyses using a combination of Vensim software and the Exploratory Modeling Workbench (EMA Workbench). The EMA Workbench is an open-source Python library that enables users to quickly perform exploratory modelling with existing SD models and, among other things, identifies the relevant uncertainties and assess the efficacy of policy options, both of which are necessary for carrying out the various experiments in this study (Kwakkel, 2017).

To begin with, in order to map the effect of the uncertain parameters in the model on the behaviour of the KPIs, an uncertainty analysis was implemented in this study. In particular, the parameters that are based on educated assumptions made by the researcher due to lack of data are varied in this analysis. An overview of the 24 uncertain parameters that were used in this study, together with their range, can be found in Table 5.1. In view of the complexity, dynamic properties and uncertainties that the studied system of Dutch social housing entails, the outcome of a single model run alone must never be trusted. The reason for this is that any single run could be an unrepresentative outlier, due to the combination of input values used in the model. As a result, 4800 scenarios were conducted in the uncertainty analysis of this study in order to ensure that each uncertain parameter had at least 200 alternative values. Moreover, this analysis was used to identify the most influential uncertain parameters on the KPIs. By doing so, one can obtain a deeper understanding of the interactions that occur between the many different factors in the model, and ultimately, the social housing system investigated in this study.

Table 5.1: Overview of Uncertain Parameters varied in the different analyses.

Sub-model	Parameter	Unit	Base Value	Range	
				Min. Value	Max. Value
Population	Average Birth Percentage	$Dmnl/Year$	0.0101	0.0097	0.0105
	Average Immigration Percentage	$Dmnl/Year$	0.0126	0.0095	0.0156
	Average Emigration Percentage	$Dmnl/Year$	0.0088	0.0082	0.0093
	Average Death Percentage	$Dmnl/Year$	0.0089	0.0083	0.0098
	Low Middle Income Percentage	$Dmnl$	0.391	0.3	0.482
	Low Middle Household Share in Social Market	$Dmnl$	0.4	0.3	0.4
Social Housing	Average Shortage Reaction Time	$Year$	0.75	0.5	1
	Average Construction Time	$Year$	3	2	4
	Major Maintenance Delay	$Year$	1.5	1	2
	Liberalisation Interval	$Year$	1	0.8	1.2
	Focus Percentage on New Construction	$Dmnl$	0.7	0.6	0.8
	Focus Percentage on Major Maintenance	$Dmnl$	0.3	0.2	0.5
Economic	Information Delay	$Year$	0.85	0.77	0.9
	Vacancy Rate	$Dmnl$	0.04	0.02	0.06
	Average WOZ Value Alteration Percentage	$Dmnl$	0.08085	0.07	0.1
	Examination Time of Total House Shortage	$Year$	0.0808	0.07	0.1
	Average Social House Size	$m^2/House$	84	68	100
	Average Demolition Costs	$Euro/m^2$	50	30	70
	Average Foundation Costs of SGEI Houses	$Euro/House$	200,300	200,300	203,400
	Average Foundation Costs of Non SGEI Houses	$Euro/House$	215,600	215,600	241,700
	Major Maintenance Cost Part	$Dmnl$	0.8	0.6	1
	Average Construction Costs Assumption	$Euro/m^2$	300	236	321
	Minor Maintenance Cost Part	$Dmnl$	0.4	0.2	0.6
	Tax Rate	$Dmnl/Year$	0.05	0.03	0.07

In order to map the behaviour of the KPIs during policy interventions, a policy analysis was subsequently undertaken in this study. Given the scope of this research, only the policies presented in Table 5.2 – Increase Average Rent, More Subsidy for Social Housing, More Planning Capacity for Social Housing, Lower Interest Rate, and Eliminate Landlord Levy – that represent the government's most significant social housing regulations were evaluated in this analysis. For the rationale behind these policies, consult section Included Policy. In order to ensure that the investigated policies vary from the base case where the relative effects of each policy on the study's KPIs can be mapped, the specification of these policies in the model is based on the researcher's educated assumptions.

In order to gain sufficient insight into the efficacy of the multiple policies examined in this study, it was decided to map out the individual effects of each investigated policy in the individual policy analysis as well as how these policies interact with one another in the multi-policy analysis. In particular, the three most effective policies identified by the individual policy analysis were employed in the multi-policy analysis to gain a better understanding of the interactions between the studied policies. The Vensim software was used to perform these analyses.

Furthermore, it was decided to test the robustness of the policies presented in Table 5.2. In this study, this was accomplished by mapping the effects of these policies under uncertainty using the EMA Workbench. Due to time constraints and computational limitations during the execution of this study, it was decided to test the robustness of the policies investigated in this study by varying only the most influential uncertain parameters that were identified in the uncertainty analysis. The robustness of each of these policies was evaluated based on 2000 scenarios, resulting in a total of 10,000 different combinations of uncertain parameters and policies. The decision to choose 2000 scenarios per policy was made in an effort to ensure that there were enough alternative values for the most significant uncertain parameters in this study in order to accurately identify the robustness of the policies. The results of this analysis can be used to determine the effectiveness of the various policies under consideration, which can ultimately result in the creation of a policy strategy.

Table 5.2: Overview of the policies tested in the policy analysis.

Policy	Parameter	Unit	Base Value	Policy Value
More Planning Capacity for Social Housing	Planning Intended for Social Housing Percentage	$Dmnl$	0.3	0.5
Increase Average Rent	Average Rent Increase Percentage	$Dmnl/Year$	0.009	0.02
More Subsidy for Social Housing	Subsidy per SGEI House	$Euro/House$	0	50,000
Eliminate Landlord Levy	Policy Alteration of Landlord Levy Percentage	$Dmnl$	1	0
Lower Interest Rate	Interest Rate	$Dmnl/Year$	0.016	0.01

5.3. Uncertainty Analysis Results

In this part of the report, the results of the uncertainty analysis are mapped out. Given that the researcher made educated assumptions about the values of the unknown parameters in the base case, and these parameters may actually have other values in practice, it can be observed that this model has parameter uncertainties. Using this analysis, insight will first be obtained into the behaviour of the various KPIs under these uncertainties (section 5.3.1). In this study, this is done by showing the behaviour of the different KPIs for each uncertainty combination as a separate line with different colours. Since thousands of replications have been made, and the lines intertwine, it has been decided to also display the density of the lines. In this way, the bandwidth in which most values of the associated KPI are located can be mapped. Subsequently, this uncertainty analysis was used to identify which of the uncertain variables exert the most influence on the KPIs of this study (section 5.3.2). To enable these insights, the Extra-Trees feature scoring of Geurts et al. (2006) facilitated by the EMA Workbench, which is short for extremely randomized trees feature scoring, was used. Feature scoring is a family of machine learning techniques that can be used to measure the relative influence of individual input parameters on model results (Kwakkel, 2022). Since this involves a complex, dynamic system that can change over time, it was decided to use the results of the feature scoring over time. By means of this type of feature scoring, the uncertain parameters that primarily influence the KPIs can be mapped per unit of time.

5.3.1. KPIs Behaviour under Parameter Uncertainty

By comparing the results of the base case with Figure 5.6, several interesting aspects of the model can be observed. In general, it can be seen that mainly the SGEI Houses Shortage, Average Condition Score of SGEI Houses, Average Condition Score of Non SGEI Houses, and the Solvency Ratio are the KPIs that are behaviourally sensitive to the uncertain parameters. On the contrary, Non SGEI Houses Shortage is the sole KPI that behaves exactly as it did in the base case, indicating that Non SGEI Houses Shortage is numerically sensitive to the uncertain parameters studied in this analysis. The KPIs will be covered individually below to get better insight into their behaviour under these uncertainties.

To begin with, the results of the SGEI Houses Shortage show that even though the base case shows that the shortage of these types of homes will remain at around 60,000 in the coming years, this shortage could either decrease without intervention to around 25,000 homes or it could increase to approximately 300,000 homes (consult Table 5.4). It can therefore be concluded that the behaviour of the SGEI Houses Shortage is behaviourally sensitive to the uncertain parameters. In addition to the difference in behaviour between the base case and the uncertainty analysis, it should be noted that the average SGEI Houses shortage in the uncertainty analysis (128,418 homes)is considerably higher than the base case (7,540 homes). In particular, the results of Table 5.4 show that the majority of replications for this uncertainty analysis fall between the values of 112,914 and 132,519 homes, which is significantly higher than the maximum value in the base case of 62,515 dwellings (consult Table 5.3). Finally, it can be observed that the minimum SGEI Houses shortage in both analyses equals 24,701 houses (see Tables 5.3 and 5.4). This can be explained by the fact that the SGEI Houses Shortage amounted to this quantity at the start of the model's run in the base case (2012), and that the initial value of this KPI did not deviate from the base case in this analysis, as shown in Figure 5.6.

Subsequently, the Non SGEI Houses Shortage, as was previously established, is only numerically sensitive to the uncertain parameters. Figure 5.6 illustrates this by showing that the Non SGEI Houses Shortage behaves consistently with the base case regardless of the possible combinations of the uncertain parameters; the only difference is in the KPI's value. The base case shows that the housing shortage of middle-low-income households went from a housing surplus of 39,839 homes in 2012 to a housing shortage of 26,363 homes in 2050, whereby there was a housing surplus for most of the model run. Although the same can be said for the replications of this uncertainty analysis, in Figure 5.6 and Table 5.4 it can be clearly seen that most replications of the Non SGEI Houses Shortage end in the upper range of the density distribution (i.e., from 6,135 homes and upwards to and including 39,602). Due to this, it may be anticipated that without intervention the housing market of middle-low-income households will likely experience a housing scarcity.

Furthermore, on the basis of Figure 5.6, it can also be observed that the behaviour of the replications of the Average Condition Scores of the different types of housing does not remain the same as the base case. In the base case, it is first made clear that the Average Condition Score of SGEI Houses starts at a value of 3.3 scale points and gradually decreases, remaining stable at approximately 2.8 in the upcoming years. However, Figure 5.6 demonstrates that in the absence of intervention, this KPI can increase to an average condition score of 4.34 or decrease to an average condition score of 2.23. Based on the density distribution in Figure 5.6 it can be seen that most replications of the Average Condition Score of SGEI Houses are in the lower range (i.e. around an average condition score of 2.68 scale points).

In addition, the Average Condition Score of Non SGEI Houses begins with a value of 2.6 in 2012 which gradually rises over time until it reaches a value of approximately 4.5 scale points in 2050 of the base case. Figure 5.6, on the other hand, demonstrates that this KPI can gradually decline in the uncertainty analysis starting around the year 2035. In the absence of intervention, this KPI can increase to an average condition score of 4.51 or decrease to an average condition score of roughly 3.28 in the year 2050. Moreover, this observation is reinforced by the density distribution in Figure 5.6 which makes clear that most replications of the Average Condition Score of Non SGEI Houses are in the upper range (i.e. around an average condition score of 3.47 scale points).

In general, in both analyses, it can be seen that the condition of the SGEI Houses is better than that of Non SGEI Houses, as the Average Condition Score of SGEI Houses (consisting of a score of approximately 2.68) is lower than that of Non SGEI (consisting of a score of about 3.47). Even if that is the case, Table 5.4 shows that the majority of the Average Condition Score of SGEI Houses are between the values of 2.42 and 2.79 and that of the Average Condition Score of Non SGEI Houses is between 3.03 and 3.86.

Ultimately, it can be seen that the Solvency Ratio remains below 40% during the model run of the base case, while the majority of the replications of the uncertainty analysis show that the Solvency Ratio remains around the upper range (i.e. about 61% or higher) compared to the lower range (i.e. approximately 23%). Since this value reflects that the housing associations are in good condition to finance the various developments in the housing market, it may account for a sizable portion of the decrease in the SGEI House housing shortage and the condition improvement of the various types of houses compared to the base case. This can mainly be observed in the density distribution of Figure 5.6. As was previously indicated, a housing association in good financial standing can invest more in new buildings and maintenance, which reduces housing scarcity and improves housing quality. Based on Table 5.4, it can be observed that most replications of the Solvency Ratio are located in the middle range of the figure in question (i.e. between 23% and 61%).

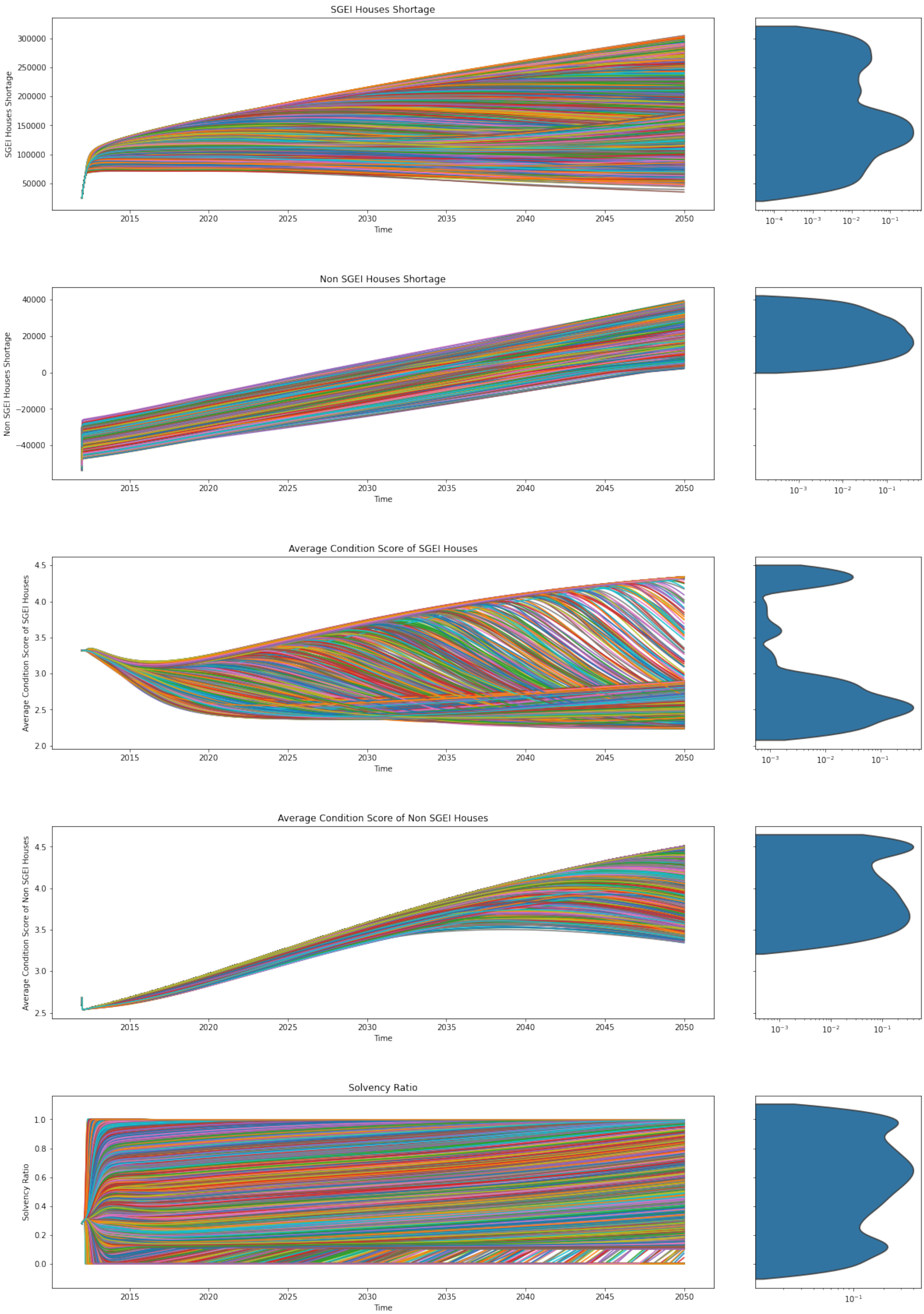

Figure 5.6: Behaviour of the KPIs under Uncertainty.

Table 5.3: Statistical Properties of KPIs at the Base Case.

Statistics	SGEI Houses Shortage	Non SGEI Houses Shortage	Average Condition Score of SGEI Houses	Average Condition Score of Non SGEI Houses	Solvency Ratio
Minimum	24,701	-39,840	2.71	2.64	0.14
Maximum	62,515	26,363	3.32	4.47	0.31
Mean	7,540	-4,545	2.82	3.60	0.27
Standard Deviation	6,597	18,055	0.15	0.58	0.04
50% Percentile	59,790	-4,527	2.77	3.65	0.28

Table 5.4: Statistical Properties of KPIs as a result of the Uncertainty Analysis.

Statistics	SGEI Houses Shortage	Non SGEI Houses Shortage	Average Condition Score of SGEI Houses	Average Condition Score of Non SGEI Houses	Solvency Ratio
Minimum	24,701	-53,887	2.23	2.54	0.00
Maximum	304,682	39,602	4.34	4.51	1.00
Mean	128,418	-8,195	2.68	3.47	0.43
Standard Deviation	33,945	17,499	0.41	0.51	0.27
25% Percentile	112,914	-22,719	2.42	3.03	0.23
50% Percentile	118,355	-7,722	2.49	3.56	0.42
75% Percentile	132,519	6,135	2.79	3.86	0.61

5.3.2. Most Influential Uncertainties per KPI

In this part of the report, the results of the Extra-Trees feature scoring are discussed. The results of this analysis are shown in Figures 5.7 - 5.11. These figures indicate per unit of time which of the 24 analyzed uncertain parameters presented in Table 5.1 has the most influence on the associated KPI at any given time. This influence is denoted by colour in these figures. The colours used to depict this impact ranges from yellow to dark blue, with yellow denoting the highest value. The value specifically denotes the KPI's level of sensitivity to a particular uncertain parameter. Particularly, the bright the colour, the higher the score, and the greater the parameter's influence on the KPI is at a given time. As the influence exerted by the uncertain parameters varies depending on the KPI, so does the range of the influence scale that is located at the far right of these figures. For instance, based on these figures it can be seen that the uncertain parameter Low Middle Income Percentage has a 0.6 influence on the Non SGEI Houses Shortage (Figure 5.8) and a 0.08 influence on the Average Condition Score of Non SGEI Houses (Figure 5.10). Since the uncertain parameters that have the greatest impact on the various KPIs vary, Table 5.5 provides a summary of all the uncertain parameters that have the greatest impact on one or multiple of the KPIs.

By comparing the results of the feature scoring analysis it can be observed that for all KPIs, except for the Average Condition Score of SGEI Houses and the Solvency Ratio, there is a gradual increase/decrease in the influence that the uncertain parameters exert over time. This can be clearly seen when comparing the results of the Non SGEI Houses Shortage in Figure 5.8 with those of the Solvency Ratio in Figure 5.11. Based on the results of the Non SGEI Houses Shortage, it can be seen that Low Middle Income Percentage and Low Middle Household Share in Social Market exert the most influence throughout the model run. However, as time passes, it can be seen that the influence of the uncertain parameters mentioned earlier gradually decreases. As an illustration, the parameter Low Middle Income Percentage exerts an influence of around 0.6 at the beginning and about 0.4 at the end.

Meanwhile, based on the results of the Solvency Ratio it can be observed that every 2 years the influence of the different uncertain parameters changes. It can be seen that the uncertain parameter Average Construction Time generally exerts an influence of around 0.044 on the Solvency Ratio. Despite this, it can be seen that in the years 2012, 2014, and 2028 this influence decreased to below 0.042. But at the same time, this variable exerts the most influence on the Solvency Ratio in the years 2036 and 2048, as it can be observed that the influence of this parameter exceeds 0.044 in the year in question. This abrupt change in the amount of influence that the uncertain parameters have on these KPIs can be attributed to the several feedback loops that simultaneously affect this KPI. In particular, the feedback loops in the social housing sub-model, in addition to the ones found in the financial sub-model affect the value of this KPI. The same can be said for the Average Condition Score of SGEI Houses.

Finally, it can also be observed that it is precisely the KPIs where there is an abrupt exchange of influence of the uncertain parameters, namely the Average Condition Score of SGEI Houses and Solvency Ratio, that contain the most uncertain parameters that exert influence. For example, there are 10 different parameters that are most influential on the Average Condition Score of SGEI Houses and 7 uncertain parameters on the Solvency Ratio.

While the KPIs SGEI Houses Shortage, Non SGEI Houses Shortage, and Average Condition Score of Non SGEI Houses have respectively 3, 2 and 2 uncertain parameters that exert the most influence, which is significantly lower than the KPIs with an abrupt exchange of parameter influence. To gain a better understanding of the different uncertain parameters that influence the KPIs, the most influential parameters per KPI are discussed below.

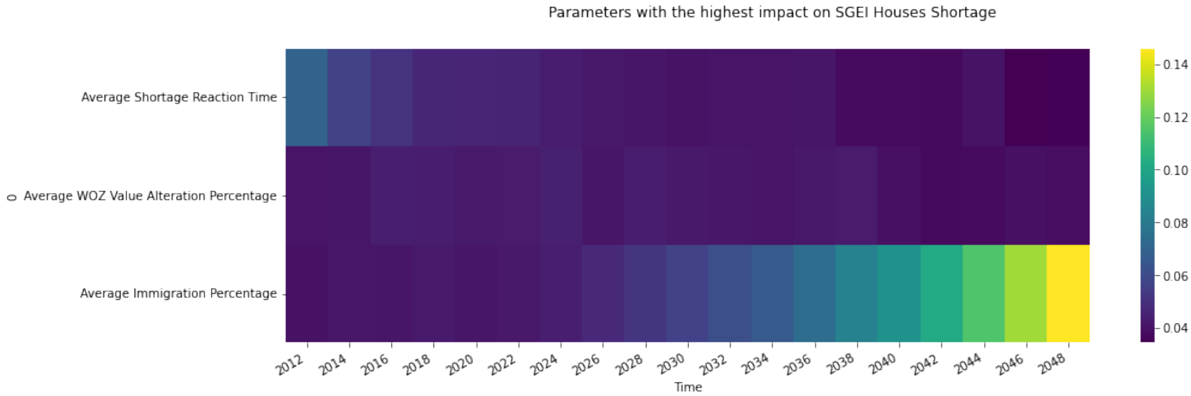

Figure 5.7: Uncertainty analysis results of the SGEI Houses Shortage.

To begin with, Figure 5.7 shows the evolution of the Extra-Trees feature scores over time for the uncertain parameters that most influence the SGEI Houses Shortage. Based on the results of the SGEI Houses Shortage, it can be seen that Average Shortage Reaction Time, Average WOZ Value Alteration Percentage and Average Immigration Percentage exert the most influence throughout the model run. However, as time passes, it can be seen that the influence of the uncertain parameters Average Shortage Reaction Time, and Average WOZ Value Alteration Percentage gradually decreases, while the influence of Average Immigration Percentage gradually increases. As a result, the Average Immigration Percentage is ultimately the most influential uncertain parameter on this KPI after 2022. This is due to the fact that the parameter Average Immigration Percentage only came into effect in this study after the year 2022 to fill the lack of data on immigration due to the fact that historical data on immigration patterns existed during this study up to and including the year 2021. As a result, the Average Immigration Percentage is ultimately the most influential uncertain parameter on this KPI after 2022.

On the one hand, Average Shortage Reaction Time shows how much time it takes housing associations to plan for new construction in order to reduce the housing shortage. If this time is very short, new-build homes will eventually become available on the market sooner as opposed to a long Average Shortage Reaction Time, which ultimately reduces the shortage of SGEI Houses faster. On the other hand, the Average Immigration Percentage causes an increase in housing demand, as this parameter indicates the number of people and ultimately the number of households that move to the Haaglandse urban region. If this percentage is high, many households in the region will move to the region in question, causing housing demand to increase faster than the developments in the housing supply, which will only widen the gap between housing demand and supply. Consequently, the housing shortage will increase faster compared to a scenario where there is a lower Average Immigration Percentage. The magnitude of the Solvency Ratio's increases and reductions is ultimately determined by the Average WOZ Value Alteration Percentage. The Solvency Ratio will deteriorate more quickly if this percentage is high and there is a high housing scarcity as opposed to a low value of this percentage. As a result, a low Solvency Ratio will also cause the housing demand to increase faster than the developments in the housing supply, which will only widen the gap between housing demand and supply. Because of the severe housing scarcity, housing associations will construct more new homes, which are financed by taking out new loans. Therefore, the Solvency Ratio will decline since the debt capital grows faster than the equity capital.

Secondly, Figure 5.8 shows the evolution of the Extra-Trees feature scores over time for the uncertain parameters that most influence the Non SGEI Houses Shortage. As mentioned before, based on the results of the Non SGEI Houses Shortage, it can be seen that Low Middle Income Percentage and Low Middle Household Share in Social Market exert the most influence throughout the model run. Even though, as time passes, it can be seen that the influence of these uncertain parameters decreases around the year 2024, it should be noted that Low Middle Income Percentage remains the most influential uncertain parameter on this KPI throughout the model's run.

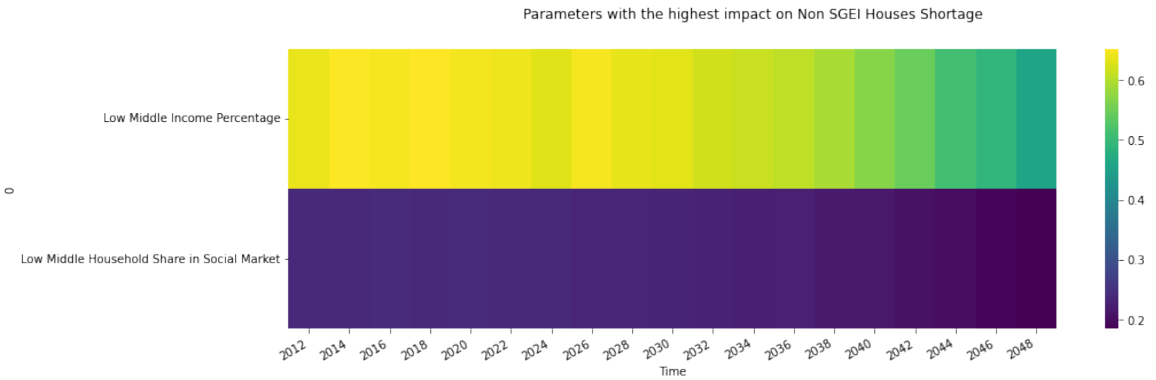

Figure 5.8: Uncertainty analysis results of the Non SGEI Houses Shortage.

In general, the parameters Low Middle Income Percentage and Low Middle Household Share in Social Market determine the housing demand of the housing market for low-middle-income households in the region in question. The portion of the population that falls within the necessary price range to be included in this housing sector is specifically indicated by the Low Middle Income Percentage. In the Dutch housing sector, dwellings in this housing market are provided by both private and social housing corporations. Since the housing supply of private corporations is not taken into account in this model, the Low Middle Household Share in Social Market has been included to show the portion of the housing demand that must be satisfied by the social housing corporations. If these factors become more prevalent, more households will fall into the low-middle income bracket, and a greater percentage of these households will look for housing with social housing corporations, causing housing demand to increase faster than the developments in the housing supply. As a result, the housing shortage for these households will worsen more quickly than in the case when these factors are lower, given that the demand for housing is smaller in the latter instance.

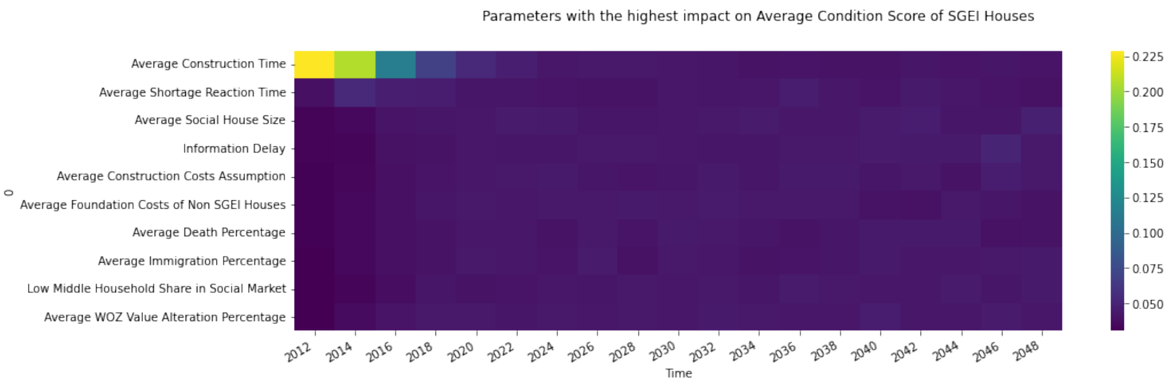

Figure 5.9: Uncertainty analysis results of the Average Condition Score of SGEI Houses.

Thirdly, Figure 5.9 shows the evolution of the Extra-Trees feature scores over time for the uncertain parameters that most influence the Average Condition Score of SGEI Houses. Based on the results of the Average Condition Score of SGEI Houses, it can be observed that from the start of the model run until about the year 2018, the Average Construction Time is the most influential. After 2018, the influence of the ten parameters changes abruptly over time, and the influence of all these uncertain parameters (including the Average Construction Time) continues to fluctuate below a value of 0.075. Since the influence of the uncertain parameters changes abruptly over time, the reason why these 10 parameters influence this KPI will be discussed. In general, these uncertain parameters can be divided into three categories, namely the category influencing housing demand – which includes parameters Average Death Percentage, Average Immigration Percentage, and Low Middle Household Share in Social Market –, the category influencing housing supply – which includes parameters Average Construction Time, and Average Shortage Reaction Time –, and the category influencing the income and expenses of the housing associations – which include the parameters Average Social Housing Size, Information Delay, Average Construction Costs Assumption, Average Foundation Costs of Non SGEI Houses, and Average WOZ Value Alteration Percentage.

With regard to the uncertain parameters in the first category, an increase in these parameters, with the exception of Average Death Percentage which has to make a decrease, will lead to higher social housing demand. As with the SGEI Houses Shortage, this will lead to a faster increase in housing demand compared to the housing supply, causing the gap between housing demand and supply to widen and thus increasing the housing shortage. The housing shortage in turn will lead to more production of new homes. More new-build development will result in a lower Average Condition Score of SGEI Houses since newly constructed homes have a condition score of 1, meaning they are in the best condition possible. Because of this, the average condition score of the houses in the social sector will decrease.

In addition, an increase in the uncertain parameters in the second category will ensure that the housing supply increases. First of all, Average Shortage Reaction Time shows how much time it takes housing associations to plan for new construction in order to reduce the housing shortage. Furthermore, the Average Construction Time provides an estimate of how long it will take to build the planned homes. If these procedures take a very short time, new-build homes will eventually become available on the market sooner as opposed to when they take a long time, which ultimately reduces the Average Condition Score of SGEI Houses. As previously noted, increased new-build construction will increase the number of properties with a condition score of 1, causing the average condition score of the properties in the social sector to decrease.

For the last category, an increase in the Average WOZ Value Alteration Percentage, and a decrease in parameters Average Foundation Costs of SGEI Houses, Average Social Housing Size, Information Delay and Average Demolition Costs Assumption will ensure that the housing associations will make profits. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases more quickly than the total capital. Ultimately, the Average Condition Score of SGEI Houses will decline as the Solvency Ratio rises as more money may be invested in new construction and upkeep of existing dwellings. As was previously indicated, the building of new homes results in a lower Average Condition Score of SGEI Houses, but maintaining existing homes can also guarantee this. Given the fact that the conditions of the buildings will be improved during the maintenance process, in this model a reduction of 1 or more scale points in the condition score of the residences (depending on the type of maintenance) that went through this procedure.

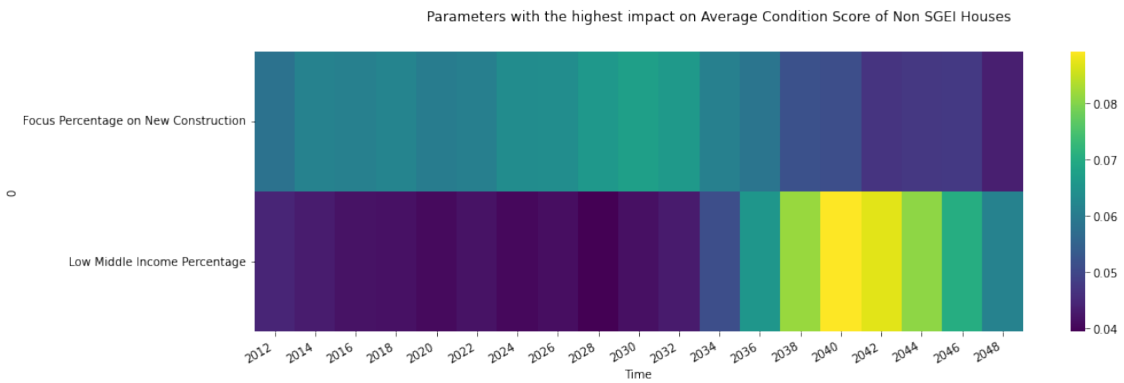

Figure 5.10: Uncertainty analysis results of the Average Condition Score of Non SGEI Houses.

Fourthly, Figure 5.10 shows the evolution of the Extra-Trees feature scores over time for the uncertain parameters that most influence the Average Condition Score of Non SGEI Houses. In view of the most influential uncertain parameters for this KPI – which include Focus Percentage on New Construction, and Low Middle Income Percentage –, it can be concluded that in contrast to the Average Condition Score of SGEI Houses – which primarily focuses on the construction of new homes –, this KPI primarily focuses on the maintenance of existing homes. This can be explained, among other things, by the low Non SGEI Houses Shortage which can be seen for most of the model run as illustrated in Figure 5.2, which represents a housing surplus. As there is generally no housing shortage for middle-low income households, no new homes will be built in this study that will reduce the Average Condition Score of Non SGEI Houses. Since in this case relatively few to no new homes are built, maintenance will mainly be responsible for keeping the existing homes in good condition. Based on Figure 5.10 it can be seen that at the start of the model run the parameter Focus Percentage on New Construction exerts the most influence on the Average Condition Score of Non SGEI Houses. However, as time passes, it can be seen that the influence of this uncertain parameter gradually decreases, while the influence of the Low Middle Income Percentage gradually increases. As a result, the Low Middle Income Percentage is ultimately the most influential uncertain parameter on this KPI after 2038.

As mentioned before, the higher the Focus Percentage on New Construction becomes, the more the housing associations invest in new construction, while fewer homes are maintained. In contrast to the Average Condition Score of SGEI Houses, an increase in new-building investment will not lead to a lower Average Condition Score of Non SGEI Houses. The reason for this is that in this model it is assumed that new construction can only take place in the event of a housing shortage, so since there is a housing surplus of Non SGEI Houses, no new homes will be built if the new construction investments increase. Just the opposite will take place. Because the majority of the investments are not in the maintenance of existing homes, the conditions of the homes will only deteriorate, causing the Average Condition Score of Non SGEI Houses to increase.

Moreover, the parameter Low Middle Income Percentage determines the housing demand of the housing market for low-middle-income households in the Haaglanden region. As previously mentioned, the portion of the population that falls within the necessary price range to be included in this housing sector is specifically indicated by the Low Middle Income Percentage. In the case that this percentage increases, more households will fall into the low-middle income bracket, causing housing demand to increase faster than the developments in the housing supply. As a result, the housing shortage for these households will worsen more quickly than in the case when this percentage is lower, resulting in a faster transition from a housing surplus to a housing shortage. Due to the housing scarcity, this housing market will invest in the construction of new homes for low-middle-income households. As previously noted, increased new-build construction will increase the number of properties with a condition score of 1, causing the average condition score of properties in the social sector to decrease.

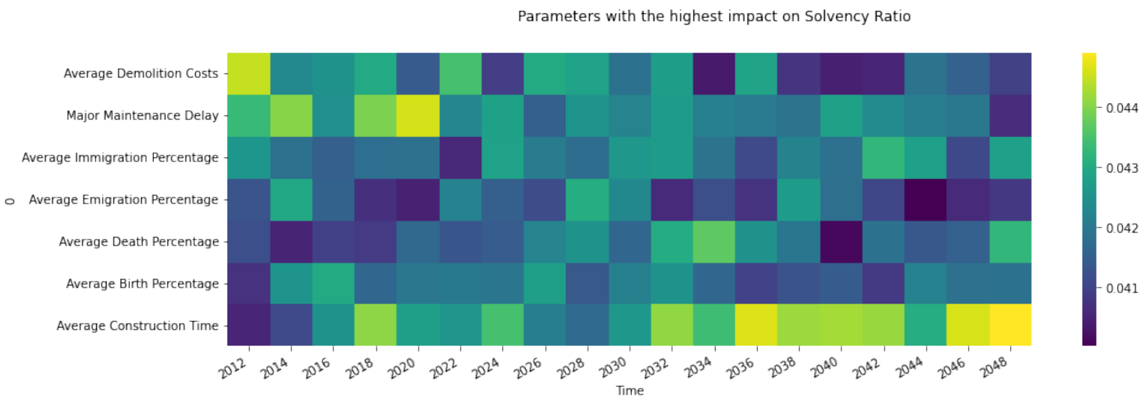

Figure 5.11: Uncertainty analysis results of the Solvency Ratio.

Finally, Figure 5.11 shows the evolution of the Extra-Trees feature scores over time for the uncertain parameters that most influence the Solvency Ratio. Since the influence of uncertainty variables changes abruptly over time, we will only discuss the reason why these 7 parameters influence this KPI. In general, these uncertain parameters can be divided into 3 categories, namely the category influencing housing demand – which includes parameters Average Immigration Percentage, Average Emigration Percentage, Average Death Percentage, and Average Birth Percentage –, the category influencing housing supply – which includes parameters Major Maintenance Delay, and Average Construction Time –, and the category influencing the expenses of the housing associations – which include the parameter Average Demolition Costs.

With regard to the uncertain parameters in the first category, an increase in these parameters, with the exception of Average Death Percentage and Average Emigration Percentage which have to make a decrease, will lead to higher housing demand. As with the SGEI Houses Shortage, this will lead to a faster increase in housing demand compared to the housing supply, causing the gap between housing demand and supply to widen and thus increasing the housing shortage. The housing shortage in turn will lead to more production of new homes. More new construction causes the total capital to increase after a while on the one hand, which leads to an increase in the Solvency Ratio. On the other hand, the production of new homes increases the debt capital almost instantaneously, as its construction is financed by taking out new loans. An increase in loan capital will lead to a decrease in the Solvency Ratio. If these two phenomena are equal, the Solvency Ratio will first decrease and after the housing stock is expanded with the new construction it will achieve an equilibrium state.

Moreover, an increase in the uncertain parameters in the second category ensures how fast the housing supply increases. First of all, the Major Maintenance Delay accounts for the amount of time it takes to do major maintenance on existing homes, and thus how long it takes existing homes to become available on the housing market. Subsequently, Average Construction Time estimates how long it will take to build new homes, and thus how long it will take new homes to become available on the housing market. As already mentioned, more new construction causes the total capital to increase after a while (which leads to a delayed increase in the Solvency Ratio), and the debt capital to increase almost instantaneously (which leads to an immediate decrease in the Solvency Ratio). Faster new dwelling construction will ensure that the houses will be accessible on the market sooner, causing the total capital and consequently the Solvency Ratio to increase more swiftly than when the construction duration was longer. Given that the maintained homes can be considered as dwellings that are added to the existing housing stock, just like new construction – because during major maintenance the homes are out of commission in order to complete the procedure (i.e., they do not form part of the available housing stock), and they are also financed through new loans –, the same conclusion can be drawn for a faster Major Maintenance Delay.

For the last category, a decrease in the Average Demolition Costs will ensure that the housing associations will have lower expenses when demolishing very old, deteriorated homes. If income remains the same, lower expenses will guarantee that the housing associations will turn a profit. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital. If the amount of demolished houses is equal to the amount that the debt capital decrease, the Solvency Ratio will arrive at an equilibrium state. If there is an increase in the Average Demolition Costs, the housing associations will be in the red as their expenses exceed their income. In the case that the housing associations are in red, the reverse will take place as the housing associations will need to take out more loans to cover all their expenses. Consequently, the debt capital will rise as new loans are closed, while the total capital will decrease as existing homes in the housing stock are demolished. Ultimately, the Solvency Ratio will decrease as a result of the decrease in total capital and increase in debt capital.

Table 5.5: Overview of the most influential uncertain parameters according to the Extra-Trees feature scoring.

Sub-model	Parameter	Unit	Base Value	Range	
				Min. Value	Max. Value
Population	Average Birth Percentage	$Dmnl/Year$	0.0101	0.0097	0.0105
	Average Immigration Percentage	$Dmnl/Year$	0.0126	0.0095	0.0156
	Average Emigration Percentage	$Dmnl/Year$	0.0088	0.0082	0.0093
	Average Death Percentage	$Dmnl/Year$	0.0089	0.0083	0.0098
	Low Middle Income Percentage	$Dmnl$	0.391	0.3	0.482
	Low Middle Household Share in Social Market	$Dmnl$	0.4	0.3	0.4
Social Housing	Average Shortage Reaction Time	$Year$	0.75	0.5	1
	Average Construction Time	$Year$	3	2	4
	Major Maintenance Delay	$Year$	1.5	1	2
	Focus Percentage on New Construction	$Dmnl$	0.7	0.6	0.8
Economic	Information Delay	$Year$	0.85	0.77	0.9
	Average WOZ Value Alteration Percentage	$Dmnl$	0.08085	0.07	0.1
	Average Social House Size	$m^2/House$	84	68	100
	Average Demolition Costs	$Euro/m^2$	50	30	70
	Average Foundation Costs of Non SGEI Houses	$Euro/House$	215,600	215,600	241,700
	Major Maintenance Cost Part	$Dmnl$	0.8	0.6	1
	Average Construction Costs Assumption	$Euro/m^2$	300	236	321

First of all, based on Table 5.5, it can be observed that there are six uncertain parameters in the population submodel that exert the most influence on the KPIs. In general, the housing demand in Haaglanden is determined by all these factors. The first four uncertain parameters – Average Birth Percentage, Average Immigration Percentage, Average Emigration Percentage, and Average Death Percentage – determine the general housing demand of the Haaglanden urban area, while the last uncertain parameters – Low Middle Income Percentage, and Low Middle Household Share in Social Market – determine the housing demand of the low-middle-income households. Based on the findings of the uncertain analysis, it is evident that the parameters affecting the general housing demand have the greatest impact on the SGEI Houses Shortage, Average Condition Score of SGEI Houses, and Solvency Ratio. In addition, the uncertainty results made it clear that the uncertain parameters that influence the housing demand for low-middle-income households are crucial for determining the Non SGEI Houses Shortage, and Average Condition Score of Non SGEI Houses.

Subsequently, the uncertain analysis makes it clear that there are four uncertain parameters in the social housing sub-model that exert the most influence on the KPIs (see Table 5.5). In general, all of these variables influence the housing supply in the Haaglanden urban region. The first three uncertain parameters – Average Shortage Reaction Time, Average Construction Time, and Major Maintenance Delay – determine how long it will take new or maintained homes to increase the housing supply, while the last uncertain parameter – Focus Percentage on New Construction – determines the amount of new (or maintained) homes that will increase the housing supply. Based on the findings of the uncertain analysis, it is evident that the parameters affecting determine how long it will take to increase the housing supply have the greatest impact on the SGEI Houses Shortage, Average Condition Score of SGEI Houses, and Solvency Ratio. Moreover, this analysis made it clear that the uncertain parameter that influences the amount of which the housing supply will increase is crucial for determining the Average Condition Score of Non SGEI Houses.

Finally, Table 5.5 illustrates that there are seven uncertain parameters in the economic sub-model that exert the most influence on the KPIs. All of these uncertain parameters collectively affect the cash flow of the housing associations in Haaglanden. In particular, the first two uncertain parameters – Information Delay, and Average WOZ Value Alteration Percentage – determine the income of the housing associations, while the rest uncertain parameters – Average Social Housing Size, Average Demolition Costs, Average Foundation Costs of Non SGEI Houses, Major Maintenance Cost Part, and Average Construction Costs Assumption – determine the expenses of the social housing associations. Based on the findings of the uncertain analysis, it is evident that the parameters affecting the income of the associations have the greatest impact on the SGEI Houses Shortage, and Average Condition Score of SGEI Houses. Besides, the results made it clear that the uncertain parameters that influence the expenses of the associations are crucial for determining the Average Condition Score of SGEI Houses, and Solvacy Ratio.

5.4. Policy Analysis Results

In this part of the report, the results of the policy analysis will be presented. Through this analysis, insight can be obtained into the effect of the various interventions that Dutch policymakers can implement on the KPIs and ultimately the social housing system. In this study, this is firstly done by comparing the individual influence of the various investigated policies presented in Table 5.2 on the KPIs with the base case (see section 5.4.1). Subsequently, the interactions between the most effective individual policies of the various investigated policies are depicted in section 5.4.2. Vensim was the only software used to execute and evaluate these comparisons. Furthermore, the robustness of the different policies was tested in section 5.4.3. In this study, this was made possible by combining the policies in Table 5.2 with the most influential uncertain parameters (see Table 5.5) to determine the effect of this combination on the behaviour of the KPIs, using the EMA Workbench.

5.4.1. Effect of Individual Policy Intervention

In this part of the report, the individual effect of the various investigated policies will be mapped out by comparing the behaviour of the various KPIs in a policy intervention with the base case. In particular, the behaviour of a KPI at the base case is referred to as ”Base Case”. While the behaviour of the KPI during a policy intervention is indicated using the name of the associated policy. For example, the behaviour of the KPIs during a model run where the policy Lower Interest Rate is applied (which ensures that there is a reduction in the interest rate that the housing corporations need to pay) is indicated by Lower Interest Rate. The results of the policy analysis can be seen in Figures 5.12-5.16.

By comparing the different results, it can be observed that all of the studied policies had a beneficial impact on the different KPIs, with the exception of the policy More Planning Capacity for Social Housing on the Solvency Ratio. To be specific, all policies that form part of this analysis, with the exception of the one specified, led to a rise in the Solvency Ratio and a decrease in the other KPIs – the SGEI Houses Shortage, Non SGEI Houses Shortage, Average Condition Score of SGEI Houses, and Average Condition Score of Non SGEI Houses. The degree of influence that these interventions have on the various KPIs is what separates them from one another. As a result, it is evident that the investigated policies mainly influence the SGEI Houses Shortage and Solvency Ratio. The reason for this is that only for these two KPIs have the most desired target behaviour changes been observed. In particular, the policy interventions studied had resulted in the largest decrease in the SGEI Houses Shortage, along with the largest increase in the Solvency Ratio compared to the base case (consult Figures 5.12 and 5.16).

To gain a better understanding of the individual effect of these policies on the KPIs, the influence of the studied policies per KPI will be discussed below. Given that each researched policy has a different degree of influence on each KPI, Table 5.6 summarizes the individual effects of these policies on the KPIs to make comparison easier.

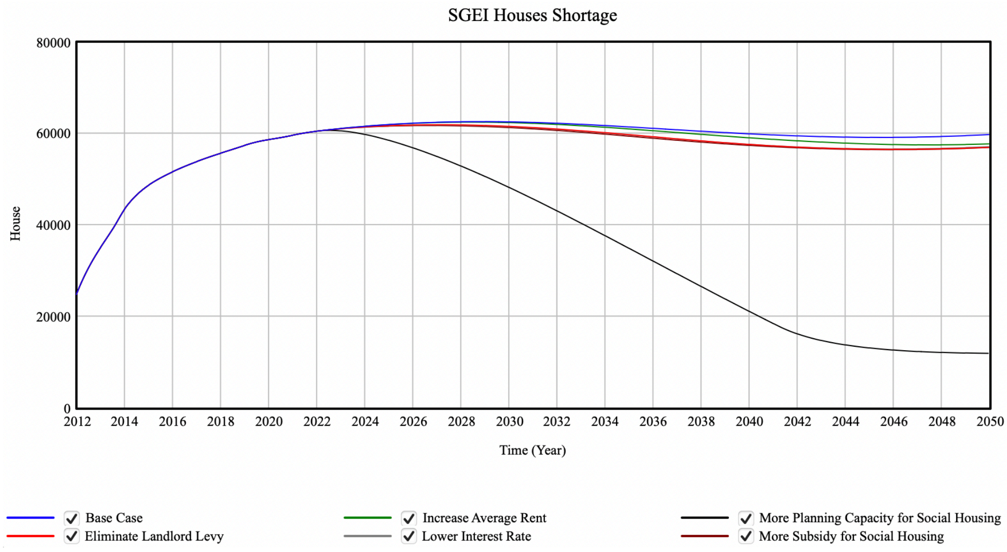

Figure 5.12: Policy analysis results of the SGEI Houses Shortage.

To begin with, Figure 5.12 shows the influence of the policy interventions on the SGEI Houses Shortage over time. Based on this figure, it can be observed that most policies, namely Elimination Landlord Levy, Increase Average Rent, Lower Interest Rate, and More Subsidy for Social Housing, generally exhibit approximately the same behaviour as the base case. Despite this phenomenon, it should be noted that the value of SGEI Houses Shortage will be lower than the base case from the year 2022 onward. This is mainly due to the fact that in this study it was decided that all policies will come into effect after the year 2022, as the current Dutch policymakers can only influence policies in the present and the future. Given the fact that all these policies improve the Solvency Ratio of the social housing associations, it can be concluded that an increase in the Solvency Ratio will only have a minor impact on the SGEI Houses Shortage. This is because the housing associations' Solvency Ratio already exceeded the 15% threshold for investments in SGEI Houses in the base case, indicating that they had sufficient financial resources to invest in SGEI Houses at that time already.

Ultimately, it can be observed that More Planning Capacity for Social Housing is the most efficient policy that policymakers can implement to significantly lower the SGEI Houses Shortage. Based on Figure 5.12, it can be observed that this policy causes the shortage of SGEI Houses to decrease from 2022 until it reaches a value of approximately 12,000 by the year 2050. And this value is significantly lower than the 60,000 housing shortage that can be seen in the base case. Through this policy, more building land will be made available to housing associations to build social housing, thereby increasing the housing supply. A faster increase in the housing supply compared to the housing demand will ultimately cause the SGEI Houses Shortage to decrease.

Subsequently, Figure 5.13 shows the influence of the policy interventions on the Non SGEI Houses Shortage over time. Based on this figure, it can be observed that most policies, namely Increase Average Rent, and More Planning Capacity for Social Housing, generally exhibit approximately the same behaviour as the base case. Despite this behaviour, it should be emphasized that starting around the year 2036, the value of the Non SGEI Houses Shortage will be less than the base case. However, due to the limited impact of these policies on the Non SGEI Houses Shortage, this is not observable in Figure 5.13. This is because, with the exception of the More Planning Capacity for Social Housing policy which has actually ensured a decline in the Solvency Ratio, the Increase Average Rent policy has only produced a small improvement in the Solvency Ratio compared to the other policies, as can be seen in Figure 5.16. A greater Solvency Ratio enables housing organizations to invest more in the construction of new Non SGEI houses, among other things, boosting the housing supply. Although a faster increase in the housing supply compared to the housing demand will ultimately cause the Non SGEI Houses Shortage to decrease, in this case, only a few houses have been built due to the limited improvement in the Solvency Ratio caused by these policies. In addition, the decline in the Solvency Ratio had no effect on this KPI since housing associations were already unable to invest in Non SGEI homes in the base case.

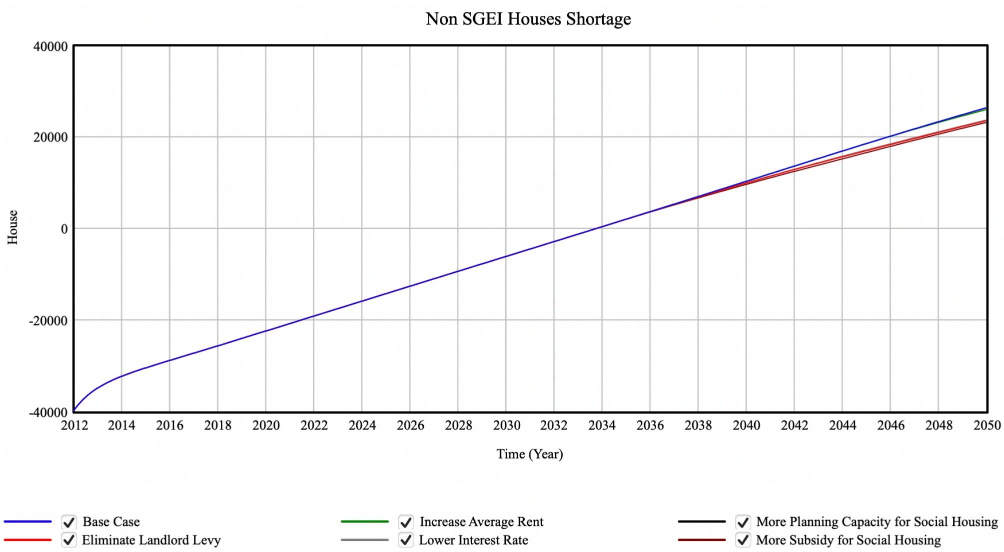

Figure 5.13: Policy analysis results of the Non SGEI Houses Shortage.

However, the implementation of policies Lower Interest Rate, Eliminate Landlord Levy, and More Subsidy for Social Housing has resulted in a decrease in the Non SGEI Houses Shortage, where the latter is the most efficient in view of the final value of the Non SGEI Houses Shortage in 2050. Besides, the Lower Interest Rate policy is the least effective of these three. The research findings indicate that when the Lower Interest Rate policy is implemented, this KPI's value was 23,672 dwellings in the year 2050. For the policy Eliminate Landlord Levy, the value of this KPI was 23,513 houses in the year 2050, while that of the policy More subsidy for Social Housing was 23,142 houses in the year in question. In general, the influence of these three policies on the Non SGEI Houses Shortage can be explained, as only these policies provide a higher Solvency Ratio than the 40% threshold, that is needed in order to invest in the Non SGEI houses. This in turn ensures that are more investments in the construction of Non SGEI houses, which ultimately expands the housing supply for low-middle-income households. Since the discrepancy between housing supply and demand in this industry will reduce as a result of a faster increase in housing supply relative to housing demand, this will ultimately result in a decrease in the Non SGEI Housing Shortage.

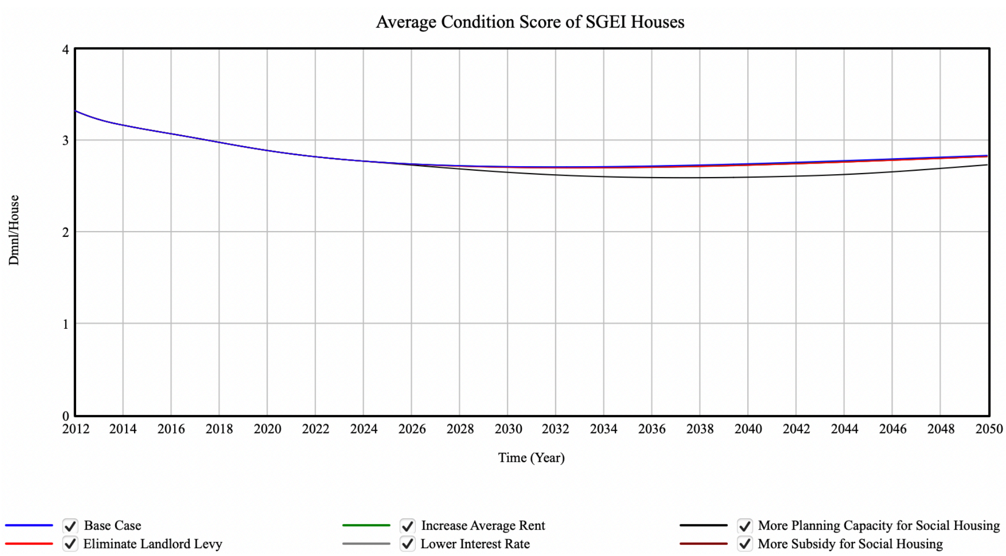

Figure 5.14: Policy analysis results of Average Condition Score of SGEI Houses.

Furthermore, Figure 5.14 shows the influence of the policy interventions on the Average Condition Score of SGEI Houses over time. Based on this figure, it can be observed that the same policies as those of the SGEI Houses Shortage, namely Elimination Landlord Levy, Increase Average Rent, Lower Interest Rate, and More Subsidy for Social Housing, generally exhibit approximately the same behaviour as the base case. Despite this, it should be noted that the value of the Average Condition Score of SGEI Houses will be lower than the base case starting approximately in the year 2026. As was previously stated, this is mainly due to the fact that in this study it was decided that all policies will come into effect after the year 2022. Given that the effect of these policies on this KPI is only apparent once the new homes have been built or the existing homes have been maintained, hence the decline in this condition score cannot be noticed in Figure 5.14 until a few years after 2022. The decrease in value of the Average Condition Score of SGEI Houses is not visible in Figure 5.14, much like the outcomes of the Non SGEI Houses Shortage, due to the limited influence of these policies on this KPI. All of these policies help increase the Solvency Ratio of the social housing associations, leading to housing organizations being better able to finance both new buildings and house upkeep of SGEI houses, which ultimately lowers the Average Condition Score of SGEI Houses. However, because the housing associations' Solvency Ratio already exceeded the threshold of 15% in the base case for investments in SGEI Houses, demonstrating that they had the financial means to do so from the start, the increase in the Solvency Ratio caused by these policies only had a minor impact on this KPI.

Ultimately, it can also be concluded from this figure that More Planning Capacity for Social Housing is the most efficient policy that policymakers can implement to significantly lower the Average Condition Score of SGEI Houses. Based on Figure 5.14, it can be observed that this policy causes the KPI to decrease from around 2027 until it reaches a value of approximately 2.75 by the year 2050. And this value is lower than the approximately 2.83 condition score that can be seen in the base case. Through this policy, more building land will be made available to housing associations to build social housing, thereby increasing the construction of new SGEI Houses. An increase in new construction will cause a reduction in the Average Condition Score of SGEI Houses, as newly constructed homes have a condition score of 1 which will pull the average housing condition down.

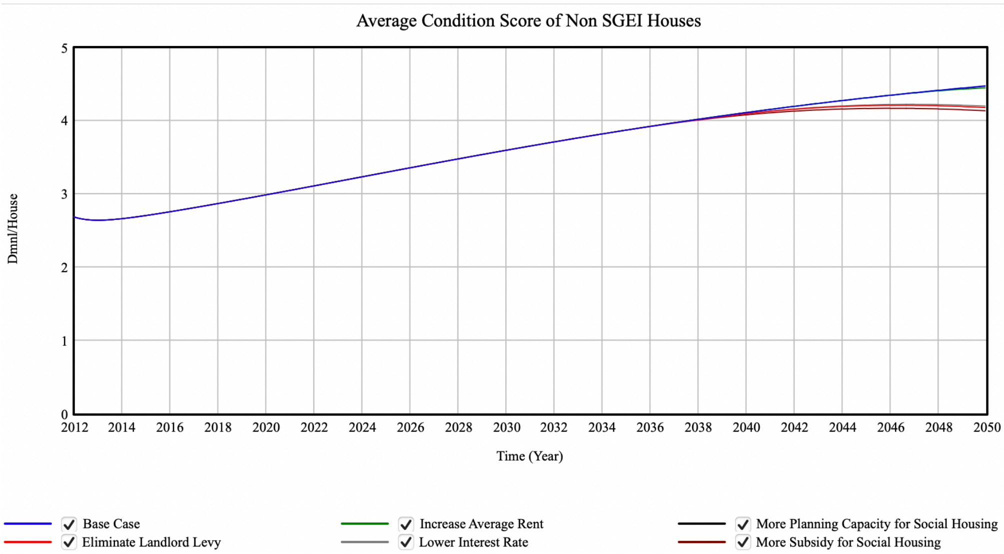

Figure 5.15: Policy analysis results of the Average Condition Score of Non SGEI Houses.

In addition, Figure 5.15 shows the influence of the policy interventions on the Average Condition Score of Non SGEI Houses over time. Based on this figure, it can be observed that the same policies as those of the Non SGEI Houses Shortage, namely Increase Average Rent, and More Planning Capacity for Social Housing, generally exhibit approximately the same behaviour and remains around the same values as the base case. Despite this, it should be emphasized that starting around the year 2038, the value of the Non SGEI Houses Shortage will be less than the base case. Given that the effect of these policies on this KPI is only apparent once the new homes have been built or the existing homes have been maintained, the decline in this condition score cannot be noticed in Figure 5.15 until a few years after 2034 (which is the year that these policies started to influence the housing sector for low-middle-income households). However, due to the limited impact of these policies on the Average

Condition Score of Non SGEI Houses, this is not observable in Figure 5.15. This is because, with the exception of the More Planning Capacity for Social Housing policy which has actually ensured a decline in the Solvency Ratio, the Increase Average Rent policy has only produced a small improvement in the Solvency Ratio compared to the other policies, as can be seen in Figure 5.16. Similar to the Non SGEI Houses Shortage, these initiatives have only slightly improved the Solvency Ratio, which has resulted in the construction of only a small number of homes in order to lower the average housing condition. Therefore, the decline of the Average Condition Score of Non SGEI Houses is restrained. Moreover, because housing associations were already unable financially to invest in Non SGEI homes in the base case, the decline in the Solvency Ratio had no effect on the Average Condition Score of Non SGEI Houses.

As with the results of the Non SGEI Houses Shortage, it can be noted that a significant difference in value can be seen between the base case and the policies Eliminate Landlord Levy, Lower Interest Rate, and More subsidy for Social Housing, where the latter is the most efficient in view of the final value of the Average Condition Score of Non SGEI Houses in 2050 and the first one being the least effective. The research findings indicate that when the Lower Interest Rate policy is implemented, this KPI's value was 4.20 in the year 2050. For the policy Eliminate Landlord Levy, the value of this KPI was 4.18 in the year 2050, while that of the policy More subsidy for Social Housing was 4.13 in the year in question. In general, the impact of these three policies on the KPI can be explained, as all these policies offer a higher Solvency Ratio than the 40% threshold, which is needed in order to invest in the construction of new Non SGEI houses, as well as the maintenance of these houses. On the one hand, since newly built homes have a condition score of 1, increasing the investment in the building of Non SGEI homes will ultimately result in a decrease in the Average Condition Score of Non SGEI Houses. On the other hand, increasing the investment in the construction of Non SGEI homes will ultimately lead to a decrease in the Average Condition Score of Non SGEI Houses because the conditions of the properties will be improved during the maintenance process, reducing each maintained Non SGEI house by 1 or more scale points depending on the type of maintenance.

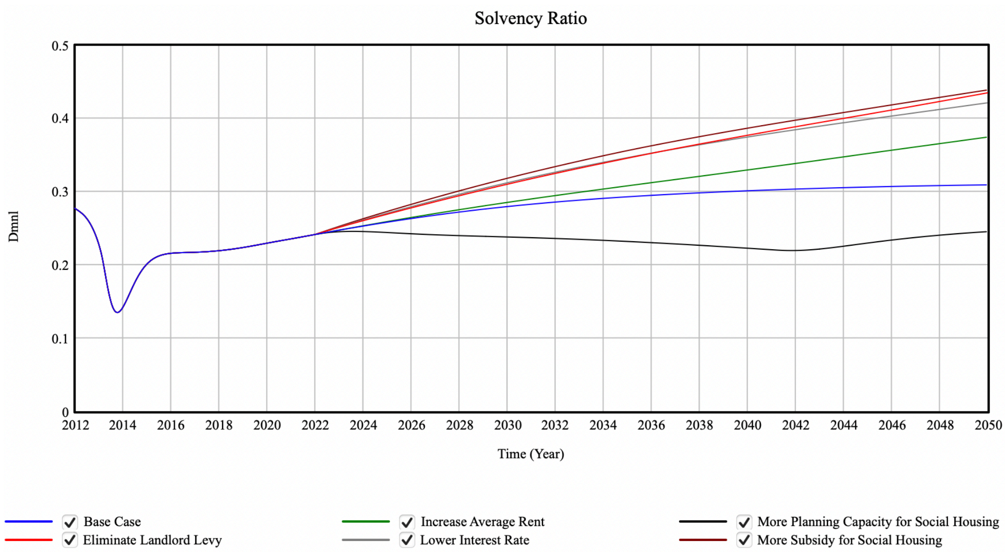

Figure 5.16: Policy analysis results of the Solvency Ratio.

Finally, Figure 5.16 shows the influence of the policy interventions on the Solvency Ratio over time. Based on this figure, it can be observed that there is no single policy that causes the KPI to exhibit the same behaviour as the base case. The results show that the policy More Planning Capacity for Social Housing is the least efficient for the Solvency Ratio. The reason for this is that this policy ensures that the Solvency Ratio stays about the same at about 25% instead of increasing to about 31% in the base case. In short, this policy ensures that the Solvency Ratio is lower than the base scenario, while a value higher than the base case is desirable for this KPI. Given that this policy ensures that housing associations will have access to additional land for the development of new social housing, it will lead to the massive building of SGEI homes in order to reduce the shortage from roughly 60,000 to 12,000 dwellings, as illustrated in Figure 5.12. Since the finance for new home building comes from taking out new loans, a big increase in the production of SGEI homes will cause a speedy rise in debt credit. Due to a delay in home planning and construction, the debt credit is increasing more quickly than the total credit, which will cause the Solvency Ratio to decline.

Ultimately, it turns out that of the other policies, More Subsidy for Social Housing is the policy that is most efficient for the Solvency Ratio. With this policy, this KPI amounts to a value of approximately 44% in the year 2050, well above the threshold for the various housing types. This is because this policy guarantees that housing associations will have more income. If the expenses of these associations remain the same, a higher income will guarantee that the housing associations will turn a profit as their income exceed their expenses. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital.

Table 5.6: Impact of the policies tested in the policy analysis on the KPIs.

	SGEI Houses Shortage	Non SGEI Houses Shortage	Average Condition Score of SGEI Houses	Average Condition Score of Non SGEI Houses	Solvency Ratio
More Planning Capacity for Social Housing	Very High	Very Low	Very High	Very Low	Negative
Increase Average Rent	Very Low	Low	Medium	Low	Low
More Subsidy for Social Housing	High	Very High	Low	Very High	Very High
Eliminate Landlord Levy	Medium	High	High	High	High
Lower Interest Rate	Low	Medium	Very Low	Medium	Medium

The efficiency of the various policies evaluated in this study can be determined by the various results generated in the individual policy analysis and Table 5.6. The individual impact of the studied policies on the different KPIs is specifically presented in Table 5.6 on a 5-point scale ranging from ”Very Low” to ”Very High”, with ”Very Low” denoting the policy with the least positive impact and ”Very High” denoting the policy with the most positive impact. As previously mentioned, all of the studied policies had a beneficial impact on the different KPIs, with the exception of the policy More Planning Capacity for Social Housing on the Solvency Ratio. Therefore, the word ”Negative” is used to indicate the negative impact that this policy has on the Solvency Ratio instead of the normal 5-point scale.

The first thing that can be seen from Table 5.6 is that, despite being the least successful for the other KPIs, the More Planning Capacity for Social Housing policy is the most effective for lowering the SGEI Houses Shortage and the Average Condition Score of SGEI Houses. It should be highlighted that this policy intervention works best for the housing shortage and improves the housing conditions of SGEI homes while having the least impact on the housing shortage and conditions of Non SGEI homes. This leads to the conclusion that the policy More Planning Capacity for Social Housing is the most suitable to reduce the housing shortage and improve the housing conditions of SGEI homes.

Subsequently, this table demonstrates that the More Subsidy for Social Housing policy is the most effective in lowering the Non SGEI Houses Shortage and the Average Condition Score of Non SGEI Houses while raising the Solvency Ratio. Although this policy has less of a beneficial impact on the other KPIs, Table 5.6 shows that the SGEI Houses Shortage is more positively affected by this policy than the Average Condition Score of SGEI Houses. This leads to the conclusion that the policy More Subsidy for Social Housing is most suited to reduce the scarcity of Non SGEI houses, enhance the living standards of Non SGEI houses, and strengthen the financial situation of social housing associations.

Finally, this table demonstrates that the policy Eliminate Landlord Levy is the best among the remaining policies investigated in this analysis. This is due to the fact that policies Increase Average Rent and Lower Interest Rate generally have a medium to a low positive impact on the KPIs, whereas the policy Eliminate Landlord Levy has a medium to a high positive impact on the KPIs. Particularly, Table 5.6 shows that this policy had a high impact on most of the KPIs, with the exception of SGEI Houses Shortage, where it had a moderate impact.

5.4.2. Effect of Multiple Policy Intervention

Since the individual policy analysis in the preceding section demonstrated that there is no single policy that can most effectively improve all of the studied KPIs, it was decided to conduct a multi-policy analysis. In this multi-policy analysis, the three most effective policies from the individual policy analysis were combined. The policy combinations listed in Table 5.7, – specifically (1) More Planning Capacity for Social Housing + More Subsidy for Social Housing, (2) More Planning Capacity for Social Housing + Eliminate Landlord Levy, and (3) More Subsidy for Social Housing + Eliminate Landlord Levy –, were examined in this analysis. In particular, the first two policy combinations lead to improved cash flow and better land allocation for the social housing associations. It is important to note that every combination enhances this cash flow in a different way. To be more exact, the first combination involves increasing associations' income, whilst the second involves reducing associations' costs. The main objective of the third policy combination is to raise social housing associations' income while concurrently reducing their expenses in order to increase their cash flow.

Table 5.7: Policy combinations based on the most effective individual policies.

	More Planning Capacity for Social Housing	*More Subsidy for Social Housing*	*Eliminate Landlord Levy*
More Planning Capacity for Social Housing		1	2
More Subsidy for Social Housing	1		3
Eliminate Landlord Levy	2	3	

In this section of the report, the effect of the most efficient policies in this study will be mapped out by comparing the behaviour of the various KPIs in an individual policy intervention with the policy combinations of the most effective policies. Similar to the individual policy analysis, the behaviour of a KPI at the base case is referred to as the "Base Case". While the behaviour of the KPI during a policy intervention is indicated using the name of the associated policy. However, the titles of policies More Planning Capacity for Social Housing and More Subsidy for Social Housing have been condensed in the figures of this analysis to avoid having overly long policy names. For example, the behaviour of the KPIs during a model run where the policy combination More Planning Capacity for Social Housing + More Subsidy for Social Housing is applied is indicated by More Planning Capacity + More Subsidy. The results of the policy analysis can be seen in Figures 5.17 - 5.21.

By comparing the different results, it can be observed that all of the studied policies in the multi-policy analysis had a beneficial impact on the different KPIs, with the exception of the policy More Planning Capacity for Social Housing together with the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) on the Solvency Ratio (consult Figure 5.21). To be specific, all policies that form part of this analysis, with the exception of the one specified, leading to a rise in the Solvency Ratio and a decrease in the other KPIs – the SGEI Houses Shortage, Non SGEI Houses Shortage, Average Condition Score of SGEI Houses, and Average Condition Score of Non SGEI Houses. Similar to the individual policy analysis, it can be observed that the degree of influence that these interventions have on the various KPIs is what separates them from one another. Also in this analysis, it is evident that the investigated policies mainly influence the KPIs SGEI Houses Shortage and Solvency Ratio. The reason for this is that only for these two KPIs have the most desired target behaviour changes been observed. In general, the policy combinations studied in this analysis had resulted in the largest decrease in the SGEI Houses Shortage, along with the largest increase in the Solvency Ratio compared to the base case and the individual policy analysis (see Figures 5.17 and 5.21). This is primarily attributable to the fact that with the exception of the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3) on the Average Condition Score of SGEI Houses, all policy combinations outperform the individual policies in the condition score. In order to gain a better understanding of the effect of the different policies studied in the multi-policy analysis on the KPIs, the influence of these policies per KPI will be discussed below. Given that each researched policy has a different degree of influence on each KPI, Table 5.8 summarizes the individual effects of these policies on the KPIs to make comparison easier.

To begin with, Figure 5.17 shows the influence of the policy interventions on the SGEI Houses Shortage over time. Based on this figure, it can be observed that the policies More Subsidy for Social Housing and Elimination Landlord Levy, as well as the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3), generally exhibit approximately the same behaviour as the base case. Despite this phenomenon, it should be noted that the value of SGEI Houses Shortage may be lower than the base case from the year 2022 onward. As was already mentioned, this is mainly due to the fact that in this study it was decided that all policies will come into effect after the year 2022. Given that the main objective of each of these policy initiatives is to increase the cash flow of social housing associations, which will subsequently improve their Solvency Ratio, it can be concluded that similarly to the individual policy analysis, a significant increase in the Solvency Ratio will only have a minor impact on the SGEI Houses Shortage. This is due to the fact that, as was already indicated, the housing associations' Solvency Ratio already exceeded the 15% threshold for investments in SGEI Houses in the base case, demonstrating that the associations already had the necessary financial means to do so from the start. Although this KPI was slightly decreased by these policy interventions, it should be emphasized that policy combination 3 had the most beneficial effects.

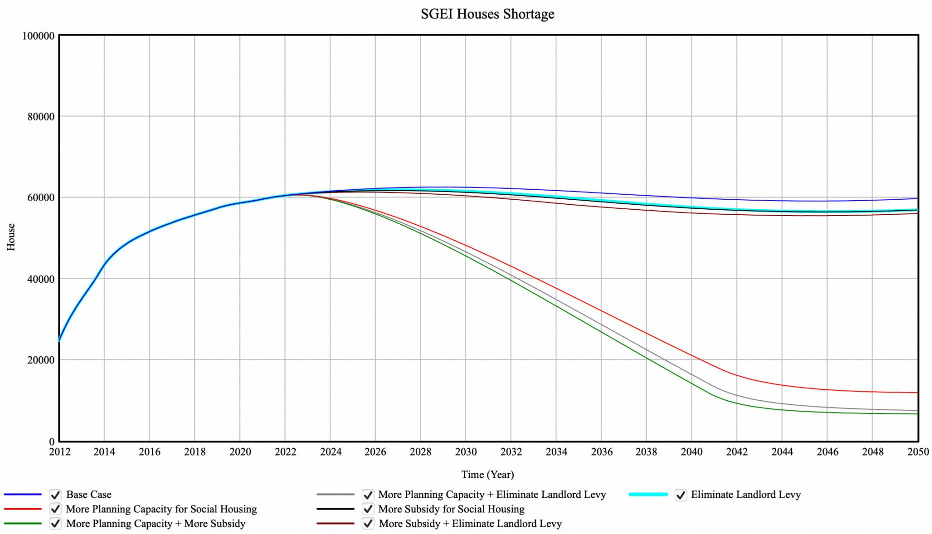

Figure 5.17: Multi-Policy analysis results of the SGEI Houses Shortage.

Ultimately, it can be observed that the policy More Planning Capacity for Social Housing, as well as the policy combinations More Planning Capacity for Social Housing + More Subsidy for Social Housing (1), and More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) are the most efficient policy interventions that policymakers can implement to significantly lower the SGEI Houses Shortage. Based on Figure 5.17, it can be seen that these policy combinations outperform the More Planning Capacity for Social Housing as an individual policy, with policy combination 1 being the most effective policy intervention at reducing the SGEI Houses Shortage. The individual policy reduced the shortage of SGEI homes from 2022 to a value of about 12,000 by the year 2050, which is significantly lower than the 60,000 housing shortage in the base case. However, the policy combinations reduced the SGEI Houses Shortage from that same year to values that were even lower by the year 2050, with policy combination 1 reaching 6,626 homes and policy combination 2 reaching 7,452 homes by that time. These policy combinations allow for improved cash flow and better land distribution for social housing associations, which not only guarantees that more land will be made available for the construction of social housing, but also that these associations will have the financial resources to maximize the production of SGEI houses on the additional lands, causing a rapid increase in the housing supply. A faster increase in the housing supply compared to the housing demand will ultimately cause the SGEI Houses Shortage to decrease.

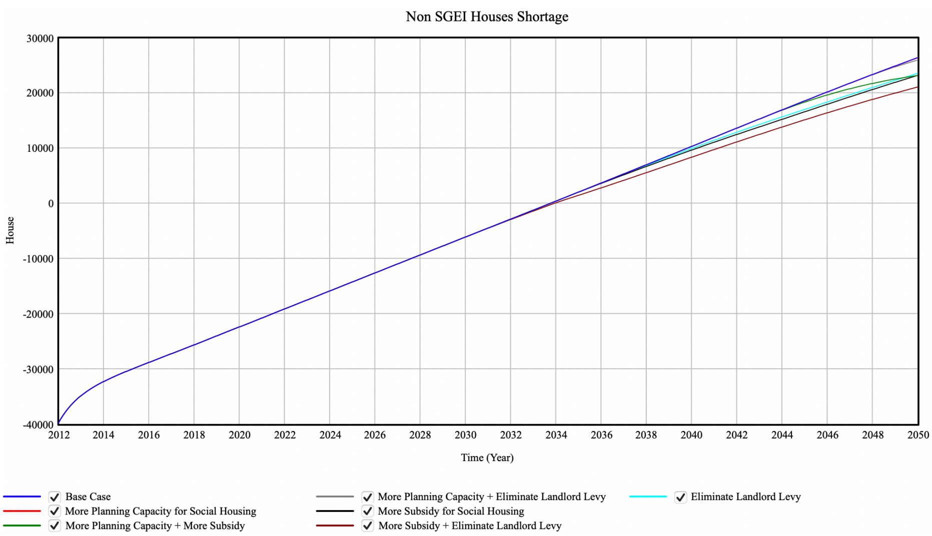

Figure 5.18: Multi-Policy analysis results of the Non SGEI Houses Shortage.

Subsequently, Figure 5.18 shows the influence of the policy interventions on the Non SGEI Houses Shortage over time. Based on this figure, it can be observed that the policy More Planning Capacity for Social Housing, as well as the policy combinations More Planning Capacity for Social Housing + More Subsidy for Social Housing (1), and More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) generally exhibit approximately the same behaviour as the base case. Despite this behaviour, it should be emphasized that starting around the year 2036, the value of the Non SGEI Houses Shortage will be less than the base case. However, due to the limited impact of these policy interventions on the Non SGEI Houses Shortage, this is not observable in Figure 5.18, except for policy combination 1, where the decline of the Non SGEI Houses Shortage will start to show around the year 2046. This is because, with the exception of the More Planning Capacity for Social Housing policy and policy combination 2 which has actually ensured a decline in the Solvency Ratio, policy combination 1 has only produced a small improvement in the Solvency Ratio compared to the other investigated policy interventions, as can be seen in Figure 5.21.

As was said previously, a greater Solvency Ratio enables housing organizations to invest more in the construction of new Non SGEI houses, among other things, boosting the housing supply. Although a faster increase in housing supply compared to housing demand will ultimately lead to a decrease in the Non SGEI Houses Shortage, in this case, only a few homes have been built as of 2046 because of the limited improvement in the Solvency Ratio brought on by the policy combination 1 that took some time to reach the required 40% threshold to invest in the construction of Non SGEI homes. Besides, there would be no house construction even if housing organizations had access to more available land if they lacked the financial resources to spend on Non SGEI homes. In light of this and the fact housing associations were already unable financially to invest in Non SGEI homes in the base case, the decline in the Solvency Ratio together with the better land distribution for social housing associations had no effect on the Non SGEI Houses Shortage. It should be noted that although these policy interventions marginally decreased the Non SGEI Houses Shortage, policy combination 1 had the most beneficial effects on this housing shortage, while the policy More Planning Capacity for Social Housing had the least favourable effects.

However, the implementation of policies Eliminate Landlord Levy, and More Subsidy for Social Housing, as well as the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3) has resulted in a decrease in the Non SGEI Houses Shortage, where the latter is the most efficient in view of the final value of the Non SGEI Houses Shortage in 2050. Besides, the Eliminate Landlord Levy policy is the least effective of these three. The research findings indicate that when policy combination 3 is implemented, this KPI's value was approximately 21,000 dwellings in the year 2050. For the policy Eliminate Landlord Levy, the value of this KPI was 23,513 houses in the year 2050, while that of the policy More subsidy for Social Housing was 23,142 houses in the year in question. In general, the influence of these three policies on the Non SGEI Houses Shortage can be explained, as only these policies provide a higher Solvency Ratio than the 40% threshold, that is needed in order to invest in the Non SGEI houses. This in turn ensures that are more investments in the construction of Non SGEI houses, which ultimately expands the housing supply for low-middle-income households. Since the discrepancy between housing supply and demand in this industry will reduce as a result of a faster increase in housing supply relative to housing demand, this will ultimately result in a decrease in the Non SGEI Housing Shortage. Ultimately, the lowest Non SGEI Housing Shortage is guaranteed by policy combination 3 because it achieves a higher Solvency Ratio faster than the policies Eliminate Landlord Levy and Increase Subsidies for Social Housing.

Furthermore, Figure 5.19 shows the influence of the policy interventions on the Average Condition Score of SGEI Houses over time. Based on this figure, it can be observed that the same policy interventions as those of the SGEI Houses Shortage, namely More Subsidy for Social Housing and Elimination Landlord Levy, as well as the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3), generally exhibit approximately the same behaviour as the base case. Despite this, it should be noted that the value of the Average Condition Score of SGEI Houses will be lower than the base case starting approximately in the year 2026. As was previously stated, this is mainly due to the fact that in this study it was decided that all policies will come into effect after the year 2022. Given that the effect of these policies on this KPI is only apparent once the new homes have been built or the existing homes have been maintained, hence the decline in this condition score cannot be noticed in Figure 5.14 until a few years after 2022. The decrease in value of the Average Condition Score of SGEI Houses is not visible in Figure 5.14, much like the outcomes of the Non SGEI Houses Shortage, due to the limited influence of these policies on this KPI. All of these policies help increase the Solvency Ratio of the social housing associations, leading to housing organizations being better able to finance both new buildings and house upkeep of SGEI houses, which ultimately lowers the Average Condition Score of SGEI Houses. However, because the housing associations' Solvency Ratio already exceeded the threshold of 15% in the base case for investments in

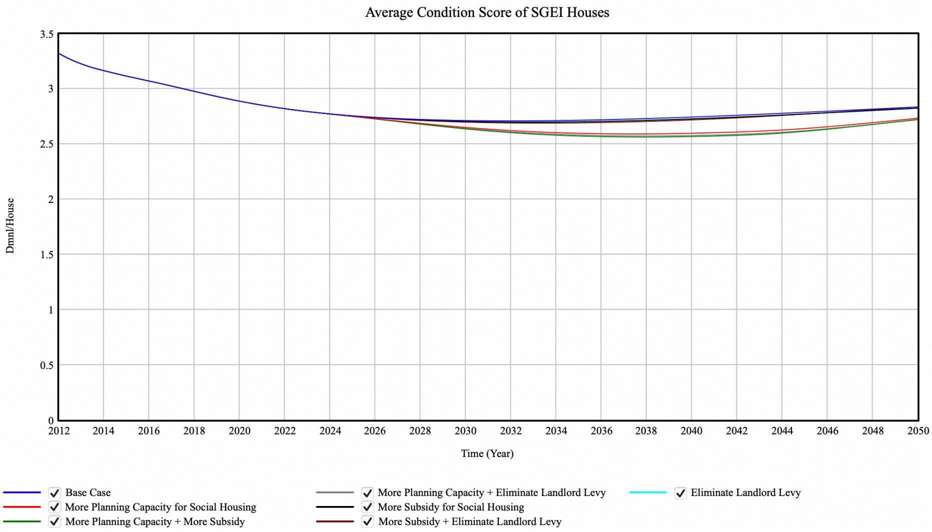

Figure 5.19: Multi-Policy analysis results of Average Condition Score of SGEI Houses.

SGEI Houses, demonstrating that they had the financial means to do so from the start, the increase in the Solvency Ratio caused by these policies only had a minor impact on this KPI. Although this KPI was slightly decreased by these policy interventions, it should be emphasized that policy combination 3 had the least beneficial effects compared to the policies More Subsidy for Social Housing and Elimination Landlord Levy.

Ultimately, it can also be concluded from this figure that the policy More Planning Capacity for Social Housing, as well as the policy combinations More Planning Capacity for Social Housing + More Subsidy for Social Housing (1), and More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) are the most efficient policy interventions that policymakers can implement to significantly lower the Average Condition Score of SGEI Houses. Based on Figure 5.17, it can be seen that these policy combinations outperform the More Planning Capacity for Social Housing as an individual policy, with policy combination 1 being the most effective policy intervention at reducing the Average Condition Score of SGEI Houses. The individual policy causes the KPI to decrease from around 2027 until it reaches a value of about 2.75 by the year 2050, which is lower than the approximately 2.83 condition score that can be seen in the base case. However, the policy combinations reduced the SGEI Houses Shortage from that same year to a value of about 2.72 by the year 2050. These policy combinations allow for improved cash flow and better land distribution for social housing associations, which not only guarantees that more land will be made available for the construction of social housing, but also that these associations will have the financial resources to maximize the production of SGEI houses on the additional lands, causing a rapid increase in the housing supply. A faster increase in SGEI house construction will cause a reduction in the Average Condition Score of SGEI Houses, as newly constructed homes have a condition score of 1 which will pull the average housing condition down.

In addition, Figure 5.20 shows the influence of the policy interventions on the Average Condition Score of Non SGEI Houses over time. Based on this figure, it can be observed that the same policies as those of the Non SGEI Houses Shortage, namely the policy More Planning Capacity for Social Housing, as well as the policy combinations More Planning Capacity for Social Housing + More Subsidy for Social Housing (1), and More Planning Capacity for Social Housing + Eliminate Landlord Levy (2), generally exhibit approximately the same behaviour and remains around the same values as the base case. Despite this, it should be emphasized that starting around the year 2038, the value of the Non SGEI Houses Shortage will be less than the base case. Given that the effect of these policies on this KPI is only apparent once the new homes have been built or the existing homes have been maintained, the decline in this condition score cannot be noticed in Figure 5.20 until a few years after 2034 (which is the year that these policies started to influence the Non SGEI housing sector). However, due to the limited impact of these policies on the Average Condition Score of Non SGEI Houses, this is not observable in Figure 5.20. This is because, with the exception of the More Planning Capacity for Social Housing policy which has actually ensured a decline in the Solvency Ratio, the Increase Average Rent policy has only produced a small improvement in the Solvency Ratio compared to the other policies, as can be seen in Figure 5.21, except for policy combination 1, where the decline of the Non SGEI Houses Shortage will start to show around 2046.

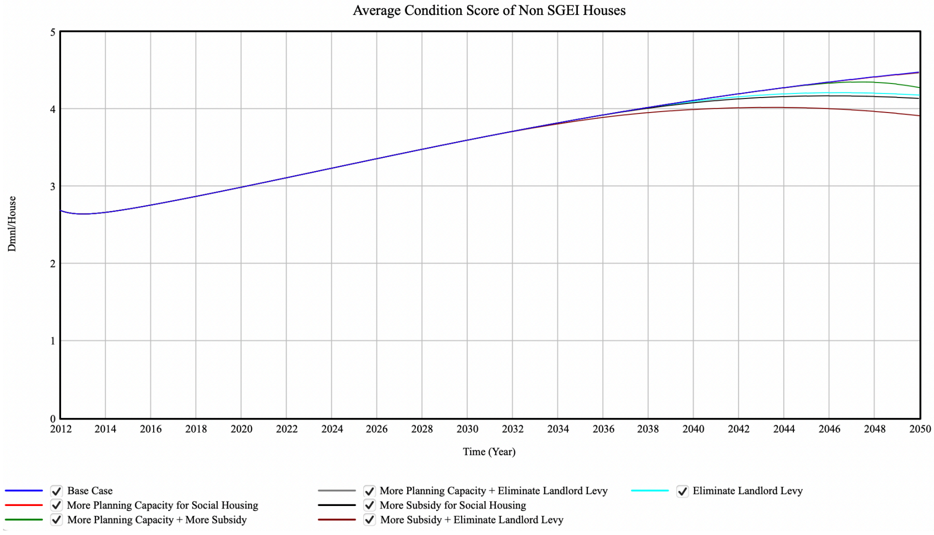

Figure 5.20: Multi-Policy analysis results of the Average Condition Score of Non SGEI Houses.

Similar to the Non SGEI Houses Shortage, only policy combination 1 has slightly improved the Solvency Ratio, which has resulted in the construction of only a small number of homes as of 2046 in order to lower the average housing condition. Therefore, the decline of the Average Condition Score of Non SGEI Houses starting from 2046 is restrained. Moreover, the More Planning Capacity for Social Housing policy and policy combination 2 which has actually ensured a decline in the Solvency Ratio. As mentioned before, even if housing associations have access to more available land, if they lack the financial resources to invest in the Non SGEI homes, there would be no housing construction in order to improve the housing conditions. In light of this and the fact housing associations were already unable financially to invest in Non SGEI homes in the base case, the decline in the Solvency Ratio and the better land distribution for social housing associations had no effect on the Average Condition Score of Non SGEI Houses. It should be noted that although these policy interventions marginally decreased the Non SGEI Houses Shortage, policy combination 1 had the most beneficial effects on this housing shortage, while the policy More Planning Capacity for Social Housing had the least favourable effects.

As with the results of the Non SGEI Houses Shortage, it can be noted that a significant difference in value can be seen between the base case and the policies Eliminate Landlord Levy, and More Subsidy for Social Housing, as well as the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3), where the latter is the most efficient in view of the final value of the Average Condition Score of Non SGEI Houses in 2050. The research findings indicate that when policy combination 3 is implemented, this KPI's value was 3.91 in the year 2050. For the policy Eliminate Landlord Levy, the value of this KPI was 4.18 in the year 2050, while that of the policy More subsidy for Social Housing was 4.13 in the year in question. In general, the impact of these three policies on the KPI can be explained, as both policies offer a higher Solvency Ratio than the 40% threshold, which is needed in order to invest in the construction of new Non SGEI houses, as well as the maintenance of these houses. On the one hand, since newly built homes have a condition score of 1, increasing the investment in the building of Non SGEI homes will ultimately result in a decrease in the Average Condition Score of Non SGEI Houses. On the other hand, increasing the investment in the construction of Non SGEI homes will ultimately lead to a decrease in the Average Condition Score of Non SGEI Houses because the conditions of the properties will be improved during the maintenance process, reducing each maintained Non SGEI house by 1 or more scale points depending on the type of maintenance. Finally, the lowest Average Condition Score of Non SGEI Houses is guaranteed by policy combination 3 because it achieves a higher Solvency Ratio faster than the individual policies Eliminate Landlord Levy and Increase Subsidies for Social Housing.

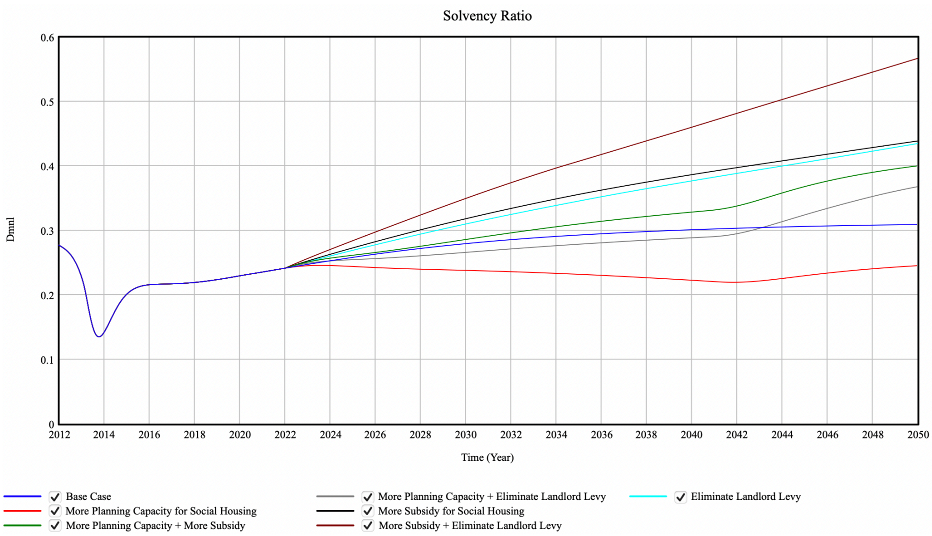

Figure 5.21: Multi-Policy analysis results of the Solvency Ratio.

Finally, Figure 5.21 shows the influence of the policy interventions on the Solvency Ratio over time. Based on this figure, it can be observed that there is no single policy that causes the KPI to exhibit the same behaviour as the base case. The results show that the policy More Planning Capacity for Social Housing and the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) are the least efficient for the Solvency Ratio. The reason for this is that the individual policy ensures that the Solvency Ratio stays about the same at about 25% instead of increasing to about 31% in the base case. Even if this policy combination results in a little increase in the Solvency Ratio as soon as they go into effect in 2022, this policy intervention will remain below the Solvency Ratio of the base case until 2043. In short, these policy interventions ensure that the Solvency Ratio is lower than the base scenario for (the majority) of the model run, while a value higher than the base case is desirable for this KPI. Given that these interventions ensure that housing associations will have access to additional land for the development of new social housing, it will lead to the massive building of SGEI homes in order to reduce the shortage from roughly 60,000 to 12,000 dwellings in the case of the individual policy and 7,452 in the case of the policy combination, as illustrated in Figure 5.17. Since the finance for new home building comes from taking out new loans, a big increase in the production of SGEI homes will cause a speedy rise in debt credit. Due to a delay in home planning and construction, the debt credit is increasing more quickly than the total credit, which will cause the Solvency Ratio to decline.

Ultimately, it turns out that of the other policy interventions, the More Subsidy for Social Housing + Eliminate Landlord Levy (3) is the policy combination that is most efficient for the Solvency Ratio. With this policy, this KPI amounts to a value of approximately 57% in the year 2050, which is well above the threshold for the various housing types. This is because this policy guarantees to raise social housing associations' income while concurrently reducing their expenses in order to increase their cash flow. As a result, the social housing associations will turn a profit as their income exceed their expenses. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital.

Table 5.8: Impact of the multi-policy analysis on the KPIs.

	SGEI Houses Shortage	Non SGEI Houses Shortage	Average Condition Score of SGEI Houses	Average Condition Score of Non SGEI Houses	Solvency Ratio
More Planning Capacity for Social Housing	Slightly High	Very Low	Slightly High	Very Low	Negative
More Subsidy for Social Housing	Low	High	Low	High	High
Eliminate Landlord Levy	Very Low	Slightly High	Slightly Low	Slightly High	Slightly High
More Planning Capacity for Social Housing + More Subsidy for Social Housing	Very High	Slightly Low	Very High	Slightly Low	Slightly Low
More Planning Capacity for Social Housing + Eliminate Landlord Levy	High	Low	High	Low	Negative
More Subsidy for Social Housing + Eliminate Landlord Levy	Slightly Low	Very High	Very Low	Very High	Very High

The efficiency of the various policy interventions evaluated in this study can be determined by the various results generated in the multiple policy analysis and Table 5.8. The individual impact of the studied policies on the different KPIs is specifically presented in Table 5.8 on a 6-point scale ranging from ”Very Low” to ”Very High”, with ”Very Low” denoting the policy with the least positive impact and ”Very High” denoting the policy with the most positive impact. As previously mentioned, all of the studied policy interventions had a beneficial impact on the different KPIs, with the exception of the policy More Planning Capacity for Social Housing together with the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) on the Solvency Ratio. Therefore, the word ”Negative” is used to indicate the negative impact that this policy has on the Solvency Ratio instead of the normal 6-point scale.

The first thing that can be seen from Table 5.8 is that, despite being slightly ineffective for the other KPIs, the policy combination More Planning Capacity for Social Housing + More Subsidy for Social Housing (1) is the most effective for lowering the SGEI Houses Shortage and the Average Condition Score of SGEI Houses. Following this, in descending order of effectiveness, are the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) and the individual policy More Planning Capacity for Social Housing the most effective for lowering these KPIs. It should be noted that as these three policy interventions become less effective in lowering the SGEI Houses Shortage and the Average Condition Score of SGEI Houses, their effectiveness also lowers for the other KPIs. This leads to the conclusion that the policy combination of More Planning Capacity for Social Housing + More Subsidy for Social Housing (1) is the most suitable to reduce the housing shortage and improve the housing conditions of SGEI homes.

Subsequently, this table demonstrates that the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3) is the most effective in lowering the Non SGEI Houses Shortage and the Average Condition Score of Non SGEI Houses while raising the Solvency Ratio. Although this policy has less of a beneficial impact on the other KPIs, Table 5.8 shows that the SGEI Houses Shortage is more positively affected by this policy combination than the Average Condition Score of SGEI Houses. Following this, in descending order of effectiveness, are the policies More Planning Capacity for Social Housing, and Eliminate Landlord Levy the most effective for these KPIs. Despite being the least efficient of these policy interventions, Table 5.8 demonstrates that the policy Eliminate Landlord Levy has the opposite impact on the other KPIs compared to policy combination 3. In particular, the Average Condition Score of SGEI Houses is more positively affected by this policy combination than the SGEI Houses Shortage. This leads to the conclusion that the policy combination of More Subsidy for Social Housing + Eliminate Landlord Levy (3) is most suited to reduce the scarcity of Non SGEI houses, enhance the living standards of Non SGEI houses, and strengthen the financial situation of social housing associations.

5.4.3. Policy Effect under Uncertainty

The robustness of the examined policies was put to the test in this section of the chapter. In this study, this was made possible by combining the policies in Table 5.2 with the most influential uncertain parameters (see Table 5.5) to determine the effect of this combination on the behaviour of the KPIs, using the EMA Workbench. Because thousands of replications have been made and the KPI behaviour during the different policies intertwine, it was decided to also show the density distribution per KPI at the end of the model run. As a result, the bandwidth of the policy effect can be better displayed.

Given that the majority of the KPIs in this research are behaviorally sensitive to the investigated uncertain parameters, it was decided to examine the policies' robustness over both a short (until 2036) and a long term (until 2050). Figure 5.22 specifically shows the outcomes of the short-term analysis, whereas Figure 5.23 shows the outcomes of the long-term analysis. Below, a comparison of the short-term and long-term results will be covered in order to better understand the robustness of the various policies examined in this analysis.

By comparing the different results, it can be observed that there is a lot of overlap between the bandwidth of the various policy influences on the various KPIs. As a result, it can be concluded that in general there is not much difference between the robustness of the investigated policies. The most robust policies for each KPI in the short and long terms will be discussed here to better understand how the different analyzed policies' levels of robustness differ from one another. First of all, Figures 5.22 and 5.23 show that More Planning Capacity for Social Housing is the most reliable policy for reducing the SGEI Houses Shortage, both in the short and long terms, as the majority of the replications produced by this policy are at the lowest range attainable compared to the other policies.

Furthermore, Figure 5.22 makes it evident that for the Non SGEI Houses Shortage, all of the analyzed policies, with the exception of Increase Average Rent, are robust in the short term due to their similar bandwidths which are located at the lower range of the density distribution, with the Eliminate Landlord Levy policy outperforming the others. In fact, Figure 5.23 demonstrates that, when compared to other policies, the policy Eliminate the landlord Levy is the most effective way to address the shortage of Non SGEI houses over the long term because its bandwidth consists of the replications with the lowest Non SGEI Houses Shortage values.

Subsequently, based on the results it can be observed that the most robust policy for the average condition score of SGEI and Non SGEI houses in the short term is Increase Average Rent as its bandwidth is located at the lower range of the density distribution and consists of the replications with the lowest values (see Figure 5.22).

On the other hand, Figure 5.23 shows that the More Planning Capacity is the most robust policy for the Average Condition Score of SGEI Houses in the long term since its bandwidth peak at the lowest range of the density distribution. In spite of the fact that all other policies – aside from the More Planning Capacity for Social Housing policy – peak at the lowest range, the bandwidth of this policy contains the replications with the lowest Average Condition Score of Non SGEI Houses values. Therefore, it may be inferred that if this policy is implemented rather than the other policies, the policymakers will assume higher risks in terms of the reduction of the Average Condition Score of Non SGEI Houses.

In addition, the policy More Subsidy for Social Housing, which has a bandwidth that consists of the lowest Average Condition Score of SGEI Houses values and the highest peak at the lower range of the density distribution of the Average Condition Score of Non SGEI Houses, is the second-best option that is the most robust for both types of housing on the long run.

Finally, based on the findings, it can be concluded that the most robust policy for the Solvency Ratio in the short term is Increase Average Rent, whereas the most robust policy for this KPI, in the long run, is More Planning Capacity for Social Housing. The reason for this is that the bandwidths of both policies have the greatest peaks at the higher range of the density distribution.

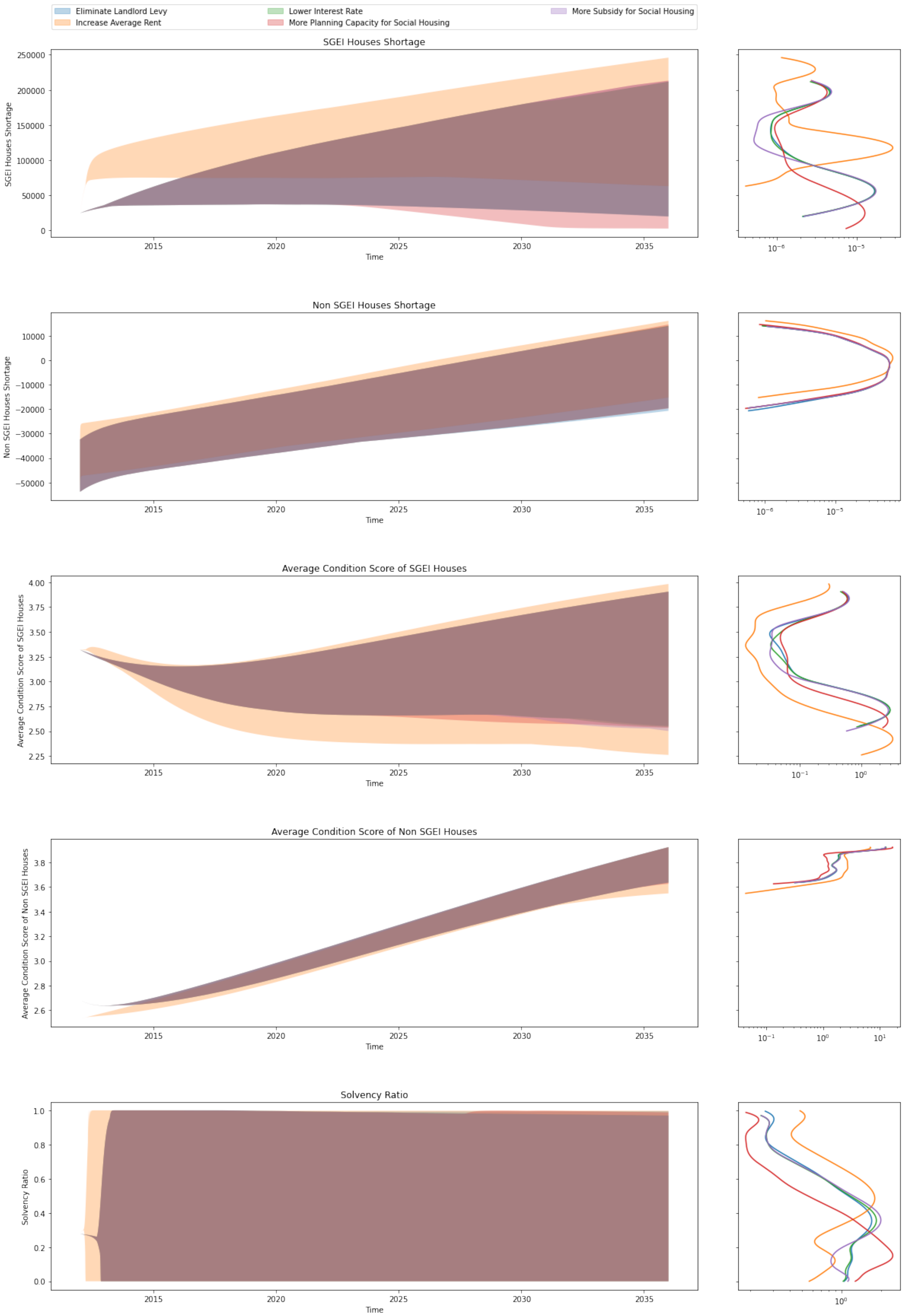

Figure 5.22: Behaviour of the KPIs per policy as a result of the short-term policy analysis.

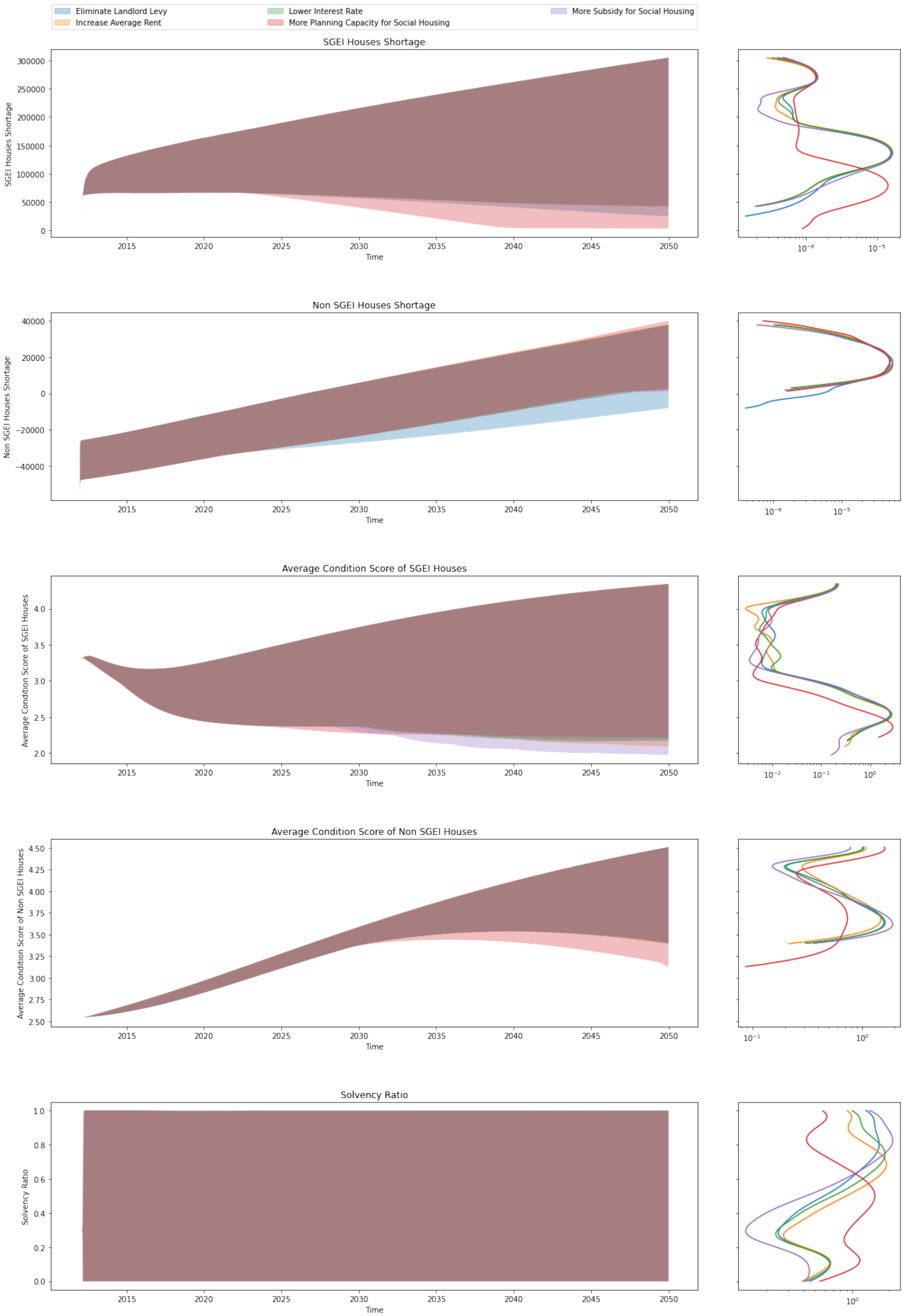

Figure 5.23: Behaviour of the KPIs per policy as a result of the long-term policy analysis.

6
Conclusion & Discussion

Despite the fact that adequate housing is a fundamental human right, it has become a critical concern in many European Union (EU) countries, particularly in the Netherlands (OHCHR, 2009; Rosenfeld, 2015; European Parliament, 2020). The Dutch government, similar to many other contemporary governments in the EU, has revived its interest in social housing as a solution to fulfil the rising demand for suitable housing in their nation (Madsen & Ghekière, 2021). However, Dutch social housing is currently confronted with a conundrum of rising demand and limited financial resources, indicating that it is unable to adequately handle its social obligation. As a result, addressing the present housing crisis through the social housing market will necessitate additional legislative initiatives.

Nevertheless, present policies in the Netherlands have failed to alleviate the current housing scarcity, which may be partially attributable to a lack of understanding of the social housing market's changing mechanisms. Therefore, the focus of the present study is to gain a better understanding of the Dutch housing sector, particularly the dynamic mechanisms that operate in this complex system, in hopes of identifying a policy strategy that Dutch policymakers can implement to help the social housing providers to increase the availability of adequate rental housing in order to meet the rising housing demand.

Given the fact that the severity of the social housing problem varies greatly across Dutch urban regions, it was decided to investigate the underlying mechanisms in the social sector in the Haaglanden region. Due to the severity of the social housing sector in the Haaglanden urban region, potential policy measures identified to address the housing issues in this region are likely to be successful in other regions of the Netherlands. In this study, this policy strategy was identified by conducting various analyses (including uncertainty and policy analyses) using a simulation model that adheres to the system dynamics (SD) methodology. Contrary to what has been typically done by Dutch studies in this field, these analyses are accomplished by combining the SD technique with the Exploratory Modeling and Analysis (EMA) methodology – which employs computer experiments to support decision-making under uncertainties. Given the dynamic complexity and deep uncertainty linked to the researched system, this method was performed to draw valid conclusions regarding the Dutch social housing market.

In order to acquire a better understanding of the findings of this study, the main conclusions reached based on the obtained results of the performed analyses will be discussed first in this chapter (section 6.1). Subsequently, the academic discussion can be found in section 6.2.

6.1. Conclusion

Based on the results of the various analyses conducted in this study, different insights can be obtained about the Dutch social housing system. This section of the conclusion will provide a clear depiction of these insights. Firstly, the current situation of the Dutch social housing market is presented in section 6.1.1. Subsequently, section 6.1.2 provides detailed information regarding how the social housing system is expected to evolve over time. Finally, the relative impact of the studied policies on the studied social housing system will be discussed in section 6.1.3.

6.1.1. Existing Social Housing

In this section of the conclusion, the insights regarding the current condition of the Dutch social housing market will be discussed. These findings, in particular, were discovered through a literature review. Besides, it was decided to divide the learned insights into three categories – Housing Shortage, Housing Quality, and Policy – in order to present them in a clear and concise manner.

Housing Shortage

As a result of the country's rapid population growth in comparison to the expansion of the housing supply, the Netherlands is currently experiencing a housing shortage of approximately 314,700 properties – which accounts for 3.9% of the existing housing supply (Groenemeijer, 2022). To make matters worse, a recent study predicts that the housing shortage will only worsen over the next few years, reaching 316,000 units in 2024, due to the rapid increase in the number of (one-person) households in the Netherlands (Capital Value, 2022). Additionally, Greater Amsterdam (6.7% in 2022), Delft and Westland (6.5% in 2022), and Flevoland (5.5% in 2022) will see the greatest housing shortages in the Netherlands. Consequently, Capital Value (2022) predicts that over the next five years, more than 1.3 million households will look for a home on average, with 46% of the yearly household seekers opting for rental properties. Of the potential tenants, 75% are looking for regulated rental properties, while 25% are looking for liberalized rentals (Capital Value, 2022). This is due to the fact that the regulated rental market, where annual demand exceeds supply by 64,000 dwellings, exhibits the biggest disparities between supply and demand today (Capital Value, 2022). Subsequently, the current liberalized rental market also has a significant gap, with annual demand surpassing supply by 16,000 properties (Capital Value, 2022).

Since 2018, housing associations have been the largest group of landlords in the rental sector, with over 2.1 million social rental homes, 92% of which are under the liberalization limit of €752.33 per month in 2021 (BZK, 2021c). However, recent research suggests that housing associations are unable to properly handle their social responsibilities in the current environment in the Netherlands (Penders, 2020). First of all, housing associations are expected to construct more than 25,000 new social houses each year until 2035, with the number of dwellings that must become more sustainable gradually increasing from 25,000 to over 60,000 (Penders, 2020; Madsen & Ghekière, 2021). According to Penders (2020), approximately €116 billion is required for all investments up to and including 2035, however, around €30 billion in social tasks (nearly 25% of the total amount) will not be accomplished since housing associations' expenditures (interest, taxes, maintenance, and management) are rising faster than their income, namely rentals. Several recent studies believe that the landlord levy's rise over time is mostly to blame for the current housing associations' financial difficulties and that it should be repealed (Aedes, 2020; Lijzenga et al., 2020). However, the study of Briene et al. (2019) on tax reductions in the period 2012-2016 found no significant positive relationship between the degree of intensity of the tax reduction and the investment ratio of housing associations in new housing construction, despite the fact that approximately 77% of housing associations used it and received on average €1.5 billion in tax reductions.

Furthermore, Capital Value (2022) anticipates that it will be very challenging to supply acceptable, inexpensive rental housing in the upcoming years, in part because of the sharp increase in construction costs and the high land costs (which together comprise the foundation costs of social housing corporations). The foundation cost per m^2 grew by 13% from €2,256 in 2019 to €2,560 in 2020 (Van Dalen & Van Eijs, 2021). According to Van Dalen & Van Eijs (2021), the main cause of this rise in foundation costs is an increase in construction prices, which rose by as much as 18% in 2021 in a single year. Another factor that contributes to the current Dutch home industry's surge in foundation costs is high land expenses. In particular, land costs increased by 3% last year, bringing the average land costs to €22,861 per social house (Van Dalen & Van Eijs, 2021).

Housing Quality

To assesses the appropriateness of existing homes in the Netherlands, several techniques are currently utilized. The adequacy of the homes in the social housing stock is first and foremost evaluated by residential satisfaction[8]. According to the WoON 2021, 87% of all households in the Netherlands reported being content with their residences in 2021 (Stuart-Fox et al., 2022). Despite a slight improvement from the last survey in 2018 (+1%), the residential satisfaction is still lower than it was in 2009, when residential satisfaction stood at 90% (Kullberg & Ras, 2020; Stuart-Fox et al., 2022; Swagerman, 2022b). Besides, a recent study by Stuart-Fox et al. (2022)

[8] Residential satisfaction is the perception of the discrepancy between residents' expectations and reality regarding their homes, which is utilized to identify the elements that affect how satisfied a person is with their residence (Campbell et al., 1976; Amérigo & Aragones, 1997; Adriaanse, 2007).

asserts that current tenants have lower housing satisfaction than owner-occupiers, as evidenced by the fact that the housing satisfaction of tenants in both the social and private rental sectors is equal to 72% and lower than that of owner-occupiers (95%). Stuart-Fox et al. (2022) contends that this is primarily because, compared to owner-occupants, more renters feel that their property is not well maintained.

Furthermore, there are a number of methods that are also used in the Netherlands to evaluate the adequacy of the current housing stock that place a greater emphasis on the physical condition of the homes in comparison to residential satisfaction. The approaches that measure the home's energetic state, such as the Nearly Zero Energy Buildings (NZEB) for new construction and the energy label for existing properties, together with the condition measurement serve as a few examples of these evaluation methods (Van Plateringen, 2013; BZK, 2020; NEN, n.d.). Nevertheless, the main focus of this study was the condition measurement since recent research suggests that this is the most effective and objective methodology to gain the necessary knowledge about housing conditions to estimate maintenance costs, prioritize repairs, and enable better management and control of the building stock (Kuijper & Bezemer, 2016; Di Giulio et al., 2020; Piaia et al., 2021).

Recent data from the Aw was examined by the research editors of RTL Nieuws and revealed that one in every 25 (± 80 000) social rental properties for which a so-called condition score[9] is known is in moderate to very bad condition, i.e. from the condition score 4 onward (De Regt & Bunskoek, 2021). Inspector Roel Warring encourages housing associations to aim for a condition score of 2 (the ideal score) and to avoid buildings with conditions above the condition score of 4, as a house in this condition would soon (within three years) require considerable maintenance (De Regt & Bunskoek, 2021). More than 80 housing organizations around the nation appear to find this to be effective, although this is undoubtedly not the case for all housing associations. As an illustration, nearly half (49%) of the residences owned by the Woonstad Rotterdam fell into condition scores 4 to 6 (moderate to very poor).

Although three-quarters of the current social housing stock in the Netherlands is at least 30 years old (given the fact that the vast majority of the social dwellings were built before 1990), experts claim, "The fact that they are older is no excuse." (De Regt & Bunskoek, 2021; Aw, 2021). Poor conditions, such as leaks, mouldy walls and ceilings, or other hazards, might endanger people's safety or drastically lower their quality of life. According to Madsen & Ghekière (2021), people who live in substandard conditions may experience a range of diseases, stress, and social and economic isolation. In the social housing industry, deferred maintenance affects 36% of tenants who rent from housing associations. Aedes claims that there aren't enough resources to satisfy the rising demands that the Dutch housing associations must meet, including new home constructions and maintaining a high housing quality through proper maintenance (De Regt & Bunskoek, 2021).

Policy

The Dutch government has established a number of regulations to control this market ever since the first Housing Act was passed in 1901, which divided responsibility for the Dutch social housing market between the government and housing organizations (R. De Jong, 2013). According to Aw, home remodelling will continue to be crucial in the coming years (Aw, 2021; IenW, 2022). At the present rate of new building, purchase, demolition, and sale, it would theoretically take 130 years to replace the entire housing stock, which is insufficient to maintain a good quality of life (Aw, 2021). The Ministry of BZK has taken a variety of actions to make it attainable to provide enough high-quality, affordable housing in a friendly environment for individuals who need it.

First off, the Ministry of BZK is particularly interested in accelerating the completion of major housing projects by, among other things, offering financial support to municipalities (BZK, 2021a). Subsequently, the Ministry of BZK believes that the removal of the landlord tax will provide housing associations with adequate financial resources to resume their role in the social housing sector (De Jonge, 2022). Despite this, the housing associations in the Netherlands still lack the resources necessary to satisfy the growing demands, which include new construction and regular upkeep of the existing houses (De Regt & Bunskoek, 2021). This can be supported by the study of Briene et al. (2019) on tax reductions that found no significant positive causal relation between the degree of intensity of tax reduction and the investment ratio of housing associations in new housing construction. Due to the elevated household growth forecast of 848,000 families from 2021 to 2034, representing a 10.5% increase, the social housing deficit in the Netherlands would only get worse if the current situation is not resolved (Gopal et al., 2021).

[9]According to NEN (n.d.), a condition score is an objective value stated on a six-point scale (1 to 6, with 1 serving as the highest score and, consequently, the best level in terms of building condition) that represents the technical condition of a building component (see table 2.3).

6.1.2. Social Housing Evolution

This section will describe how the Dutch social housing system is anticipated to change over time in light of the base case and the uncertainty analyses carried out with the Dutch Social Housing Model developed in this study to indicate how the studied system will behave up until the year 2050. When examining the model's structure, three sub-models can be identified, namely the population sub-model, the housing market sub-model and the financial sub-model. First of all, the population sub-model provides insights into the extent of the housing demand in the Haaglanden region. Subsequently, the housing market sub-model displays the social housing supply in Haaglanden at any given time. In addition, the average condition score of the homes in this sub-model sheds light on the quality of these dwellings. Ultimately, the financial sub-model specifies how the homes that are added to or removed from the current home stock will be financed and what financial consequences these alterations entail for housing associations. To convey the obtained insights in a clear and simple manner, it was chosen to divide these insights into three categories: Housing Shortage, Housing Quality, and Uncertainty.

Housing Shortage

First of all, the results show that up to and including 2050 there will be a housing shortage in both the social housing market (hereinafter referred to as SGEI) and the housing market for middle-low-income households (hereinafter referred to as Non SGEI) in the Haaglanden urban region. In particular, the shortage of SGEI homes will remain at around 60,000 homes from now until 2050, while the shortage of Non SGEI homes will continue to rise to about 20,000 homes. This can be explained by the difficult financial situation of the social housing associations, which cannot meet their social obligations. The introduction of the landlord levy, which became active in 2013, has among others ensured that the housing associations had fewer financial resources to invest in new dwellings and/or maintenance of existing homes.

This study shows that the financial situation of the housing associations in the Haaglanden region will gradually increase throughout the coming years – in particular, the Solvency Ratio[10] show an increase from about 25% in the year 2022 to just over 30% in 2050 –, as the equity of the social housing associations increases faster than the debt capital. Due to the fact that properties become more expensive when demand is high and supply is limited, the value of social housing in this model and hence the equity is expected to increase in conjunction with the growing housing shortage of Non SGEI dwellings. In the coming years, it is anticipated that the social housing associations' expenditures, which are financed by taking out new loans, and thus the debt capital, will generally remain constant because they will only invest in the construction of a fixed number of SGEI homes due to its shortage remaining at around 60,000 homes after 2022. Additionally, beyond the year 2022, construction expenses in this model remain unchanged.

Despite the anticipated gradual increase in the Solvency Ratio, this study shows that the social housing corporations in this sector only have enough financial resources to invest in the social housing market, but not for the housing market for middle-low-income households. In the Netherlands, it has been found that a Solvency Ratio above 15% is required to be able to build SGEI houses, while this threshold is 40% for the Non SGEI houses. As a result, the lack of new housing construction in the market for middle-low-income households in the upcoming years, which accounts for the growth in the housing shortage in this sector, is explained by the fact that the 40% threshold to invest in Non SGEI houses has not been exceeded throughout this model simulation.

Subsequently, the results of this study showed that there are several factors in this system that are of importance for the housing shortage in Haaglanden. First of all, immigration and the proportion of the population designated to the Haaglanden social housing market or the housing market of middle-low income households are important for the housing shortage, as these factors influence the extent to which the housing demand increases. A high level of immigration, for instance, will increase the number of households that migrate to the location in question, leading housing demand to rise more quickly than the developments in the housing supply, which will only expand the gap between supply and demand for housing. As a result, the housing scarcity will worsen more quickly than it would if fewer households moved into the area. The same holds true if a higher portion of the population came to be appointed in the social housing market or the housing market of middle-low income households.

Furthermore, the housing shortage in Haaglanden is greatly impacted by factors that affect the housing supply, such as how quickly new homes become available on the housing market and the financial situation of the social housing associations. The amount of time it takes housing associations to plan for new construction is crucial to reduce the housing shortage. If this time is very short, new-build homes will eventually become available on the market sooner as opposed to a scenario where it takes a very long time to do so, which ultimately reduces the

[10] A key performance indicator (KPI) in this study that provides an overview of the financial situation of social housing organizations by demonstrating the extent to which their financial capacity will allow them to cover costs, achieve expansion, and grow.

shortage of SGEI Houses faster. As was previously stated, the financial situation of the social housing associations plays an important role in determining the housing shortage. This is because this factor determines whether these corporations have the financial means to fund the construction of new homes. The better their financial situation, the more new construction they can finance. A poor financial situation will, however, result in a lack of housing stock expansion, which will cause the housing demand to rise more quickly than the developments in the housing supply. As a result, there will be a greater housing shortage. Because of the severe housing scarcity, housing associations will construct more new homes in order to meet the rising housing demand. Given that these developments are financed by taking out new loans, the financial situation of the social housing associations will only worsen since the debt capital grows faster than the equity capital.

Housing Quality
In this study, it was decided to use the condition measurement method, which is stated in the average condition score, to describe the quality of the residences. As was already noted, a condition score is an objective value expressed on a six-point scale that reflects the technical condition of a building component. This component's six-point scale ranges from 1 to 6, with 1 representing the highest score and, consequently, the best building condition. The average condition score of existing houses is decreased by house maintenance since the conditions of the houses are improved during this process. In this study, a distinction is made between minor maintenance (including, among other things, the outside painting, and repairing the window frames) and major maintenance (including, among other things, the addition of extra insulation materials or the installation of a central heating system). Therefore, increasing maintenance expenditures will generally result in lower condition scores. Besides this direct influence that the maintenance exerts on the condition of the homes, there is also an indirect influence via the new-build development. More new-build development will result in a lower average condition score since newly constructed homes have a condition score of 1, meaning they are in the best condition possible.

The results of this study show that investing in more maintenance of homes will lead to better housing quality, in comparison to the production of new homes. Since the influence that the latter exerts on the housing quality is very limited, it is anticipated that thousands of new homes will need to be constructed before the average quality of existing homes improves to a comparable amount to maintenance. This study shows that up to and including the year 2050 there are sufficient financial resources to finance the maintenance of housing in the social housing market and not in the housing market of middle-low-income households. This can be observed as the average housing quality of the homes in the social sector will decrease by a 0.5 scale point in the year 2050 compared to the value in 2012, leading to a quality improvement of the houses in the social sector of the Haaglanden region. The Solvency Ratio has consistently exceeded that 15% threshold to invest in SGEI houses, resulting in the maintenance of these houses over the whole model run, which explains why the quality of SGEI homes is expected to improve. Meanwhile, in the housing market of middle-low-income households, the results of this research show an increase of almost 1.0 scale point in the year 2050 when compared with the value in 2012, representing a quality deterioration in this housing sector. The lack of maintenance in the market for middle-low-income households in the upcoming years, which accounts for the quality deterioration in this housing sector, is explained by the fact that the 40% threshold to invest in Non SGEI houses has not been exceeded throughout this model simulation.

Moreover, this study showed that there are several factors in this system that are of importance for the housing quality in the Haaglanden urban region. First of all, the results have shown that in the coming years mainly the number of new houses that are built will influence the determination of the housing quantity and not the speed with which these houses are made available as was the case in the past. The reason for this is that at the beginning of the model run it can be seen that the time it takes to build new homes exerted the most influence on the quality of the homes. If this time is very short, new-build homes will eventually become available on the market sooner as opposed to a scenario where it takes a very long time to do so, which ultimately reduces the average condition score of the houses faster as more homes with a condition score of 1 have entered the market.

Furthermore, it can then be seen that in the coming years it is precisely the quantity of newly built homes that will become important in determining the quality of the homes. The reason for this is that before the global crisis, more homes were planned to be built compared to after the crisis. Since the global crisis has caused housing demand to increase more strongly than housing supply due to the sharp increase in construction costs. As many homes were planned before, construction time had the most impact on the average quality of homes, as it affected how quickly new-build homes will eventually become available on the market. But now that the housing associations are in a bad financial situation and the construction costs have increased, fewer new homes can be planned. As a result, it is no longer a question of how quickly the homes will become available on the market, but the number of homes that can come on the market.

Uncertainty
Given that the researcher made educated assumptions about the values of the unknown parameters in the base case, and these parameters may actually have other values in practice, it can be observed that this model includes parameter uncertainties. Due to this, it was decided to experiment with the 24 uncertain parameters in the uncertainty analysis to examine the model behaviour (consult Table 5.1).

First of all, based on the results it can be observed that there are six uncertain parameters in the population sub-model that exert the most influence on the KPIs. In general, the housing demand in Haaglanden is determined by all these factors. The first four uncertain parameters – Average Birth Percentage, Average Immigration Percentage, Average Emigration Percentage, and Average Death Percentage – determine the general housing demand of the Haaglanden urban area, while the last uncertain parameters – Low Middle Income Percentage, and Low Middle Household Share in Social Market – determine the housing demand of the low-middle-income households. Based on the findings of the uncertain analysis, it is evident that the parameters affecting the general housing demand have the greatest impact on the SGEI Houses Shortage[11], Average Condition Score of SGEI Houses[12], and Solvency Ratio. In addition, the uncertainty results made it clear that the uncertain parameters that influence the housing demand for low-middle-income households are crucial for determining the Non SGEI Houses Shortage[13], and Average Condition Score of Non SGEI Houses[14].

With regard to the uncertain parameters affecting the general housing demand, an increase in these parameters, with the exception of Average Death Percentage and Average Emigration Percentage which has to make a decrease, will lead to higher housing demand. As with the SGEI Houses Shortage, this will lead to a faster increase in housing demand compared to the housing supply, causing the gap between housing demand and supply to widen and thus increasing the housing shortage. The housing shortage in turn will lead to more production of new homes. More new-build development will result in a lower Average Condition Score of SGEI Houses since newly constructed homes have a condition score of 1, meaning they are in the best condition possible. Because of this, the average condition score of the houses in the social sector will decrease. More new construction causes the total capital to increase after a while on the one hand, which leads to an increase in the Solvency Ratio. On the other hand, the production of new homes increases the debt capital almost instantaneously, as its construction is financed by taking out new loans. An increase in loan capital will lead to a decrease in the Solvency Ratio. If these two phenomena are equal, the Solvency Ratio will first decrease and after the housing stock is expanded with the new construction it will achieve an equilibrium state.

With regard to the uncertain parameters that influence the housing demand for low-middle-income households, if these factors become more prevalent, more households will fall into the low-middle income bracket, and a greater percentage of these households will look for housing with social housing corporations, causing housing demand to increase faster than the developments in the housing supply. As a result, the housing shortage for these households will worsen more quickly than in the case when these factors are lower, given that the demand for housing is smaller in the latter instance. Due to the housing scarcity, this housing market will invest in the construction of new homes for low-middle-income households. As previously noted, increased new-build construction will increase the number of properties with a condition score of 1, causing the average condition score of properties in the social sector to decrease.

Subsequently, the uncertain analysis makes it clear that there are four uncertain parameters in the social housing sub-model that exert the most influence on the KPIs. In general, all of these variables influence the housing supply in the Haaglanden urban region. The first three uncertain parameters – Average Shortage Reaction Time, Average Construction Time, and Major Maintenance Delay – determine how long it will take new or maintained homes to increase the housing supply, while the last uncertain parameter – Focus Percentage on New Construction – determines the amount of new (or maintained) homes that will increase the housing supply. Based on the findings of the uncertain analysis, it is evident that the parameters affecting how long it will take to increase the housing supply have the greatest impact on the SGEI Houses Shortage, Average Condition Score of SGEI Houses, and Solvency Ratio. Moreover, this analysis made it clear that the uncertain parameter that influences the amount of which the housing supply will increase is crucial for determining the Average Condition Score of Non SGEI Houses.

[11] KPI in this study that indicates the extent to which the SGEI houses supply does not satisfy demand for these houses.
[12] KPI in this study that describes the average quality of the current SGEI housing supply, with a lower condition score indicating greater quality.
[13] KPI in this study that indicates the extent to which the Non SGEI houses supply does not satisfy the demand for these houses.
[14] KPI in this study that describes the average quality of the current SGEI housing supply, with a lower condition score indicating greater quality.

An increase in the uncertain parameters affecting how long it will take to increase the housing supply will ensure that the houses will be accessible on the market sooner, causing the total capital and consequently the Solvency Ratio to increase more swiftly than when the construction duration was longer. As previously noted, increased new-build construction will also increase the number of properties with a condition score of 1, causing the average condition score of the properties in the social sector to decrease. Given that the maintained homes can be considered as dwellings that are added to the existing housing stock, just like new construction – because during major maintenance the homes are out of commission in order to complete the procedure (i.e., they do not form part of the available housing stock), and they are also financed through new loans –, causing the total capital and consequently, the Solvency Ratio to increase more swiftly than when the maintenance duration was longer.

Moreover, the higher the Focus Percentage on New Construction (the uncertain parameter that influences the amount of which the housing supply will increase) becomes, the more the housing associations invest in new construction, while fewer homes are maintained. In contrast to the Average Condition Score of SGEI Houses, an increase in new-building investment will not lead to a lower Average Condition Score of Non SGEI Houses. The reason for this is that in this model it is assumed that new construction can only take place in the event of a housing shortage, so since there is a housing surplus of Non SGEI Houses, no new homes will be built if the new construction investments increase. Just the opposite will take place. Because the majority of the investments are not in the maintenance of existing homes, the conditions of the homes will only deteriorate, causing the Average Condition Score of Non SGEI Houses to increase.

Finally, the results of this analysis illustrate that there are seven uncertain parameters in the economic sub-model that exert the most influence on the KPIs. All of these uncertain parameters collectively affect the cash flow of the housing associations in Haaglanden. In particular, the first two uncertain parameters – Information Delay, and Average WOZ Value Alteration Percentage – determine the income of the housing associations, while the rest uncertain parameters – Average Social Housing Size, Average Demolition Costs, Average Foundation Costs of Non SGEI Houses, Major Maintenance Cost Part, and Average Construction Costs Assumption – determine the expenses of the social housing associations. Based on the findings of the uncertain analysis, it is evident that the parameters affecting the income of the associations have the greatest impact on the SGEI Houses Shortage and Average Condition Score of SGEI Houses. Besides, the results made it clear that the uncertain parameters that influence the expenses of the associations are crucial for determining the Average Condition Score of SGEI Houses, and Solvency Ratio.

With regards to the uncertain parameters affecting the income of the associations, an increase in the Average WOZ Value Alteration Percentage, and a decrease in the Information Delay will ensure that the housing associations will make profits. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases more quickly than the total capital. Ultimately, the SGEI Houses Shortage and the Average Condition Score of SGEI Houses will decline as the Solvency Ratio rises as more money may be invested in new construction and upkeep of existing dwellings. As was previously indicated, the building of new homes results in a lower Average Condition Score of SGEI Houses, but maintaining existing homes can also guarantee this. Given the fact that the conditions of the buildings will be improved during the maintenance process, in this model a reduction of 1 or more scale points in the condition score of the residences (depending on the type of maintenance) that went through this procedure. However, the Solvency Ratio will deteriorate more quickly if these parameters are high and there is a high housing scarcity as opposed to a low value of this percentage. As a result, a low Solvency Ratio will also cause the housing demand to increase faster than the developments in the housing supply, which will only widen the gap between housing demand and supply. Because of the severe housing scarcity, housing associations will construct more new homes, which are financed by taking out new loans. Therefore, the Solvency Ratio will decline since the debt capital grows faster than the equity capital. The number of homes getting maintenance will also decrease as a result of the lowering Solvency Ratio, which will only worsen the average housing condition.

Besides, a decrease in the uncertain parameters that influence the expenses of the associations will ensure that the housing associations will have lower expenses. If income remains the same, lower expenses will guarantee that the housing associations will turn a profit. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital. If the amount of demolished houses is equal to the amount that the debt capital decrease, the Solvency Ratio will arrive at an equilibrium state. If there is an increase in the uncertain parameters that influence the expenses of the associations, the housing associations will be in the red as their expenses exceed their income. In the case that the housing associations are in red, the reverse will take place as the housing associations will need to take out more loans to cover all their expenses.

Last but not least, the results of the uncertainty analysis show that only the housing shortage of middle-low income households is numerically sensitive to these uncertain parameters since depending on the value combinations of these parameters, the behaviour remains the same while only the value of the shortage changes over time. However, the findings of this study demonstrate that the housing deficit of social housing, along with the housing quality, is behaviorally sensitive to these uncertain parameters because, depending on the value combinations of these parameters, it can result in a more extreme housing deficit/ worst housing quality or a housing shortage/quality that is better than the current situation.

6.1.3. Policy Impact on Social Housing

In this section, a description of how the Dutch social housing system is expected to change over time in light of the policy interventions used in this study will be provided. These insights were gained by performing various policy analyses with the developed model of this study. First, the investigated policy interventions of this study will be described. Secondly, the insights from each individual policy initiative will be discussed. Thirdly, the interaction between the most effective individual policies will be addressed. Finally, the findings regarding the robustness of the policy interventions used in this study will be presented.

Policy Description

This section will look at the policies that have been included in this research since the purpose of this study is, among other things, to identify policies that will enhance the system behaviour of the social housing market. The Dutch government has, as was previously described, implemented a variety of regulations to regulate this social housing market since the first Housing Act was passed in 1901 (R. De Jong, 2013). Of the government's most important social housing regulations from the previous century, only the policies Increase Average Rent, More Subsidy for Social Housing, More Planning Capacity for Social Housing, Lower Interest Rate, and Eliminate Landlord Levy were examined given the scope of this study (consult Table 5.2). This is due to the fact that the policies Increase Average Rent, More Subsidy for Social Housing, and Eliminate Landlord Levy all improve the cash flow of social housing associations, with Eliminate Landlord Levy lowering the expenditures while the other two policies increase the income of the social housing associations. The expectation is that improved income flow will put social housing businesses in a stronger financial position, allowing them to make more investments to address the housing shortage and quality. Furthermore, More Planning Capacity for Social Housing guarantees more land at the disposal of housing associations for the construction of new social housing and the exploitation of their existing housing compared to the current situation to meet the growing housing demand.

Individual Policy

Of the five different policies analyzed in this study, several observations could be made. In general, it can be seen that all of the policy changes under consideration, with the exception of the policy More Planning Capacity for Social Housing on the Solvency Ratio, have a favourable impact on both the housing shortage and quality, together with the financial situation of the social housing associations. In particular, each of these initiatives, with the exception of the one specified, lessens the housing shortage while improving the housing quality and financial situation of the social housing associations. Given that the More Planning Capacity for Social Housing policy ensures that housing associations will have access to additional land for the development of new social housing, it will lead to the massive building of SGEI homes in order to reduce the shortage in the social housing sector. Since the finance for new home building comes from taking out new loans, a big increase in the production of SGEI homes will cause a speedy rise in debt credit. Due to a delay in home planning and construction, the debt credit is increasing more quickly than the total credit, which will cause the Solvency Ratio to decline and remain lower than the base case through the model simulation.

Given that the majority of the policies are effective, it should be noted that the distinction between these interventions is in how much of an impact they exert on the housing shortage/quality, together with the financial situation of the social housing associations. Overall, it can be concluded that the following policies exert the most effective influence: (1) More Planning Capacity for Social Housing, (2) More subsidy for Social Housing, and (3) Eliminate Landlord Levy.

First of all, More Planning Capacity for Social Housing ensures that more building land will be made available to housing associations to build social housing, thereby reducing the housing shortage and simultaneously improving the housing quality. Through this policy, more building land will be made available to housing associations to build social housing, thereby increasing the construction of new SGEI Houses. A faster increase in the housing supply compared to the housing demand will ultimately cause the SGEI Houses Shortage to decrease. An increase in new construction will cause a reduction in the Average Condition Score of SGEI Houses, as newly constructed homes have a condition score of 1 which will pull the average housing condition down. It should be highlighted that this policy intervention works best for social housing while having the least impact on the housing for middle-low-income households. This is because the More Planning Capacity for Social Housing policy has ensured a decline in the Solvency Ratio. Moreover, because housing associations were already unable financially to invest in Non SGEI homes in the base case, the decline in the Solvency Ratio had no effect on the shortage and quality of Non SGEI houses.

More Subsidy for Social Housing and Eliminate Landlord Levy, on the other hand, promote housing associations' financial resources, enabling investment in new home construction and maintenance of existing homes, thereby reducing housing shortages while improving housing quality. It should be noted that these policy interventions work best for homes owned by middle-low-income households. In general, both policies offer a higher Solvency Ratio than the 40% threshold, which is needed in order to invest in the construction of new Non SGEI houses, as well as the maintenance of these houses. Since the discrepancy between housing supply and demand in this industry will reduce as a result of a faster increase in housing supply relative to housing demand, this will ultimately result in a decrease in the Non SGEI Housing Shortage. On the one hand, since newly built homes have a condition score of 1, increasing the investment in the building of Non SGEI homes will result in a decrease in the Average Condition Score of Non SGEI Houses. On the other hand, increasing the investment in the construction of Non SGEI homes will ultimately lead to a decrease in the Average Condition Score of Non SGEI Houses because the conditions of the properties will be improved during the maintenance process, reducing each maintained Non SGEI house by 1 or more scale points depending on the type of maintenance.

It should be noted that the policy Eliminate Landlord Levy has a medium to a high positive impact on all the KPIs studied in this research, while More subsidy for Social Housing has the most influence on the financial condition of the companies and consequently the Non SGEI housing sector, given that these policy interventions had resulted in the largest increase in the Solvency Ratio compared to the base case. This is because this policy guarantees that housing associations will have more income. If the expenses of these associations remain the same, a higher income will guarantee that the housing associations will turn a profit as their income exceed their expenses. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital. This also explains why the SGEI Houses Shortage is more positively impacted by this policy than the Average Condition Score of SGEI Houses, despite the policy having a less favourable effect on these KPIs.

Multiple Policy

Since the individual policy analysis in the preceding section demonstrated that there is no single policy that can most effectively improve all of the studied KPIs, it was decided to study a combination of the most effective policies identified in the individual policy analysis. In particular, the following combinations were examined in this analysis: (1) More Planning Capacity for Social Housing + More Subsidy for Social Housing, (2) More Planning Capacity for Social Housing + Eliminate Landlord Levy, and (3) More Subsidy for Social Housing + Eliminate Landlord Levy. Particularly, the first two policy combinations result in better land allocation for housing associations as well as enhanced cash flow. It should be emphasized that each combination improves this cash flow in a unique way. To be more precise, this is accomplished in the first combination by raising associations' income, whereas it is accomplished in the second combination by cutting costs. The third policy combination's primary goal is to increase cash flow by boosting social housing businesses' income while simultaneously cutting costs.

By comparing the different results, it can be observed that all of the studied policies in the multi-policy analysis had a beneficial impact on the different KPIs, with the exception of the policy More Planning Capacity for Social Housing together with the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) on the Solvency Ratio. To be specific, all policies that form part of this analysis, with the exception of the one specified, led to a rise in the Solvency Ratio and a decrease in the other KPIs. It was chosen not to include this in this section because the justification for these unfavourable effects was already covered in the previous section given that the rationale for the policy combination to have a negative effect on the Solvency Ratio is the same as the individual policy.

Similar to the individual policy analysis, it can be observed that the degree of influence that these interventions had on the various KPIs is what separates them from one another. In addition, with the exception of the policy combination More Subsidy for Social Housing + Eliminate Landlord Levy (3) on the Average Condition Score of SGEI Houses, all policy combinations outperform the individual policies in the condition score. This policy combination exercises the most effective increase in the Solvency Ratio of the social housing associations, leading to housing organizations being better able to finance both new buildings and house upkeep of SGEI houses, which ultimately lowers the Average Condition Score of SGEI Houses. This is because this policy guarantees to raise social housing associations' income while concurrently reducing their expenses in order to increase their cash flow. As a result, the social housing associations will turn a profit as their income exceed their expenses. With the help of this profit, the loans made will be repaid, which will increase the Solvency Ratio as the debt capital decreases faster than the total capital. However, because the housing associations' Solvency Ratio already exceeded the threshold of 15% in the base case for investments in SGEI Houses, demonstrating that they had the financial means to do so from the start, the increase in the Solvency Ratio caused by these policies only had a minor impact on this KPI.

This policy combination is the most effective at reducing the scarcity and enhancing the quality of Non SGEI homes, due to being the most effective policy intervention in raising the Solvency Ratio. More new houses can be developed and more existing homes can receive maintenance due to this increase in the Solvency Ratio, which will ultimately result in a reduction in the housing shortage and the average condition score of these homes. Following this, in descending order of effectiveness, are the policies More Planning Capacity for Social Housing, and Eliminate Landlord Levy the most effective for these KPIs. Despite being the least efficient of these policy interventions, the policy Eliminate Landlord Levy has the opposite impact on the other KPIs compared to policy combination 3. In particular, the Average Condition Score of SGEI Houses is more positively affected by this policy combination than the SGEI Houses Shortage.

Despite being slightly ineffective for the other KPIs, the policy combination More Planning Capacity for Social Housing + More Subsidy for Social Housing (1) is the most effective for lowering the SGEI Houses Shortage and the Average Condition Score of SGEI Houses. This policy combination allows for improved cash flow and better land distribution for social housing associations, which not only guarantees that more land will be made available for the construction of social housing, but also that these associations will have the financial resources to maximize the production of SGEI houses on the additional lands, causing a rapid increase in the housing supply. A faster increase in the housing supply compared to the housing demand will ultimately cause the SGEI Houses Shortage to decrease. Additionally, a faster increase in SGEI house construction will cause a reduction in the Average Condition Score of SGEI Houses, as newly constructed homes have a condition score of 1 which will pull the average housing condition down. Following this, in descending order of effectiveness, are the policy combination More Planning Capacity for Social Housing + Eliminate Landlord Levy (2) and the individual policy More Planning Capacity for Social Housing the most effective for lowering these KPIs. It should be noted that as these three policy interventions become less effective in lowering the SGEI Houses Shortage and the Average Condition Score of SGEI Houses, their effectiveness also lowers for the other KPIs.

The results of this analysis show that policy combination 1 generally exhibits approximately the same behaviour as the base case of the KPIs Non SGEI Houses SHortage and Average Condition Score of Non SGEI Houses. However, this policy combination will result in a decline in the Non SGEI Houses Shortage around the year 2046. This is because policy combination 1 only produced a small improvement in the Solvency Ratio compared to the other investigated policy interventions. As was said previously, a greater Solvency Ratio enables housing organizations to invest more in the construction of new Non SGEI houses, among other things, boosting the housing supply. Although a faster increase in housing supply compared to housing demand will ultimately lead to a decrease in the Non SGEI Houses Shortage, in this case, only a few homes have been built as of 2046 because of the limited improvement in the Solvency Ratio brought on by policy combination 1 that took some time to reach the required 40% threshold to invest in the construction of Non SGEI homes. Similar to the Non SGEI Houses Shortage, policy combination 1 has slightly improved the Solvency Ratio, which has resulted in the construction of only a small number of homes as of 2046 in order to lower the average housing condition. Therefore, the decline of the Average Condition Score of Non SGEI Houses starting from 2046 is restrained.

Policy Robustness

Of the robustness analysis carried out with the five different policies analyzed in this study, several observations could be made. By comparing the different results, it can be observed that there is a lot of overlap between the bandwidth of the various policy influences on the various KPIs. As a result, it can be concluded that in general there is not much difference between the robustness of the investigated policies.

Despite this being the case, the results of this analysis show that More Planning Capacity for Social Housing is the most reliable policy for reducing the SGEI Houses Shortage, both in the short and long terms, as the majority of the replications produced by this policy are at the lowest range attainable compared to the other policies. Nevertheless, the results make it evident that for the Non SGEI Houses Shortage is the policy Eliminate landlord Levy the most effective way to address the shortage of Non SGEI houses over the short and long term because its bandwidth consists of the replications with the lowest Non SGEI Houses Shortage values on the long run.

Subsequently, based on the results it can be observed that the most robust policy for the average condition score of SGEI and Non SGEI houses in the short term is Increase Average Rent as its bandwidth is located at the lower range of the density distribution and consists of the replications with the lowest values. In addition, the policy More Subsidy for Social Housing, which has a bandwidth that consists of the lowest Average Condition Score of SGEI Houses values and the highest peak at the lower range of the density distribution of the Average Condition Score of Non SGEI Houses, is the second-best option that is the most robust for both types of housing on the long run.

Finally, based on the findings, it can be concluded that the most robust policy for the Solvency Ratio in the short term is Increase Average Rent, whereas the most robust policy for this KPI, in the long run, is More Planning Capacity for Social Housing. The reason for this is that the bandwidths of both policies have the greatest peaks at the higher range of the density distribution.

6.2. Academic Discussion

The focus of the present study is to gain a better understanding of the Dutch housing sector, particularly the dynamic mechanisms that operate in this complex system, in hopes of identifying a policy strategy that Dutch policymakers can implement to help the social housing providers to increase the availability of adequate rental housing in order to meet the rising housing demand. In order to gain the necessary insights to achieve this goal, the system dynamics model, Dutch Social Housing System, was used. In this model a preliminary attempt was made to model adequate housing using the condition score, given that this is the core concept of this research and recent researchers suggest that the condition measurement is the most effective and objective methodology to gain knowledge about housing conditions (Kuijper & Bezemer, 2016; Di Giulio et al., 2020; Piaia et al., 2021).

Following this, a first attempt was made to model the Dutch social housing sector from the perspective of the housing associations rather than, as had previously been the case, from the standpoint of policymakers which include the entire housing market (Sanders & Sanders, 2004; De Groen et al., 2012; Eskinasi et al., 2011). This has been accomplished, in particular, by only including the social housing market which takes into account the housing demand of low- and middle-income households as well as the housing supply of homes below the liberalization limit (SGEI homes) and those sold by social housing associations on the free market (Non SGEI houses). By taking a different perspective than that of policymakers, the constraints encountered by housing organizations with respect to the social housing market and the Dutch government might be more clearly outlined.

6.2.1. Improvements

In light of the fact that the focus of the developed model in this study was on adequate rental properties, it was decided to incorporate the population sub-model in a simpler manner than the housing demand. Because some components of the feedback loop have been replaced by fixed constants, the interaction between the population and the housing market has not been properly incorporated into the SD model. It is recommended to incorporate the endogenous impact that the housing supply has on the population moving to the region studied. This will enable a more intricate population sub-model in which both the housing supply and demand will be responsive to one another.

Since the primary goal of this study is to offer Dutch policymakers information on the impact of potential policy changes that may be used to address the issues currently plaguing the social housing sector, creating a general SD model that the various Dutch regions/municipalities can customize with their own data helps achieves this. The choice to use data from the Haaglanden region was made since it currently has one of the worst financial climates for social housing associations and is expected to experience one of the highest household increases in the Netherlands (Aw, 2020; Gopal et al., 2021). As a result, it was assumed that the potential policy strategies identified in this study to improve the housing problems in the Haaglanden region are likely to be effective in the other regions in the Netherlands as well. Therefore, it is advised to apply this study to other regions in the Netherlands in order to gather data demonstrating whether this study's policy recommendations will also be successful in other areas of the Netherlands.

In order to ensure that the investigated policies vary from the base case where the relative effects of each policy on the study' KPIs can be mapped, the specification of these policies in the SD model is based on the researcher's educated assumptions. It is advised to conduct more in-depth research on these policies since their value in the model defines how effective their impact on the KPIs is in this model. If these values could resemble reality more closely, it would increase the reliability of the conclusions drawn. In particular, the specification of the subsidy policy should mainly be looked at, as it is one of the most efficient policies according to this research which could be caused by the policy specification.

6.2.2. Policy Discussion

Since there is no single policy that can improve both the housing shortage and the housing quality most effectively, it is recommended to apply a combination of policies to combat the problems of the social housing system. In Dutch social housing it is particularly recommended to use a combination of the following policies: (1) More Planning Capacity for Social Housing, (2) More subsidy for Social Housing, and (3) Eliminate Landlord Levy. The reason for this is that through policies More Subsidy for Social Housing and Eliminate Landlord Levy, policymakers can ensure that social housing associations have sufficient financial resources to meet their social obligations – ensure that there is enough adequate social housing on the market through the construction of new homes and/or the maintenance of existing homes. In addition, More Planning Capacity for Social Housing ensures that enough land is available for the new homes to be built when the housing associations invest in them.

Since the More Planning Capacity for Social Housing policy tries to expand the portion of the total planning capacity that is allocated to social housing without expanding the existing planning capacity, I believe that this policy is feasible to implement for the Dutch policymakers. Moreover, the recent pandemic not only increased the demand for social housing (England currently has 1.1 million social households and is expected to reach 2 million next year) but also diversified its target audience (Madsen & Ghekière, 2021). Recent studies indicate that aside from the poor and vulnerable, also the elderly, young adults (starters), and middle-income households, along with vulnerable and special groups are becoming increasingly interested in this housing aid (OECD, 2020; Madsen & Ghekière, 2021). That is why I think it is logical to also expand the portion of the planning capacity that is intended for the social sector. Otherwise, there will be many expensive homes being built in the Dutch housing system, but because consumers cannot afford these homes, these expensive homes will remain vacant while the housing shortage in the social sector will only increase.

In addition, the policy Eliminate Landlord Levy tries to ensure that the landlord levy does not form part of the financial burden of social housing associations anymore, since the Ministry of BZK believes that the removal of the landlord tax will provide housing associations with adequate financial resources to resume their role in the social housing sector (De Jonge, 2022). Since this policy is supported by the Ministry of BZK and this policy was first imposed in the social sector in the year 2013, which was not so long ago, I believe that the abolition of the landlord levy is feasible (Lijzenga et al., 2020; De Jonge, 2022). But since this tax was initially implemented to put the central government's finances in order, and that nowadays the Dutch government just got out of financial trouble, I expect that this tax will not be completely abolished in the short term but will continue to gradually decrease up until it reaches 0% (Lijzenga et al., 2020).

Unfortunately, subsidizing all housing corporations is not a sustainable policy in today's political arena. Since the Ministry of BZK is particularly interested in accelerating the completion of major housing projects by, among other things, offering financial support to municipalities, I believe that this policy is feasible in the short term ((BZK, 2021a). But as the years go by and the housing shortage has significantly diminished, as the homes invested in now enter the housing market, there will be less need for the government's active role and there is a good chance that those subsidies will no longer be offered. As a result, it is expected that the housing shortage will increase again. In addition, I expect that the procedure to implement these policies will cost a lot more time and money compared to the policies discussed above. Ultimately, it should be noted that although this is the most efficient policy, according to this research, this may be the result of the way this policy is implemented in the model. Namely that the housing associations receive a subsidy of 50,000 euros per social housing construction, I now think in retrospect that it is somewhat ambitiously implemented in the SD model.

Since the examined system is a social challenge due to its dynamic complexity, there are different actors with different interests tightly involved in this system (J. Sterman, 2002). In particular, these actors can be divided into housing associations, the government and housing consumers.

The results show that the first policy combination (More Planning Capacity for Social Housing + More Subsidy for Social Housing) is the most effective at reducing the housing deficit in the social sector, while it performed averagely for both the quality and the shortage of houses for middle-low-income households. Based on the impacts of this policy combination it can be suggested that the government will favour the first policy combination since it is primarily focused on the housing scarcity in the social sector in this particular case and less so on the quality of the housing for middle-low-income households. In recent years, the government has made it clear that it wants social housing organizations to concentrate primarily on the social market and less on the housing market for middle-low-income households (Elsinga & Lind, 2013; Rijksoverheid, 2022). Since housing consumers have both an interest in the quantity and quality of the social housing market, it may be inferred that this policy combination would be preferred by this actor. This actor seeks high-quality housing because they have to move in during the rental period. They also prefer a housing market where the housing shortage is as low as possible because they want to be able to find a home as quickly as possible when looking for social housing.

Subsequently, it is clear that the third policy combination (More Subsidy for Social Housing + Eliminate Landlord Levy) is the opposite of the second policy combination. Specifically, this intervention had the least impact on the housing shortage and quality of the social housing, while performing well for the housing shortage and quality for middle-low-income households. It may be inferred that this policy combination is the most financially advantageous for social housing organizations because it is the combination that improves the Solvency Ratio of these organisations most effective when compared to the other combinations. Since the social housing associations are non-profit organisations, it is expected that despite the financial opportunities that the third policy combination may offer it is precisely the second policy combination (More Planning Capacity for Social Housing + Eliminate Landlord Levy) that is expected to be preferred by the housing associations. The reason for this is that this policy intervention will ensure progress on both the housing shortage and quality of the various homes studied in this research, except for the financial situation. In addition, the robustness analysis has shown that the policy More Planning Capacity for Social Housing can be beneficial to the Solvency Ratio in the long term, leading to the observation that this policy combination might be inefficient for the financial situation in the short turn but efficient for the long term.

It is advised to ascertain the value of the most influential uncertain parameters prior to the selection of the policy strategy because the majority of the KPIs, with the exception of the housing shortage for middle-low income households, are behaviorally sensitive to uncertain parameters investigated in this study. Moreover, it is challenging to assess the robustness of the investigated policies because of the significant overlap between the findings of the several policies reviewed by the robustness study. The efficiency and robustness of the various policies mentioned in this study and their combination should therefore be thoroughly examined using the data that have been gathered of the most influential uncertain parameters. This information allows for the most precise mapping of the researched system's behaviour during the application of the policy interventions. This in turn allows policymakers to make choices regarding the housing policy that is supported by empirical data. Ultimately, it is recommended that the other actors also be included in the policymaker's selection procedure, as they may have differing opinions about the different policy candidates. The many perspectives that the actors involved have regarding the social housing system must therefore be thoroughly researched.

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A

Model Documentation

Please refer to the document ”Model Documentation” provided by the author to see the contents of this appendix.

B

Model Testing

This section of the report will critically assess whether the model developed in this study is appropriate for its intended use. In this study, the modelling objective is to create a depiction of the actual Dutch social housing market so that policies that can affect it can be examined. To find out if this is the case, a boundary adequacy test was executed first in section B.1. In addition, the dimensional consistency of the model was validated in section B.2. In section B.3, the integration error, time step and simulation length were mapped. Additionally, the insights gained from the extreme condition test can be found in section B.4. Finally, section B.5 covered the results of the sensitivity analysis.

B.1. Boundary Adequacy

According to Senge & Forrester (1980), the boundary adequacy test's performance requires evaluating the model's applicability in light of its structure, behaviour, and policy. Since there are other tests that examined the behaviour of the model in this study, the focus of this test was primarily on the structural and policy implications of the model. In order for this to be possible, the model's structural relationships were examined to determine whether they were sufficient for fulfilling the modelling objective. Theretofore, the model's aggregation level and structure are examined in section B.1.1 and B.1.2 respectively.

B.1.1. Aggregation Level

In this study, the housing market was chosen to be modelled from a high aggregation level, since this makes the most sense when examining the effects of national and regional policies on the social housing market. This is because all parties involved – including social housing corporations – must abide by these policies. Furthermore, the Dutch government designs strategies that are workable for each of the housing associations rather than one that makes distinctions between them. This has led to the development of a model that combines the housing stock as well as the finance of all housing associations in the social sector together. This has the benefit of making it simple to observe the entire housing supply of the social housing associations, including the total amount of new construction, the total amount of homes demolished, and the average condition of the dwellings. This degree of aggregation has the disadvantage that the model is unable to distinguish between the housing stock of the various housing organizations in the region in question. As a result, it is unattainable to gain an understanding of the fundamental distinctions between the different housing organizations that form part of the social housing sector. These interactions and their ramifications do not significantly affect the model output and can thus be excluded from the scope of this study because information about the social housing stock in Haaglanden as a whole is what is required for developing policy on this housing market. Since information regarding the social housing stock in Haaglanden as a whole is needed for creating policy on this housing market, these interactions and their implications do not significantly affect the model output and can therefore be excluded from the scope of this study.

In addition to the merging of all housing associations, the Haaglanden region's multiple municipalities were also amalgamated as a result of this level of aggregation, creating a model with integrated variables from all of the separate municipalities. This has the advantage of making it simple to see the complete housing supply and demand of the social housing in the Haaglanden region, as well as a broad picture of the cash flow of the housing organizations situated in this region. The drawback of this degree of aggregation is that the model cannot distinguish between the variations in the supply and demand of the many municipalities that make up the Haaglanden region. Along with the distribution of social housing supply and demand across the region in issue, insights regarding the interactions between the municipalities within the Haaglanden region have also gone unconsidered. It can be concluded that this level of aggregation is adequate to accomplish the goal of this model because other studies on the subject have shown that there is only a slight difference between models that include these types of interactions within a region compared to those that leave these interactions out (Sanders & Sanders, 2004; Uchino et al., 2005; Eskinasi, 2014).

B.1.2. Structure

When examining the model's structure, three sub-models can be identified, namely the population sub-model, the housing market sub-model and the financial sub-model. First of all, the population sub-model provides insights into the extent of the housing demand in the Haaglanden region. Subsequently, the housing market sub-model displays the social housing supply in Haaglanden at any given time. In addition, the average condition score of the homes in this sub-model sheds light on the quality of these dwellings. Ultimately, the financial sub-model specifies how the homes that are added to or removed from the current home stock will be financed and what financial consequences these alterations entail for housing associations. The structure of this model also includes the dynamic interactions between the various sub-models. This indicates that dynamic interactions occur not only within the sub-models but also between the sub-models, adding the complexity of the actual social housing system to the model.

It should be noted that the developed model in this research only partially accounts for the interaction between the population sub-model and the housing market sub-model. Various research has reported a two-sided interaction between population and housing (C. H. Mulder, 2006, 2009; Park et al., 2013; A. De Jong et al., 2019). According to A. De Jong et al. (2019), there could even be a 'chicken-egg' relationship between them (see Figure B.1). On the one hand, there is a self-reinforcing feedback loop in which urban population changes alter housing demand. As a result of urban population growth, particularly in the number of households, there is an increase in the housing shortage, housing construction, the number of housing units, housing supply, and urban appeal. The increased urban appeal in turn inevitably leads to an increase in the number of people moving to the city, resulting in increased urban population (C. H. Mulder, 2006, 2009; Park et al., 2013; A. De Jong et al., 2019). Household formation, on the other hand, is impossible to achieve (completely) without a sufficient housing supply. When the housing supply increases, so does the city's appeal, as well as the number of people moving to the city. However, as the urban population grows, the housing supply decreases, re-balancing the system (Park et al., 2013; A. De Jong et al., 2019).

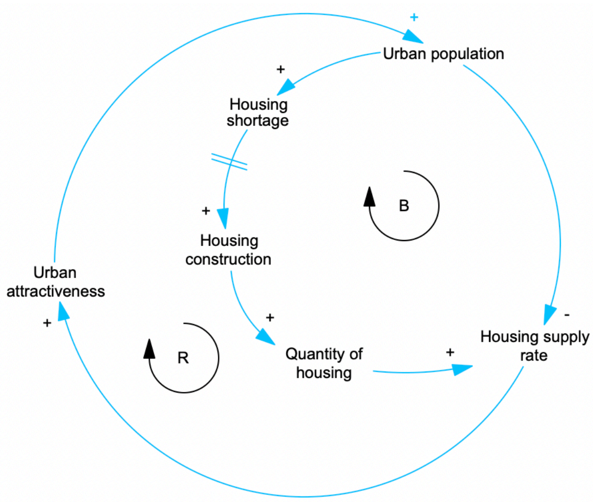


Figure B.1: Two-sided relationship between urban population and housing market (Park et al., 2013).

The model in this study primarily takes into account the interaction between population changes and the creation of new construction of social houses. The relationship between population growth and decreased housing supply, which increases the housing shortage, has also been taken into account in this model. However, these two feedback loops are not fully accounted for in this model since the housing supply does not have an endogenous impact on the population that moves to the Haaglanden region; rather, migration to the region is governed by means of a constant. As a result, it is not possible to map out the effects that these two feedback loops may have on the Haaglanden social housing market using this model. This also applies to the interactions between the markets for social housing and other types of housing in Haaglanden. In conclusion, it can be seen that the model can be expanded by turning exogenous variables endogenous, but that the model structure does have the required characteristics to represent the actual social housing market in the Haaglanden region.

B.2. Dimensional Consistency

Household, *House*, and *Euro* are the three most significant dimensions in the social housing model created in this study. With the aid of the *Household* unit, the housing demand in Haaglanden was calculated. To do this, the population ageing chain expressed in *Person* is transformed into several household kinds, specifically low-income, low-middle income, and other income households. Subsequently, the entire production up to the demolition of the social housing in Haaglanden was expressed in the *House* unit. Even the planning capacity of the social houses in the housing market sub-model is expressed in this unit. The national currency of the Netherlands is the *Euro*, hence this is the dimension in which the financial sub-model is ultimately conveyed. Finally, *Year* was selected as the unit of time to examine the adequacy of the social housing that is now available in the Haaglanden housing sector. The numerous processes that can affect the condition of social housing – including new construction development, deconstruction, maintenance, ageing, and degradation – typically take a number of months or even several years before completion. This time unit makes it possible to accurately model these processes. To ensure that the model's parameters didn't have any conflicting dimensions, the dimensional consistency test was utilized. Fortunately, the Vensim simulation software has a built-in ”unit check” function. As a result, several unit tests were actively carried out during the model's development to make sure that the equations accurately reflected real-world notions. No unit errors were discovered once the test was completed, indicating that the dimensions of the model parameters are properly implemented in Vensim.

B.3. Integration Error, Time Step, and Simulation Length

The model settings will be assessed in this section of the report. First, the integration error will be examined in section B.3.1. Following that, section B.3.2 and section B.3.3, respectively, evaluate the time step and simulation length of the social housing model developed in this study.

B.3.1. Integration Error

Euler, Runge-Kutta4 (RK4), and Runge-Kutta4 auto (RK4 auto) are the numerical integration methods that are frequently seen in system dynamics packages, according to Pruyt (2013). Research shows that RK4 is appropriate for continuous models without significant variations in the speed of dynamics and possibly oscillatory behaviour, whereas RK4 auto is suitable for continuous models with significant variations in the speed of dynamics. Models with discrete functions, on the other hand, work best using Euler. However, Euler is not sufficiently accurate for many models and patterns unless a very tiny time step is selected (Pruyt, 2013). The various equations used in the social housing model lead to the conclusion that this model is made up of a number of discrete events. Some equations that contributed to the execution of these events include ”Available Capacity for SGEI Planned Houses” and ”Loan Payment”, which uses MAX functions, ”Positive Impact of Solvency Ratio on SGEI Houses”, and ”Average Construction Costs”, which employ WITH LOOKUP functions, and ”Liberalized SGEI Houses”, which uses a IF THEN ELSE function together with a PULSE TRAIN function (see description in Appendix A). Given that the model being employed is made up of a lot of discrete events as indicated above, it was decided to use Euler as the integration method with a relatively small time step to increase the model's accuracy. For further information regarding the time step applied in this model, consult section B.3.2.

B.3.2. Time Step

In an SD model, a time step can be described as the period of time between recalculations. In a model with years as the time unit, for example, a time step of 0.25 indicates that the model's formulas are updated once every 0.25 years. The outcome of a model is more precise the smaller the time step. Unfortunately, precision comes at a cost – running the model may take longer than it would with a larger time step. Therefore, a few test steps were necessary to determine the ideal step size for this particular SD model. Particularly, the time step for this study's model was 0.25 at the beginning. Then, every time, this value is cut in half until there is no longer any difference in the behaviour of a given time step and the smaller time steps. This is because a time step decrease that is not appropriate for the generated model causes the model's behaviour to significantly alter relative to that of earlier time steps. The Non SGEI Houses Shortage's behaviour over various time steps is depicted in Figure B.2. This figure demonstrates that the model behaviour does not significantly change for time step 0.0078125 or less, indicating that this particular time step is suitable for the model in question.

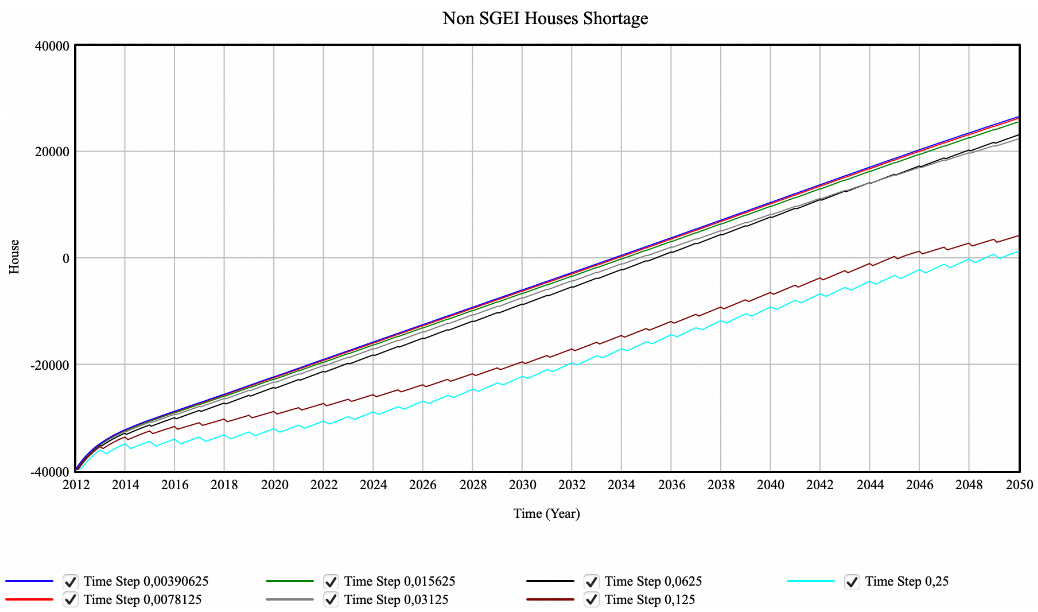


Figure B.2: Behaviour of Non SGEI Houses Shortage based on different time steps.

B.3.3. Simulation Length

The most popular forecasts that the Dutch governments employ to make significant choices on this subject provide a projection that begins 10 years before the research is conducted to guarantee that the findings have a solid historical foundation. Since I want to follow this common practice, the model must begin in 2012 because the research was performed in 2022. Additionally, the majority of the historical information utilized to develop this model can be obtained up to and including the year 2012. As a result, it was decided that the initial time of the social housing model's run is the year 2012. Furthermore, the year 2050 was chosen as the model's final time since that is the year that the majority of the forecast models that the Dutch government uses to make decisions simulate. Furthermore, over the course of 38 years, it is conceivable to test potential policy interventions that might be added throughout time and gather sufficient knowledge regarding their efficacy. The reason for this is that the numerous processes that can affect the condition of social housing – such as new construction development, deconstruction, maintenance, ageing, and degradation – typically take a number of months or even several years before completion. As the condition score of the existing homes rises by one scale point every ten years, the process that takes the longest in this SD model is housing degradation. Over the course of 38 years, procedure can be repeated more than three times, allowing this SD model to generate more accurate results and, as a result, sufficient insights regarding the behavior of the KPIs with or without policy interventions.

The simulation length has been doubled to see if the model still stands the test of time if it is extended. In order to evaluate this, it was chosen to run the model until the year 2100. The KPIs' behaviour in Figure B.3-B.7 demonstrates that, aside from the SGEI Houses Shortage and the Average Condition Score of Non SGEI Houses, the model behaviour remains roughly the same as the simulation length is extended.

First off, a greater increase in housing demand than in housing supply can explain the rise of the SGEI Houses Shortage (see Figure B.3). The reason for this is that while the Solvency Ratio stabilizes at a level of roughly 30% throughout this model run (see Figure B.7), the supply of housing similarly reaches an equilibrium level in which the same number of residences are added to the social housing stock through new construction as are removed from the social housing stock through demolition, sale, and liberalization. Therefore, the SGEI Houses Shortage will continue to rise as long as there is not enough housing supply to meet the growing demand for social housing brought on by population growth

Additionally, it can be observed in Figure B.6 that the Average Condition Score of Non SGEI Houses will actually start to decline after the year 2050, and this decline will occur in a phased fashion around 2070. This can be explained by the fact that no Non SGEI Houses would be constructed or maintained while the Solvency Ratio is below the 40% benchmark, which is the case throughout this model run (see Figure B.7). Nevertheless, the Non SGEI houses in poor condition or that are too old will be demolished and sold. As a result, the housing supply of middle-low income households will only consist of properties that are in decent condition, causing the Average Condition Score of Non SGEI Houses to decrease. Furthermore, the phased pattern can be accounted for by the fact that every year, SGEI Houses in good condition (i.e., with a code score lower than 4) and within a certain age group (between 10 and 70 years) will be rented out in the Non SGEI Houses sector. Since these homes don't have the same condition scores as the housing stock of Non SGEI Houses, this KPI may rise; but, due to sales and demolished, it will progressively fall until a new wave of SGEI Houses enters this market. around the year 2070. Given that there is a considerable increase in the number of liberalized SGEI Houses around 2070 compared to earlier years due to the housing ageing, this pattern is apparent beyond the year 2070.

As a result, it can be concluded that the simulation period of 2012–2050 generally offers an accurate portrayal of the system behaviour over time.

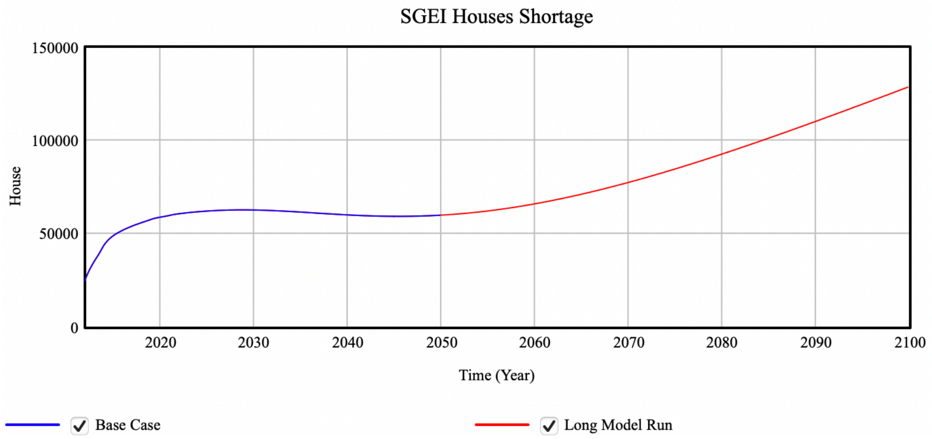


Figure B.3: SGEI Houses shortage in Haaglanden with an extended model run.

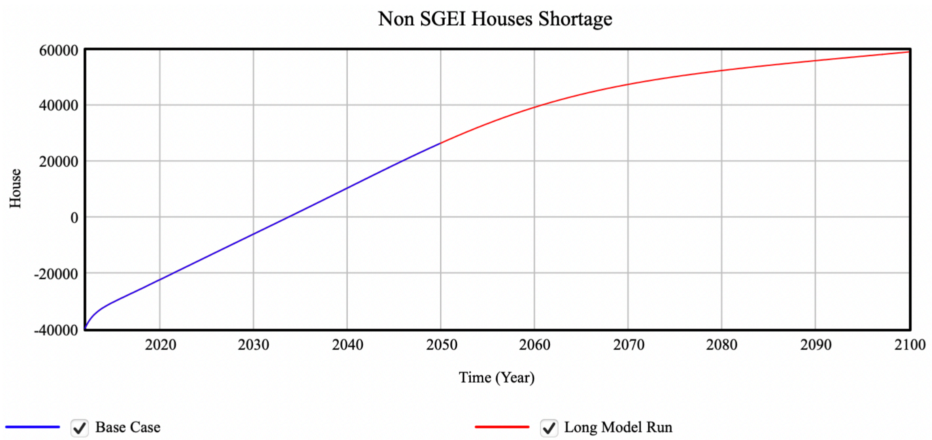


Figure B.4: Non SGEI Houses shortage in Haaglanden with an extended model run.

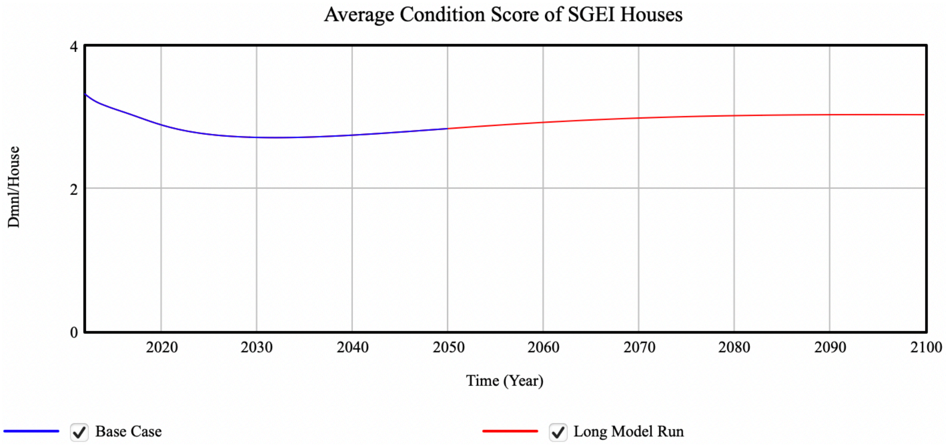


Figure B.5: Average condition score of SGEI Houses in Haaglanden with an extended model run.

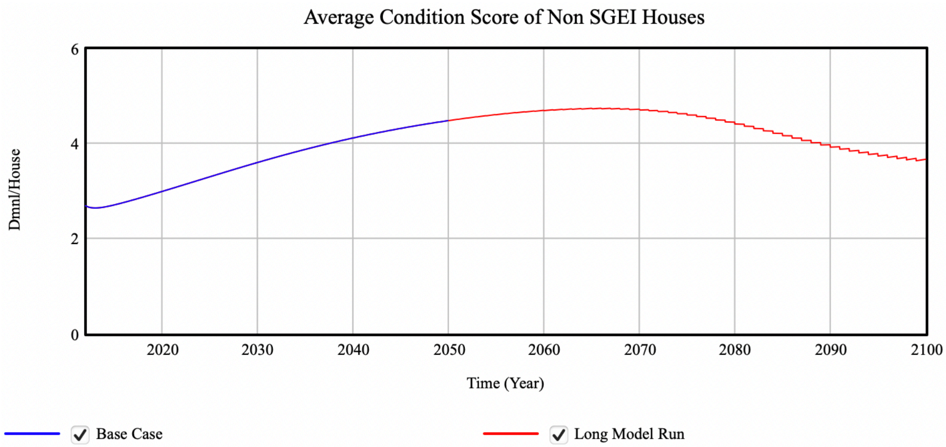


Figure B.6: Average condition score of Non SGEI Houses in Haaglanden with an extended model run.

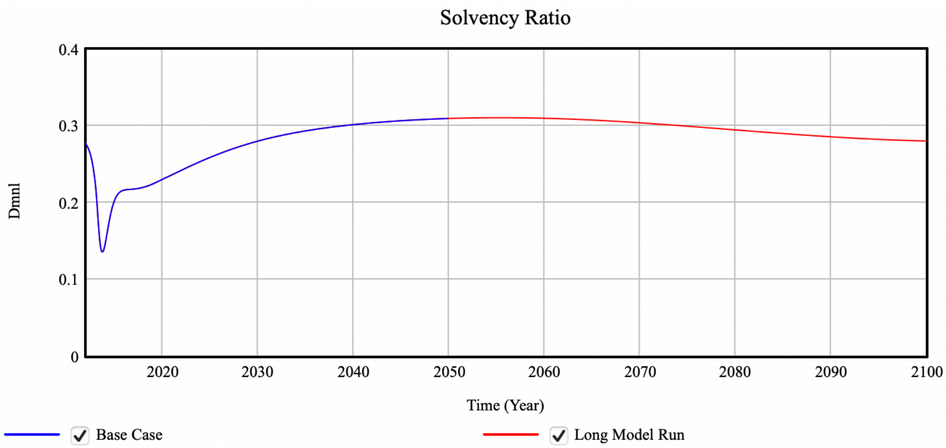


Figure B.7: Solvency Ratio of the social housing providers in Haaglanden with an extended model run.

B.4. Extreme Condition Tests

The extreme condition test will be covered in this section of the model testing. In particular, the extreme condition test is used to evaluate the behaviour of the model when the input parameter is set to extreme values. In particular, this test makes it possible to determine whether the model responds logically in the face of extreme circumstances. The following model characteristics will be evaluated in this study: (1) Housing Demand, and (2) Housing Supply. An extremely low value and an extremely high value will be used to vary each of these characteristics. The details of each of these tests and the outcomes will be covered in more depth below. Ultimately, Table B.1 provides an overview of the findings from this test.

B.4.1. Housing Demand

The extreme condition test of the housing demand will be covered in this section of the appendix. In this particular test an initial value of 0 for the population was chosen in order to specify the extremely low value for housing demand. Subsequently, the initial population is multiplied by 10,000 in order to specify the extremely high value for housing demand in this test. The following parameters have been made sure to take on the specified values for this extreme condition test: *Initial Children*, *Initial Young Adult*, *Initial Adult*, and *Initial Elderly*.

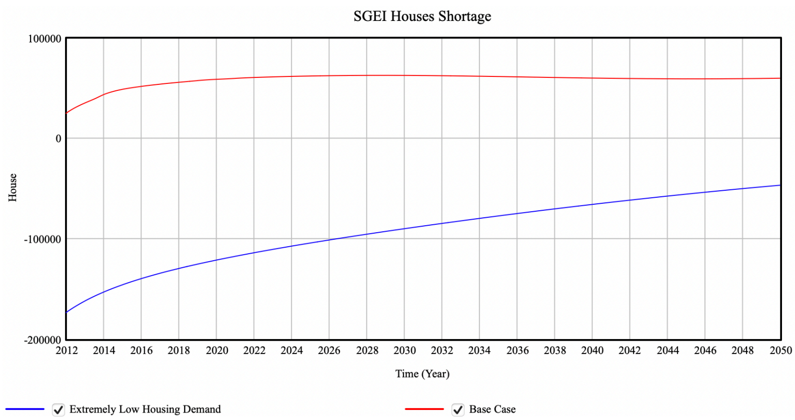


Figure B.8: SGEI Houses shortage in Haaglanden with an extremely low housing demand.

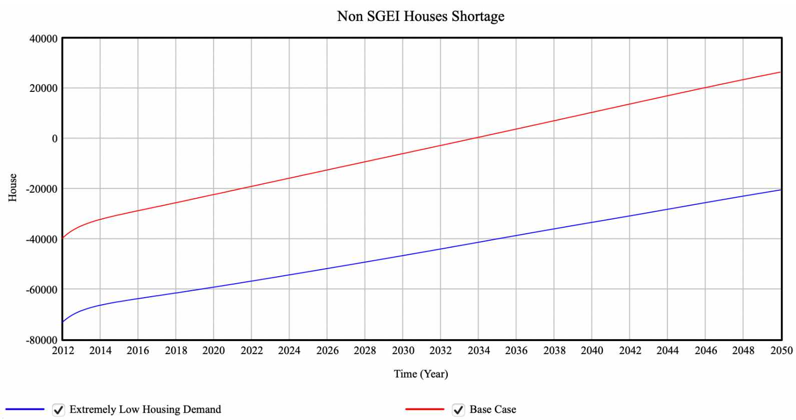


Figure B.9: Non SGEI Houses shortage in Haaglanden with an extremely low housing demand.

It is anticipated that the initial housing shortfall of the various types of houses in this model would be smaller than the base case, leading to a housing surplus because the initial housing demand is predicted to be exceptionally low in comparison with the housing supply. This is due to the fact that there are initially more homes available than there is demand in the housing market. Subsequently, it is anticipated that the housing surplus would worsen as the population increases, the population grows faster than the construction of new homes. Figures B.8, and B.9 show that during an extremely low housing demand, the housing shortage behaved as predicted.

Because the initial housing demand is forecast to be very high in relation to the housing supply, it is anticipated that the initial housing deficit of the various types of houses in this model would be larger than the base case, resulting in a severe housing shortage. This is due to the fact that from the outset of the model, demand for these properties is much higher than supply. As a result, it is projected that the housing scarcity would get worse as the population grows, as the population grows faster than the construction of new homes. Figures B.10, and B.11 show that during an extremely high housing demand, the housing shortage behaved as predicted.

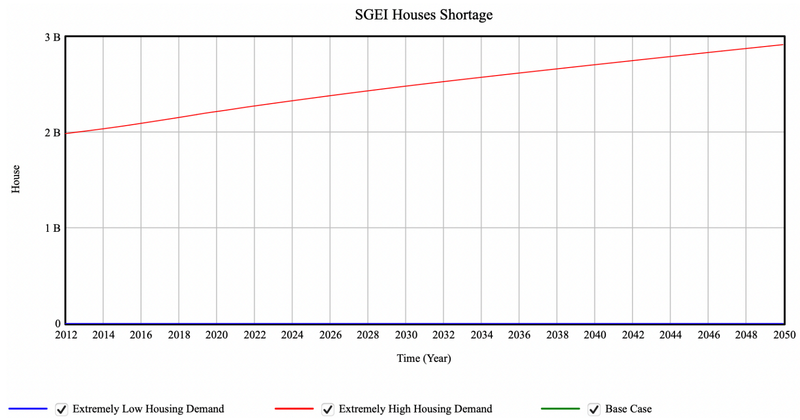


Figure B.10: SGEI Houses shortage in Haaglanden with an extremely low/high housing demand.

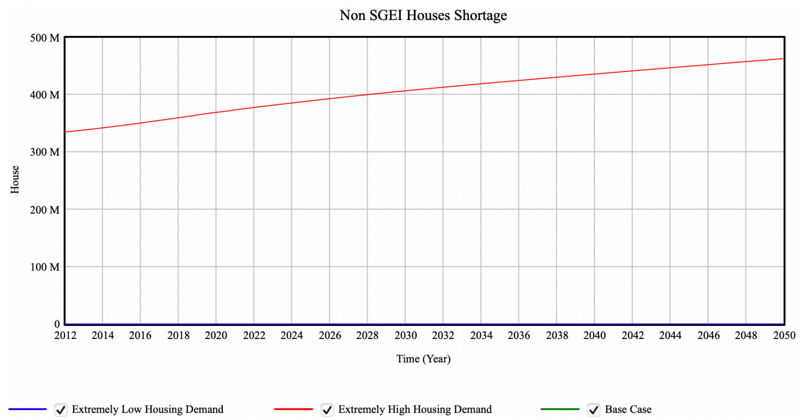


Figure B.11: Non SGEI Houses shortage in Haaglanden with an extremely low/high housing demand.

As was already mentioned, a housing surplus is anticipated when there is a severe lack of housing demand. This phenomena indicate that no new buildings will be constructed because it is expected in this model that new homes will only be built in the case of a housing shortage. As a result, no new loans need to be established in order to finance this development. As a result, the debt capital will deplete significantly from the equity capital, causing the Solvency Ratio to increase higher than the base case. Figure B.12 shows that during an extremely low housing demand, the Solvency Ratio behaves as predicted. Furthermore, the average condition score of the dwellings will decline relative to the base case as a result of a higher Solvency Ratio, given that an increased Solvency Ratio will ensure that more maintenance is performed in this scenario than in the base case. Figures B.13 and B.14 show that during an extremely low housing demand, the housing quality behaved as predicted.

Furthermore, a housing shortage is anticipated when there is a housing demand that is larger than the housing supply. This phenomena is expected to result in the construction of the greatest number of new structures for which there is sufficient building land, as in this model, new dwellings are only expected to be built if there is sufficient land available for them. As a result, numerous new loans must be required in order to fund this scale of construction. The debt capital will consequently rise significantly faster than the equity capital (due to the delay caused by the construction time), resulting in a lower Solvency Ratio than in the base scenario. For these reasons and the fact that the tremendous demand for these homes throughout the model run will continue to increase faster than the creation of new homes, it is anticipated that the Solvency Ratio of this extreme scenario will remain lower than the base case throughout the model simulation. Figure B.12 shows that during an extremely high housing demand, the Solvency Ratio behaves as predicted. Despite the decrease in the Solvency Ratio, if this KPI is higher than the 15% threshold to invest in SGEI houses, it will ensure that the average condition score of SGEI houses is roughly equal to the base case. Since from the base case the Solvency Ratio was lower than the 40% threshold to invest in Non SGEI houses, this decrease in Solvency Ratio will ensure that this KPI remains equal to the base case. Figures B.13 and B.14 show that the housing quality behaved as predicted under these circumstances.

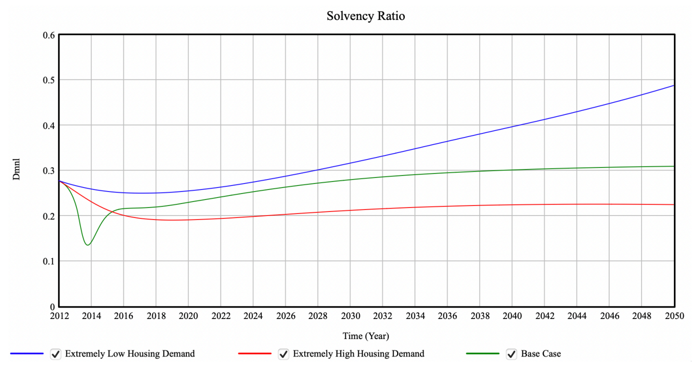


Figure B.12: Solvency Ratio of the social housing providers in Haaglanden with an extremely low/ high housing demand.

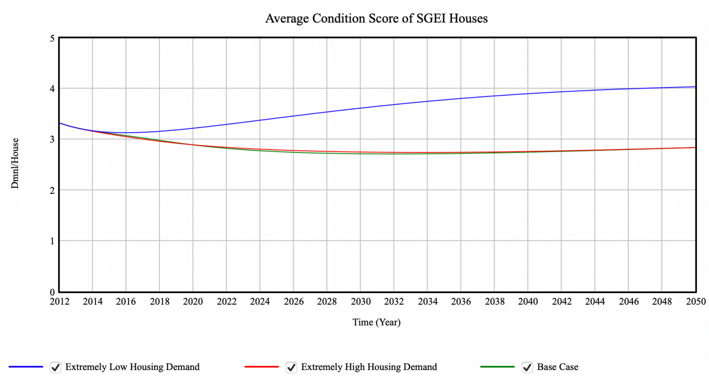


Figure B.13: Average condition score of SGEI Houses in Haaglanden with an extremely low/high housing demand.

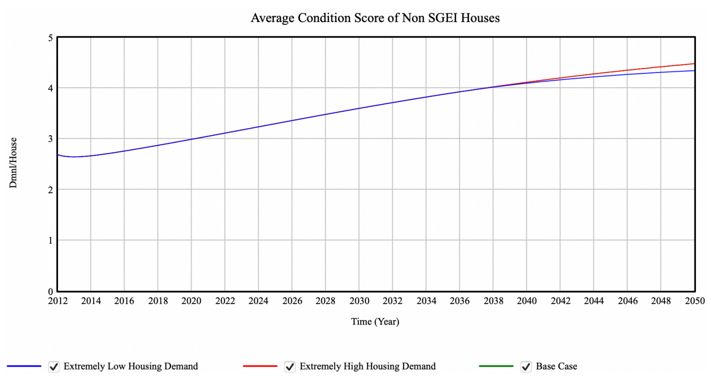


Figure B.14: Average condition score of Non SGEI Houses in Haaglanden with an extremely low/ high housing demand.

B.4.2. Housing Supply

The extreme condition test of the housing supply will be covered in this section of the appendix. In this particular test an initial value of 0 for the population was chosen in order to specify the extremely low value for housing demand. Subsequently, the initial housing stock is multiplied by 1,000 in order to specify the extremely high value for housing supply in this test. The following parameters have been made sure to take on the specified values for this extreme condition test: *Initial SGEI Housing*, and *Initial Non SGEI Housing*. Besides, it was decided to set the initial values of the homes under construction to zero in order to execute the extremely low housing supply because it wouldn't make sense to expect new homes to be built under these conditions. The following parameters, in particular, have been changed in order to execute this: *Initial SGEI Houses under Construction*, and *Initial SGEI Houses under Construction*.

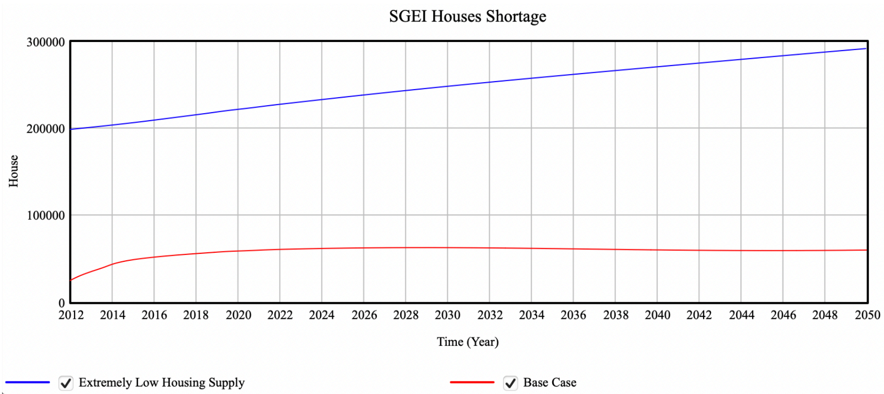


Figure B.15: SGEI Houses shortage in Haaglanden with an extremely low housing supply.

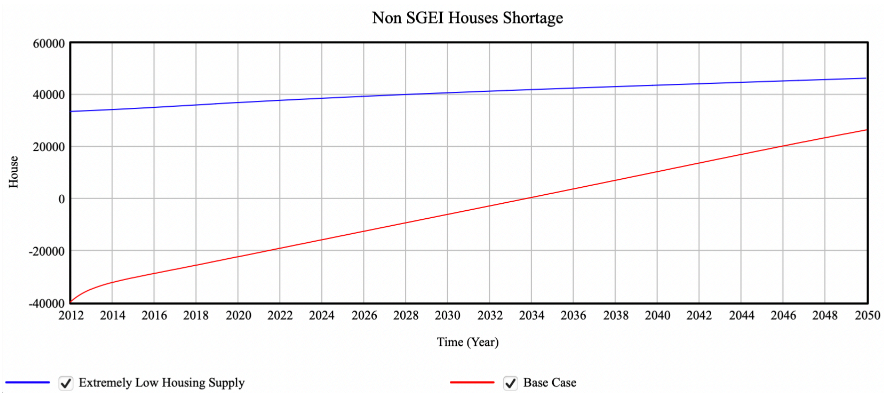


Figure B.16: Non SGEI Houses shortage in Haaglanden with an extremely low housing supply.

Because the initial housing supply is forecast to be very low in relation to the housing demand, it is anticipated that the initial housing deficit of the various types of houses in this model would be larger than the base case, resulting in a severe housing shortage. This is due to the fact that from the outset of the model run, demand for these properties is much higher than the supply. As a result, it is projected that the housing scarcity would get worse as the population grows, as the population grows faster than the construction of new homes. Since no new homes will be built as a result of the low Solvency Ratio, it is anticipated that the housing shortage will exhibit the same behavior as housing demand. Figures B.15, and B.16 show that during an extremely high housing supply, the housing shortage behaved as predicted.

Furthermore, it is anticipated that the initial housing shortfall of the various types of houses in this model would be smaller than the base case, leading to a housing surplus because the initial housing supply is predicted to be exceptionally high in comparison with the housing demand. This is due to the fact that there are initially more homes available than there is demand in the housing market. Subsequently, it is anticipated that the housing surplus would worsen as the population increases, the population grows faster than the construction of new homes. Figures B.17, and B.18 show that the housing shortage behaved as predicted during extremely low housing supply.

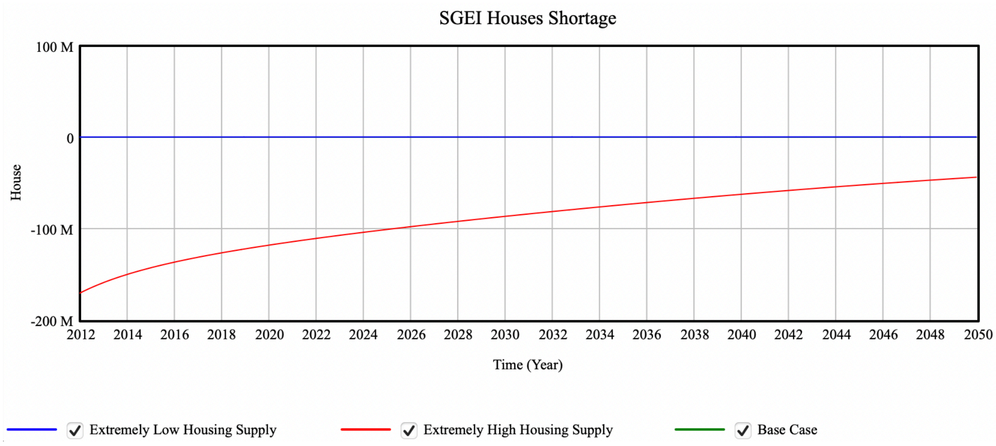


Figure B.17: SGEI Houses shortage in Haaglanden with an extremely low/high housing supply.

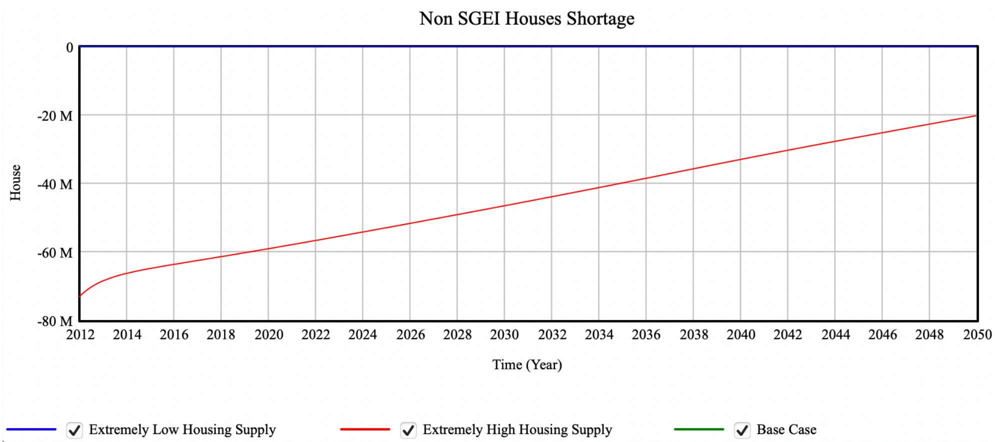


Figure B.18: Non SGEI Houses shortage in Haaglanden with an extremely low/high housing supply.

Figure B.19: Solvency Ratio of the social housing providers in Haaglanden with an extremely low/ high housing supply.

As was already said, a housing shortage is anticipated when there is a severe lack of housing supply. This phenomena is normally expected to result in the construction of a high number of new structures for which there is sufficient building land. Although there is a housing shortage, it is anticipated that no new dwellings will be constructed in this model since the Solvency Ratio is set to zero at the beginning of the model simulation. Since no new homes will be constructed, neither the equity of the housing associations nor their debit credit will increase, causing this KPI to remain at 0 throughout the model simulation. The condition score for these houses is anticipated to also remain at 0, as there won't be any houses in this model to calculate its condition over the entire model run. Figures B.19, B.20 and B.21 show that during an extremely low housing supply, the Solvency Ratio as wel as the housing quality behaved as predicted.

Furthermore, a housing surplus is anticipated when there is a housing supply that is severely larger than the housing demand, as was already indicated. This phenomena indicate that no new buildings will be constructed because it is expected in this model that new homes will only be built in the case of a housing shortage, whereby no new loans need to be taken in order to finance the housing development. As a result, the debt capital will deplete significantly from the equity capital, causing the Solvency Ratio to increase higher than the base case. Figure B.19 shows that during an extremely high housing supply, the Solvency Ratio behaves as predicted. Furthermore, the average condition score of the dwellings will increase relative to the base case despite the higher Solvency Ratio. Even though higher Solvency Ratio will lead to more upkeep of these homes, it is anticipated that upkeep alone won't be sufficient to slow the rate at which existing homes are deteriorating and eventually being demolished since the housing associations' focus is not on investment in maintenance but rather new construction (model default). The conditions of these residences are consequently anticipated to be lower than the base case given the increased proportion of deteriorating homes compared to their maintenance. Figures B.13 and B.14 show that during an extremely high housing supply, the housing quality behaved as predicted.

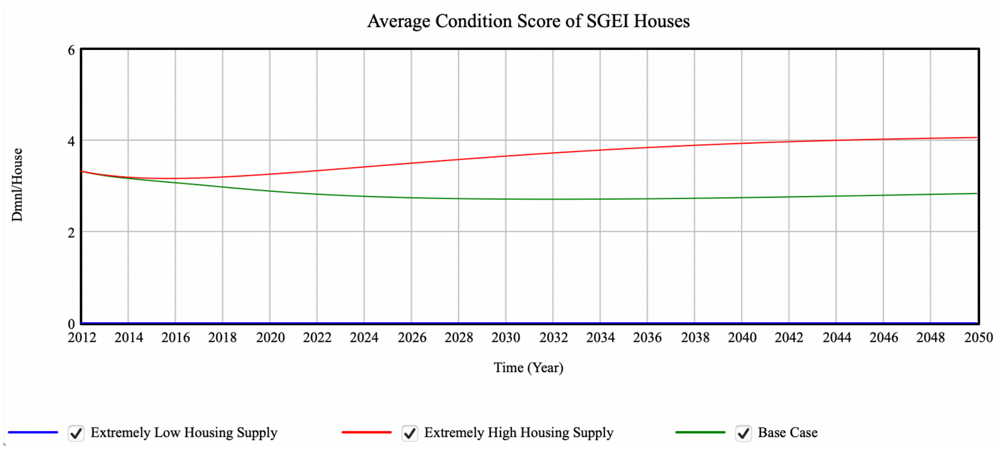


Figure B.20: Average condition score of SGEI Houses in Haaglanden with an extremely low/high housing supply.

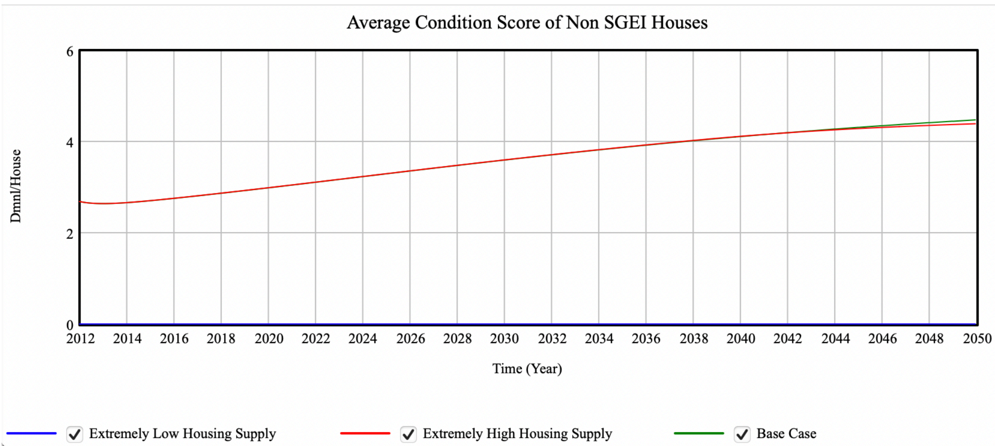


Figure B.21: Average condition score of Non SGEI Houses in Haaglanden with an extremely low/ high housing supply.

Table B.1: Result of the extreme condition test.

Extreme Condition Test		Result
Housing Demand	Extremely Low Housing Demand	Test Passed
	Extremely High Housing Demand	Test Passed
Housing Supply	Extremely Low Housing Supply	Test Passed
	Extremely High Housing Supply	Test Passed

B.5. Sensitivity Analysis

The sensitivity analysis, a form of structure-oriented behaviour validation test, examines how the model behaves when minor variations in particular parameters are made (Pruyt, 2013). This makes it easier to spot areas of the model where the behaviour is more sensitive to inputs than it is in the base case. To understand the unique impact of each variable on the KPIs, the Univariate technique was used (consult section B.5.1). Additionally, the Multivariate approach was used to evaluate the combined impact of these variables on the KPIs when they are altered simultaneously (see section B.5.2). The baseline values of the variables in Table B.2 were changed by ±10% to do both of the sensitivity analyses. It was decided to perform the sensitivity analysis using these constants as these are the researcher's assumptions that are not supported by any data.

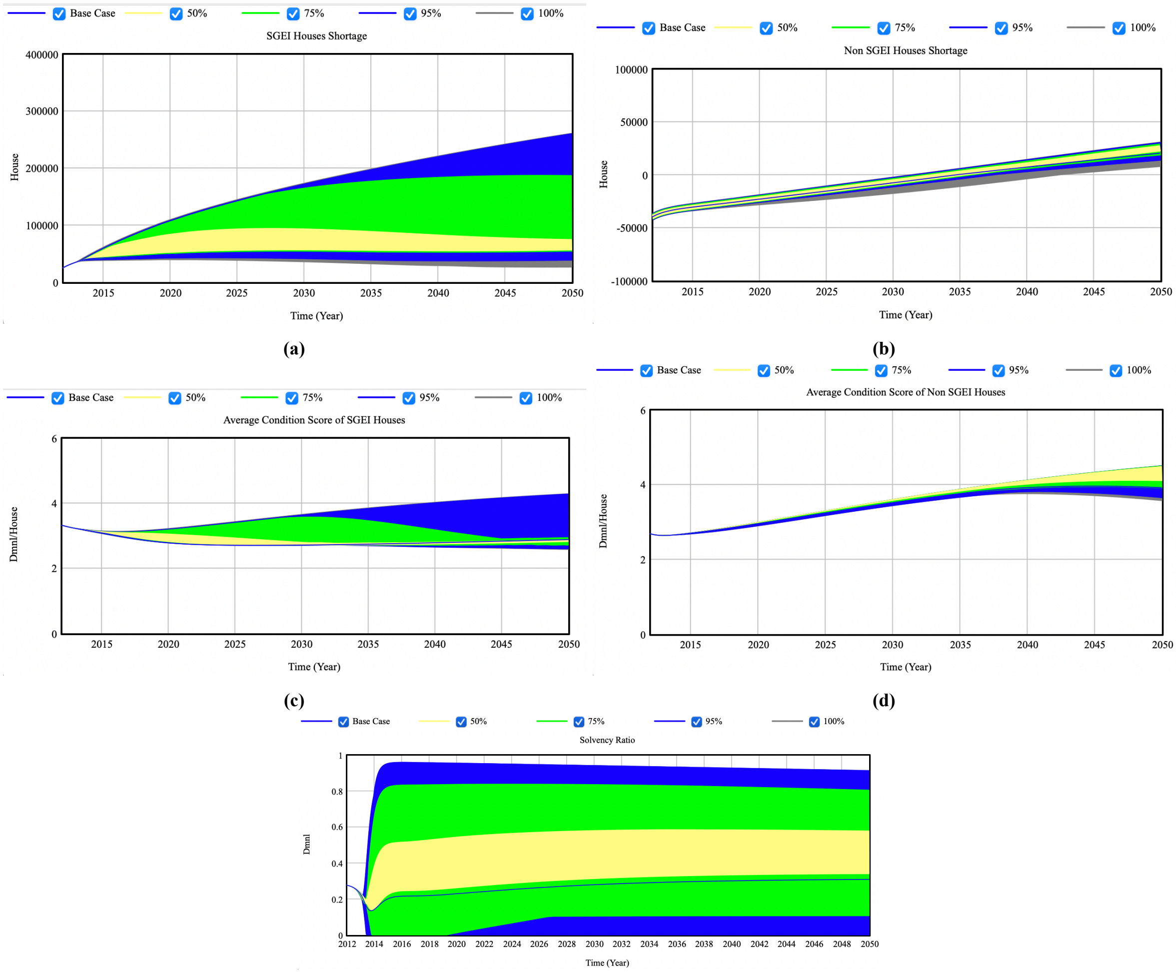
Table B.2: Constants varied in the sensitivity analysis.

Constant	Base Value	Min. Value	Max. Value
Low Middle Household Share in Social Market	0.4	0.36	0.44
Average Shortage Reaction Time	0.75	0.675	0.825
Average Construction Time	3	2.7	3.3
Liberalisation Interval	1	0.9	1.1
Vacancy Rate	0.04	0.036	0.044
Information Delay	0.85	0.765	0.935
Average WOZ Value Alteration Percentage	0.08085	0.07277	0.08894
Examination Time of Total House Shortage	0.0808	0.07272	0.08888
Major Maintenance Cost Part	0.8	0.72	0.88
Minor Maintenance Cost Part	0.4	0.36	0.44

B.5.1. Univariate Sensitivity Analysis

According to Pruyt (2013), three types of sensitivity to (small) changes in a model are typically distinguished: (1) numerical sensitivity (only a minor numerical change), (2) behaviour mode sensitivity (change in behaviour pattern), and (3) policy sensitivity (change in the preference order of policies). The numerical sensitivity and the behaviour mode sensitivity are essential to this analysis since it seeks to evaluate how sensitive the KPIs of this model are to the chosen constants rather than to the policy. As a result, a univariate sensitivity analysis was carried out in this study using the Vensim software. The "sensitivity analysis" function of Vensim was implemented to provides insights into the numerical and behavioural sensitivity of the investigated constants. To execute this sensitivity analysis, the baseline values of the variables in Table B.2 were altered by ±10% using a RANDOM-UNIFORM distribution. The findings of this sensitivity analysis are presented in Table B.3, where *x* designates whether the corresponding KPI exhibits a numerical and/or behavioural sensitivity for the constant in question.

Various insights on the behaviour and numerical sensitivity of the KPIs can be gained based on the results shown in Table B.3. To begin with, it is evident that all KPIs are behaviorally and numerically sensitive to the constant Low Middle Household Share in Social Market which influences how much housing is demanded (see Figure B.22). The housing scarcity will worsen if housing demand rises faster than the number of new dwellings being constructed. In order to reduce the shortfall, more houses will be constructed. A low Solvency Ratio, in turn, limits the amount of new construction that can be created, which raises the housing shortage. Additionally, as existing homes' conditions continue to degrade as a result of reduced upkeep owing to a poor Solvency Ratio, the average condition score of the residences will rise, which means that the average conditions of these homes are deteriorating.



(e)

Figure B.22: Results of the univariate sensitivity analysis per KPI when the constant Low Middle Household Share in Social Market had a ±10% variant - (a) SGEI Houses Shortage, (b) SGEI Houses Shortage, (c) Average Condition Score of SGEI Houses, (d) Average Condition Score of Non SGEI Houses, (e) Solvency Ratio.

Figure B.22 illustrates that the Non SGEI Houses Shortage and Average Condition Score of Non SGEI Houses are the least affected by the ±10% change in the constant Low Middle Household Share in Social Market among the various KPIs, as the bandwidth of these KPIs are the narrowest. Since there is a surplus of Non SGEI houses for the majority of the model simulation, a minor change in this constant would have limited impact on how the scarcity of Non SGEI houses behave, which in turn affects the housing quality of Non SGEI houses. Given that new homes are only constructed when there is a housing shortage in this model, the influence of this constant on these KPIs behaviour could therefore primarily been seen when there is a shortage of Non SGEI dwellings. Additionally, Figures B.22b and B.22d demonstrate that the majority of behavioral deviations from these KPIs occur once the KPI Non SGEI Houses Shortage has become positive, which means that there is a scarcity of Non SGEI houses.

Additionally, all KPIs are numerically sensitive to the constants Average Shortage Reaction Time, Average Construction Time, Information Delay, Average WOZ Value Alteration Percentage, and Examination Time of Total House Shortage, as can be seen in Table B.3. The new building's ability to address the housing need depends on constant Average Construction Time, just like it does on constant Average Shortage Reaction Time. Contrarily, the constants Information Delay, Average WOZ Value Alteration Percentage, and Examination Time of Total House Shortage affect the rate and magnitude of the Solvency Ratio's response to the housing scarcity. Solvency Ratio can, on one hand, have an indirect impact on the housing crisis because it affects both new home development and home sales – which, among other things, impacts the housing supply. In particular, a high Solvency Ratio expands the housing supply since it provokes more new homes to be built and fewer ones to be sold. The state of the dwellings in the social housing market is also influenced by the Solvency Ratio, given the fact that the Solvency Ratio affects how well the properties are maintained. Particularly, increased home maintenance is a result of greater solvency.

Furthermore, it can be observed that only the Solvency Ratio is numerically sensitive to constants Major Maintenance Cost Part and Minor Maintenance Cost Part because it is based on this that maintenance expenses are established, hence determining the amount of money that must be borrowed in foreign capital. Since the Solvency Ratio is calculated as the quotient of equity and total equity (the sum of equity and foreign capital), a rise in foreign equity will result in a decrease in the Solvency Ratio. However, since the effect of these constants on the Solvency Ratio is so small that changes in the Solvency Ratio are not significantly affecting new construction, homes sold, or maintenance, making the other KPIs less susceptible to these constants. Moreover, it is clear that all KPIs – with the exception of Average Condition of Non SGEI Houses – are quantitatively sensitive to constant Vacancy Rate. Since this constant primarily impacts the amount of rental income received by housing associations and, consequently, whether or not loan capital must be obtained in order to finance housing development, it can be observed that this constant primarily has an impact on the Solvency Ratio. Because the Solvency Ratio in this study is calculated in such a way that more loans result in lower the Solvency Ratio, changes in the Solvency Ratio will have an indirect impact on other variables, such as the housing scarcity and the average condition score of homes.

Finally, it can be said that no KPI, either in terms of a numerical value or behaviorally, is sensitive to constant Liberalisation Interval. This is because the constant merely affects how frequently SGEI homes are liberalized and does not significantly alter the housing supply to affect the KPIs of this model. As a result, the behaviour and magnitude of the various KPIs remain the same as the base case in this analysis.

B.5.2. Multivariate Sensitivity Analysis per KPI.

In this case, the multivariate sensitivity analysis was applied to determine the influence of the various assumptions described in Table B.2 on the KPIs. As was previously mentioned, this analysis was implemented to evaluate the combined impact of these variables on the KPIs when they are altered simultaneously. To enable these insights, the Extra-Trees feature scoring of Geurts et al. (2006) facilitated by the EMA Workbench, which is short for extremely randomized trees feature scoring, was used. Feature scoring is a family of machine learning techniques that can be used to measure the relative influence of individual input parameters on model results (Kwakkel, 2022). Furthermore, it was chosen to run 100 different values of each constant, totaling 1000 separate tests, in order to enable results comparison. Latin Hypercube Sampling (LHS), which assures equal sampling throughout the uncertainty ranges for each of the input parameters, was used to modify the default values of the input parameters to produce the values for each experiment in this investigation.

Table B.3: Results of Univariate sensitivity analysis per KPI.

KPI	Constants	Sensitivity	
		Behaviour	**Numerical**
SGEI Houses Shortage	Low Middle Household Share in Social Market	*x*	*x*
	Average Shortage Reaction Time		*x*
	Average Construction Time		*x*
	Liberalisation Interval		
	Vacancy Rate		*x*
	Information Delay		*x*
	Average WOZ Value Alteration Percentage		*x*
	Examination Time of Total House Shortage		*x*
	Major Maintenance Cost Part		
	Minor Maintenance Cost Part		
Non SGEI Houses Shortage	Low Middle Household Share in Social Market	*x*	*x*
	Average Shortage Reaction Time		*x*
	Average Construction Time		*x*
	Liberalisation Interval		
	Vacancy Rate		*x*
	Information Delay		*x*
	Average WOZ Value Alteration Percentage		*x*
	Examination Time of Total House Shortage		*x*
	Major Maintenance Cost Part		
	Minor Maintenance Cost Part		
Average Condition Score of SGEI Houses	Low Middle Household Share in Social Market	*x*	*x*
	Average Shortage Reaction Time		*x*
	Average Construction Time		*x*
	Liberalisation Interval		
	Vacancy Rate		
	Information Delay		*x*
	Average WOZ Value Alteration Percentage		*x*
	Examination Time of Total House Shortage		*x*
	Major Maintenance Cost Part		
	Minor Maintenance Cost Part		
Average Condition of Non SGEI Houses	Low Middle Household Share in Social Market	*x*	*x*
	Average Shortage Reaction Time		*x*
	Average Construction Time		*x*
	Liberalisation Interval		
	Vacancy Rate		*x*
	Information Delay		*x*
	Average WOZ Value Alteration Percentage		*x*
	Examination Time of Total House Shortage		*x*
	Major Maintenance Cost Part		
	Minor Maintenance Cost Part		
Solvency Ratio	Low Middle Household Share in Social Market	*x*	*x*
	Average Shortage Reaction Time		*x*
	Average Construction Time		*x*
	Liberalisation Interval		
	Vacancy Rate		*x*
	Information Delay		*x*
	Average WOZ Value Alteration Percentage		*x*
	Examination Time of Total House Shortage		*x*
	Major Maintenance Cost Part		*x*
	Minor Maintenance Cost Part		*x*

The result of the multivariate sensitivity analysis can be seen in Figure B.23. This figure indicate the influence of the various assumptions described in Table B.2 throughout the various model replications. This influence is denoted by colour and number presented in each cell of this figure. The colours used to depict this impact ranges from yellow to dark blue, with yellow denoting the highest value. The value specifically denotes the KPI's level of sensitivity to a particular constant. Particularly, the bright the colour, the higher the score, and the greater the constants's influence on the KPI in question is. In addition, the columns in this figure denote the KPIs, while the rows represent the constants.

Figure B.23 shows that, with the exception of constant Low Middle Household Share in Social Market, the altered constants generally had the same effect on each of the studied KPIs. It can be seen that for the SGEI Houses Shortage, most of the constants – aside from the exception mentioned – generally exert an influence between the values of 0.085 and 0.092. In contrast, the constant Low Middle Household Share in Social Market has the greatest impact on this KPI with a value of 0.21, indicating that the SGEI Houses Shortage is most sensitive to the constant Social Market when the studied constants are altered simultaneously. Given that the same observation can be made for the other KPIs of this study, it can be concluded that all KPIs are most sensitive to the constant Low Middle Household Share in Social Market when the studied constants are altered simultaneously.

Looking closely at the Figure B.23's colors reveals that, out of all the KPIs, this constant will have the most impact on the KPIs Non SGEI Houses Shortage and Average Condition Score of Non SGEI Houses. This can be explained by the fact that this constant controls the demand for Non SGEI homes. If this constant increases, a higher portion of the population will search for homes in the Non SGEI sector, increasing the demand for Non SGEI homes. More new Non SGEI homes will be constructed to address the growing housing shortage if the demand for these dwellings rises faster than the supply does The Non SGEI Houses shortage will be reduced as more of these homes are built. In addition, this will also cause the Average Condition Score of Non SGEI Houses to decrease, as the production of new homes, which have a condition score of 1, will pull the average condition score down.

Figure B.23: Results of Multivariate sensitivity analysis.

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