THE TRANSFORMATION PROCESS FROM OBSOLETE INDUSTRIAL SITES TO RESIDENTIAL AREAS: A System Dynamics Approach

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Rentian Zhang

Student Number: s136792 / 0870891

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Colophon

Title

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Author

Name	R. (Rentian) Zhang
Student ID	s136792 / 0870891
E-mail Address	rentian.z@outlook.com
Telephone Number	0684655818

Graduation Committee

Prof.dr.ir. B. (Bauke) de Vries	(TU/e)
Dr. Q. (Qi) Han	(TU/e)
PhD. T. (Tong) Wang	(TU/e)

Institute and Graduation Program

University	Eindhoven University of Technology
Department	Built Environment
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TU/e Technische Universiteit **Eindhoven** University of Technology

Content

Summary

The importance of sustainable land use development should not be ignored in urban development nowadays, especially for a densely populated country like the Netherlands. In some regions of the Netherlands, for example, the province Noord-Brabant, on one hand, there exist several obsolete industrial sites caused by technique outdating, poor accessibility and industry relocation, which bring adverse effects to the urban environment and thus lower the spatial quality. On the other hand, since the number of urban population is growing continuously, as a result, the housing demand is increasing, which, with the limited residential areas, leads to a tight housing market. Both of the two problems have to do with the matter of land use development and planning. Transformation of land use from the obsolete industrial area into the residential area is a solution for both problems. This research aims to provide a better understanding of the important factors play in the transformation process and give advice to the local government. The main research question is: What factors should be paid specific attention during the transformation from obsolete industrial sites to residential areas?

The research begins with a literature study that covers existing researches about obsolete area transformation process and the current industrial sites obsolescence situation, demographic condition as well as housing demand in the country of the Netherlands and the province Noord-Brabant. Through the literature study, factors playing in the transformation process are definite. The findings indicate that main stakeholders in the process are the public authority and private developers. While drivers of the transformation include scarce land, growing interests on sustainable development, the tendency of reducing adverse effects of obsolescence and marketing need as well as profitability. Barriers that hinder the transformation process are complicated procedure, overmuch liability and high cost. The factors can be divided into four aspects, which are site attributes, the project relevance, government offers and policies, as well as regional condition. Government offers and policies include procedure simplification, economic incentive and liability reduction. Furthermore, methodologies in this field are reviewed and System Dynamics modeling is selected because it provides an integrated theoretical framework for modeling complex systems into a simpler and understandable model. The research question, which is finding out the most contributing factors, can be answered. In addition, through the System Dynamics modeling a broader view on such a complex problem like the transformation of obsolete industrial sites is shown, which gives decision-makers opportunities to make more deliberate choices because the modeling process and analysis results enable better understand the interactions among simulation variables and interrelationships of these variables in the system.

The System Dynamics modeling process starts with structuring a Causal Loop Diagram. After the Causal Loop Diagram is finalized, it is transferred into a Stock Flow Model. The model cannot get running until the equation of each variable is determined and is logically correct. The equations are setup based on existing data and findings of researches. To answer the research question, except for the benchmark scenario, three scenarios are designed, each of which represents a strategy the government would take to improve the transformation. Through analyzing and comparing the outcomes of different scenarios, the conclusion can be drawn out that although the other two strategies also have influences on improving the transformation process, among the three, procedure simplification is the most effective one. Thus, simplifying procedure should be paying most attention by the public authorities. Procedure simplification can be achieved by reducing the response time in handling the transformation-related affairs and applications of relevant agencies.

The scientific value of this research locates in the depth it reaches. Though there are wealthy researches on land use transformation related questions already and there are also considerable researches regarding obsolete industrial sites transformation process. This research goes further by finding out the decisive factors and looks into the possible interactions between obsolete industrial sites and residential areas demand solely. It creates an analysis tool for studying the two issues and analyzing factors that are playing in the process. A model is provided and gives elaboration on aspects that are important in the field of construction management and urban development (CMUD) and integrates them into one model, paves the way for further research from which an optimal decision support method can be obtained.

The societal added value of this research is related to municipalities and property developers as well as the urban environment spatial quality. It gives advice on properly dealing with obsolete industrial sites transformation to achieve in a more sustainable built environment, improving the spatial quality, better understanding important factors in urban development process and creating attractive transformation sites. An attractive transformation site will improve the urban environment, bring opportunities for investments and promote regional development. Also, this research provides insights for all municipalities that are looking for ways to deal with over-stock industrial sites and growing housing demand in this regard. It contributes to strengthen the negotiation and collaboration between the two stakeholders to create a better urban environment.

Abstract

With the aim of analyzing the transformation process from obsolete industrial area to residential area, finding out factors that play biggest parts and providing insight as well as giving advice to the Noord-Brabant government, a simulation analysis based on existing researches and statistics using System Dynamics modeling method is conducted. The result shows that though all the three governmental strategies: financial funding, liability reduction and procedure simplification have effects on improving the chance of transformation, among the three, simplifying the procedure of handling related applications and shortening the response time is the most effective one. Despite the terrain limitation, the analysis tool can be served as a general analyzing tool for ant areas as long as there is data available. The research reaches to a depth in the current field of sustainable development of urban land use planning, contributes to the development of smart cities and improvement of spatial quality and provides insights for all municipalities that are looking for ways to deal with over-stock industrial area or industrial sites obsolescence. The simulation model helps both public authorities and private developers in deciding an appropriate strategy or selecting a proper project depends on their own specific situations and can serve as a new platform for negotiation between the two players.

Chapter 1 Introduction

Dutch municipalities are confronted with the problem of high obsolescence rate in industrial sites. This is mainly due to two reasons: the oversupply land market (Seebus, 2012) and low spatial quality. The Dutch Ministry of Infrastructure and Environment (VROM) has pointed out in the 2.5 year 'Beautiful Netherlands' (Mooi Nederland) innovation program report that industrial sites with low spatial quality do not reach the requirement and redevelopment or transformation is necessary. They are contaminated, technically outdated or with poor accessibility (VROM, 2011).

Data from the Statistics Netherlands (Centraal Bureau voor de Statistiek (CBS)) shows that the Netherlands is a small country with a population of nearly 17 million people (CBS, 2015b). Therefore, carefully attention should be paid to urban land use and urban area expansion. Transformation of old, vacant industrial sites into other use like residential areas might provide a reasonable solution. However, not all obsolete sites are suitable for transformation and there are many factors playing in the transformation process, which requires further investigation.

The research will provide an analysis tool for better looking into the transformation from obsolete industrial sites to residential areas in province Noord-Brabant. This chapter presents the fundamental knowledge and research design in general. In the first section, the problem is explored. Obsolete industrial sites and their transformation are introduced; followed by problem analysis, research question, research objectives and limitations. In the third section, the research methodology and research design is illustrated in detail. A description of results, added value as well as societal relevance of the research is presented in the fourth section.

1.1 Problem Definition

Before the research is designed and carried out, an analysis of the problem should be made to reveal the importance of the problem and the research and draw out the research question. In the following paragraphs, first an overview of the industrial sites obsolescence in the Netherlands will be presents. Then the housing demand situation will be given, followed by an introduction of the land use transformation.

1.1.1 Obsolete industrial sites

According to the 2012 annual industrial sites report of the Ministry of Infrastructure and Environment (VROM) made by ARCADIS and IBIS, there are 3722 industrial sites through the Netherlands. Among the 3722 industrial sites 28% are obsolete, 56% are not obsolete and the rest 16% are unknown due to no data accessible. Figure 1-1 shows the number of obsolete and non-obsolete industrial sites by province. In some provinces the number of obsolete sites reaches to one third of the total number of industrial sites, and in Noord-Holland the obsolete rate is 47.2% (VROM, 2013). Though it is not possible to make supply fully match with the demand, a lower vacancy rate is preferred. Therefore, at the moment the industrial sites market is not a good one from the perspective of grant and vacancy rate.

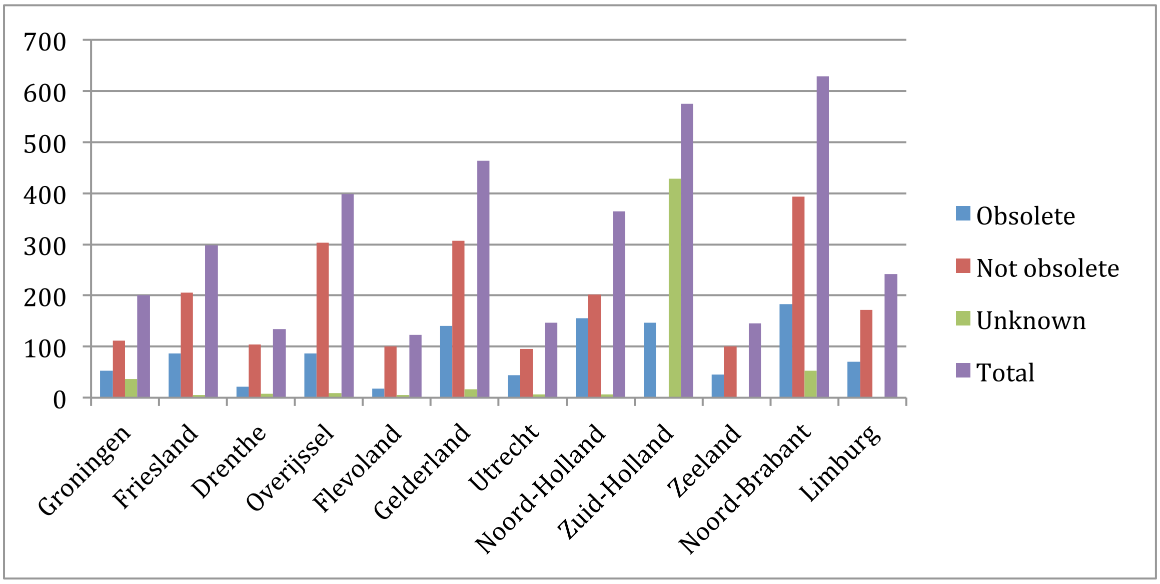


Figure 1-1 Number of obsolete and not obsolete industrial sites by province (including seaport areas and economic zones), till Jan. 1st 2013 (ARCADIS & IBIS, 2013)

At the end of 2009, an agreement, namely the 'Industrial Estates Covenant 2010-2020' (Convenant Bedrijventerreinen 2010-2020) was made between the Dutch national government and provincial as well as municipal authorities. The agreement includes clauses aiming at improving and regulating the redevelopment and transformation of obsolete industrial sites and preventing the depreciation of the existing industrial land market. Funding is distributed for stimulating the redevelopment and transformation process (JLL OnPoint, 2010).

1.1.2 Residential areas and housing demand

The Netherlands is a small and densely populated country with a population of nearly 17 million (CBS, 2015b). As a result, housing demands in some large cities are intense. For example, the municipality of Eindhoven as a high-tech and intelligent city with 4 public institutions of higher and adult education, bears a population of over 220,000, among which one third are foreigners. There are many university employees and students. The student accommodation supply in Eindhoven usually falls behind the demand. It is difficult to find an affordable accommodation. More available resources of housing are in need. Since there exist industrial sites need to be transformed, transformation into residential areas to meet the demand is a possible and beneficial solution.

1.1.3 Obsolete industrial sites transformation

The transformation process involves two main stakeholders that it requires in-depth cooperation and collaboration between public authorities and private parties (van Bronkhorst, Glumac, van Rhee, Kunen, & Schaefer, 2014). First, investments from private parties are essential because resources possessed by and could be utilized by public authorities are far from enough. Therefore, public authorities will encourage private parties and invite them to participate in the transformation process (VROM, 2013). However, before making the decision, private parties such as property developers will investigate in the surrounding environment and technical aspects of the site, assessing the regional factors and evaluating the project and relative policies. Thus the site attributes, surrounding environment, project relevance, local condition, market needs and relative policies and offers are important factors playing in the process.

1.2 Research Question

With a brief introduction of the problem given, the research question can be drawn out, in following paragraphs the research question and sub-questions, the objectives and limitations of the research are given.

1.2.1 Problem Analysis and research question

To solve the oversupply of industrial land and deal with the problem of obsolete industrial sites, redevelopment and transformation measures are often taken by municipalities. A successful transformation process improves the spatial quality and urban environment, meets market demand and brings profits. However, there are many factors playing in the process. Some factors are more deciding than others. Also, not all obsolete industrial sites are appropriate for transformation. Therefor, if the important factors playing in the process and suitable industrial sites type are figured out, the transformation process will be more efficient. Studies in this field are far from enough, which needs in-depth investigation and research.

Based on above analysis, the main research question is:
What factors should be paid specific attention during the transformation from obsolete industrial sites to residential areas?

And there are three sub-questions:
Sub-question 1 – What factors have influence on obsolete industrial sites transformation?
Sub-question 2 – Which factors are the most influential in transformation process?
Sub-question 3 – What kind of advices can be provided to municipalities and property developers in this regard?

1.2.2 Research objectives and limitations

The purpose of this research is to provide an analyzing tool for exploring the transformation of obsolete industrial sites into residential areas, which is based on the situation of province of Noord-Brabant, and improves the transformation process. Since the Netherlands is a densely populated, small country with limited land area, municipalities can make use of this approach to achieve in better spatial quality and more sustainable built environment. However, there are some limitations. First, the research will be conducted in a limited time, thus it is not possible to cover all aspects of transformation process. Second, the obsolete industrial sites transformation process is a dynamic one and is changing over time, which leads to the limitations in accuracy of data manipulation and also inconsideration. It is not possible to take all possibilities into consideration in this research.

1.3 Research Design

In this section the methodology applied in this research will be given, followed by the research design and interpretations.

1.3.1 Methodology justification

According to the research objectives, the research question is a macroscopic one and in real situation it is dynamic and complicated, using a centralized, top-down method to analyze the problem and answer the question is preferred. Therefore, a System Dynamics approach is necessary. Since the environment is dynamic, many uncertainties will occur, which makes a scenario analysis indispensable. In the following paragraphs the research procedure and research model will be introduced.

1.3.2 Research model

The process of this research consists of several phases (Figure 1-2). Approaches that will be used in the research process to answer the research question are literature study, case study, System Dynamics modeling, and validation and scenario analysis.

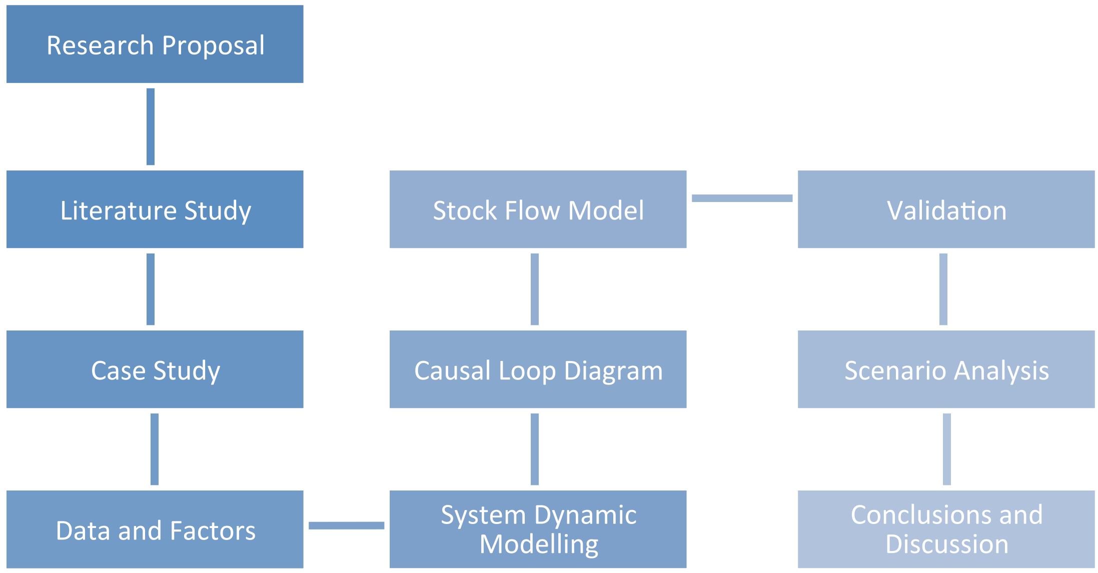


Figure 1-2 Research Design

As shown in Figure 1-2, after the research proposal, the first stage of this research begins with a literature study of existing researches and official statistics related to obsolete industrial sites, the housing demand and the transformation of obsolete industrial sites. It is conducted with the aim to extract useful information of the Netherlands and province Noord-Brabant in this regard as well as information such as interested groups, drivers, barriers and factors that are playing in the process of transformation. After literature study, case study will be conducted, in which practical cases will be looked into and summarized.

During the literature study and case study, insights about the decision making process in the urban development domain will be drawn out, data and factors that are relevant will be searched and reviewed (and sub-question 1 answered).

After that the System Dynamics approach will be employed. A system dynamics model will be developed to reveal the possible inner connections between obsolete industrial sites and residential areas and show the influence played by related variables and their relationship. First, according to the connections between different variables a Causal Loop Diagram (CLD) will be structured using the Vensim software (Ventana, 2014). When the CLD is designed, it will be checked and adjusted. After the CLD is determined, it will be transformed into a Stock and Flow Model (SFM). The CLD and SFM will present the overall relationship among different variables. Several sub-types of industrial land use will also be included in the SFM. After the model is finished, validation of the model will be tested to make sure the model is designed structurally. Then data will be put into the model for the simulation and results of different scenarios will be drawn out. Different scenarios will be compared and analyzed. In the scenario analysis phase, the sub-question 2 is answered. After that the conclusions and discussion will be presented, in which there are advice and insights, which answers the sub-question 3.

1.4 Expected Results

The findings of this research will provide an overview of important factors that are playing in the process of transforming obsolete industrial sites into residential areas. In addition, a visualized model that analyzes the behaviors of the system and interactions between variables will be developed by means of system dynamics approach. Also, a more detailed, quantified model will be developed to study the question in a quantification way. Furthermore, scenario analysis will give advice on what can be improved in the transformation process and what factors are playing bigger part in the transformation process. Following paragraphs presents the research added value and societal value of the research.

1.4.1 Research Added Value

There are rich researches on land use transformation related questions available already. Also, researches regarding obsolete industrial sites transformation process are many. However, this research goes further by finding out the decisive factors and looks into the possible interactions between obsolete industrial sites and residential areas demand solely. It creates an analysis tool for studying the two issues and analyzing factors that are playing in the process. A model will be provided. It gives elaboration on aspects that are important in the field of construction management and urban development (CMUD) and integrates them into one model, paves the way for further research from which an optimal decision support method can be obtained using algorithm design.

1.4.2 Societal Value

The societal added value of this research is related to municipalities and property developers as well as the urban environment spatial quality. It gives advice on properly dealing with obsolete industrial sites transformation to achieve in a more sustainable built environment, improving the spatial quality, better understanding important factors in urban development process and creating attractive transformation sites. An attractive transformation site will improve the urban environment, bring opportunities for investments and promote regional development. Also, this research provides insights for all municipalities that are looking for ways to deal with over-stock industrial sites and growing housing demand in this regard. It contributes to strengthen the negotiation and collaboration between the two stakeholders to create a better urban environment.

Chapter 2 Glossary

- Acceptance chance: The chance that the property developer will take the transformation project.

- Accessibility: The distance of nearest transportation network to the site.

- Brownfield: Abandoned, idled or underused industrial and commercial properties where real or perceived contamination complicates expansion or redevelopment.

- Cost: The total cost of the transformation project; includes cost of acquiring the land, cost of redesign and reconstruct.

- Economic growth: The annually economic growth percentage of the region.

- Economic incentive: Financial funding offered by the government to promote transformation projects.

- Industrial area: A work location with a size of at least 1 hectare gross marked and suitable for trade, industry and business.

- Liability afterwards: The total liabilities the developer of the transformation project should bear after the project is finished. For example, the liability of maintaining the building and surrounding green space after the transformation project is done.

- Liability afterwards reduction: The policies of reducing liabilities of property developers released by the government that aims to promote transformation projects.

- Obsolete industrial area: Industrial areas that are obsolete or unoccupied because of technique outdated, contaminated or poor accessibility.

- Other mutation (of the residential area): Changes of the residential area except for the part that is contributed by transformation projects.

- Procedure simplification: The policies of simplifying application procedure and related affairs handling time released by the government that aims to promote transformation projects.

- Remediation: Cleaning the soil of the site to make it harmless for human health and make the environment suitable for living.

- Residential area: An area for living includes the green space and facilities around, of which land use is residential and in which housing predominates, as opposed to industrial and commercial areas.

- Soil quality: The soil condition of the site that whether there needs remediation.

- Surrounding image: The surrounding environment of the site, such as whether there are enough green space and the appearance of the area.

- Transformation project: The project that is conducted under sustainable principle, redesigns and reconstructs the obsolete industrial area and transforms the land use type of issued area to residential area.

- Transformation time: The total time spent on the transformation project.

Chapter 3 Literature Review

The existing researches and methods about obsolete industrial sites transformation and factors that play in the transformation process are comprehensive and rich. In order to get an overview of the findings and find out what ulterior contribution can be made, before the modeling phase, a literature review will be conducted. In this chapter the findings of existing literatures will be presented. There are three parts; the first part (Part A) presents the findings in industrial sites obsolescence and the sustainable transformation process, its interested groups, drivers, barriers and factors; the second part (part B) presents the current housing and population situation in Noord-Brabant and the reason of transformation; the third part (Part C) provides an overview of methods that are commonly used in this field to research the sustainable land development problem.

Part A: Obsolete Industrial Sites and Transformation Process

Industrial area takes a relatively big portion in the global urban land use. On one hand, it is contributing to regional economic development. On the other hand, it cannot be ignored that industrial area adds to global carbon dioxide emissions and creates adverse effects such as security problems and urban sprawl, which causes negative influence to urban environment.

The industry revolution starts in 18^{th} century brought profit and advancement to Europe from then on. However, the European countries are seeing industrial relocation in recent decades. Industries are moving out from west Europe. The phenomenon that companies are closing down or outsourcing and moving away to other regions is not unusual (Györffi & Oren, 2006). Furthermore, the global economic crisis from 2008 and the European debt crisis from 2009 lead to economic decline; more industrial sites are outdated and become obsolete. There are fears that Europe may continuing lose its industries (manufactory, services and R&D) to other regions and suffer from problems of economy and employment (European Communities, 2009). The loss of industries also affects the Dutch municipalities. Industrial and business areas are over-supplied and the Dutch municipalities are facing the problem of industrial sites obsolescence (JLL EMEA Ofice Research, 2014; Knight Frank Research, 2013; Seebus, 2012).

Industry change and relocation is not the only reason that leads to industrial sites obsolescence. Other causers include contamination and technique outdate. According to what is stated by VROM, industrial sites that are contaminated or technically outdated and becoming obsolete cannot be put into use until they are cleaned up (VROM, 2011). An obsolete industrial site will either be redeveloped then put into industrial use again or transformed into other land use types such as residential area, recreation or commercial and service area. No matter what solution is given, the process will follow the principle of sustainable development because that is the reason of redevelopment and transformation. Since this research focuses on transformation, the details of redevelopment process will not be covered.

In the following sections of this part, introduction of industrial sites in the Netherlands, Noord-Brabant province and interpretation of obsolete industrial sites sustainable development based on existing researches and studies will be given. The first section (3.1) explains what are industrial sites by giving the definition of IBIS; the second section (3.2) introduces the distribution of industrial sites in the Netherlands and province Noord-Brabant; the third section (3.3) summarizes the transformation and sustainable development of obsolete industrial sites. The last section (3.4) concludes this part.

3.1 Industrial Sites by IBIS

Industrial sites are defined as workplaces by IBIS (VROM, 2013). According to the definition; an industrial site is:

"A work location with a size of at least 1 hectare gross marked and suitable for trade, industry and business. On these sites some commercial and non-commercial services, like office buildings and shopping, could be present, but these functions only have a small share in the total surface of the area. The following areas are not industrial areas: a seaport area, an economic zone, an office location, an area for extraction of raw materials, an area for oil and gas extraction, an area for collection of water, an area with purely agricultural goals and an area for waste dumping".

The following section will make introduction of industrial sites distribution and obsolescence in the Netherlands and province Noord-Brabant.

3.2 Industrial Sites in the Netherlands

In the country of the Netherlands, during the year of 1990 and 1996 the surface of urban environment has added 39800 hectare, which is taken from the countryside. In the expansion area, the industrial and business areas occupy relatively a big part, which is over 13673 hectare. There are 16.3% increasing in industrial and business area and 14.2% in business with green area (Harts, Maat, & van Emmichoven, 2000). According to statistics proving by CBS, from 1996 to 2010, the industrial and business area is increasing from 59980 hectare to 81358 hectare (CBS, 2015a). In 2006, among the industrial areas of the whole country the province of Noord-Brabant, with industrial area surface 5,139 hectare, takes up a share of 23% in the Netherlands and ranks the first among twelve provinces (Traa & Knoben, 2009).

In this section, the distribution and obsolescence of industrial sites in the country of the Netherlands as well as in the province of Noord-Brabant will be introduced.

3.2.1 The Distribution and Obsolescence of Industrial Sites in the Netherlands

The industrial sites in the Netherlands are monitored by the 'IBIS Werklocaties'. According to the 2012 annual industrial sites report of the Ministry of Infrastructure and Environment (VROM) made by IBIS, there are 3722 industrial sites through the Netherlands. Among the 3722 industrial sites 28% are obsolete, 56% are not obsolete and the rest 16% are unknown due to no data accessible. Figure 3-1 shows the number of obsolete and non-obsolete industrial sites by province. In some provinces (Friesland, Gelderland and Zeeland) the number of obsolete sites reaches to about one third of the total number of industrial sites, and in Noord-Holland the obsolete rate is 47.2%. (VROM, 2013)

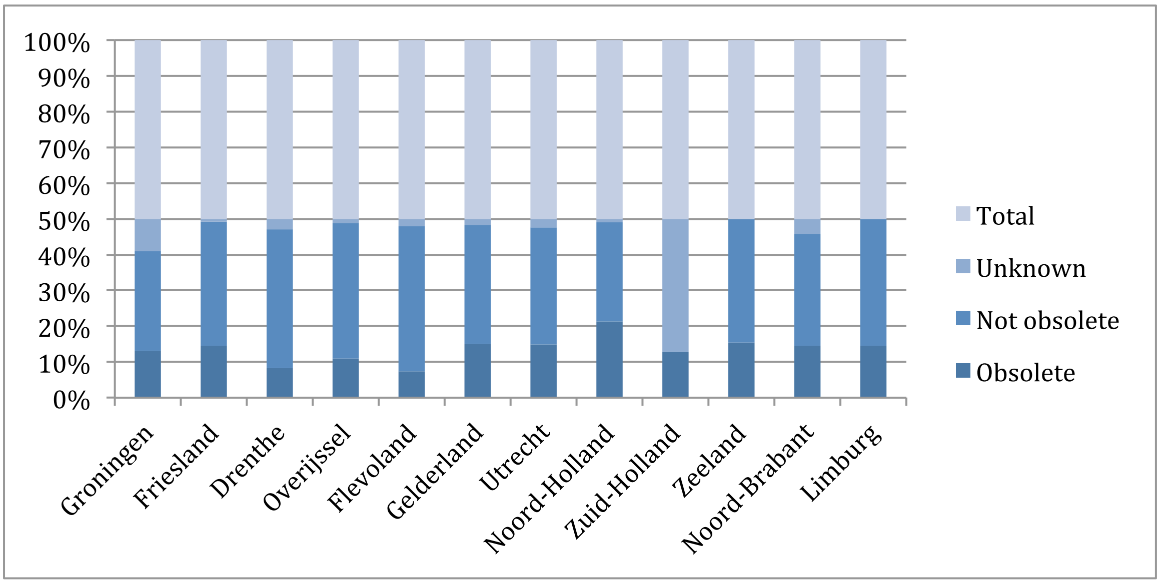


Figure 3-1 Number of obsolete and not obsolete industrial sites by province (including seaport areas and economic zones), till Jan. 1st 2013, data accessed from VROM (2013)

In the land market, there is an indicator, namely vacancy rate, for property developers and experts to evaluate the condition of the local, regional and national land market as well as the local, regional and national economic status. Vacancy rate is a standard that calculates the proportion of the volume of unoccupied areas in the whole volume of areas in the market. For instance, a neighborhood that has 2,000 apartments in total and 100 vacant apartments bears a vacancy rate of 5.0 percent (100÷2,000). With vacancy rate, the equilibrium and change between supply and demand of land in the land market could be explored. (Floyd & Allen, 2002)

Because both buyers or tenants and leasers need time to look for a good deal, it is not possible to make supply fully match with the demand. However the lower the vacancy rate is, the more lands are occupied, and more commercial activities are about to happen and more employment is required, which shows a productive economy status. While on the other hand, high vacancy rate indicates that demand for commercial production is decreasing and economic condition is not allowing optimism (Ferstl Valuation Services, 2014). Therefore, according to the data about obsolete industrial sites by IBI, at the moment the industrial land market is not a good one from the perspective of grant and vacancy rate.

3.2.2 The Distribution and Obsolescence of Industrial Sites in the Noord-Brabant

Industrial sites obsolescence is not a new problem in the province of Noord-Brabant. A survey, conducted by Royal Haskoning (2010) on the request of the Noord-Brabant provincial government with the objective of getting the total (gross) size of obsolete industrial areas (till the end of 2009), evaluates the obsolescence status of approximately 600 industrial sites in the province based on spatial quality. It is estimated the surface of obsolete industrial sites in Noord-Brabant are 2,504 hectare. Table 3-1 below shows the distribution of these obsolete industrial sites by region in the province, the surface each region has their percentage in total surface is recorded. As data from the municipalities of Eindhoven and Hilvarenbeek are missing, the data from Eindhoven's own research is added and the total gross surface of obsolete industrial sites (including Eindhoven and Hilvarenbeek) in Noord-Brabant is approximately 2,700 hectare. Table 3-2 below shows by region to what extent these obsolete industrial sites may need to be considered redevelopment (which includes transformation). (Provincie Noord-Brabant, 2010)

Table 3-1 Distribution of obsolete industrial sites by region, source: Kwaliteit en veroudering bedrijventerreinen Noord-Brabant, Royal Haskoning (2010)

Region	**Surface of obsolete industrial sites**	
	Surface (in hectare)	Percentage (rounded)
1. West-Brabant	896	36%
2. Central-Brabant	288	12%
3. Northeast-Brabant	476	19%
4. Southeast-Brabant	844	34%
Total (without missing data)	2,504	100%

Table 3-2 Distribution of possible redevelopment projects by regions, source: Kwaliteit en veroudering bedrijventerreinen Noord-Brabant, Royal Haskoning (2010)

Region	**Obsolescence (hectare)**
West-Brabant	Heavy redevelopment: 28 ha
	Redevelopment: 868 ha
Central-Brabant	Heavy redevelopment: 4 ha
	Redevelopment: 284 ha
Northeast-Brabant	Heavy redevelopment: -
	Redevelopment: 476 ha
Southeast-Brabant	Heavy redevelopment: -
	Redevelopment: 844 ha
Total (without missing data)	Heavy redevelopment: 32 ha
	Redevelopment: 2,472 ha

From Table 3-1 and Table 3-2 it can be known that the west and southeast region of

Noord-Brabant take relatively large share (together 70%) in the total surface of obsolete industrial sites. However, the actual situation in southeast and central region is higher than indicated in Table 3-2 because data from the municipalities of Eindhoven and Hilvarenbeek is not included (data unavailable). (Provincie Noord-Brabant, 2010)

The province Noord-Brabant provides a figure as shown below that in 2013 the industrial sites obsolescence percentage (Figure 3-2).

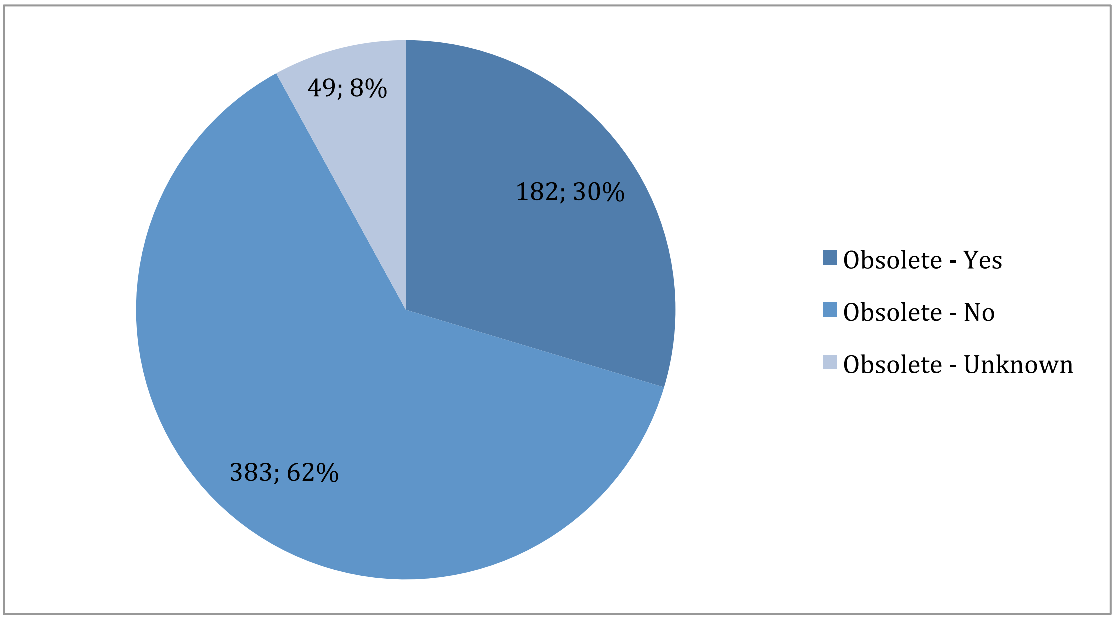


Figure 3-2 Obsolete industrial sites - Yes/No 2013 Province: Noord-Brabant (Provincie Noord-Brabant, 2013)

3.3 Transformation and Sustainable Development of Obsolete Industrial Sites

According to the statistics of Centraal Bureau voor de Statistiek (CBS), the Netherlands has a population of nearly 17 million (CBS, 2015b). The government of such a small and densely populated country should pay attention to land use plan issue. With industrial obsolesce rate such high, transformation is a good way to solve the problem (Nijkamp, Rodenburg, & Wagtendonk, 2002). And the transformation process of obsolete industrial sites should be feasible and should not violate the principal of sustainable development. (Traa & Knoben, 2009)

In 1987, the Brundtland Commission proposed sustainable development in their report "Our Common Future" and argues "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." (Burton, 1987)

In 1990s, the idea of sustainable land use is put forward. There are mainly three aspects in sustainable land use (Nijkamp et al., 2002):

1. The *husbandry* concept: exploiting natural resources with the aim of making sure that natural resources can be used in long period. Take care when exploiting and using scarce natural resources is one of the actions that obey the husbandry concept.

2. The *interdependence* concept: preserving the form and spatial quality of the natural-human interaction, using land without destroying the natural system. Traditional agriculture is one example, in which the farm and the surrounding environment achieve equilibrium.
3. The *ethics* concept: obligation on the next generations. Bequests value, existence value and values alike are put forward from this point of view.

Recent years have seen an increasing interest in sustainable urban land development policy and strategy research because efficient and sustainable environment planning contributes to energy conservation, urban appearance improvement and creates externality profits in the long run (Alberini, Longo, Tonin, Trombetta, & Turvani, 2005; Verburg, de Nijs, Ritsema van Eck, Visser, & de Jong, 2004). But there are also factors that limit the process of urban development and land use transformation. For example, financial restriction, procedure complicacy and fear for extra liability. (Korthals Altes & Tambach, 2008; Erik Louw, 2008; Thornton, Franz, Edwards, Pahlen, & Nathanail, 2007)

At the end of 2009, an agreement, namely the 'Industrial Estates Covenant 2010-2020' (Convenant Bedrijventerreinen 2010-2020) was made between the Dutch national government, provincial and municipal authorities. The agreement includes clauses aiming at redeveloping and transforming obsolete industrial sites and preventing the depreciation of the existing industrial land market. Funding is distributed for stimulating the redevelopment and transformation processes. (JLL OnPoint, 2010)

The following paragraphs of this section will introduce parties that are being affected by the redevelopment project and thus involved in the obsolete industrial sites transformation (3.3.1), drivers and barriers for the transformation (3.3.2), factors that are influencing the transformation project (3.3.3), the transformation process (3.3.4). Also, the societal value brought by transformation projects (3.3.5) and existing practices (3.3.6) will be given.

3.3.1 Interested Groups

The transformation process of obsolete industrial sites requires in-depth collaboration and cooperation between public authorities and private parties on one hand. On the other hand, the process has influences on these parties regarding different aspects. The interested parties will react to the promotion of transformation project differently according to the detailed project. These parties are interested-related to the transformation project. (Nijkamp et al., 2002; Remøy & van der Voordt, 2006)

3.3.2 Drivers and Barriers

Land use is an issue that relates to different interested groups. Stakeholders have their own recognitions regarding the transformation process of obsolete industrial sites. Since recent years sustainable development is under highlight, sustainable land use planning is put to the center of discussion. In the past, urbanization, or land development is on the opposite side of environmental preservation. Nowadays as land resources scarcer than before, researchers and authorities are looking into the sustainable way of land use development. In the Netherlands, municipal governments have policies of providing sufficient industrial land, which is good for entrepreneurs on one hand but on the other hand the negative effect is new industrial land creates old industrial area and becomes problems in urban environment. The growing emphasis on sustainable land use and decreasing land are two main drivers for obsolete industrial sites transformation. Other triggers include the local demographic condition, objective of reducing the adverse effects of obsolescence to urban environment and security, meeting market needs and creating profits. Table 3-3 below concludes the most recognized drivers of transformation projects. (Alberini et al., 2005; Korthals Altes & Tambach, 2008; Erik Louw & Bontekoning, 2007; Remøy & van der Voordt, 2006; Verburg et al., 2004)

Table 3-3 Drivers of transformation projects

	Growing interest	Scarce land	Demographic conditions	Reducing adverse effects	Meeting market need, Creating profits
(Nijkamp et al., 2002)	x	x			
(Verburg et al., 2004)	x	x	x		
(Alberini et al., 2005)				x	x
(Remøy & van der Voordt, 2006)			x	x	x
(Altes & Tambach, 2008)		x		x	
(Louw & Bontekoning, 2007)				x	

However, the project high initiate cost and time-consuming, complicated process are impeding private developer to invest in transformation and redevelopment projects. Another barrier is the soil pollution. In the study of evaluating brownfield redevelopment approaches and practices in Europe conducted by UK national regeneration agency English Partnerships (EP), CABERNET members participated in through interviews and one member points out a barrier for the brownfield sites redevelopment with such saying that "Brownfields are legacies from an industrial past. Some forms of industry became obsolete and the soil problems they created remained unknown for many decades. The discovery of the social and economic impact of dealing with soil pollution became a barrier for the redevelopment of these brownfield sites." (CABERNET, 2003) Table 3-4 below concludes the most recognized barriers from existing studies. (Erik Louw & Bontekoning, 2007; Nijkamp et al., 2002)

Table 3-4 Barriers of transformation projects

	Soil pollution	Liability	High cost	Complicated procedure
(Nijkamp et al., 2002)	x		x	x
(Alberini et al., 2005)	x	x		
(Remøy & van der Voordt, 2006)				x
(Altes & Tambach, 2008)			x	
(Thornton et al., 2007)	x		x	
(Louw, 2008)				x

3.3.3 Factors

According to existing researches and studies, there are many factors playing in the transformation process of obsolete industrial site. The factors can be categorized into several aspects: land attributes, local condition, property developer recognitions and public authority actions. (Alberini et al., 2005; Syms, 1999; Thornton et al., 2007)

Factors that decide whether or not to initiate a brownfield redevelopment project can be concluded into six groups in the Table 3-5 below, according to the study of Syms (1999). These factors could also be used in the case of obsolete industrial site transformation process because brownfields, defined by Simons (1998) and the U.S. Environmental Protection Agency (EPA) (2002) as “abandoned, idled or underused industrial and commercial properties where real or perceived contamination complicates expansion or redevelopment”, are taking a considerable portion in obsolete industrial sites. When the land that is going to be transformed is pristine, factors in relate to soil condition and treatment way could be excluded from consideration so the feasibility of transforming a pristine obsolete industrial site into other use is higher than brownfields.

Table 3-5 Decision-making factors in brownfield redevelopment process (Syms, 1999)

Factor Groups	Factors
Site specific factors	Size
	Nature of the soil and subsoil
	Topography/relief
	Attractiveness/image
Community considerations	The location of the site within the settlement
	The supply of and demand for development land
	The image and homogeneity of the settlement;
	The municipal structure
	Time constrains
Transport considerations	The proximity of disposal and supply

Factor Groups	Factors
	systems
	Connections to local road networks
	Connections to the motorway network; and
	Public transport services.
Specific environmental factors	Groundwater reformation
	Groundwater quality
	Soil quality
	Air quality; and
	Whether there is a prevalence of contaminative land uses in the vicinity
Risk assessment in relation to human beings, eco systems, crops and domestic animals as well as buildings.	Possible changes in legislation
	Possible changes in accepted treatment methods/procedures
	The financial standing of the organization undertaking the remediation; and
	The availability of insurance cover
Further considerations	Opportunities or restrictions on use
	Planning or other official approvals
	Liability protection, and credit viability; and
	Taxation incentives or penalties

In the previous section the barriers of a transformation project is concluded (see Table 3-5). Since attributes of an obsolete industrial site such as the soil quality of the site and the nearest transportation network around the site, the project relevance such as the complexity of the project, the project cost and time horizon as well as how long can the investment be returned and the governmental offers and policies such as financial funding, liability reduction and procedure simplifications, play important role in whether or not to initiate the transformation project. They are influential factors for the transformation process and could be summarized as following points (Alberini et al., 2005; Korthals Altes & Tambach, 2008; Erik Louw, 2008; Nijkamp et al., 2002; Thornton et al., 2007):

- Contamination (need remediation, need no remediation);
- Availability of transportation (within 10 km, within 20 km and with 30 km);
- Availability of liability relief: Availability of certificate of completed cleanup that relieves the developer from liability for further cleanups;
- Response time for approval of development and cleanup plans by appropriate government departments (6 month or shorter, 24 month or longer);
- Direct financial incentives.
- Location: Presence/Absence of a city with 20 km of the site to capture access to markets and suppliers;

Because high initiate cost, time-consuming and complicated process and enormous liabilities as well as the fear of long time before investment can get returned are impeding private developers to invest in and take the transformation projects, the government should be proactive and release related policy to attract developers. Thus, except for the above factors that are site attributes and project associated, the role public authority plays is also important and decisive. Researches have indicated that actions of the local government will influence the transformation project and process as well. Public authorities participate into the transformation project decision-making process through making policies and providing offers to property developers and other private parties that involved in the project. In the Netherlands, local authorities also play the role of developer. In this way they play a part in the local land market (E. Louw, Krabben, & Priemus, 2003; van der Krabben & Jacobs, 2013).

Table 3-6 The role of liability, regulation and economic incentives in obsolete industrial sites transformation (Alberini et al., 2005; Korthals Altes & Tambach, 2008; Syms, 1999; Thornton et al., 2007)

<table>
<tr><td></td><td></td><td colspan="2">Obsolete industrial sites</td><td colspan="3">Recognitions</td></tr>
<tr><td></td><td></td><td>Pristine site</td><td>Brownfield</td><td colspan="3" rowspan="2"></td></tr>
<tr><td></td><td></td><td>More attractive</td><td>Less attractive</td></tr>
<tr><td rowspan="4">Public authorities Market-based incentives</td><td>Procedure</td><td colspan="2">Reduction in regulatory burden and response time.</td><td></td><td rowspan="3">Attractive to inexperienced developers.</td><td rowspan="4">Inexperienced & With prior experience private parties (Developers)</td></tr>
<tr><td rowspan="2">Liability</td><td>Relief from liability for future clean up.</td><td></td><td rowspan="2">Most valued, worth 21% of the project value.</td></tr>
<tr><td colspan="2">Relief from afterwards maintenance and liabilities.</td></tr>
<tr><td>Economic incentives</td><td colspan="2">Subsidies.</td><td>Influenced by prior experience of incentives.</td><td>Attractive to developers with prior experiences.</td></tr>
</table>

In the researches conducted by Alberini et al. (2005), Thornton et al. (2007), Korthals Altes and Tambach (2008)the role of local authority in stimulating obsolete industrial site transformation process is explored and interpreted. What a local authority can provide is mainly divided into three parts: procedure simplification, liability relief and economic incentives. The policy of procedure simplification works on shortening and expediting the response time of approval of development plans and applications submitted by private parties and simplifying the procedure by cutting down unnecessary procedures. Offer financial funding is another policy, which works on reducing the investment of private parties by providing them with financial funding. The third governmental intervention the government can take is liability relief, which works on reducing the afterwards liabilities of property developers such as maintenance of green spaces and facilities. These actions and strategies influence the reactions and considerations of property developers, which then have influences on the acceptance chance of the initiation of the transformation project. The three strategies and their influence on private parties are summarized in the Table 3-6 above.

According to the obtained information, factors playing in the transformation process from different aspects (site characteristics, project relevance, government strategies and local economic and demographic condition) could be concluded as the following table based on existing researches (Table 3-7). The site characteristics include soil quality, accessibility, surrounding image and size. The project relevance covers the cost and duration of the project. Government strategies are government offers and policies that the government would make to improve the transformation process. And local economic and demographic condition is the economic condition and housing demand of the region.

Table 3-7 Factors of transformation process

		(Syms, 1999)	(Nijkamp et al., 2002)	(Alberini et al., 2005)	(Remøy & van der Voordt, 2006)	(Altes & Tambach, 2007)	(Thornton et al., 2007)
Site Attributes	Soil quality	x		x	x	x	
	Accessibility	x		x	x		
	Surrounding image	x			x	x	
	Size	x					
Project Relevance	Cost		x	x			
	Duration			x			
Government Offers and policies	Economic incentive	x	x	x			x
	Procedure simplification	x	x	x		x	x
	Liability afterwards reduction	x	x	x		x	x
Region condition	Economic				x	x	x
	Housing demand				x	x	x

3.3.4 Process

The transformation project is complicated than construction project, however it shares similarities with the process of constructing new buildings and surroundings. The process goes as follows: initiation, feasibility study, design, execution, risk management and finalization. Because the transformation is a project that executed on the basis of an existing project, there are more uncertainties during the process than construction project in an empty site. (Remøy, 2010)

3.3.5 Societal Values

Proper urban land transformation will bring benefit to the local authority and developers in that it improves the regional spatial quality and creates development potential, financial revenue as well as ecological advantages. When the obsolete sites is remediated and transformed, the urban environment will get upgraded, which will raise recognition and acceptance among publics as well as attracts more investment and creates profits. (Halleux, Marcinczak, & van der Krabben, 2012; Ploegmakers & Beckers, 2012; van Der Krabben, 2014) Especially in a densely populated country with small national land area like the Netherlands, the sustainable development and transformation of industrial land will contribute to equilibrium of land market and make long-term profit for both the public authorities and private parties.

3.3.6 Practices

There are many practical cases existing in the field of urban land use redevelopment and transformation already. In the Netherlands, the projects of transformation from obsolete industrial areas into residential buildings for old people or youth people such as student dormitory are various. In the following paragraphs several successful practices will be reviewed.

Figure 3-3 Havnestad in 1991 and 2009

One successful example is the redevelopment of “Havnestad” (Figure 3-3) on the Copenhagen waterfront, Denmark. The site was severely contaminated due to previous industrial land use. In late 1990s fewer industries were left and the area becomes a brownfield. In order to redevelop this area and transform it into a mixed-use area that connects to and interacts with other parts in the city, a master plan was worked out as the result of good collaboration and intensive cooperation between public authority (the municipality of Copenhagen) and private party (such as East Asiatic Company (EAC)). The area is transformed into a mixed-use urban area that has residential buildings and catering as well as other servicing industry inside. The differences before the planning is carried out and after the project is finished can be seen in Figure 3-3 above. (CABERNET, 2004)

Figure 3-4 Havnestad Syd in 2001 and 2010

Within the Havnestad area there were many outstanding factories and after 1990s some of them closed down and some moved away. After the master plan of redeveloping and transforming ‘Havnestad’ is carried out, Company Sjælsø takes the mission of refurbishment and transformation of part of Havnestad Syd (Figure 3-4), which starts in 2003 and finished in 2008. The Havnestad Syd is a newly developed residential area and it is started as a transformation project of the old soybean cake factory area that primarily occupied by outstanding industrial buildings. Now, residential buildings and green spaces dominate the area and in total 850 dwellings are realized by Sjælsø. The housing projects in Havnestad Syd have in common that all residents will have significant views, lots of light, terraces and gardens or balconies. What is more, the proximity to the port creates a unique maritime environment in the neighborhood. A comparison before the plan is carried out and after the project is finished can be seen from Figure 3-4 above. (Sjælsø Management, 2009)

Figure 3-5 Aerial view on the Buiksloterham, 1971. Source: Dienst Ruimtelijke Ordening Gemeente Amsterdam (Figure source: (Dembski, 2013))

One successful domestic practice in the Netherlands is the transformation of Buiksloterham, which is still undergoing. The Buiksloterham is a postindustrial estate area in Amsterdam and it is going through a slowly and gradually taken transformation process and currently serves as a mixed-use (both residential and commercial use) urban area in the city. The aerial view on this area in 1971 is shown in Figure 3-5 above and an aerial view in 2009 is in Figure 3-6 below. The timeframe of the transformation project is planned to be 25 years, from 2005 to 2030. The total gross area of the Buiksloterham is 100 hectare and the goal of the municipality is to transform it into a mixed-use neighborhood. The principles that this transform follows include mixing should be realized on all levels include the total area, each building and each individual plot and the area should reflect industrial character after transformation. Investment covers soil remediation, public space and facilities and municipal planning costs. From the date the transformation has taken place 2,700 dwellings will be realized and from the present 2,000 more will be realized. Also, jobs opportunities are increasing that job positions are created from 3,000 in the past to up to 10,000 positions. (Dembski, 2013)

Figure 3-6 View on the Johan van Hasselt Canal from the West, 2009. Photograph: Doriann Kransberg. Stadsarchief Amsterdam

The projects in refurbishing and transforming Buiksloterham are dynamic and multi-actors involved. Through an innovative urban, landscape, and social development master plan the sustainable development of the area of Nedcoat en Air Products (Figure 3-7 below) in the harbor area Buiksloterham is under realization.

Figure 3-7 Cityplot Buiksloterham Bird's Eye View (Cityplot Buiksloterham, 2015)

The mono-functional industrial park is gradually transformed into a vibrant new part of the city with spaces for experimentation and improvement. The dynamic master plan is the basis for future developments. In the area there are about 550 dwellings and at least 4,000 m^2 of work studios and catering as well as other service commercial industries realized. (DELVA, 2015)

Figure 3-8 Typical floor plans of the conversion of the office building into housing, before and after (Figure source: (Remøy & van der Voordt, 2006))

Another successful practice is a transformation project for an office building built in 1958 that locates in the municipality of Eindhoven (Figure 3-8). Eindhoven is an industry city and has many old office buildings. The building in the case became obsolete and the municipal government decided to put it into reuse and transform it into residential building because there is housing demand created by increasing population. After conducting a feasibility study and a tender completion, the developer who won the tender transformed the building into residential use; technical defects and imperfections are fixed and improved.

Staircases and elevators are kept and reused. Soon after the transformation project the apartments are bought by a housing cooperation. (Remøy & van der Voordt, 2006)

3.4 Conclusions

In this part, the distribution of obsolete industrial sites in the Netherlands and the province of Noord-Brabant is introduced. In the Noord-Brabant province the obsolescence of industrial sites has reached to nearly one third of the total area in 2013. After investigating the industrial obsolescence situation, with the purpose of obtaining necessary information for simulation modeling in the next phase, existing researches and studies are reviewed. Stakeholders, drivers and barriers of the transformation project and factor that play a part in the pre-transformation project stage as well as in the transformation process is studied.

Stakeholders of the transformation projects can be divided into public parties such as the local government and private parties such as property developers. Drivers and barriers of initiating the transformation are various. The drivers can be concluded as growing emphasis of sustainable urban development, scarce land, adverse effect of obsolescence and market needs, The barriers includes soil contamination, complicated procedure and long time period for rate of return, high costs and enormous liabilities. The factors, that have influence on the acceptance chance by private parties to start the project, include characteristics of the site, the project relevance, government offers and policies and the local situation regards economy and demography.

Moreover, three successful practices are reviewed, which are the refurbishment and transformation of Havnestad from old industrial park into residential and recreation areas in Denmark, the still under transformation projects of Buiksloterham from old industrial estates area into mixed-use urban area in Amsterdam and the transformation of an old 1958 office building into a residential building in Eindhoven. The three practices are in common that all of them involve both public and private parties in all stages and have gone through times of modifications and negotiations and achieved in high level of collaboration and the transformed areas include residential area. However there are various directions of land transformation other than residential land use such as recreation, commercial and landscape or park, etc.

Despite the wealth amount of existing researches about obsolete industrial sites transformation and factors that play in the transformation process, the insights into specific factors that affect the process most significantly and play comparatively bigger role in the transformation of obsolete industrial sites into residential areas are still limited, especially in the regard of a specific region. Thus an analysis tool for analyzing the factors is in need. In the next section another reason why such analysis tool is necessary will be given, which is the increasing housing demand in the region of Noord-Brabant that asks for more residential area. And transformation of obsolete industrial sites can be a solution because the transformation will not only meet the needs of increasing housing demand but also follows the principle of sustainable urban development.

Part B Demand in Housing Stock

Population growth is a global issue. In most urban areas, the growing population creates significant demands for different services such as medical, transportation, infrastructure and housing accordingly. Housing as one of the three basic needs of human, is important factor in influencing the urban development. Undersupply of adequate housing is one cause that contributes to urban sprawl. (Bhatta, 2010; Femi & Khan, 2014; Schultink, 2007)

The Netherlands as a densely populated country has a population of nearly 17 million at present; according to the Centraal Bureau voor de Statistiek (CBS), population of the Netherlands is increasing and will reach to 18 million by the year of 2040 (CBS, 2015b). As a result, housing demands are growing and the housing market in urban areas is tight.

3.5 The Noord-Brabant Housing Demand

Within the province of Brabant, the population is increasing every year and is growing faster than expected in 2011. It will keep increasing until the year of 2040 (Figure 3-9).

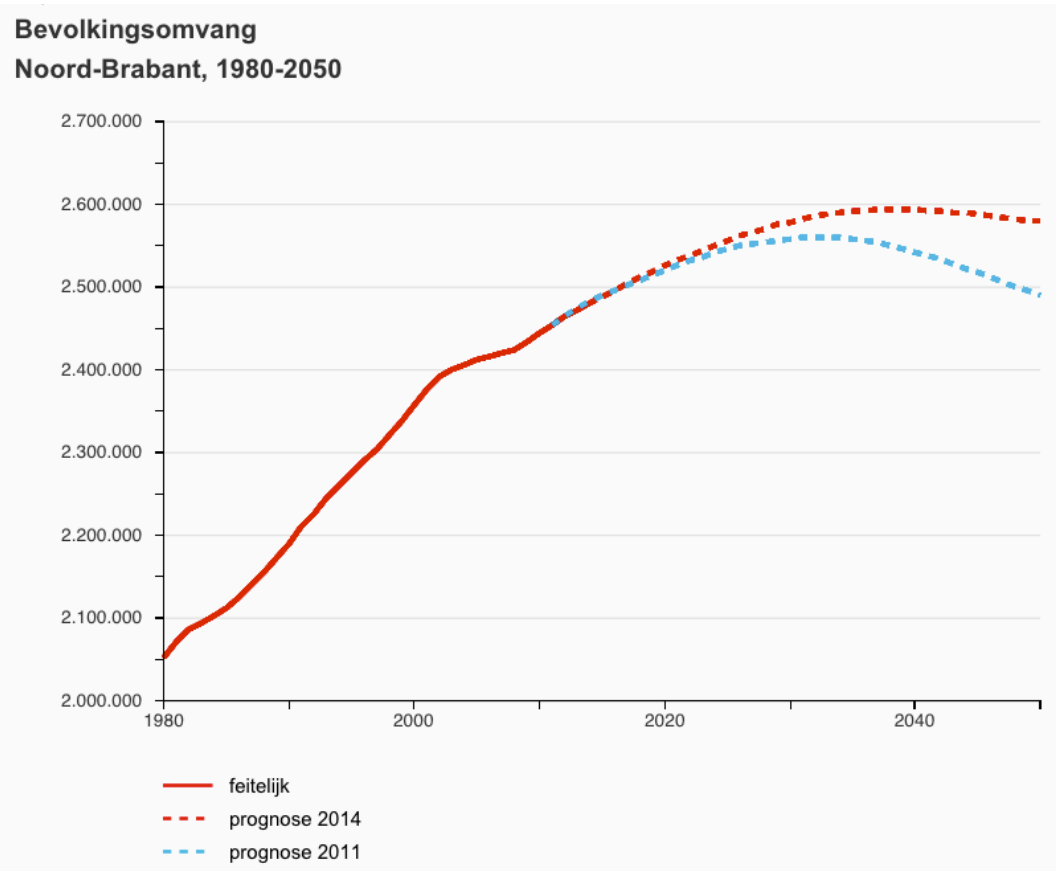


Figure 3-9 Population Size and Forecast of Noord-Brabant, 1980-2050 (Provincie Noord-Brabant, 2014)

The main reasons for the fast growing population are adjusted higher life expectation and higher foreign migration composition. According to the latest provincial population forecast, the population of Noord-Brabant will reach to a maximum of about 2.595 million people in 2040, and the population is nearly 2.48 million in 2014 as reported. Which means in the next 25 years, the population will have a growth of approximately 115,000. (Hartman, 2014; Provincie Noord-Brabant, 2014)

With population increase, there is extra housing demand. According to the provincial forecast of Noord-Brabant, housing stock will expand to a higher level than expected in 2011, this is not only because of population growth but also and mainly due to the influence of population ageing and individualization. It is expected that there will be approximately 1.22 million houses in Noord-Brabant by 2050, which is 160,000 more than the housing stock at the end of 2013 (Figure 3-10) (Provincie Noord-Brabant, 2014). And during the next 10 years more than 100,000 houses should be added to the housing stock to meet the demand, which means the demand for extra houses until the year of 2025 is over 10,000 per year (Hartman, 2014; Provincie Noord-Brabant, 2014).

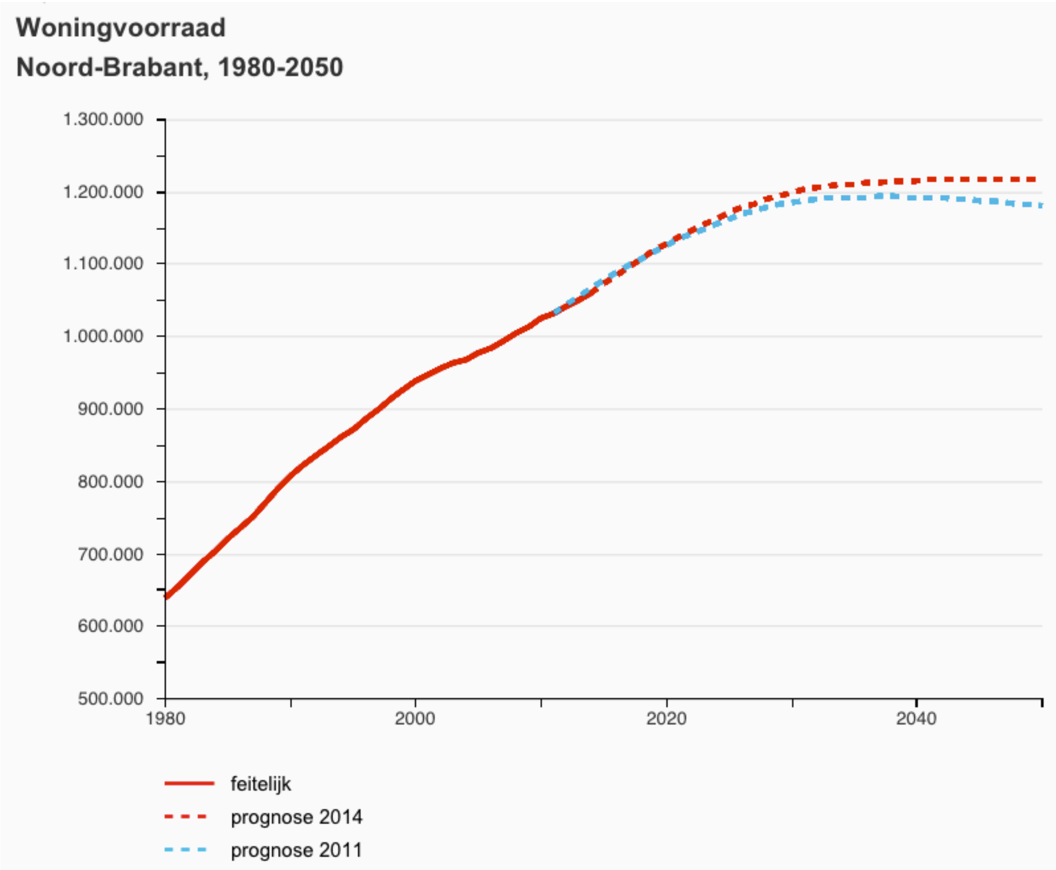


Figure 3-10 Housing Stock and Forecast of Noord-Brabant, 1980-2050 (Provincie Noord-Brabant, 2014)

3.6 Conclusions

In this part, forecasts of population size and housing stock in Noord-Brabant during the next 25 years are given. The provided figures indicate that residential dwellings are in continuously demand in the next 25 years. Moreover, province Noord-Brabant has the Brainport high-tech campus, which contains most innovative companies and institutions and is attracting knowledge workers immigrants who are contributing to the housing demand as well.

With housing demand increasing and the problem of industrial obsolescence in this region as investigated in the previous part, transformation of obsolete industrial sites into residential area can be a good solution because this on one hand solves the problem of obsolescence (to a certain extent) and on the other hand meets the needs of more residential buildings. Since transformation of obsolete industrial sites into residential areas is a possible solution to meet the demand, an analysis tool that investigates to what extent the factors as reviewed in the previous part (Part A) are playing on the process will be good for assessing the process. The statistics of population and housing provided by Noord-Brabant can be put into use in this analysis tool and thus offering insights to the local government.

Part C Research Approaches in Land Use Transformation

Many approaches could be used in studying and analyzing urban land use development and transformation. For example, researchers can use Game Theory, Geographic Information System (GIS) and simulation methods such as Agent Based Modeling (ABM) and System Dynamics (SD). Also, scenario design is frequently used, when combined with the above-mentioned methods, as an analyzing tool for both researchers and decision-makers to evaluate the situations that may occur in the future. In the following paragraphs, different modeling methods will be introduced and the reason of selected method of this research will be given.

3.7 Game Theory

Game theory is a behavior-based analysis approach that emphasizes on the calculation and assessment of opponent or competitor's behavior and attitudes toward specific situations in the game. In each game there are at least two players involved. With game theory, the strategies of players can be identified and solved through analyzing, predicting and explaining behaviors of players. The strategies of players are the options they can choose. The options are linked to a certain pay-off, which decides what strategy a player would play. Making optimum options that bring the most profitable result in a game is the goal of each player. In game theory rationality is assumed, which means when a player behaves in a non-rational manner game theory cannot be applied. (Barough, Shoubi, & Skardi, 2012; Ott, 2013)

Game theory is widely used in fields such as economics, political, military and sociology sciences to analyze the decision-making process and make forecast of expected results (Barough et al., 2012). In land use planning and urban environment development field, game theory is used to analyze behaviors of public authorities and private developers to reach an optimum result and is especially used for solving the conflicting situation in construction and development projects. (Ott, 2013; Samsura, van der Krabben, & van Deemen, 2010)

3.8 Geographic Information System (GIS)

GIS is a useful tool for analyzing urban development problem. It could make use of different databases and combine them. GIS is often used with other analysis tools. (Harts et al., 2000)

3.9 Agent Based Modeling (ABM)

Agent Based Modeling (ABM) is one of the approaches of a class of computational modeling, that models a system with a group of independent decision making objects called agents, to simulate the behaviors of these independent agents and interactions between them. Each agent individually evaluates its situation and makes decisions on the basis of a set of simple principles of behavior. This approach aims to look into the behavior of agents according to easy instructions for interpretive understanding rather than invent problem-solving resolution for explicit situation. It realistically simulates the true world; fundamentals of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming are integrated in this approach. (Bonabeau, 2002; Niazi & Hussain, 2011)

ABM is also getting popular in land-use related problems; researchers are increasingly using this simulation method as an approach to provide insights for stakeholders. ABM allows researchers to combine the impact decision-making has on land use with social interactions, modifications and decision-making at different levels in a mechanical and spatially precise way. (Matthews, Gilbert, Roach, Polhill, & Gotts, 2007)

3.10 System Dynamics (SD)

System dynamics can be applied to a range of problems in the social and physical sciences. It is a well-established methodology that provides a theoretical framework for modeling complex systems into a simpler and understandable model. The target groups that use these models will have a broader view on the complex problems which they are dealing with, and in this way it gives them an opportunity to make a more deliberate choice. For example, a company wants to increase the efficiency of the production process, but has no idea of where the change or progress should be made to achieve the goal of higher efficiency. When System Dynamics approach is applied the whole production process and its affecting variables will be visible clearly through the help of this method and the company would be able to make a founded choice. A System Dynamics simulation enables decision makers to better understand the interactions among the simulation variables and interrelationships of these variables. (Fong, Matsumoto, & Lun, 2009; Shen et al., 2009; Sterman, 2004)

3.11 Conclusions

For the modeling method of this research System Dynamics approach is selected. The research problem in question is a complex and dynamic one, which contains different aspects with different inputs and variables. In addition, the answer of the research question is related to strategic planning to provide insights for the public authorities and property developers to improve their decision making, which focuses more on macro level instead of on details. Because Game Theory plays its part better in analyzing the behaviors of players in different situations, which focuses more on details and Agent Based Modeling also gives very detailed viewpoint, which, though is good for looking into the problem but is unnecessary in this research. Therefore, System Dynamics as a well-established method that analyzes the big picture from a systematic point of view and is on a strategic planning level is selected. Using System Dynamics approach to analyze the interrelationship and mutual influences between different parts in this system is indispensible in this research. Previously the systems of industrial land use and residential land use are mostly considered and studied in isolation. Through integrating them into one system and studying the interactions of different variables, strategies that take these parts into consideration can be drawn out. What is more, using scenario design adds to the research value in analyzing different situations and giving out corresponding strategies and results.

Through System Dynamics and scenario design analysis, variables that play a part in the system are visualized, how they influence the process and to what extent they are playing the role could be accurately evaluated. Therefore, to study a complex problem that involves a number of stakeholders and is influenced by a good deal of factors, try to find the solution of improving it, System Dynamics is the choice.

Chapter 4 A System Dynamics Approach

The research will focus on simulation and analysis of the transformation from obsolete industrial sites into residential area in the province Noord-Brabant. The modeling will use the simulation method System Dynamics. In this chapter, how the method works will be interpreted. The first section (4.1) gives an overview of the problem and the importance of this research. Then in the second section (4.2) the detailed structure and set up of the model, data manipulation, running and calibration, scenario design and analysis will be given. This chapter ends with the result of this research in the last section (4.3).

4.1 Introduction

The province of Noord-Brabant is the second largest province of the Netherlands (5,082 square kilometer, which is 12.2% of total area of the country). It has a Gross Regional Domestic Product (GRDP) of 92 billion Euros. What is more, Noord-Brabant has the Brainport, which is one of the most innovative and creative areas across the Europe continent that creates and produces many new technologies and businesses everyday. (DG Growth, 2015) Such an innovative, productive region should, and so does it, pay more attention on developing smart city and sustainable land-use strategies.

Monitored by the IBIS, it is reported that in 2013 among the 614 industrial sites in the province Noord-Brabant 182 are obsolete (and 49 are unknown, 383 are not obsolete). The gross obsolescence percentage is 30%. In order to develop the urban environment in a sustainable way, transformation of obsolete industrial sites into residential area to meet the housing demand is one of the strategies that can be applied.

Existing researches about transformation of obsolete industrial sites provide information and research results in relate to the transformation process in this regard. For example, stakeholders who are interested-related to the transformation, drivers that trigger and barriers that hinder the process and factors that play a part in the process (see Table 3-3, 3-4, 3-5, 3-6 and 3-7 in Section 3.3), which will be used in building the model to analysis the problem and answer the research question. Since the System Dynamics simulation method provides systematic overview of the whole picture and enables comparison of different scenarios as is concluded in the previous chapter, it is selected as the analysis approach of this study.

The next section gives a detailed interpretation of the modeling process and the functions and scenarios design of the model using System Dynamics modeling.

4.2 Method

The modeling methodology is System Dynamics, which is a simulation method that concludes the whole picture systematically. The modeling procedure will be as follows: First, a causal loop diagram (CLD) will be structured; during this phase part of needed statistics will be definite. Then the CLD will be adjusted and prepared for transfer into the stock flow model (SFM). The variables of the model are divided into several aspects:

- Site attributes,
- Project relevance,
- Government strategies,
- Local economy,
- Obsolete industrial sites,
- Residential area and
- Population.

‘Site attributes’ are the attributes of the site that have direct or indirect influence on cost and time of the project, which include ‘soil quality’, ‘accessibility’, ‘surrounding image’ and ‘size’. ‘Project relevance’ is to what extent the project is a complicated one and is influenced by the ‘size’ as well as if the site needs remediation, which is decided by ‘soil quality’. ‘Government strategies’ contains the governmental interventions that the government would take to influence the transformation project acceptance chance, which covers three aspects, regulatory, financial and liability. And the actions of each aspect are ‘procedure simplification’, ‘economic incentive’ and ‘liability afterwards reduction’. ‘Local economy’ in the model is measured by the ‘economic growth’, which is the regional economic growth every year. ‘Obsolete industrial sites’ contains the obsolete site stock, the obsolescence and transformation of the obsolete sites. ‘Residential area’ includes the transformation from obsolete sites and other surface changes. And ‘Population’ includes the regional population volume and changes. Data of all variables are obtained through statistics provided by Central Bureau of Statistics (CBS) or Noord-Brabant Databank and is manipulated based on the literature review.

In the following paragraphs, the causal loop diagram (CLD) and the stock flow model (SFM) will be interpreted, as well as the data manipulation and model set up, the running of the model, calibration and the scenario design analysis. First there will be explanations of the causal loop diagram and each loop in the CLD (4.2.1). The second section explains the transferred stock flow model (4.2.2), following with data manipulation and equation setup of each variable in the model (4.2.3), the running of the model and calibration (4.2.4) and scenario design and analysis (4.2.5).

4.2.1 The Causal loop diagram (CLD)

The finalized causal loop diagram (CLD) (Figure 4-1) contains 6 loops, of which 2 are balancing loop and 4 are reinforcing loop. The 6 loops are built based on logical connections and relationships between variables in the system obtained through existing researches and together cover from the drivers and barriers to factors of the transformation process. The diagram expresses the whole structure of the system in a logical manner. In the following paragraphs each loop will be interpreted in detail.

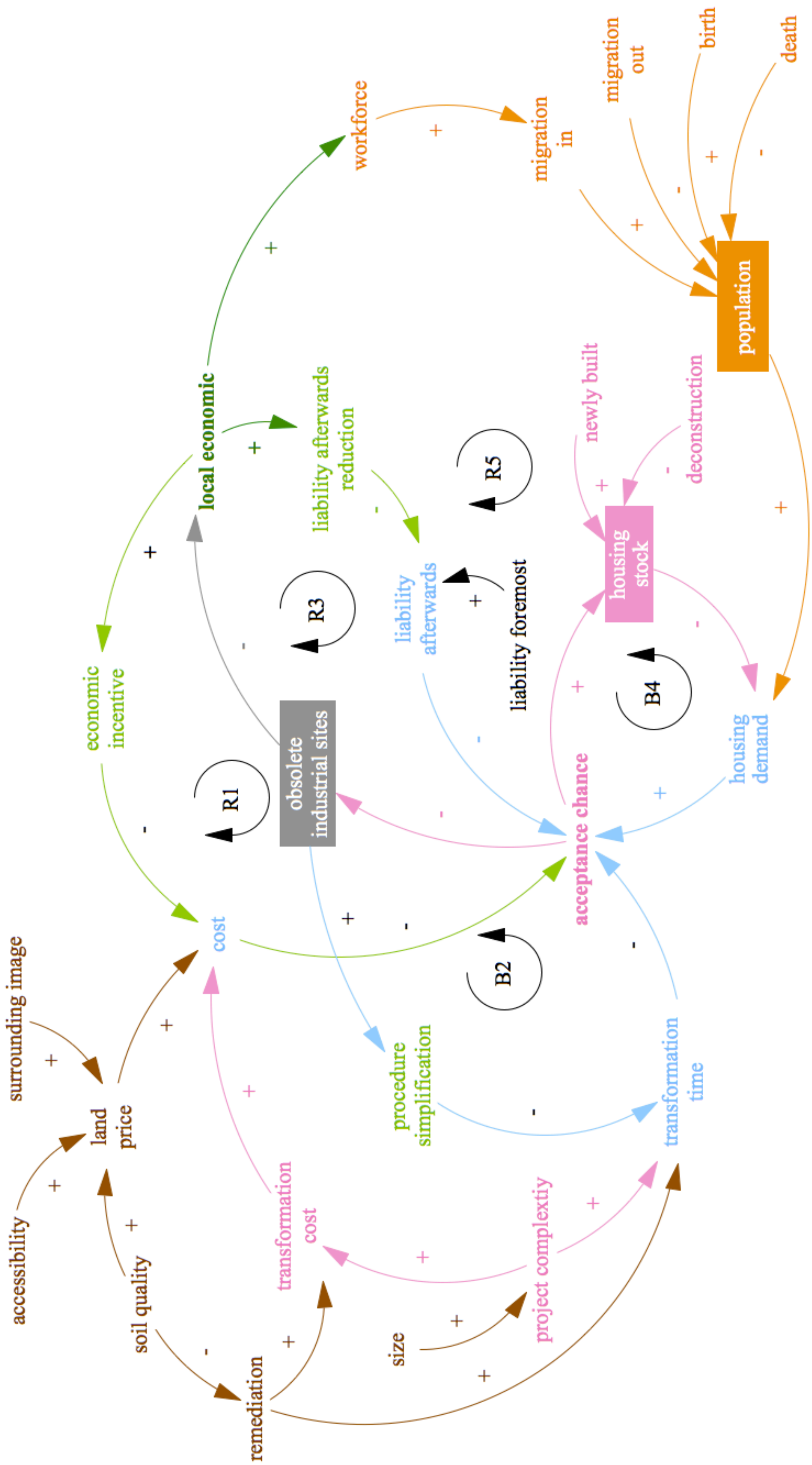


Figure 4-1 Causal Loop Diagram

The first loop is 'Economic Incentive Loop' (Figure 4-2) and it is a reinforcing loop. This loop starts with the variable 'cost', which is the total cost of the transformation project. When 'cost' increases, the chance that private developer accepts the project, i.e. 'acceptance chance', will decrease. And when 'acceptance chance' decreases, the surface of obsolete industrial sites, i.e. 'obsolete industrial sites' that will not get transferred will increase. When 'obsolete industrial sites' increases, the local economy, i.e. 'local economic' will be influenced negatively and thus the funding that government could provide to transformation project, i.e. 'economic incentive' will decrease, which then influences 'cost' as when 'economic incentive' decreases the 'cost' will increase. So this loop is a reinforcing loop.

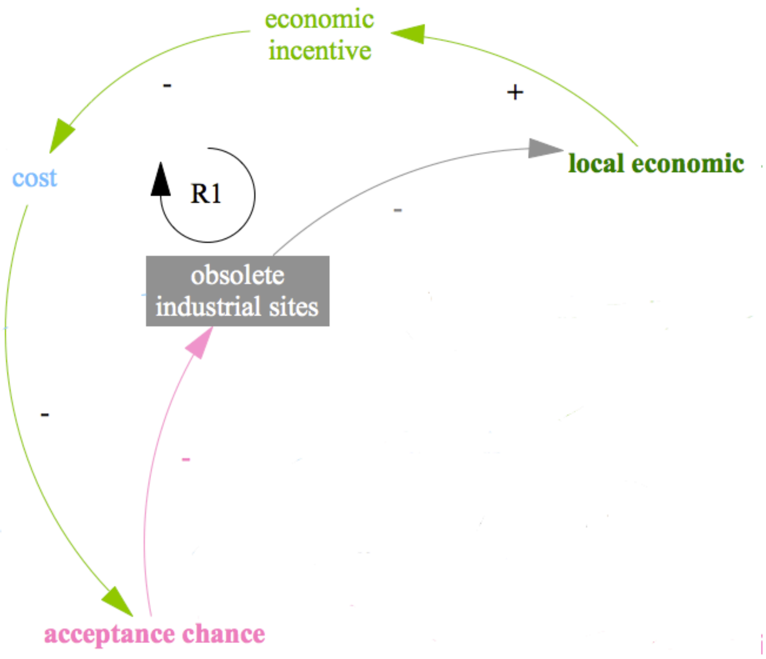


Figure 4-2 CLD Loop 1 – Economic Incentive Loop

The variable 'cost' (Figure 4-3) is influenced jointly by three variables, 'land price', which is the price of the land concerned, 'transformation cost', which is the cost of the transformation process and 'economic incentive', which is the funding offered by the government. The 'land price' (see Figure 4-3), according to table 3-5 in Section 3.3, is influenced jointly by the following site attributes: 'soil quality' (soil condition of the concerned site, whether the soil is contaminated and need remediation or not), 'surrounding image' (the surrounding image of the site, whether the site is with a good view or a bad view) and 'accessibility' (the transportation accessibility of the site, whether it is a convenient site with transportation network nearby). All three variables influence 'land price' positively.

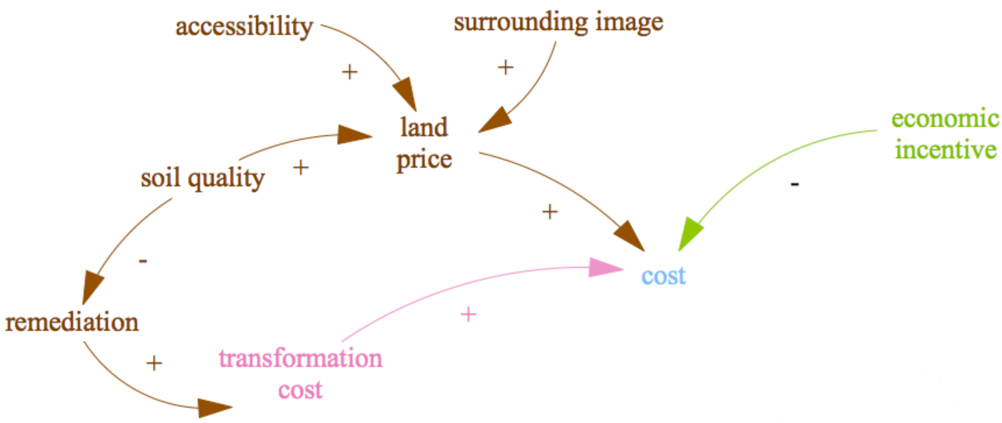


Figure 4-3 Cost

The 'transformation cost' (Figure 4-4) is influenced by 'project complexity' and 'remediation', as the transformation cost of a more complex project and a project that needs remediation is more expensive than a relatively simple project and a project that needs no remediation. The 'project complexity' (see Figure 4-4) is influenced by 'size', i.e. the size of the project, as when the 'size' is bigger, the project is more complex. The 'remediation' (see Figure 4-4) is influenced by 'soil quality', as when soil quality of the site does not reach the demanding level then remediation is needed and when the soil quality reaches the requirement then no remediation is in need. The 'economic incentive' (see Figure 4-2) is influenced by 'local economic', which is the economic condition of the region and in the model it will be measured by the regional economic growth per year; when the economic condition of the region is better, more governmental funding can be offered to the transformation project.

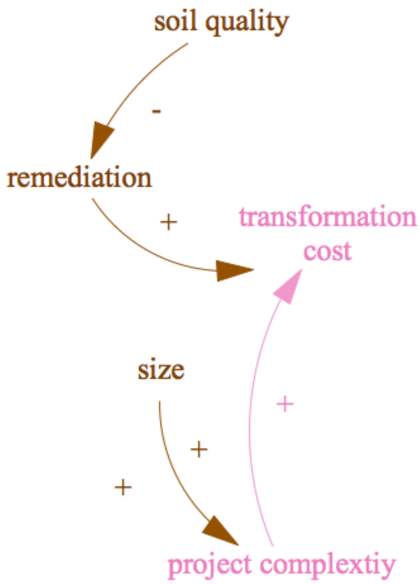


Figure 4-4 Transformation cost

The second loop is 'Procedure simplification loop' (Figure 4-5), which is a balancing loop. The loop starts with 'transformation time', which is the estimated time taken in total to complete the transformation project. When it is estimated that longer 'transformation time' will be taken, 'acceptance chance' will decrease, which then increases 'obsolete industrial sites' as more obsolete sites will be left unchanged. When 'obsolete industrial sites' increases the government will intervene by taking actions to simplify the procedure of related governmental agencies in handling transformation related applications and documentation matters, i.e. the 'procedure simplification' will increase and as a result the 'transformation time' will be shortened. So this is a balancing loop.

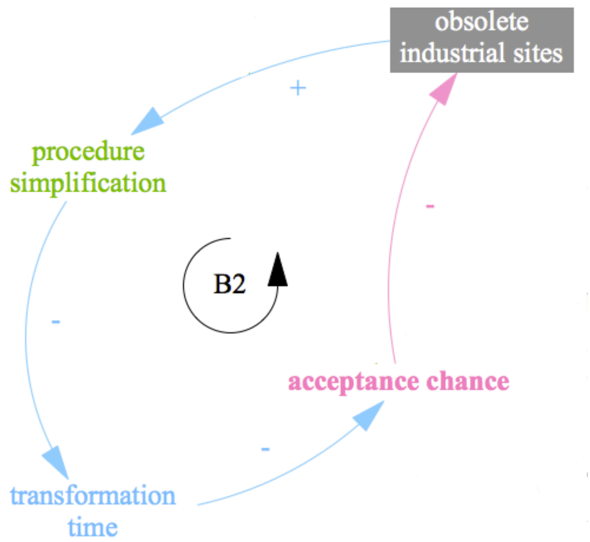


Figure 4-5 CLD Loop 2 – Procedure simplification loop

The 'transformation time' (Figure 4-6) is influenced jointly by 'project complexity', 'remediation' and 'procedure simplification'. The reason that 'project complexity' and 'remediation' influence 'transformation time' is the same with the variable 'transformation cost' that a more complex project and a project that needs remediation will takes longer transformation time than a relatively simple project and a project that needs no remediation. And as explained in the previous paragraph, 'procedure simplification' is the governmental intervention taken to shorten the transformation time.

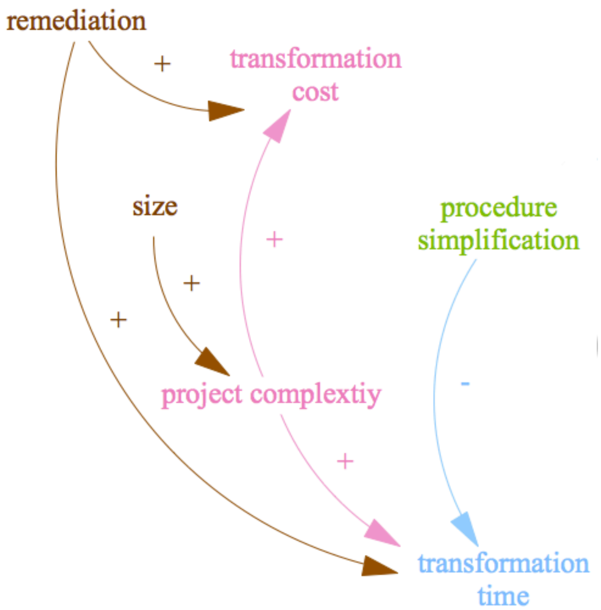


Figure 4-6 Transformation time

The third loop is 'liability reduction loop' (Figure 4-7), which is a reinforcing loop. The loop starts with 'liability afterwards', which contains liabilities, for example, maintenance and related services of the property developer after the transformation project is finished. When 'liabilities afterwards' assumed are more than expectation of the property developer, 'acceptance chance' will decrease, which then increases 'obsolete industrial sites' as more obsolete sites will be left unchanged. When 'obsolete industrial sites' increases the regional economic condition will be influenced and the extent to which the governmental intervention of reducing the afterwards responsibilities the property developer should take, i.e. the 'liability afterwards reduction' will decrease and as a result 'liability afterwards' will increase. So this is a reinforcing loop. The 'liability afterwards' (Figure 4-7) is decided by 'liability foremost', which is the original liabilities should be covered and 'liability afterwards reduction'.

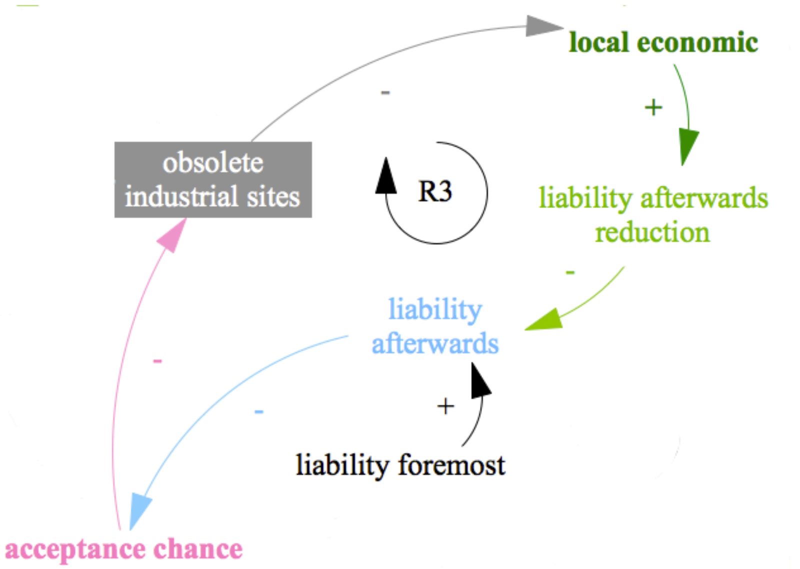


Figure 4-7 CLD Loop 3 – Liability afterwards reduction loop

The fourth loop is housing loop (Figure 4-8), which is a balancing loop. The loop starts with 'housing demand' and is measured by the number of residents per hectare in the model. When 'housing demand' increases, 'acceptance chance' will decrease, which then increases the 'housing stock' as more houses will be available. When 'housing stock' increases 'housing demand' will decrease. So this is a balancing loop.

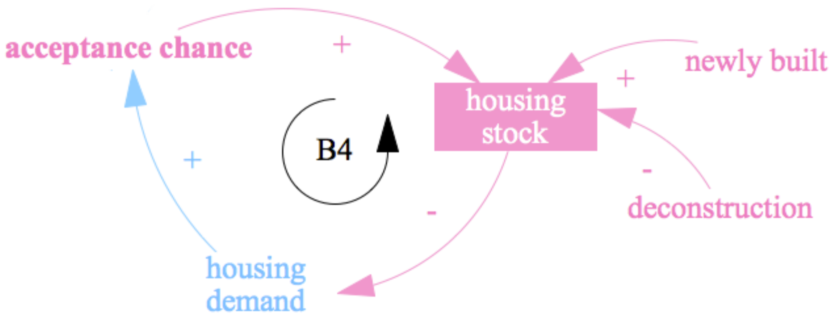


Figure 4-8 CLD Loop 4 – Housing loop

The fifth loop is 'overall loop' (Figure 4-9), which is a reinforcing loop that includes the third loop and fourth loop in and covers the five main variables, 'acceptance chance', 'obsolete industrial sites', 'local economic', 'population' and 'housing stock'. As previous paragraphs already give interpretation of the third and fourth loop that 'housing demand' will influence positively on 'acceptance chance' and 'acceptance chance' influence negatively on 'obsolete industrial sites'. As a result when the 'local economic' is decreasing, the job market will be influenced and 'workforce' will decrease, which then decrease the population because there will be less immigrants. The population (see Figure 4-9) is influenced by birth, death, immigration and emigration.

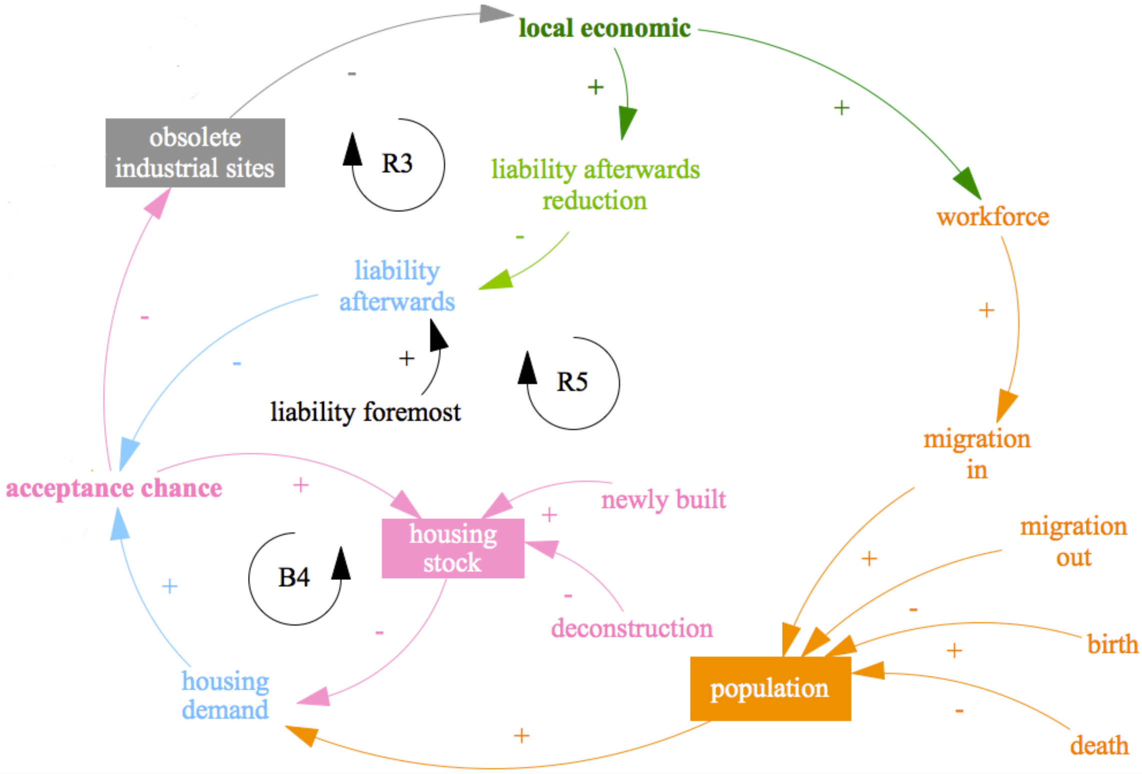


Figure 4-9 CLD Loop 5 – Overall loop

The causal loop diagram gives a whole picture of how factors are interacting with each other. The following step is build the model that analyzes these interactions and figures out which factor plays a relatively bigger role in the transformation process. In this way advice can be provided to government that among actions they take which is the most important one and which they should focus on. In the next section the Stock Flow Model (SFM) will be interpreted.

4.2.2 Stock flow model (SFM)

After finalizing the Causal Loop Diagram (CLD), the Stock Flow Model (SFM) could be structured on the basis of CLD. First the time-step, i.e. the time period this model is going to cover, needs to be settled. The time-step of this model is set as 25 years and increment is 1 year, which covers the past 10 years (from 2005 to 2014) and the present to the future 15 years (from 2015 to 2029). Second, stocks, flows and auxiliary variables need to be definite.

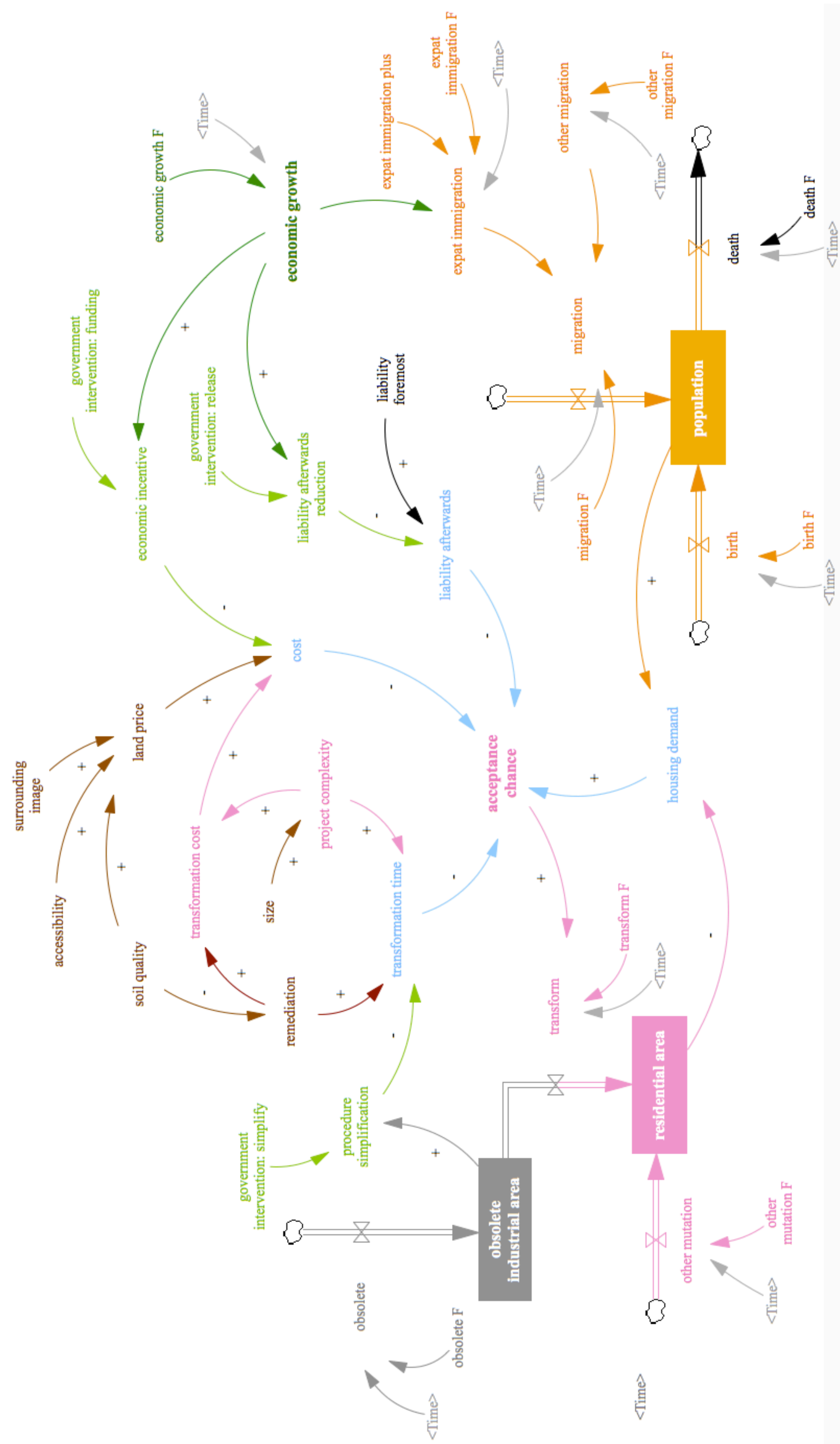


Figure 4-10 Stock Flow Model

The finalized SFM is in Figure 4-10. A list of causer trees of all the variables that express causal relationships between variables can be found in Appendix II. The following paragraphs will give a detailed view on the model. And in the next section the data manipulation and equation setup of each variable in the model will be explained.

First, stocks need to be definite. In the indicated model, three stocks are set: Obsolete Industrial Area, Residential Area and Population (Figure 4-11 and 4-12). Connected to the three stocks are flows, which will also be definite according to the finalized causal loop diagram. The flows connected to 'Obsolete Industrial Area' are 'obsolete' and 'transform'. Flow 'obsolete' represents the obsolete rate of industrial area and flow 'transform' represents the rate that obsolete industrial areas are transformed into residential rear. And the flows connected to 'Residential Area' are 'transform' and 'other mutation'. Flow 'other mutation' includes newly built and changes other than transformed areas. The flows connected to 'Population' are 'birth', 'death' and 'migration'. Data will be retrieved from the Noord-Brabant Databank.

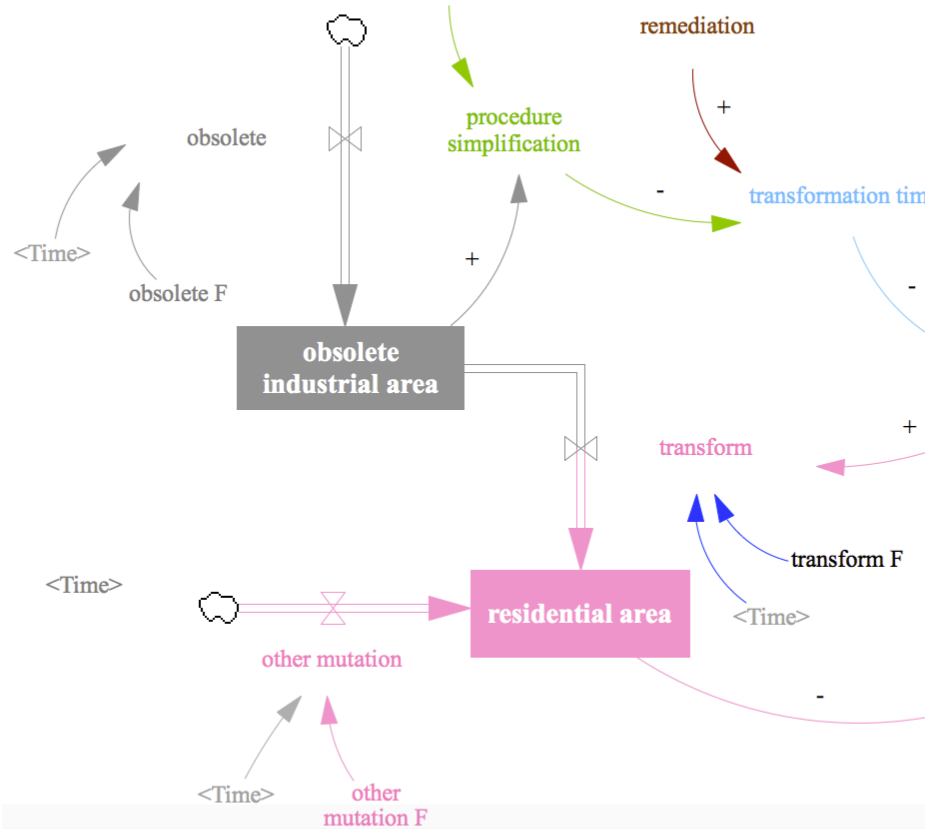


Figure 4-11 Stock 'obsolete industrial area' and 'residential area', flow 'obsolete', 'transform' and 'other mutation'

The inputs of each flow are as follows (see Figure 4-11 and 4-12). Flow 'obsolete' is decided by a LOOKUP function 'obsolete F' and a shadow variable '<Time>'. Likewise, flow 'transform' is decided by a LOOKUP function 'transform F' and a shadow variable '<Time>' but also it is influenced by another variable 'acceptance chance'. Flow 'other mutation' is the total changes of residential area except for the transform amount increase to the residential area of every year and is decided by a LOOKUP function 'other mutation F' and a shadow variable '<Time>'. Inputs of flow 'birth' and 'death' are LOOKUP function variable and shadow variable '<Time>' likewise.

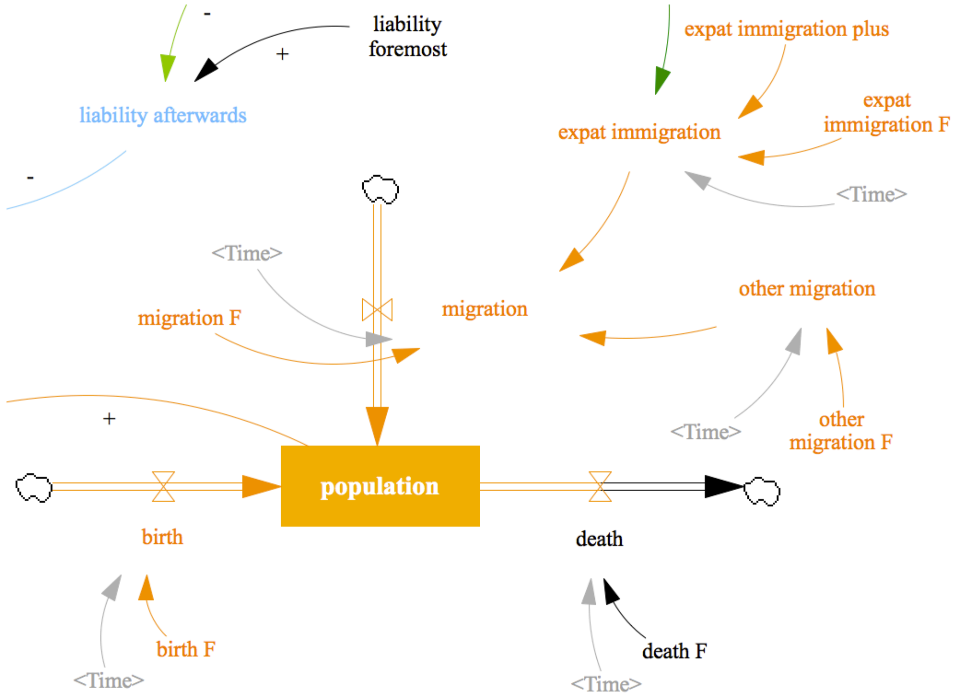


Figure 4-12 Stock 'population', flow 'birth', 'death' and 'migration'

The 'acceptance chance' is the chance that a property developer will take the transformation project and it is affected by four factors: 'liability afterwards', 'cost', 'transformation time' and 'housing demand' (see Figure 4-13).

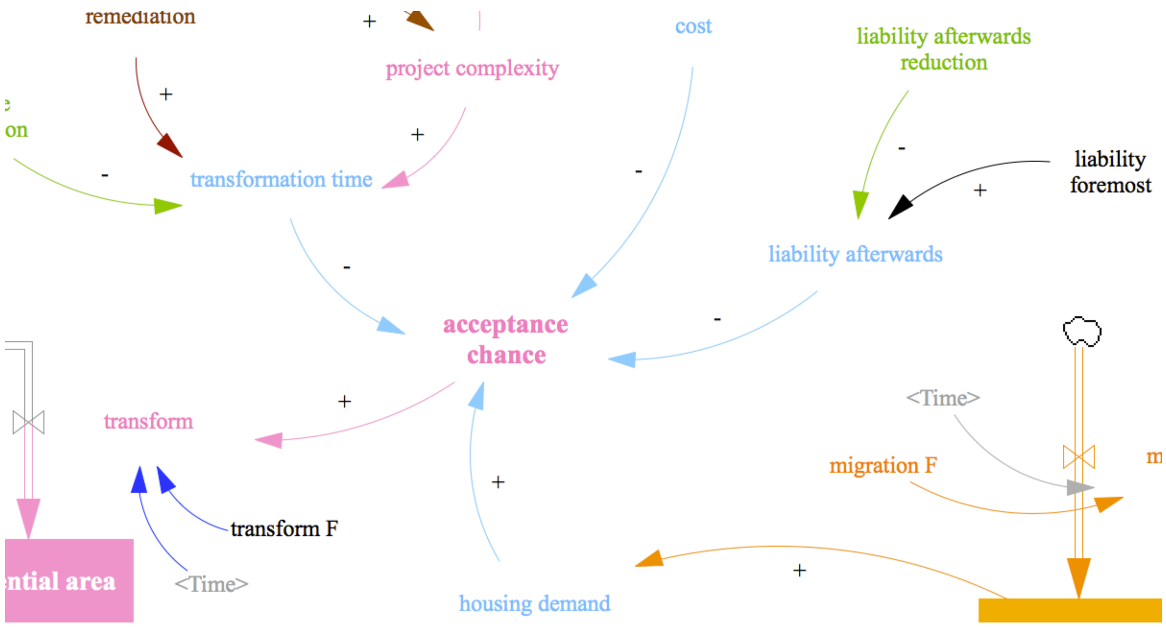


Figure 4-13 Variable 'acceptance chance'

As for the site and project relevance part, the model looks like Figure 4-14 below. Since site attributes variables are auxiliary variables and they are playing their parts in the transformation process as external variables, the structure in the Stock Flow Model is same with the structure in the Causal Loop Diagram. Detailed interpretation could be found in previous section.

Figure 4-14 Site attributes and project relevance

The governmental interventions are ‘procedure simplification’, ‘liability afterwards reduction’ and ‘economic incentive’. Among the three strategies ‘liability afterwards reduction’ and ‘economic incentive’ are economic-associated. The economic part of this model is shown as below (Figure 4-15). The variable ‘economic growth’ is decided by a LOOKUP function ‘economic growth F’, which includes the Noord-Brabant yearly regional economic growth data, and the shadow variable ‘<Time>’.

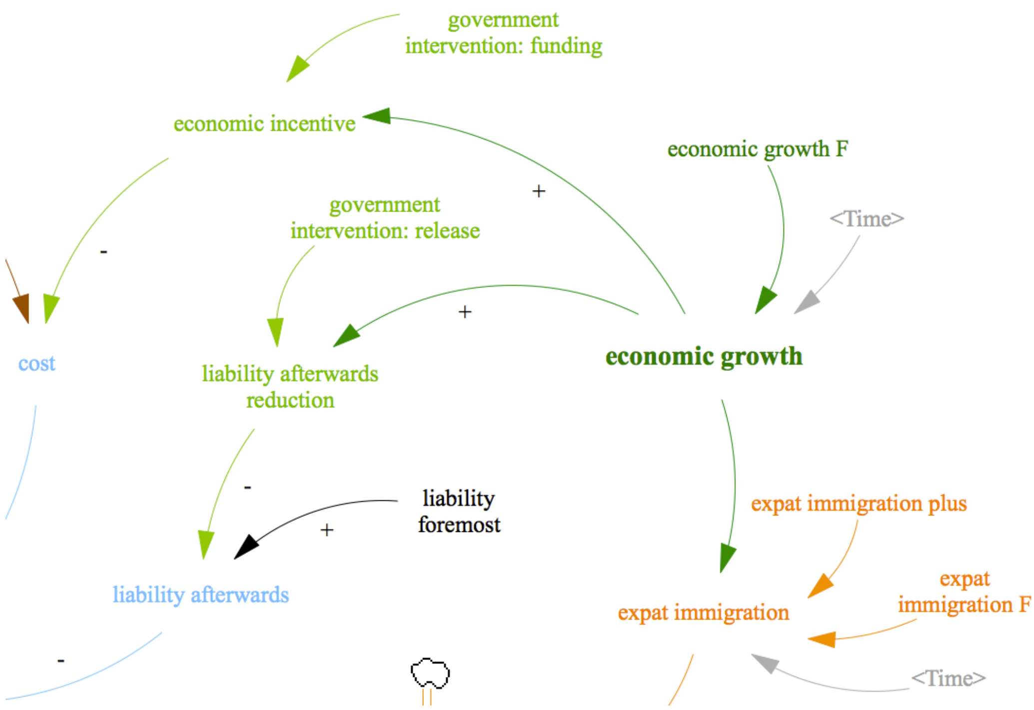


Figure 4-15 Economic growth and economic-associated government interventions

With the model structure finished, before it can get running, the next step is filling in the equation of each variable. Among the variables some have existing data that can be directly used in equations and the equations of other variables needed to be determined based on their logical and interactive connections with other variables. In the next section interpretation of how equations of the variables are set will be given.

4.2.3 Data manipulation

In this section how the data of variables are manipulated will be given. Data is obtained in CBS database and Noord-Brabant databank and needs to be put in equations of each variable. How the equation of each variable is set up will be interpreted. Variables with existing statistics and existing official forecasting data include 'obsolete industrial area', 'residential area', 'population' and 'economic growth'; the source of data of them is listed in Table 4-1 below.

Table 4-1 Data source

<table>
<tr><th colspan="2">Variables</th><th>Obtained from</th><th>Source</th></tr>
<tr><td rowspan="2">Obsolete industrial area</td><td>Obsolete</td><td>Noord-Brabant databank</td><td>IBIS</td></tr>
<tr><td rowspan="2">Transform</td><td>Noord-Brabant databank</td><td>CBS, IBIS</td></tr>
<tr><td rowspan="2">Residential area</td><td>Noord-Brabant databank</td><td>CBS, IBIS</td></tr>
<tr><td>Other mutation*</td><td>Noord-Brabant databank</td><td>CBS</td></tr>
<tr><td rowspan="3">Population</td><td>Birth</td><td>Noord-Brabant databank</td><td>CBS</td></tr>
<tr><td>Death</td><td>Noord-Brabant databank</td><td>CBS</td></tr>
<tr><td>Migration*</td><td>Noord-Brabant databank</td><td>CBS</td></tr>
<tr><td colspan="2">Economic growth</td><td>CBS</td><td>CBS</td></tr>
</table>

*Other mutation includes newly built area and deconstruction.

*Migration includes immigration and emigration.

Obsolete industrial area

The data of obsolete industrial area is obtained from CBS. Data obtained are listed in Table 4-2 below. The data is obtained and calculated form IBIS and IenM / DG Ruimte from IBIS Registratie werklocaties. However, most data is missing, the equation only contains existing data, which may lead to error in the future calculating. But the differences between different scenarios are clear and correct since the difference is controlled by different input of the three governmental interventions. So the missing data of industrial area here will not cause a problem.

Table 4-2 Statistics: Industrial area

Year	Gross surface [Ha]	Obsolete Yes [Numb]	Obsolete No [Numb]	Obsolete Unknown [Numb]	Obsolete [Ha]
2005	16428.93	-	-	-	
2006	16684.05	-	-	-	
2007	16768.91	-	-	-	
2008	16885.99	-	-	-	

Year	Gross surface [Ha]	Obsolete Yes [Numb]	Obsolete No [Numb]	Obsolete Unknown [Numb]	Obsolete [Ha]
2009	17042.65	-	-	-	2700
2013	17918.57	182	383	49	3906.538111

Residential area

The data of residential area is listed in Table 4-3 below. The data is obtained and calculated from CBS Bodemgebruik, CBS bewerking ABF Research, ABF Research Systeem woningvoorraad (Syswov), CBS Statistiek bouwvergunningen and CBS Bouwen en Wonen. All the data are put in the equations of residential area related stock and flow and variables. In the model, the variable 'other mutation' includes all changes (the 'total mutation' in the table below) in residential area except for transformation.

Table 4-3 Statistics: Residential area

Year	Residential area [Ha]	Total mutation [D]	Total mutation [Ha]	Surface per mutation [Ha]	Other Increase (transformation) [D]	Transformation [Ha]
2005	38182		166		842	20.37195744
2006	38348	6861	173	0.024194724	690	12.97923236
2007	38521	9197	172	0.018810482	1486	20.96563038
2008	38693	12191	50	0.014108769	786	4.731519384
2009	38743	8306	49	0.006019745	887	3.692379577
2010	38792	11771	0	0.004162773	410	
2011	38792	7201	0		661	
2012	38792	8348	0		-	

Population

The data of population is obtained from CBS Bevolkingsstatistiek. In the model, all the data are put in the equations of population related stock and flow and variables.

Table 4-4 Statistics: Population

Year	In total [person]	Change in total [person]	Natural increase [person]	Births [person]	Deaths [person]	Net migration [person]	Immigration in total [person]
2005	2411359	4587	7123	26301	19178	478	94195
2006	2415946	3096	6869	26007	19138	-406	96924
2007	2419042	5785	6310	25327	19017	2264	98749
2008	2424827	9733	6541	25987	19446	4976	102596
2009	2434560	9598	6315	25599	19284	6074	95699
2010	2444158	10057	6042	25545	19503	6678	96760

Year	In total [person]	Change in total [person]	Natural increase [person]	Births [person]	Deaths [person]	Net migration [person]	Immigration in total [person]
2011	2454215	9471	5240	25015	19775	7449	99732
2012	2463686	7325	3571	24027	20456	6793	102092
2013	2471011	8263	3013	23558	20545	7065	106614
2014	2479274	-	-	-	-	-	-

The data of forecast of population of Noord-Brabant is also put in the model. The data is obtained from 'Provincie Noord-Brabant – Prognoses 2014' and is listed in Table 4-5 below.

Table 4-5 Forecast – Population 2014-2030, Province: Noord-Brabant

Year	Total [person]	Growth [person]	Natural growth [person]	Births [person]	Deaths [person]	Total migration [person]
2014	2479580	8556	3055	24395	21340	5501
2015	2488136	8172	2874	24644	21770	5298
2016	2496308	7770	2674	24856	22182	5096
2017	2504078	7456	2555	25142	22587	4901
2018	2511534	7111	2408	25366	22958	4703
2019	2518645	6807	2256	25588	23332	4551
2020	2525452	6597	2097	25783	23686	4500
2021	2532049	6328	1930	25966	24036	4398
2022	2538377	6052	1701	26105	24404	4351
2023	2544429	5861	1463	26235	24772	4398
2024	2550290	5613	1215	26360	25145	4398
2025	2555903	5343	894	26416	25522	4449
2026	2561246	4994	545	26424	25879	4449
2027	2566240	4605	156	26414	26258	4449
2028	2570845	4201	-248	26383	26631	4449
2029	2575046	3809	-640	26355	26995	4449
2030	2578855	3387	-1062	26296	27358	4449

Economic growth

The data of economic growth is obtained from CBS Regional accounts and it put in the equation of economic growth.

Table 4-6 Statistics: Economic growth

Year	GDP, volume changes %
2005	3.06
2006	3.90

Year	GDP, volume changes %
2007	3.30
2008	1.10
2009	-5.20
2010*	1.90
2011	3.50
2012**	-1.60
2013*	-1.00
2014*	1.70

Equations of the other variables will be determined based on their logical and interactive relationship with other variables. In the following paragraphs the interpretation of these other variables equation set up is divided into four aspects: Cost; Liability; Transformation time; Acceptance chance. Each part covers related variables in the aspect. A list of all the equations in the model is given in the appendix; in this section only explanation will be made.

Cost

As is interpreted in previous sections, variable 'cost' is influenced by 'land price', 'transformation cost' and 'economic incentive'. And 'land price' is influenced by three site attributes: 'surrounding image', 'soil quality' and 'accessibility'. The 'transformation cost' is influenced by whether there needs 'remediation' and the 'project complexity', which is influenced by 'size' of the project. The 'economic growth' is influenced by the local economic condition, which in this model will be measured by the regional economic growth. In the following paragraphs parameters of these influencing variables will be given and interpreted.

First the levels of 'land price' will be determined. It is influenced by 'surrounding image', 'soil quality' and 'accessibility'. Based on the literature review, levels of these attributes will be determined. For 'surrounding image' (Table 4-7), because residential areas have requirement regards the quality of the surrounding view and image so that a good surrounding image improves the chance the obsolete site be transformed, 2 levels are set, which are bad and good; to stand for the 2 statues in the equation constant 0 and 1 is used correspondently. For 'soil quality' (Table 4-7), since it decides whether there needs remediation and cleaning of the soil or not, there are 2 statues set, need remediation and need no remediation, in the variable equation constant 0 and 1 is used correspondently. For 'accessibility' (Table 4-7), according to existing studies, the distance of nearest transportation network also has influence on the acceptance chance of the transformation project, thus 3 levels are settled, which are transportation network within 30 kilometers, within 20 kilometers and within 10 kilometers, and in the equation constant 30, 20 and 10 is used correspondently. Table 4-7 below summarizes the levels of 'surrounding image', 'soil quality' and 'accessibility'.

Table 4-7 Levels: Surrounding image, soil quality and accessibility

Surrounding image		Soil quality		Accessibility	
Bad	0	Need remediation	0	Road network within 30 km	30
Good	1	Need no remediation	1	Road network within 20 km	20
				Road network within 10 km	10

And the 'land price' (Table 4-8) as is influenced by these three factors; it has five levels (from 5 the lowest price to 25 the highest price, with 5 as increment) according to different levels combinations of factors.

Table 4-8 Levels: Land attributes and land price

Surrounding image, Soil quality, Accessibility	0, 0, 30	0, 0, 20	0, 0, 10	0, 1, 30	0, 1, 20	0, 1, 10	1, 0, 30	1, 0, 20	1, 0, 10	1, 1, 30	1, 1, 20	1, 1, 10
Land price	5	10	15	10	15	20	10	15	20	15	20	25

The second factor that influences 'cost' is 'transformation cost'. It is decided by whether 'remediation' is needed, which is decided by 'soil quality' and the 'project complexity', which is influenced by 'size' of the project. For 'remediation', according to the levels of 'soil quality' (0 and 1), there are relatively the levels of 'remediation' (Table 4-9), which are yes and no. In the equation constant 0 is used to stand for yes and 1 is used to stand for no.

Table 4-9 Levels: Soil quality and remediation

Soil quality		Remediation	
Need remediation	0	Yes	0
Need no remediation	1	No	1

The variable 'size' (Table 4-10) has three levels, which are determined based on existing studies that size of the site has influence on the size of the project and thus influences the project complexity. Therefore, 3 levels, small, medium and large, are settled. In the equation constant 0, 1 and 2 is used relatively to stand for the three levels. Accordingly, the 'project complexity' (Table 4-10), which is influenced by the size of the project, has also 3 levels according to the three levels of 'size', which are easy, medium and complex, in the equation constant 0, 1 and 2 is used correspondently.

Table 4-10 Levels: Size and project complexity

Size		Project complexity	
Small	0	Easy	0
Medium	1	Medium	1
Large	2	Complex	2

The variable 'transformation cost' (see Table 4-11) is jointly decided by whether there is remediation or not and project complexity and has 4 levels (from 5 the lowest to 20 the highest, with increment 5) according to different combinations of levels of the two variables ‘project complexity’ and ‘remediation’.

Table 4-11 Levels: Transformation cost

Remediation		Project complexity		Transformation cost
No	1	Easy	0	5
Yes	0			10
No	1	Medium	1	10
Yes	0			15
No	1	Complex	2	15
Yes	0			20

The third variable that has influence on ‘cost’ is ‘economic incentive’. In the model, it has two inputs, the ‘economic growth’ and ‘government intervention: funding’. The ‘economic growth’ uses official statistics of Noord-Brabant yearly economic growth and in the model according to existing researches it is divided into 3 segments, less than 1%, between 1% and 3% and bigger than 3%. The equation of ‘government intervention: funding’ is set as constant and has 3 levels, from 0 to 8, with increment 4. The ‘economic incentive’ has 4 levels (from 0 to 8, with increment 2) according to the value of ‘economic growth’ and different values of ‘government intervention: funding’. The variable ‘economic growth’ is the economic growth of the year (Source: CBS), when it is less than 1% there will be no incentive and when it is between 1% and 3% the ‘economic incentive’ is equal to half of the funding and when the economic growth is bigger than 3%, the economic incentive is equal to the funding. (Table 4-12)

Table 4-12 Levels: Economic growth, government intervention – funding and economic incentive

Economic growth	Government intervention: funding	Economic incentive	
<0.01	0	0	
0.01⩽growth<0.03	0	0.5*‘government intervention: funding’	0
	4		2
	8		4
⩾0.03	0	1*‘government intervention: funding’	0
	4		4
	8		8

The variable ‘cost’ is equal to ‘land price’ plus ‘transformation cost’ then minus ‘economic incentive’. It has different levels according to different levels of its inputs. Table 4-13 in Appendix III summarizes the combinations of different levels of these inputs and the levels of ‘cost’.

Liability

As is interpreted in previous sections, variable ‘liability afterwards’ has two inputs, which are ‘liability foremost’ and ‘liability afterwards reduction’. The equation is ‘liability foremost' minus 'liability afterwards reduction'. In the model, the 'liability foremost' will not be changed and is a fixed value, which in the equation is set as constant 10. The value of 'government intervention: release' has 3 different levels, which are none reduction, medium reduction and many reduction, in the equation relatively using constant 0, 2 and 4 to stand for (see Table 4-14). The 'liability afterwards' has 4 levels (10, 9, 8 and 6) according to the value of 'economic growth' and different values of 'government intervention: release'. The variable 'economic growth' is the regional economic growth of the year (Source: CBS), when it is less than 1% there will be no reduction and when it is between 1% and 3% the 'liability afterwards reduction' is equal to half of the funding and when the economic growth is bigger than 3%, the liability afterwards reduction is equal to the release. (Table 4-14)

Table 4-14 Levels: Liability afterwards reduction and liability afterwards

Economic growth	Government intervention: release	Liability afterwards reduction		Liability foremost	Liability afterwards
<0.01	0	0		10	10
0.01⩽growth<0.03	0	0.5*'government intervention: release'	0		10
	2		1		9
	4		2		8
⩾0.03	0	1*'government intervention: release'	0		10
	2		2		8
	4		4		6

Transformation time

The variable 'transformation time' is influenced by whether there is remediation or not and project complexity as well as to what extent the procedure is simplified. And to what extent the procedure is simplified is decided by the surface of obsolete industrial area in the region. In the model, the variable 'procedure simplification' (Table 4-15) has two inputs, which are 'obsolete industrial area' and 'government intervention: simplify'. The value of 'government intervention: simplify' has 3 levels, which are fully simplify, medium simplify and none simplify, in the equation constant 2, 1 and 0 is used correspondently. The 'obsolete industrial area' uses official statistics provided by province Noord-Brabant and according to existing researches it is divided into 3 segments: larger than 6000 hectare, between 5500 hectare and 6000 hectare and smaller than 5500 hectare. The 'procedure simplification' has 4 levels (2, 1, 0.5 and 0) according to the value of 'obsolete industrial area' and different values of 'government intervention: simplify'. When the obsolete industrial area is more than 6000 hectares, the simplification is equal to the 'government intervention: simplify' and when the obsolete industrial sites stock is between 5500 and 6000 hectares, the 'procedure simplification' will be half of the 'government intervention: simplify' and when the obsolete industrial sites stock is less than 5500 hectares, there will be no procedure simplification.

Table 4-15 Levels: Procedure simplification

Obsolete industrial area	Government intervention: simplify	Procedure simplification	
⩾6000	2	1*‘government intervention: simplify’	2
	1		1
	0		0
5500<area<6000	2	0.5*‘government intervention: simplify’	1
	1		0.5
	0		0
⩽5500	0	0	

According to different values of ‘remediation’, ‘project complexity’, ‘obsolete industrial area’ and ‘procedure simplification’, which are influencing factors of ‘transformation time’, the variable ‘transformation time’ has 7 levels (from 1 to 7 with increment 1) (see Table 4-16 in Appendix III).

Acceptance chance

The variable ‘acceptance chance’ is jointly influenced by ‘cost’, ‘liability’, ‘transformation time’ and ‘housing demand’ (see Table 4-17 in Appendix III). Since the value of variable ‘cost’ is varying in a relatively large scale, in order to have a better understanding and visualization of the charts and diagrams when running the model, analyzing and comparing different scenarios, in the equation of ‘acceptance chance’ the value of ‘cost’ is divided into 3 segments, which are bigger than 31, between 15 and 31 and smaller than 15. Also, for the same reason, in the equation the value of ‘liability afterwards’ is divided into 3 segments, 10, 8 or 9 and 6. And value of ‘transformation time’ is divided into 2 segments, bigger than 4 and smaller than 4. At last, the value of ‘housing demand’, which uses data provided by Noord-Brabant databank, is divided into 2 segments, less than 63 and more than 63. The ‘acceptance chance’ is jointly decided by these variables and has 7 levels (from 1 to 7 with increment 1), its equation can be found in Appendix III.

Transform

For the flow ‘transform’ (Table 4-18), the value of its input ‘acceptance chance’ is divided into 3 segments in the equation, small than 2, between 2 and 6 and bigger than 6, the corresponding output is as follows. The equation could be found in Appendix III.

Table 4-18 Levels: Transform rate

Acceptance chance (dmnl)	Transform (Hectare/Year)
⩽2	35
2<acceptance chance<6	85
≥6	135

4.2.4 Running and calibration

Before scenario design and analysis, first the model needed to get running and calibrated. The modeling software Vensim has a function that allows users to calibrate through compare the realistic data and the running outcome in a table or a diagram, which is the 'ReferenceMode' function. The 'ReferenceMode' enables users to put existing realistic statistics in. After putting official history data of 'population', 'residential area' and 'obsolete industrial area' in 'ReferenceMode', running the model under scenario 'current', compare the outcome of 'current' with the 'ReferenceMode', the diagrams is shown as follows. From the figures it can be seen that the running outcome of 'population' and 'residential area' is match with the existing data. And according to the output table the 'obsolete industrial area' has 0.4% error, which is within accepted range 3%. (See Figure 4-16, 4-17 and 4-18.)

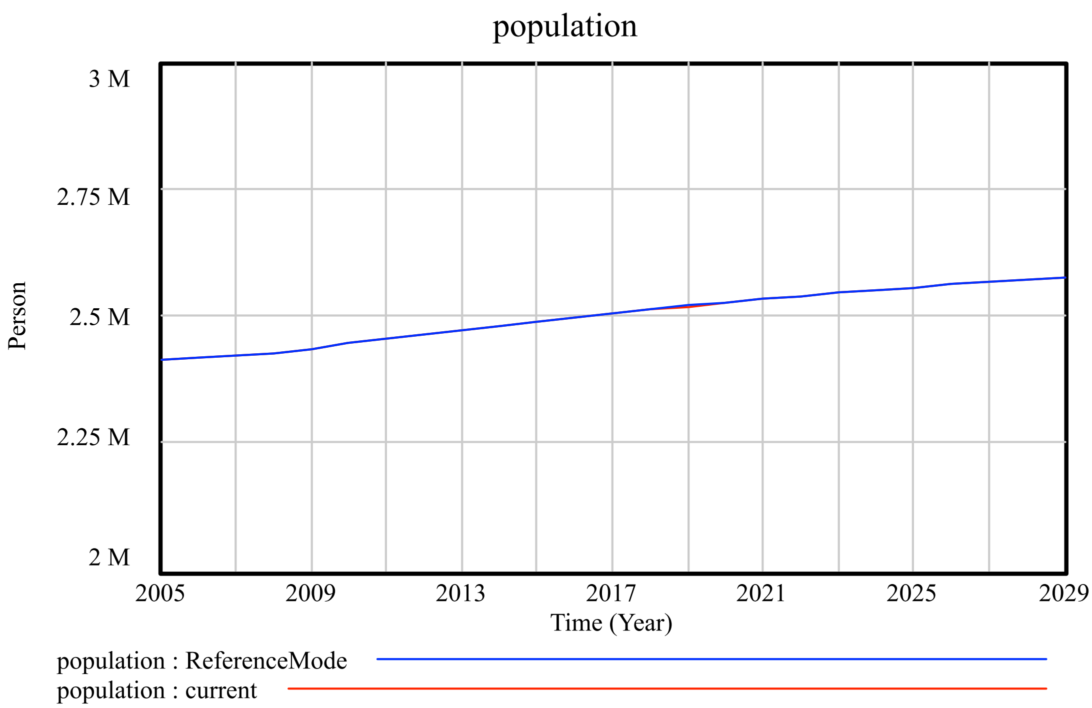


Figure 4-16 Run 'current' – population

From Figure 4-17 below it can be seen that the running results of 'residential area' in the 'current' mode is matched with its 'ReferenceMode'.

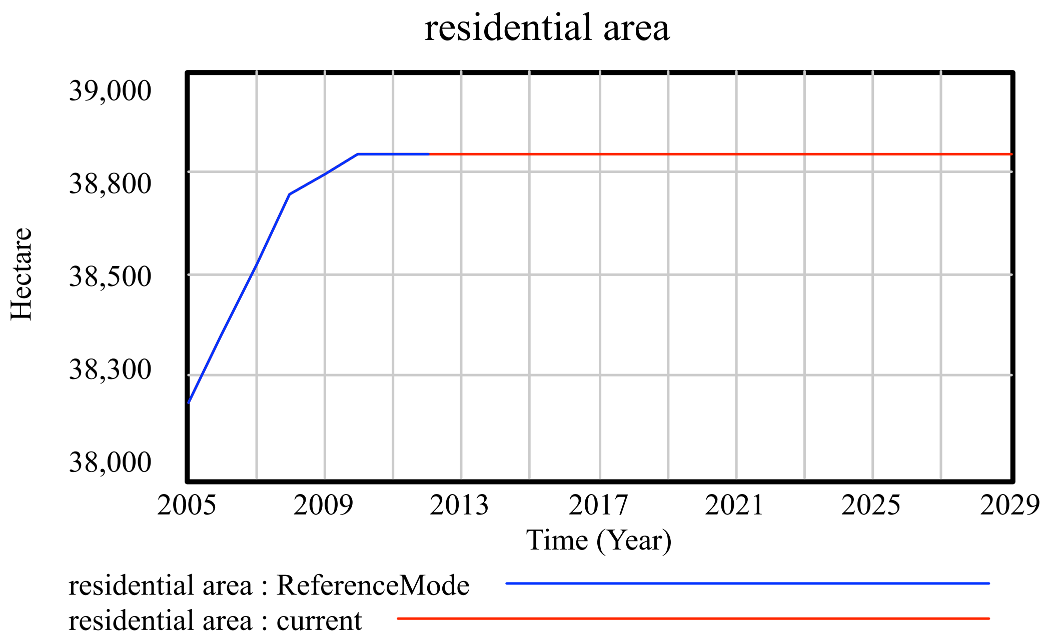


Figure 4-17 Run 'current' – residential area

From Figure 4-18 below it can be seen that though there is error, the error is within the acceptance range. According to the output table the 'obsolete industrial area' has 0.4% error, which is within accepted range 3%.

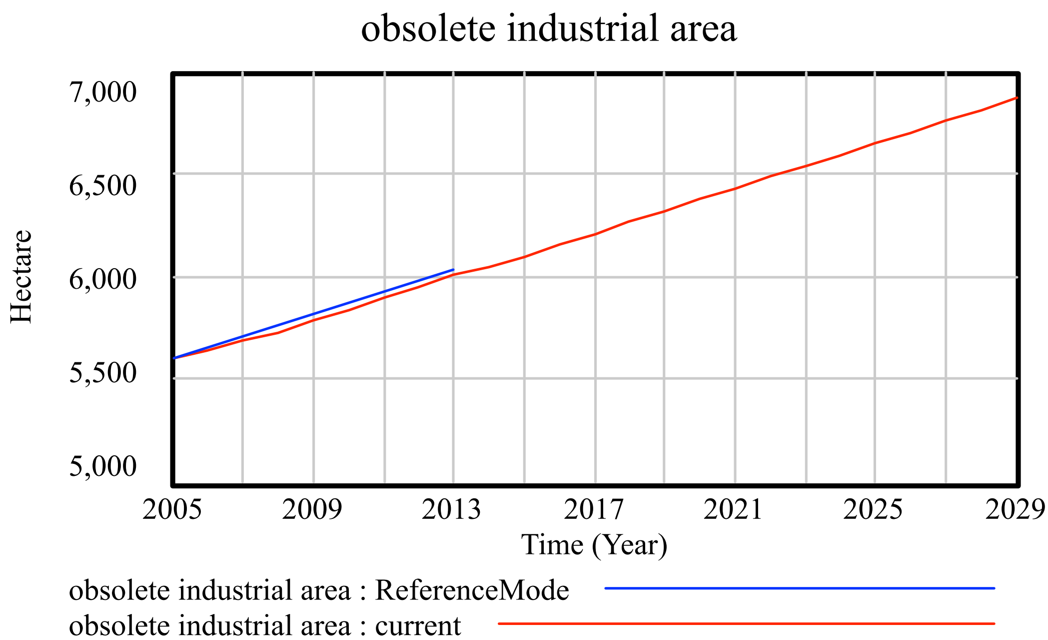


Figure 4-18 Run 'current' – obsolete industrial area

4.2.5 Scenarios design and analysis

In order to answer the research question, several scenarios are designed and simulated. The scenarios are listed as below:

- Scenario A: No governmental strategy (The running mode: 'current'.)

- Scenario B: Procedure simplification (The running mode: 'simplify1'.)
- Scenario C: Economic incentive and Liability afterwards reduction (The running mode: 'release2+funding4'.)
- Scenario D: Economic incentive and Liability afterwards reduction plus Procedure simplification (The running modes: 'simplify1+release2+funding4' and 'simplify2+release4+funding8'.)

The first scenario, Scenario A is running under the mode 'current'. In this scenario no government strategy is taken and values of the three 'government intervention' variables are set as 0. The outcomes are shown as Figure 4-16, 4-17 and 4-18 above. This scenario is used as a benchmark in this simulation and its outcome is put in comparison with outcomes of running of the other scenarios. Through analyzing the comparison the research question can bet answered and the factor plays most part can be definite.

Scenario B is running under the mode 'simplify1'. In this scenario the only strategy taken by the government is procedure simplification. With 'government intervention: simplify' values 1. The changes of residential area and obsolete industrial area can be seen in figures below (see Figure 4-19 and 4-20). From the figure it can be seen that after taking government intervention on procedure simplification the residential area is increasing and surface of obsolete industrial area is becoming smaller.

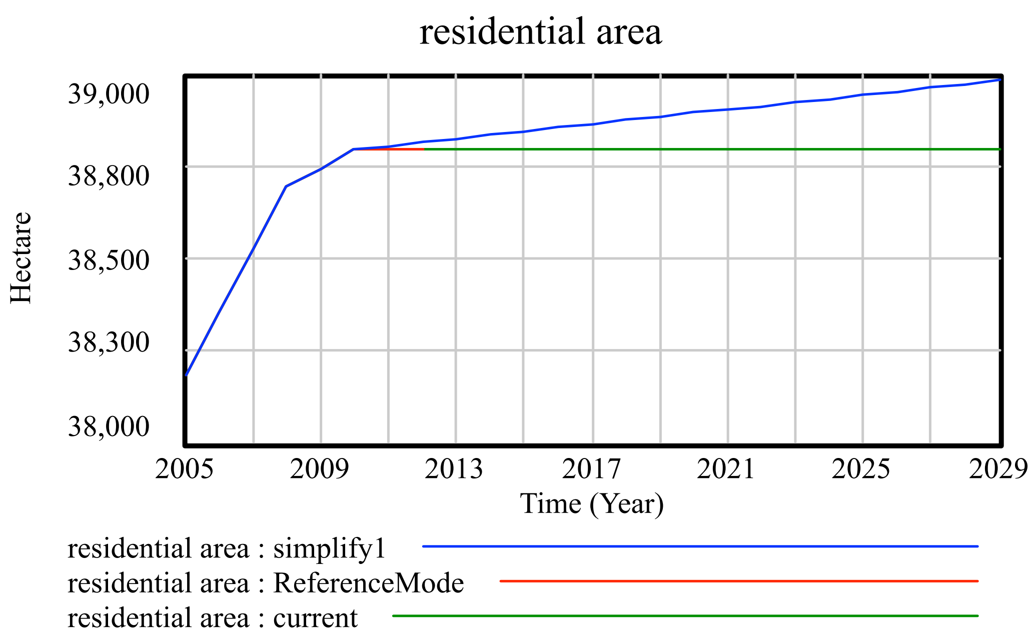


Figure 4-19 Run 'simplify1' – residential area

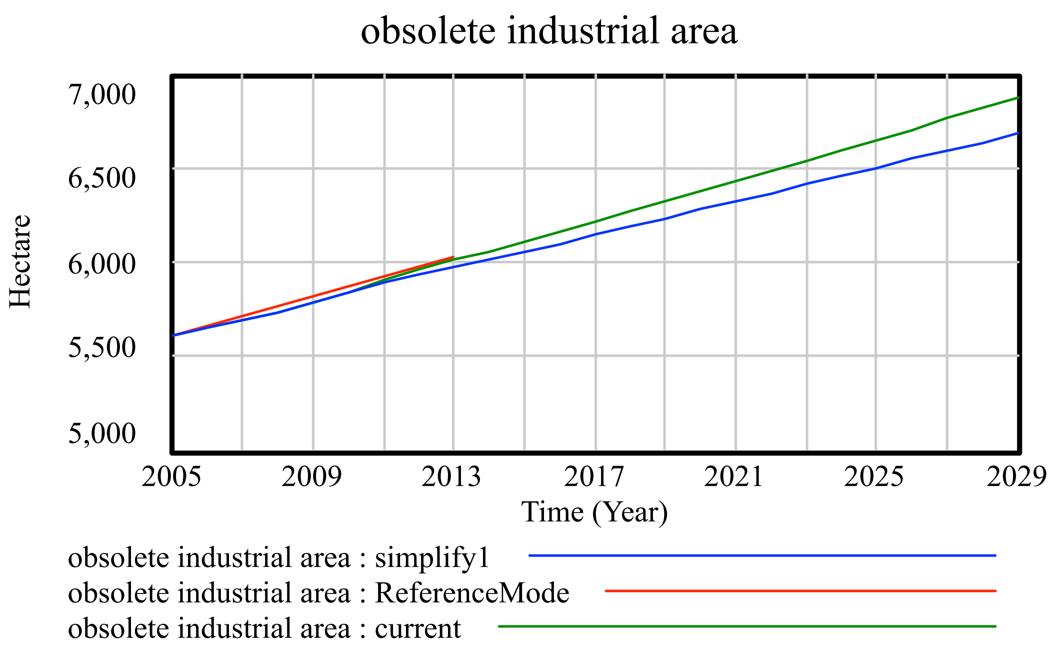


Figure 4-20 Run 'simplify1' – obsolete industrial area

Scenario C is running under the mode ‘release2+funding4’. In this scenario there are two strategies taken by the government, providing economic incentive and reducing liability afterwards. Both strategies are economic-associated. The ‘government intervention: release’ values 2 and ‘government intervention: funding’ values 4. The outcome is shown in Figure 4-21 and 4-22 below. From the outcomes it can be seen that procedure simplification (i.e. run ‘simplify1’) is more effective in proposing transformation project than liability relief and economic incentive, the residential area increase more than when government intervenes by relieving liabilities and funding and surface of obsolete industrial area is smaller, which is contrary to expectation because at the first place it is considered that liability relief and economic incentive are playing a bigger part. The reason of such outcomes lies in the influential connection between these strategies and the other variables in the system. For procedure simplification it is directly linked with the stock of obsolete industrial area while the other two strategies are influenced by local economic situation. Thus the obsolete industrial area has direct influence on the procedure simplification, which then works more effectively than the other strategies.

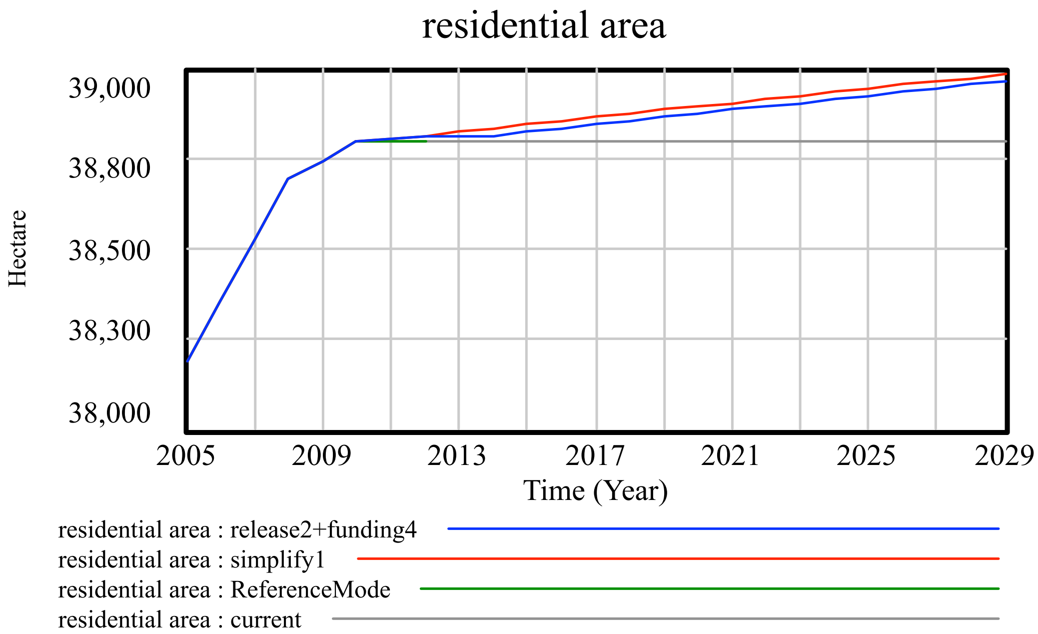


Figure 4-21 Run 'release2+funding4' – residential area

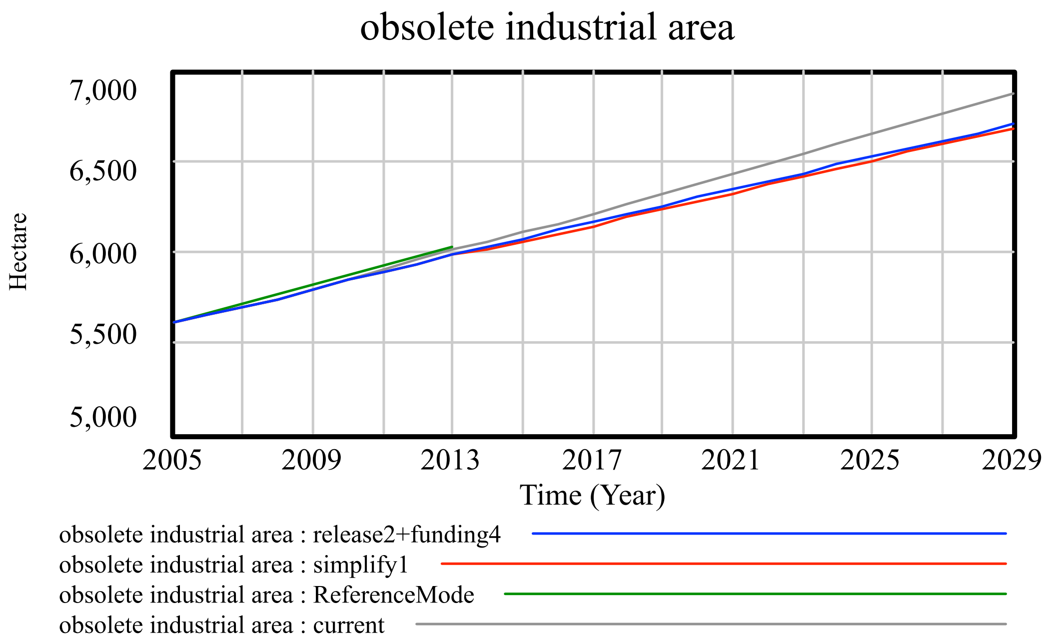


Figure 4-22 Run 'release2+funding4' – obsolete industrial area

Scenario D includes two running modes, which are 'simplify1+release2+funding4' and 'simplify2+release4+funding8'. In this scenario all three governmental policies are taken and in the first run the strength of policies is lighter than in the second run. When all three government interventions are taken at a light degree, the outcome is almost overlapped with when there is only procedure simplification i.e. 'simplify1' (see Figure 4-23 and 4-24). When the interventions are at a heavy degree, the outcomes are as shown in Figure 4-25 and 4-26. The increasing of residential area is biggest and also obsolete industrial area is decreasing to the largest extent.

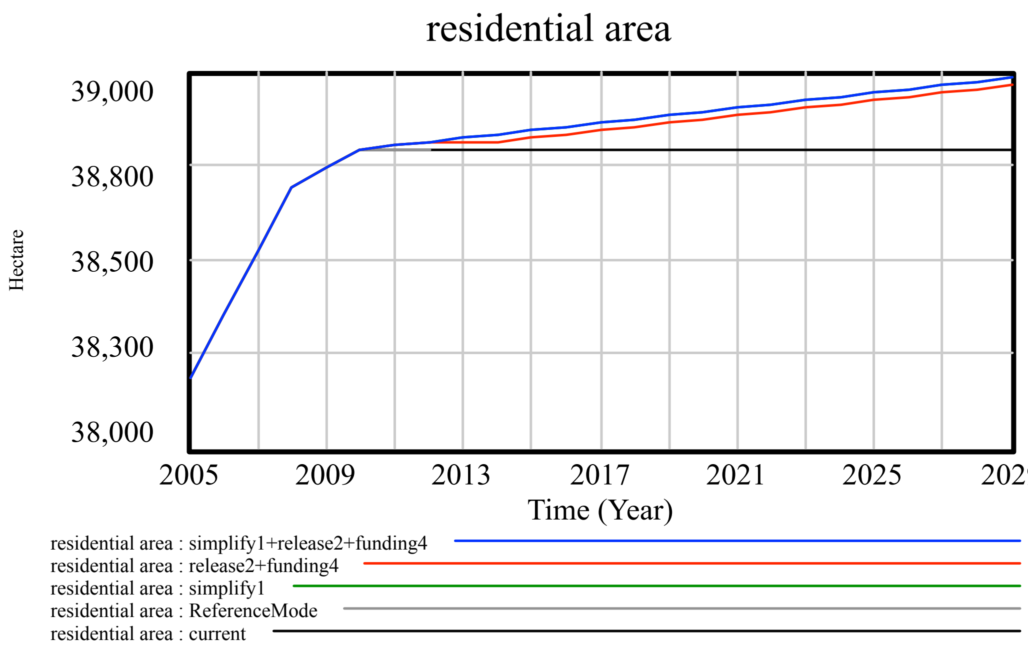


Figure 4-23 Run ‘simplify1+release2+funding4’ – residential area

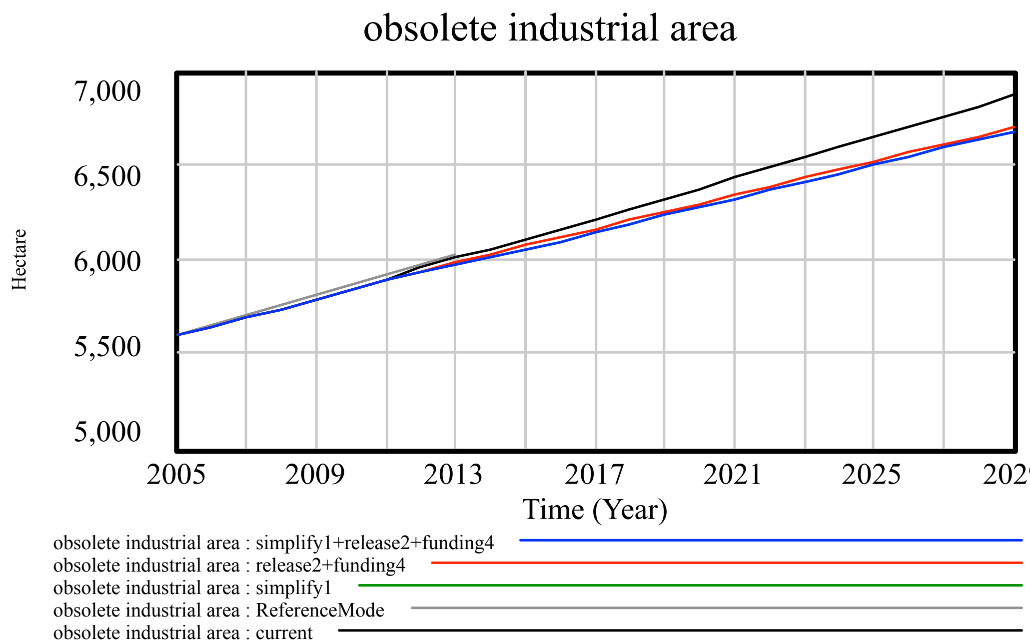


Figure 4-24 Run ‘simplify1+release2+funding4’ – obsolete industrial area

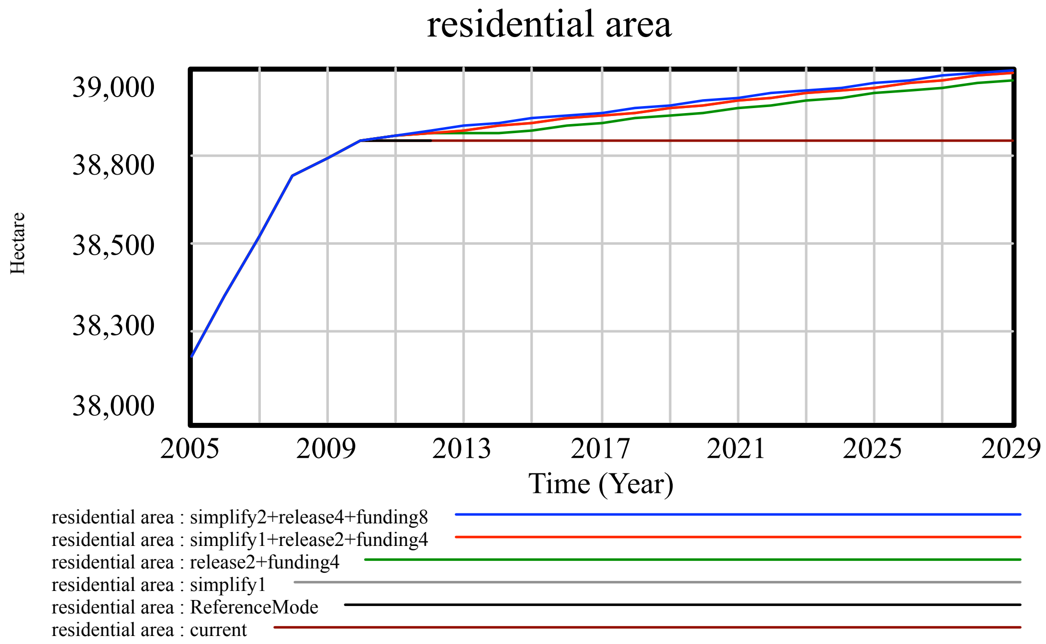


Figure 4-25 Run 'simplify2+release4+funding8' – residential area

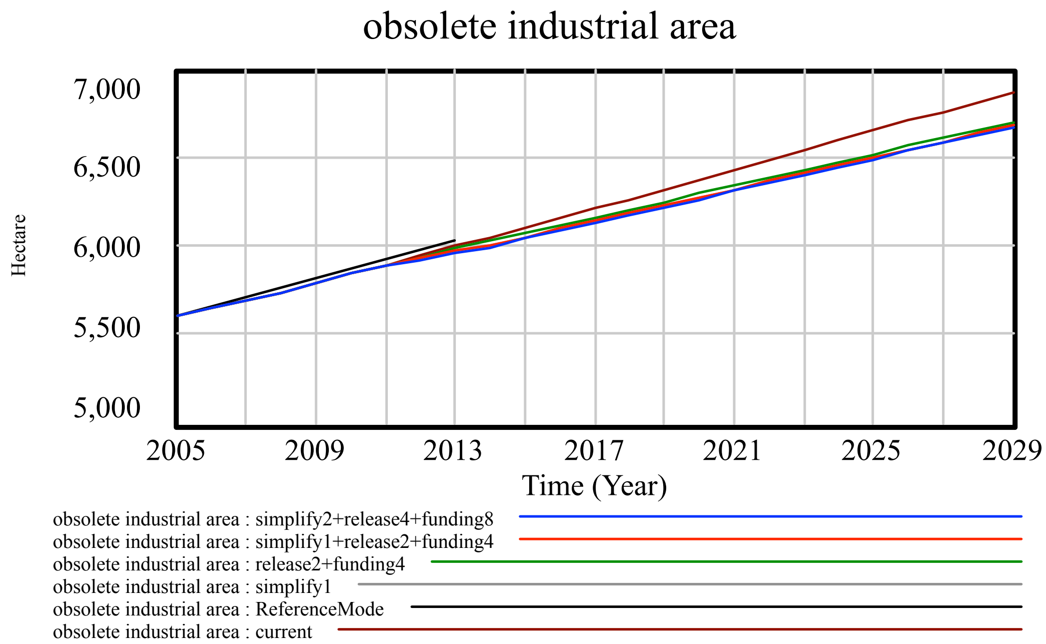


Figure 4-26 Run 'simplify2+release4+funding8' – obsolete industrial area

4.3 Results

Through structuring the model, conducting the simulation and comparing the outcomes of the four scenarios, it can be concluded that though each of the three governmental strategies, procedure simplification, economic incentive and liability afterward reduction, plays a part in improving the chance of transformation, reducing the obsolete industrial area and increasing the residential area, meeting the housing demand. Among all procedure simplification is the most effective strategy. It plays the biggest part than the other two policies and offers that through procedure simplification the chance of transformation is improved more than when applying the other two strategies.

What can be indicated from such results of the analysis is that besides providing financial funding and liability relief to private developers, public authority should focus more on shortening the response time and expediting work efficiency of related agencies when handling the applications of transformation issues. Along with shortening the response time the procedure should be simplified to better serve for property developers. The outcomes also indicate that the effectiveness of implementing all three strategies at a heavy degree is highest. However, since implementing all three strategies jointly, especially at a heavy degree, is costly, when proposing the transformation projects it is better to focus most on simplifying the procedure and reduce the response time of related applications and affairs.

Reasons why procedure simplification is more effective than the other two economic-related strategies are located in the logical connections in the model. Because in the model the procedure release and to what extent it is released is directly depends on the stock of obsolete industrial sites in this region, of which the logical relationship is built on the basis of literature review and the situation of the analyzed region. It can be inferred that if the property developer recognizes economic incentive much more than procedure simplification or the market needs such as housing demand of the region is not that in urgent need, the logical interrelationship will change and thus the decisive strategy may change.

The results can only apply to the situation of province Noord-Brabant as the model is constructed based on the specific situation of Noord-Brabant. It reflects limitation of this research that due to the limited statistic and limited timeframe, the outcomes can only be served as a simple forecast. Moreover, in this research it is not possible to cover all aspects of transformation process and take every possibility into consideration because the obsolete industrial sites transformation process is a dynamic one, which changes over time and area. What is more, because of the limited timeframe, the data is manipulated on the basis of existing researches and data instead of exacting from direct interviews and questionnaires with stakeholders.

The uncertainty can be solved through narrowing the time unit in this model and conducting Analytic Hierarchy Process (AHP) as well as interviewing relative expects and officers through questionnaires. For example, currently the unit of time in the model is ‘Year’, it can be narrowed to ‘quarter’, ‘month’ or even ‘week’ or ‘day’. But narrowing the unit of time also means more accurate data is necessary and more workload of the research. As long as the time permits and there is statistics that meets the requirement available, the uncertainty can be reduced to a certain extent.

However, the advantage of this analysis tool is that it can be served as a general analyzing tool. Any areas, as long as there are statistics available can have this tool applied. It can also be applied to any scenarios when scenarios are designed. The government of a region can make use of this analysis tool in researching the problem of urban land use transformation and finds out the decisive factors need to be paid attention to. What is more, the government can also use this analysis model as a tool to negotiate with private developers. In this way the public party and private party collaborates with each other better and more effectively because the analysis tool serves as a platform that connects the two players in discussing urban design and planning issues. As a result the urban environment and spatial quality can be improved more effectively and following the principle of sustainability.

Chapter 5 Conclusion

This research looks into the problem of industrial sites obsolescence and tries to answer the question that what factors should be paid specific attention during the transformation from obsolete industrial sites to residential areas. With the purpose of answering this research question, providing advice and giving insights on the problem, through reviewing existing researches, the most important factors in transformation from obsolete industrial sites into residential area are studied. An analysis tool that is based on the situation of province Noord-Brabant in the Netherland is created by the means of literature study, System Dynamics simulation modeling and scenario design analysis. The analysis and results give insights and provide advice for urban planning decision makers as public authorities and private property developers that the related government agencies should focus on simplifying the procedure and expediting the process of handling applications and relevant affairs by means of removing some unnecessary sections and shortening response time. This research paves the way for further studies in the field of sustainable land use development in urban design and planning. In the following paragraphs, the societal relevance, scientific relevance and beneficiary relevance of this research will be given.

5.1 Societal relevance

The research contributes in the development of smart cities and spatial quality improvement, both of which are trends in the field of urban design and planning around global countries. Through land use transformation the problem of over-supplied industrial area and obsolete industrial sites that lead to adverse effects to urban environment can be solved to a certain extent. Among different transformation directions, transformation into residential areas meets the demand created by increasing urban population and solves the problem of shortage of land. Nowadays either developed countries that have already gone through the industrial relocation and industry transformation or developing countries like China and India that still have heavy industries development undergoing need such solution in the urban redesign and planning phase to improve the spatial quality and create a better urban environment.

5.2 Scientific relevance

The scientific value of this research locates in the depth it reaches. Though there already exist wealthy researches on land use transformation related questions and there are considerable researches regarding obsolete industrial sites transformation process. This research goes further by finding out the decisive factors and looks into the possible interactions between obsolete industrial sites and residential areas demand solely.

Through connecting the two issues in realistic complicated system and making use of existing data, an analysis tool for studying the sustainable land development in a specific direction, analyzing factors that are playing in the process and figuring out the most important one is created. The model gives elaboration on aspects that are important in the field of construction management and urban development (CMUD) and integrates them into one system, paves the way for further research from which an optimal decision support method can be obtained. Also, since the analysis tool creates a logical system and it can be served as a general analysis tool, it not only can serve the specific situation of a region but also various other regions and various other scenarios as long as there is data input available.

5.3 Beneficiary relevance

The beneficiary relevance of this research is related to municipalities and property developers as well as the urban environment spatial quality. It provides insights for all municipalities that are looking for ways to deal with over-stock industrial area or industrial sites obsolescence and growing housing demand in this regard. The simulation model helps both public authorities and private developers in deciding a proper strategy or selecting a proper project depends on their own situations. Negotiation and collaboration between public authorities and private developers can be made based on the model and its analyses. Advices are given on properly deal with obsolete industrial sites transformation to achieve in a more sustainable built environment, improve the spatial quality, better understand important factors in urban development process and create attractive transformation sites.

An attractive site from transformation will improve the urban environment, bring opportunities for investments and promote regional development, all of which are welcoming results by local government. Moreover, such sustainable development brings profits to private developers and is hard to be refused. This research provides insights for all municipalities that are looking for ways to deal with over-stock industrial sites and growing housing demand in this regard. It contributes to strengthen the negotiation and collaboration between the two stakeholders to create a better urban environment.

References

Alberini, A., Longo, A., Tonin, S., Trombetta, F., & Turvani, M. (2005). The role of liability, regulation and economic incentives in brownfield remediation and redevelopment: evidence from surveys of developers. *Regional Science and Urban Economics, 35*(4), 327-351. doi: 10.1016/j.regsciurbeco.2004.05.004

Barough, A. S., Shoubi, M. V., & Skardi, M. J. E. (2012). Application of Game Theory Approach in Solving the Construction Project Conflicts. *Procedia - Social and Behavioral Sciences, 58*, 1586-1593.

Bhatta, B. (2010). Causes and Consequences of Urban Growth and Sprawl *Analysis of Urban Growth and Sprawl from Remote Sensing Data* (pp. 17-36): Springer.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences, 99*(suppl 3), 7280-7287.

Burton, I. (1987). Report on Reports: Our Common Future: The World Commission on Environment and Development. *Environment: Science and Policy for Sustainable Development, 29*(5), 25-29.

CABERNET. (2003). State of the Art – Country Profile: Netherlands (1st Draft). In CABERNET (Ed.), *CABERNET Brownfield Country Profiles* (1st ed.).

CABERNET. (2004). “Havnestad” on the Copenhagen waterfront, Denmark. In CABERNET (Ed.), *Social And Cultural Issues Working Group Case Study*.

CBS. (2015a). Land use; Industrial area, 1996-2010. *Statistics Netherlands.* Retrieved Mar. 28th, 2015, from http://cbs.overheidsdata.nl/70262ENG

CBS. (2015b). Population counter. *Statistics Netherlands.* Retrieved Mar. 9th, 2015, from http://www.cbs.nl/en-GB/menu/themas/bevolking/cijfers/extra/bevolkingsteller.htm

Cityplot Buiksloterham. (2015). Buiksloterham. *Cityplot Buiksloterham.* Retrieved May 27th, 2015, from http://www.cityplot-buiksloterham.nl/

DELVA. (2015). Dynamisch Masterplan Buiksloterham – Amsterdam. *DELVA Landscape Architects / Urbanism.* from http://delva.la/projecten/dynamisch-masterplan-buiksloterham-amsterdam-2/

Dembski, S. (2013). Case study Amsterdam Buiksloterham, the Netherlands: the challenge of planning organic transformation *CONTEXT Report 2*. AISSR programme group Urban Planning, Amsterdam.

DG Growth. (2015). Regional Innovation Monitor Plus: North Brabant. *The Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs.* Retrieved May 29th, 2015, from https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/north-brabant

EPA. (2002). Brownfields Definition. *Brownfields and Land Revitalization.* Retrieved Mar. 4th, 2015, from http://www.epa.gov/brownfields/overview/glossary.htm

European Communities. (2009). Economic Crisis in Europe: Causes, Consequences and Responses *European Economy* (Vol. 7). Luxembourg.

Femi, A. B., & Khan, T. H. (2014). Bridging the Gap between Housing Demand and Housing Supply in Nigerian Urban Centres: A Review of Government Intervention So Far. *British Journal of Arts and Social Sciences, 18*(II), 94-107.

Ferstl Valuation Services. (2014). What (If Anything) Does the Industrial Vacancy Rate Mean For Commercial Real Estate in Arkansas? *Commercial Property Appraisals.* Retrieved Mar. 7th, 2015, from http://arkansasappraisers.com/anything-industrial-vacancy-rate-mean-commercial-real-estate-arkansas/

Floyd, C. F., & Allen, M. T. (2002). *Real Estate Principles*: Dearborn Real Estate Education.

Fong, W.-K., Matsumoto, H., & Lun, Y.-F. (2009). Application of System Dynamics model as decision making tool in urban planning process toward stabilizing carbon dioxide emissions from cities. *Building and Environment, 44*, 1528-1537.

Györffi, M., & Oren, G. (2006). Relocation of EU Industry: An Overview of Literature. In Policy Department Economic and Scientific Policy (Ed.).

Halleux, J.-M., Marcinczak, S., & van der Krabben, E. (2012). The adaptive efficiency of land use planning measured by the control of urban sprawl. The cases of the Netherlands, Belgium and Poland. *Land Use Policy, 29*(4), 887-898. doi: 10.1016/j.landusepol.2012.01.008

Hartman, H. (2014). Woningmarkt Noord-Brabant: behoefte aan 10.000 extra woningen per jaar. *Hans Hartman: ontwikkelen en herbestemmen.* Retrieved Feb. 10th, 2015, from http://www.hanshartman.eu/noord-brabant-prognose-behoefte-aan-nieuwe-woningen-blijft-groot/

Harts, J. J., Maat, C., & van Emmichoven, M. Z. (2000). *Urban Density and Land Use in The Netherlands*. Paper presented at the 3rd AGILE Conference on Geographic Information Science, Helsinki/Espoo, Finland.

JLL EMEA Ofice Research. (2014). Eindhoven Office Market Profile – Q2 2014.

JLL OnPoint. (2010). Dutch Warehousing Market Bulletin – 2010.

Knight Frank Research. (2013). 2013 Dutch office market report: Occupier market trends in the Randstad. The Netherlands.

Korthals Altes, W. K., & Tambach, M. (2008). Municipal strategies for introducing housing on industrial estates as part of compact-city policies in the Netherlands. *Cities, 25*(4), 218-229. doi: 10.1016/j.cities.2008.04.005

Louw, E. (2008). Land assembly for urban transformation—The case of 's-Hertogenbosch in The Netherlands. *Land Use Policy, 25*(1), 69-80. doi: 10.1016/j.landusepol.2006.09.002

Louw, E., & Bontekoning, Y. (2007). Planning of industrial land in the Netherlands: Its rationales and consequences. *Tijdschrift voor economische en sociale geografie, 98*(1), 121-129.

Louw, E., Krabben, E. v. d., & Priemus, H. (2003). Spatial development policy: changing roles for local and regional authorities in the Netherlands. *Land Use Policy, 20*(4), 357-366. doi: 10.1016/s0264-8377(03)00059-0

Matthews, R. B., Gilbert, N. G., Roach, A., Polhill, J. G., & Gotts, N. M. (2007). Agent-based land-use models: a review of applications. *Landscape Ecology, 22*(10), 1447-1459.

Niazi, M., & Hussain, A. (2011). Agent-based computing from multi-agent systems to agent-based models: a visual survey. *Scientometrics, 89*(2), 479-499.

Nijkamp, P., Rodenburg, C. A., & Wagtendonk, A. J. (2002). Success factors for sustainable urban brownfield development: A comparative case study approach to polluted sites. *Ecological Economics, 40*(2), 235-252.

Ott, U. F. (2013). International business research and game theory: Looking beyond the Prisoner's Dilemma. *International Business Review, 22*(2), 480-491.

Ploegmakers, H., & Beckers, P. (2012). Evaluating regeneration policies for rundown industrial sites in the Netherlands. *PBL Working Paper*. Retrieved from

Provincie Noord-Brabant. (2010). Provinciaal herstructureringsprogramma bedrijventerreinen: Noord-Brabant 2009 t/m 2013.

Provincie Noord-Brabant. (2013). Obsolete industrial sites - Yes/No 2013.

Provincie Noord-Brabant. (2014). Prognoses vergeleken. *Bevolkingsprognose: De bevolkings- en woningbehoefteprognose Noord-Brabant.* Retrieved Mar. 14th, 2015, from http://bevolkingsprognose.brabant.nl/hoofdstuk/prognoses-vergeleken

Remøy, H. T. (2010). *Out of Office: A Study on the Cause of Office Vacancy and Transformation as a Means to Cope and Prevent.* (Doctoral dissertation), Delft University, Amsterdam, The Netherlands.

Remøy, H. T., & van der Voordt, T. J. M. (2006). *A new life. Transformation of vacant office buildings into housing.* Paper presented at the CIB W70 2006 Trondheim International Symposium, Trondheim.

Royal Haskoning. (2010). Kwaliteit en veroudering bedrijventerreinen Noord-Brabant.

Samsura, D. A. A., van der Krabben, E., & van Deemen, A. M. A. (2010). A game theory approach to the analysis of land and property development processes. *Land Use Policy, 27*(2), 564-578. doi: 10.1016/j.landusepol.2009.07.012

Schultink, G. (2007). Sustainable Land Use and Urban Growth Management: Demand-Supply Factors and Strategic Planning Considerations. *Journal of Agricultural, Food and Environmental Sciences, 1*(1).

Seebus, J. (2012). Conversion gains ground – slowly. *Property Magazine, 4,* 38-45.

Shen, Q., Chen, Q., Tang, B.-s., Yeung, S., Yu, Y., & Cheung, G. (2009). A system dynamics model for the sustainable land use planning and development. *Habitat International, 33*(1), 15-25.

Simons, R. A. (1998). Turning brownfields into greenbacks. *Washington, DC: Urban Land Institute*.

Sjælsø Management. (2009). HAVNESTAD SYD. *Sjælsø Management.* Retrieved May 27th, 2015, from http://www.sjaelsoemanagement.com/references/havnestad-syd

Sterman, J. (2004). Business dynamics: systems thinking and modelling for a complex world.

Syms, P. (1999). Redeveloping brownfield land The decision-making process. *Journal of Property Investment & Finance, 17*(5), 481-500. doi: 10.1108/14635789910294903

Thornton, G., Franz, M., Edwards, D., Pahlen, G., & Nathanail, P. (2007). The challenge of sustainability: incentives for brownfield regeneration in Europe. *Environmental Science & Policy, 10*(2), 116-134. doi: 10.1016/j.envsci.2006.08.008

Traa, M., & Knoben, J. (2009). Veroudering en herstructurering op bedrijventerreinen. Een verkenning. In PBL (Ed.), *De Bedrijfslocatiemonitor*. Den Haag/Bilthoven.

van Bronkhorst, B., Glumac, B., van Rhee, M., Kunen, T., & Schaefer, W. (2014). *The Dutch Land Market: A Regional Tool for Policy Impact on Vacancy and Grant Rates*. Paper presented at the 21st Annual European Real Estate Society Conference, Bucharest, Romania.

van Der Krabben, E. (2014). *Private–Private Cooperation in Urban Redevelopment Projects*. Paper presented at the FIG Congress 2014 'Engaging the Challenges – Enhancing the Relevance', Kuala Lumpur, Malaysia.

van der Krabben, E., & Jacobs, H. M. (2013). Public land development as a strategic tool for redevelopment: Reflections on the Dutch experience. *Land Use Policy, 30*(1), 774-783. doi: 10.1016/j.landusepol.2012.06.002

Verburg, P. H., de Nijs, T. C. M., Ritsema van Eck, J., Visser, H., & de Jong, K. (2004). A method to analyse neighbourhood characteristics of land use patterns. *Computers, Environment and Urban Systems, 28*(6), 667-690. doi: 10.1016/j.compenvurbsys.2003.07.001

VROM. (2011). MOOI NEDERLAND: 2,5 jaar innovatie en waardecreatie. Den Haag.

VROM. (2013). *IBIS Werklocaties: De Stand Van Zaken in Planning En Uitgifte Van Werklocaties Op 1 Januari 2013 En Ee Uitgifte in 2012*

Appendix I Figures

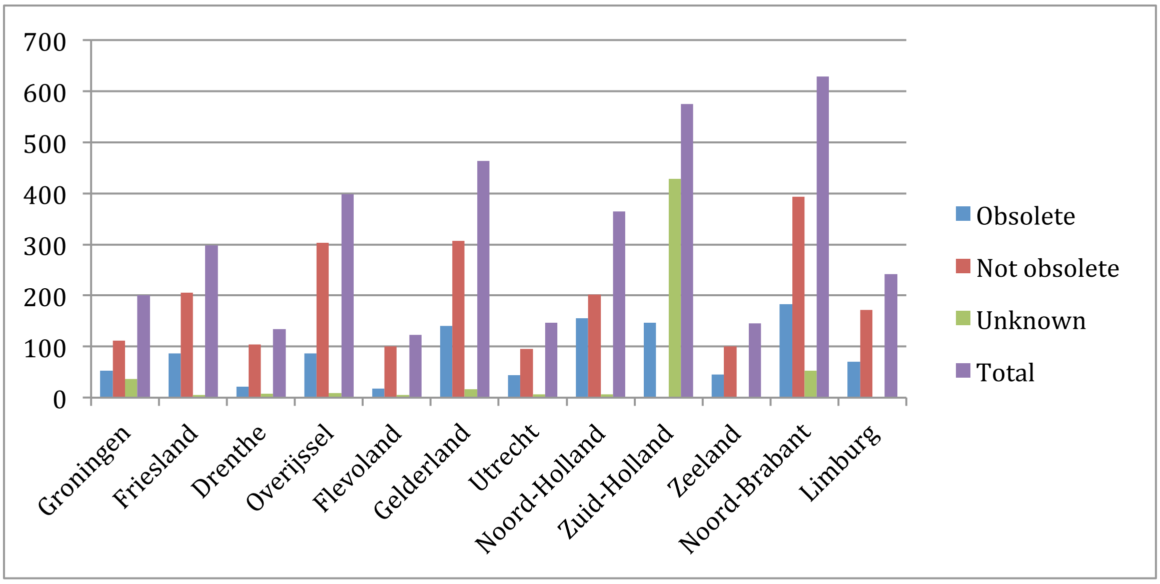


Figure 1-1 Number of obsolete and not obsolete industrial sites by province (including seaport areas and economic zones), till Jan. 1st 2013 (ARCADIS & IBIS, 2013)

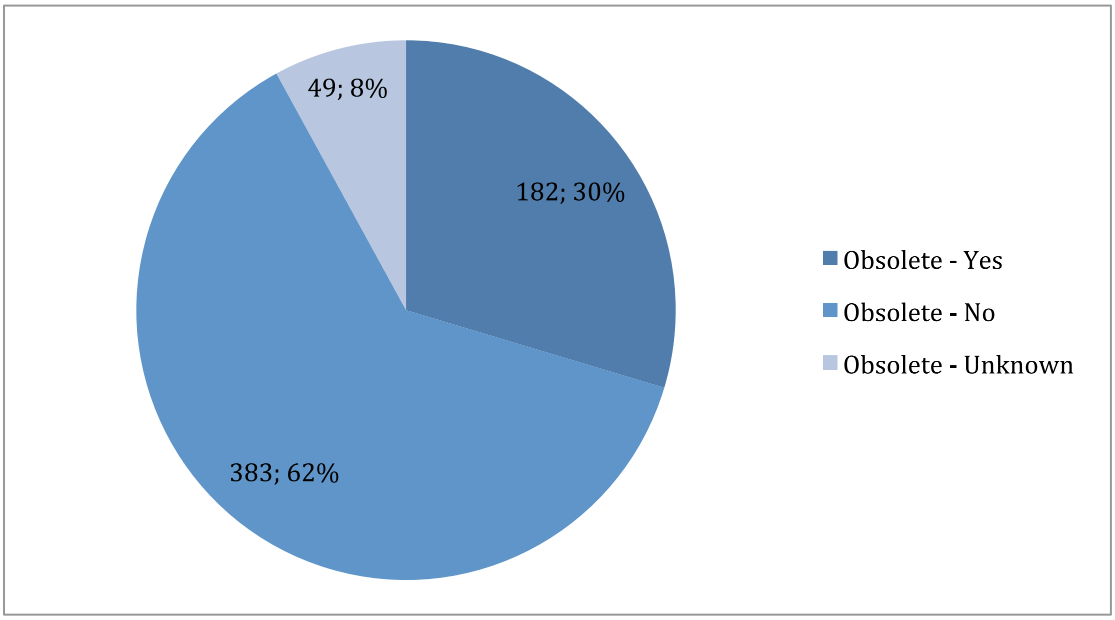


Figure 3-2 Obsolete industrial sites - Yes/No 2013 Province: Noord-Brabant (Provincie Noord-Brabant, 2013)

Figure 3-3 Havnestad in 1991 and 2009

Figure 3-4 Havnestad Syd in 2001 and 2010

Figure 3-5 Aerial view on the Buiksloterham, 1971. Source: Dienst Ruimtelijke Ordening Gemeente Amsterdam (Figure source: (Dembski, 2013))

Figure 3-6 View on the Johan van Hasselt Canal from the West, 2009. Photograph: Doriann Kransberg. Stadsarchief Amsterdam

Figure 3-7 Cityplot Buiksloterham Bird's Eye View (Cityplot Buiksloterham, 2015)

Figure 3-8 Typical floor plans of the conversion of the office building into housing, before and after (Figure source: (Remøy & van der Voordt, 2006))

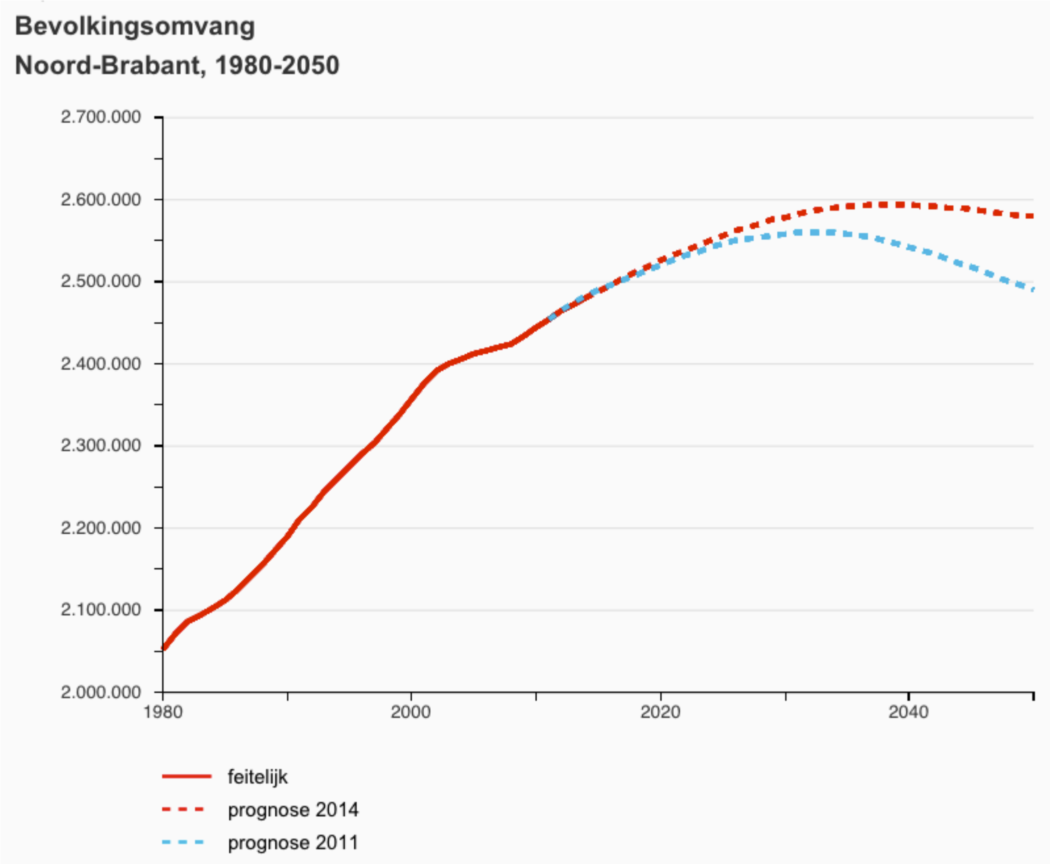


Figure 3-9 Population Size and Forecast of Noord-Brabant, 1980-2050 (Provincie Noord-Brabant, 2014)

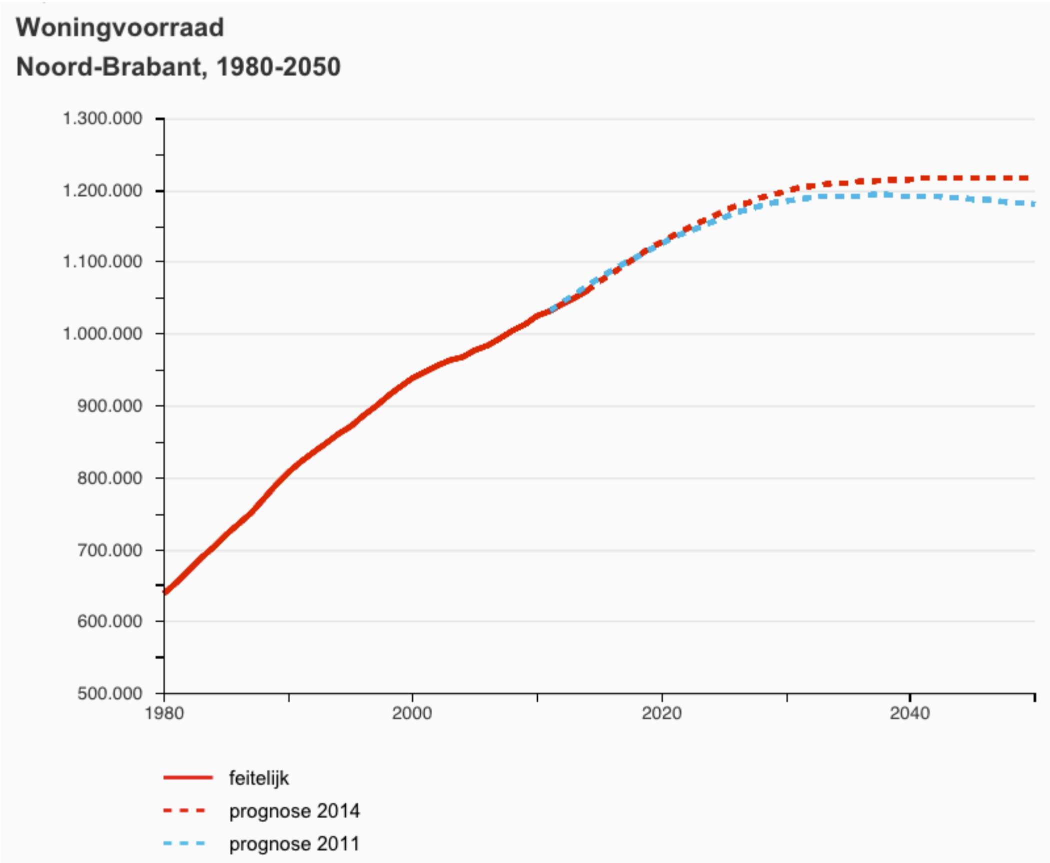


Figure 3-10 Housing Stock and Forecast of Noord-Brabant, 1980-2050 (Provincie Noord-Brabant, 2014)

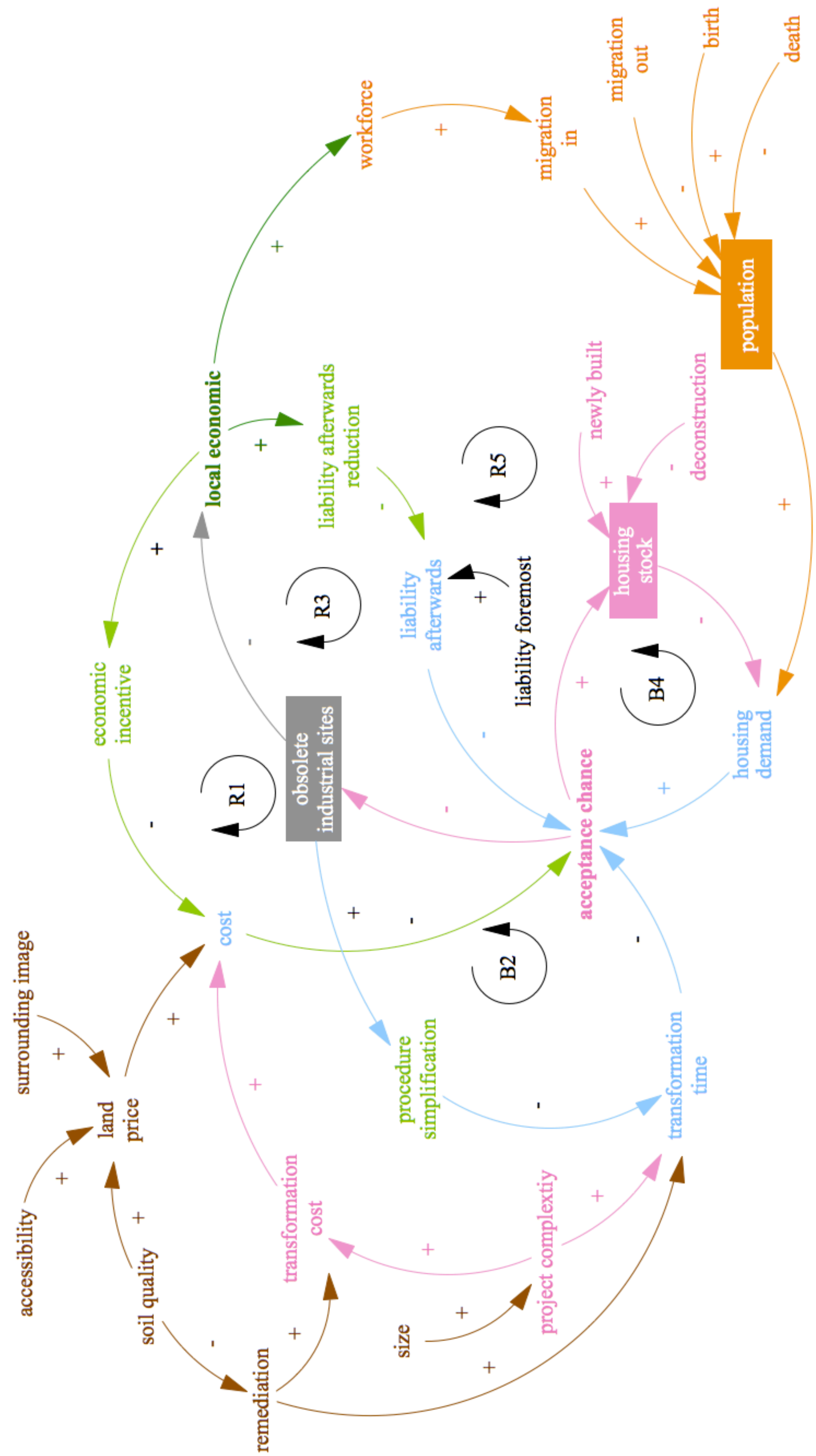


Figure 4-1 Causal Loop Diagram

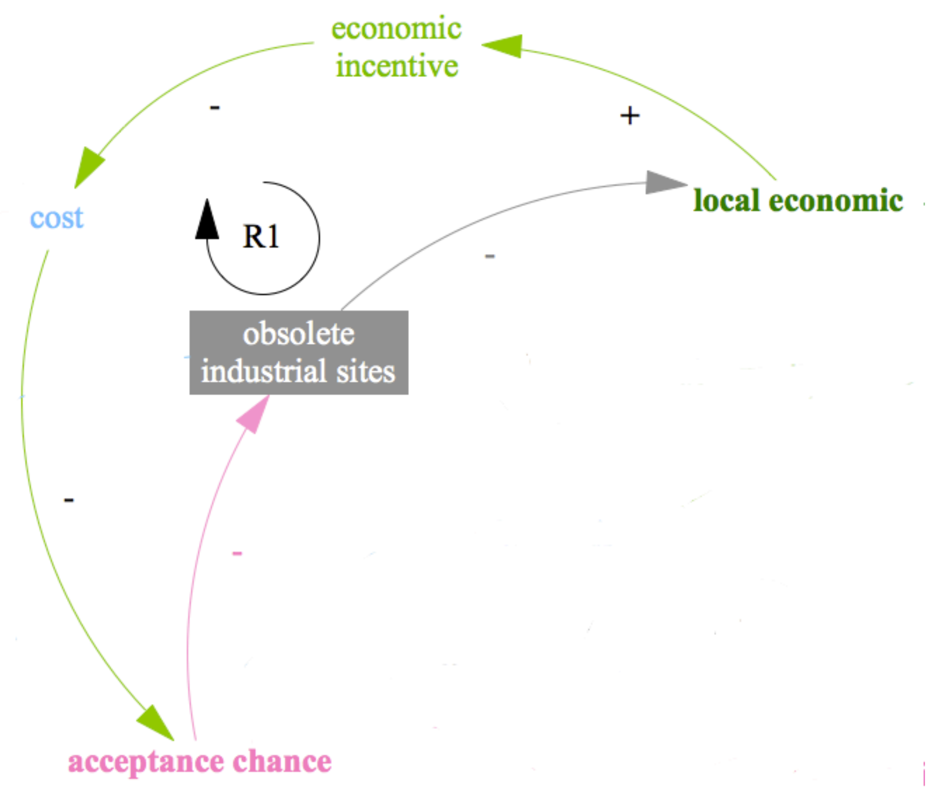


Figure 4-2 CLD Loop 1 – Economic Incentive Loop

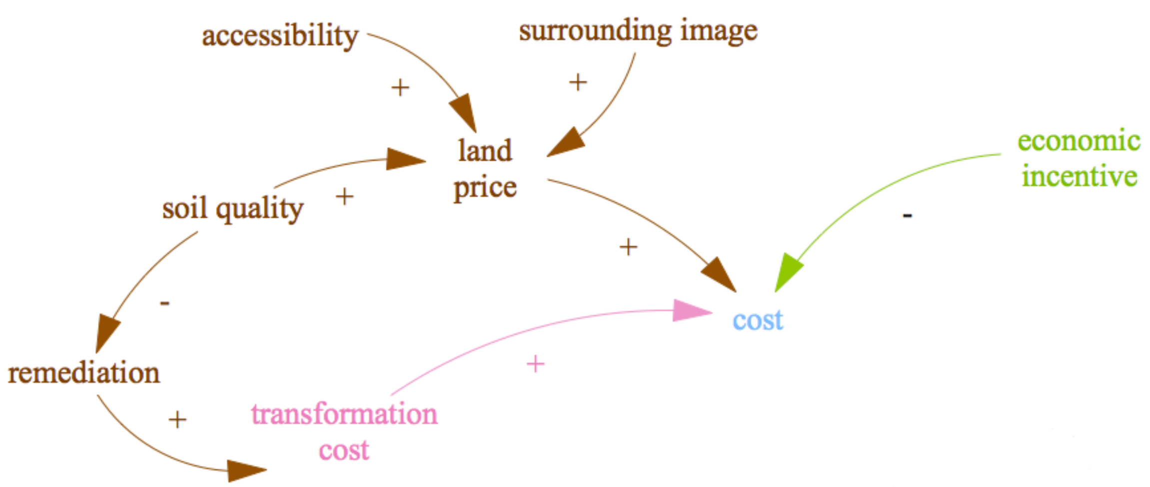


Figure 4-3 Cost

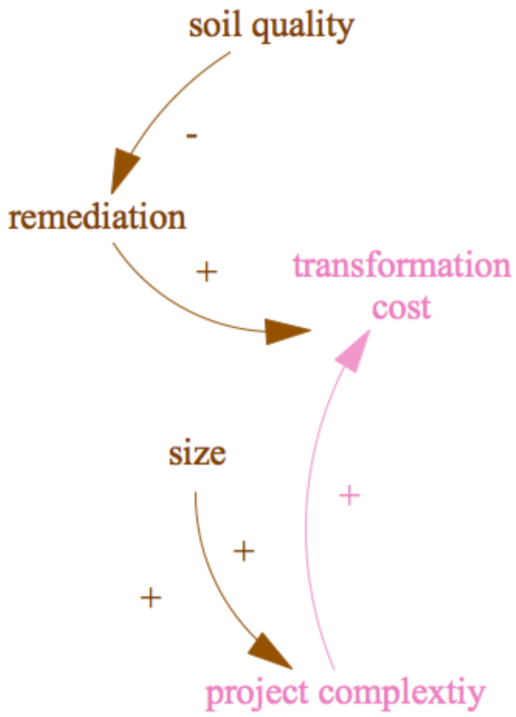


Figure 4-4 Transformation cost

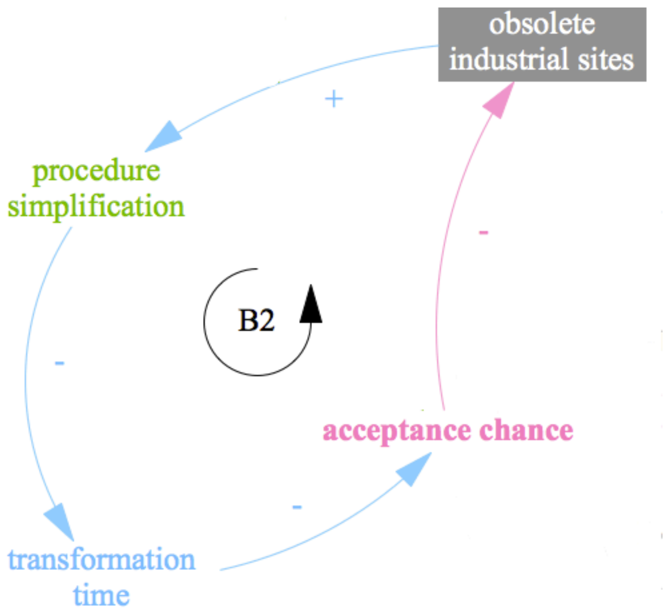


Figure 4-5 CLD Loop 2 – Procedure simplification loop

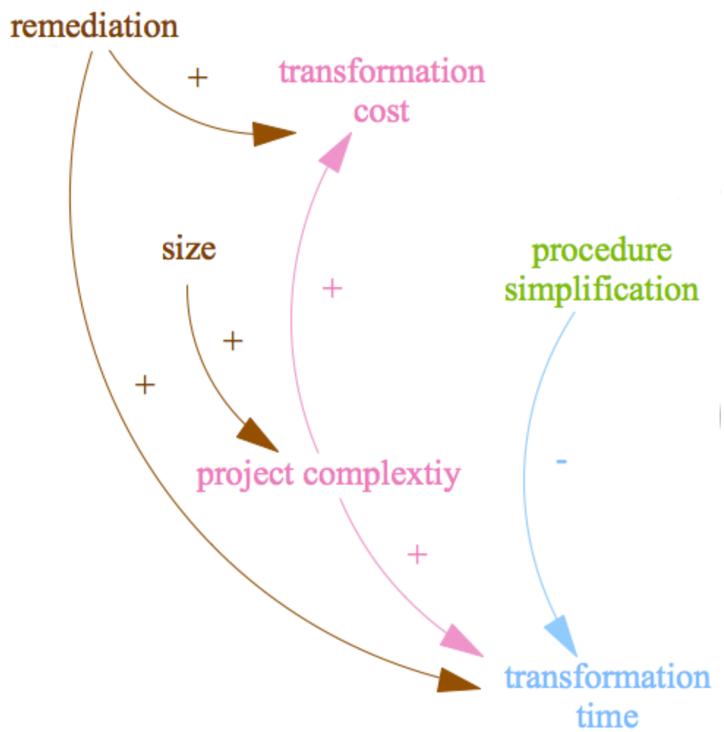


Figure 4-6 Transformation time

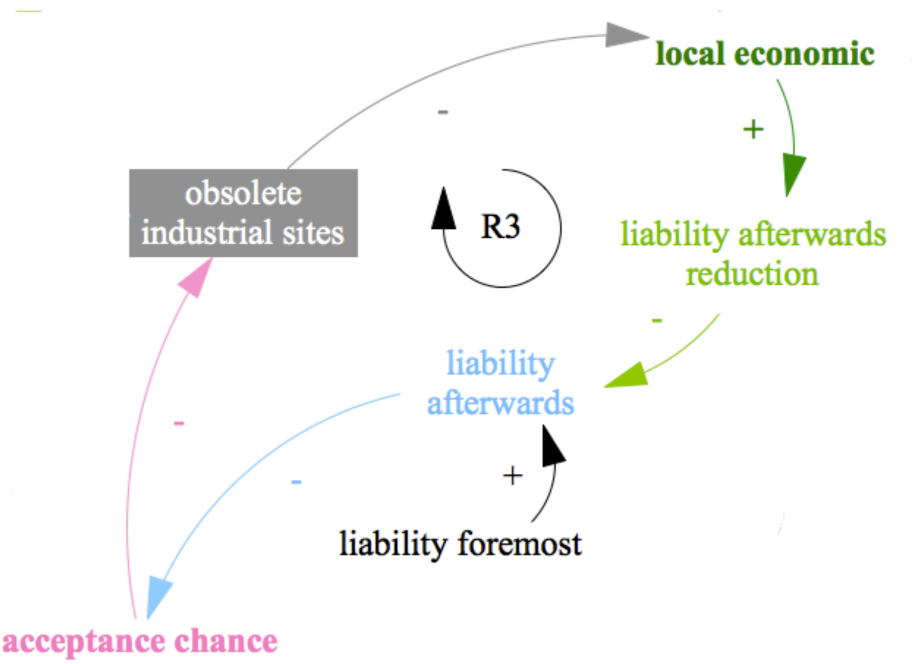


Figure 4-7 CLD Loop 3 – Liability afterwards reduction loop

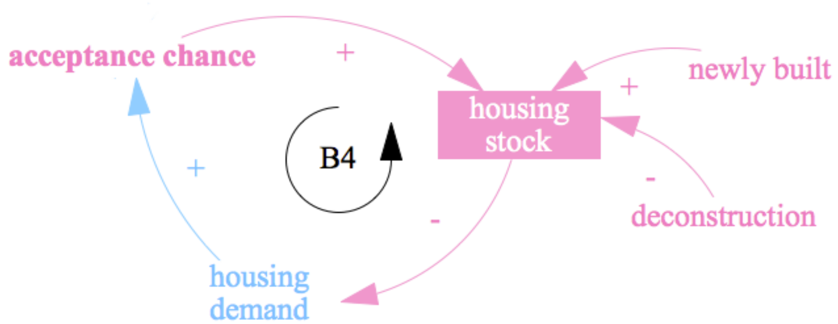


Figure 4-8 CLD Loop 4 – Housing loop

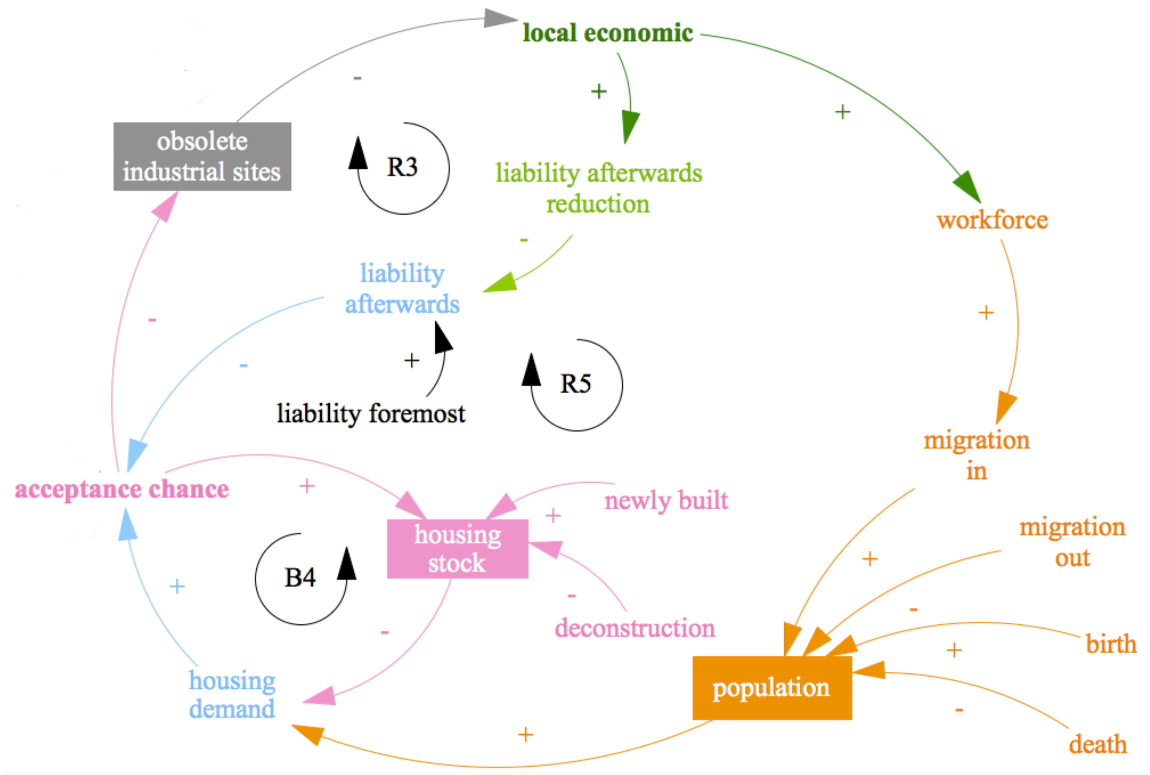


Figure 4-9 CLD Loop 5 – Overall loop

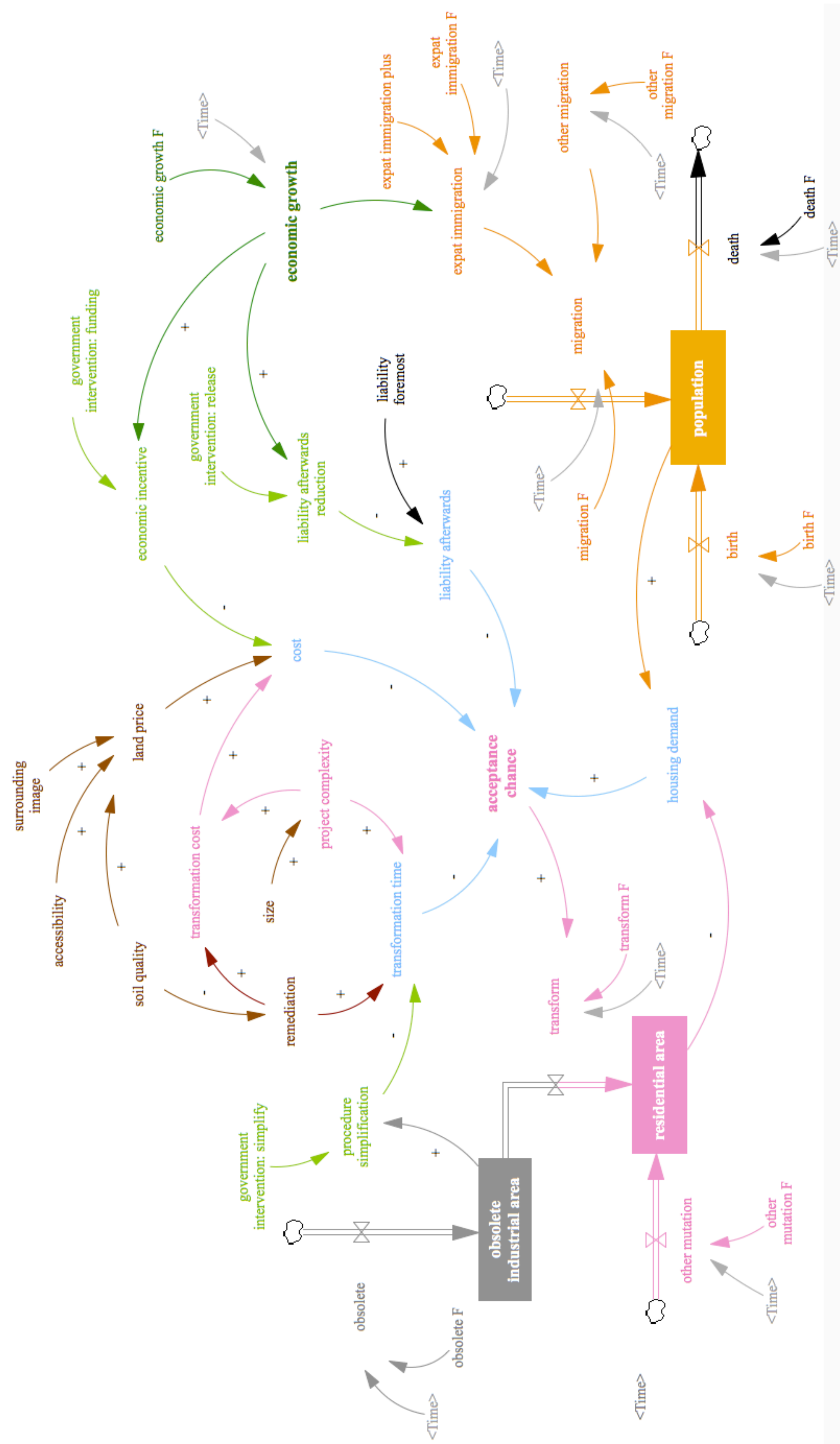


Figure 4-10 Stock Flow Model

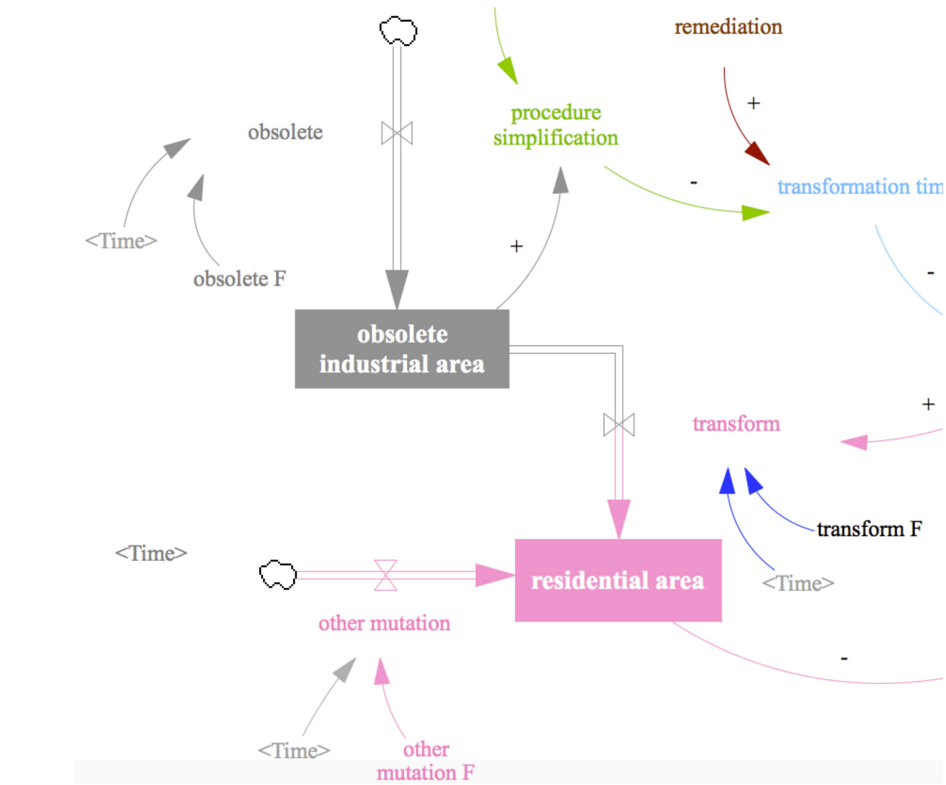


Figure 4-11 Stock 'obsolete industrial area' and 'residential area', flow ‘obsolete’, ‘transform’ and ‘other mutation’

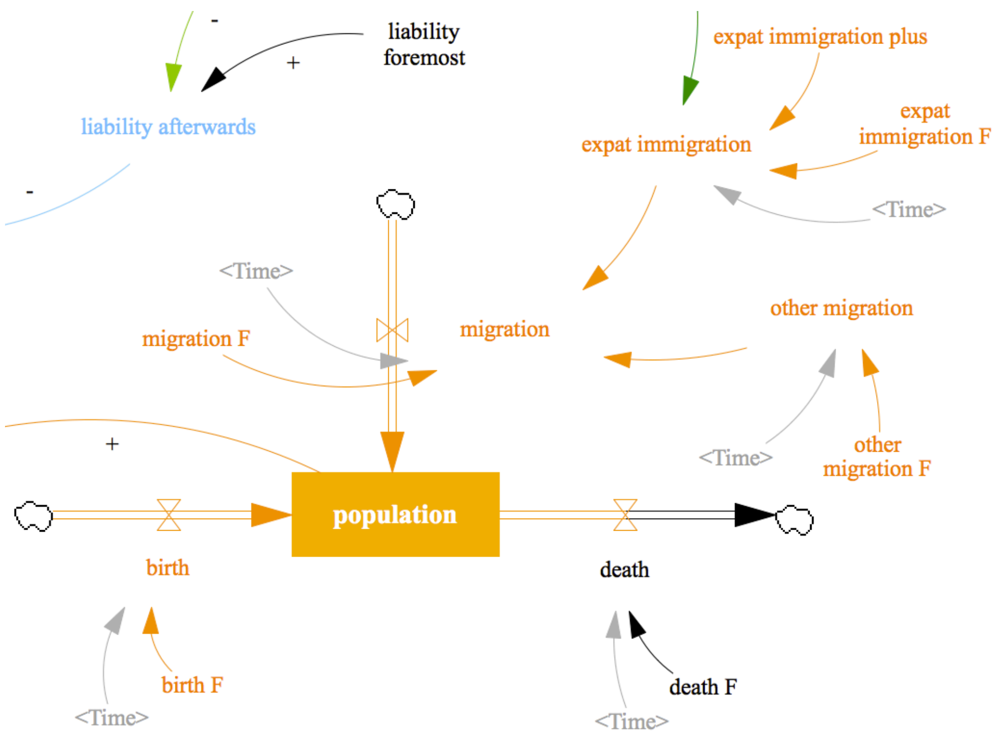


Figure 4-12 Stock 'population', flow ‘birth’, ‘death’ and ‘migration’

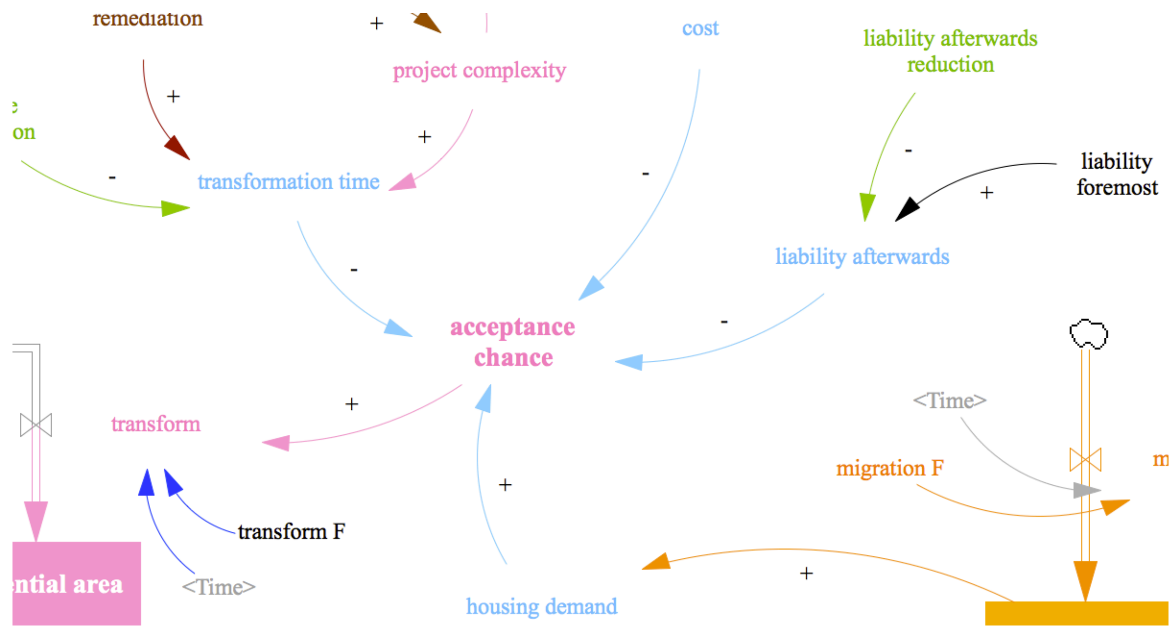


Figure 4-13 Variable 'acceptance chance'

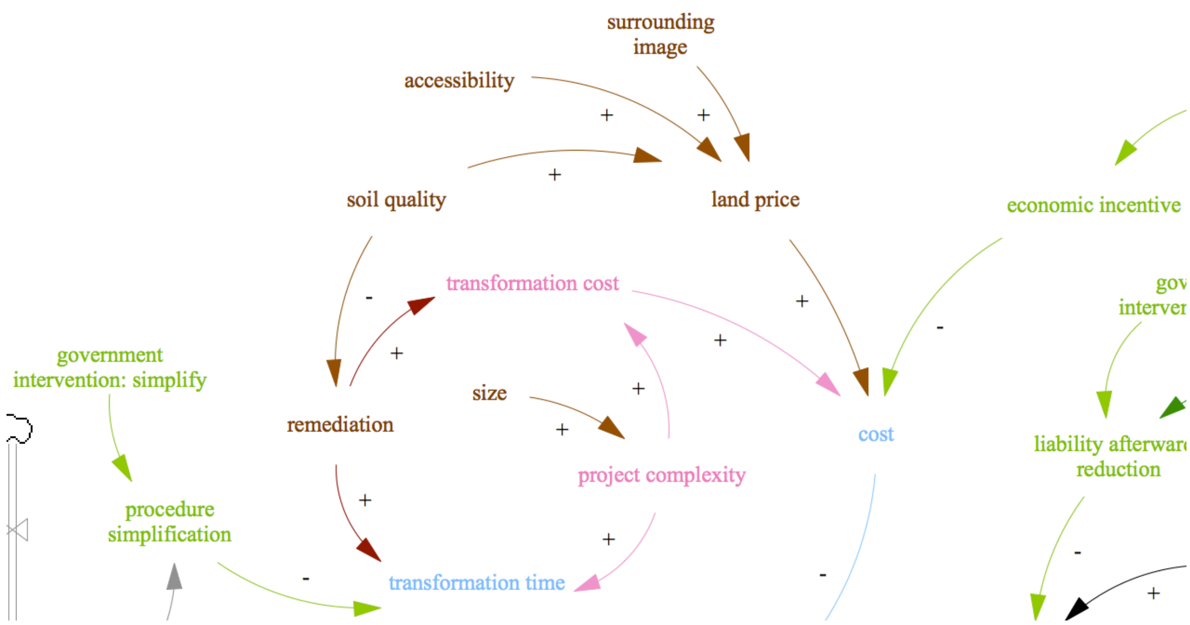


Figure 4-14 Site attributes and project relevance

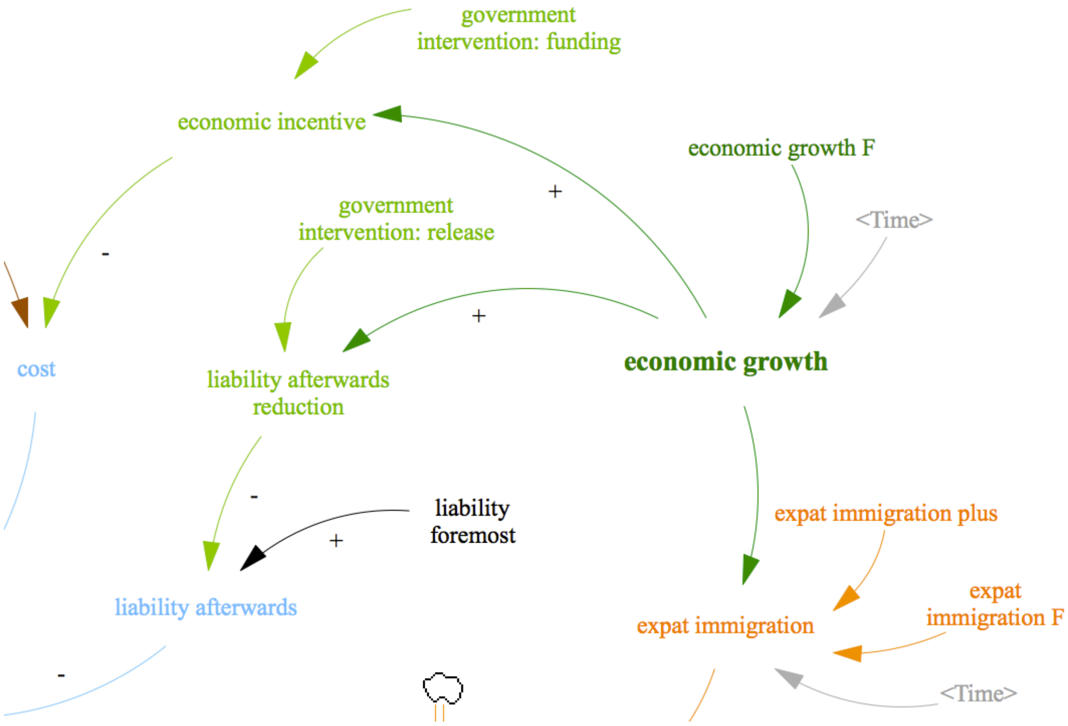
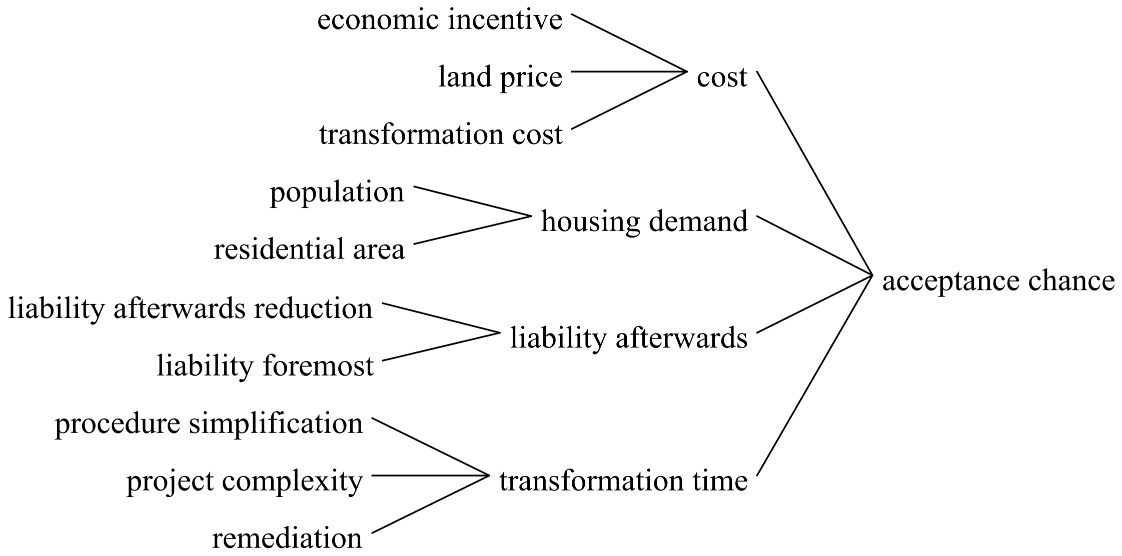


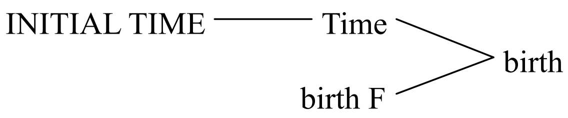
Figure 4-15 Economic growth and economic-associated government interventions

Appendix II Causes Tree

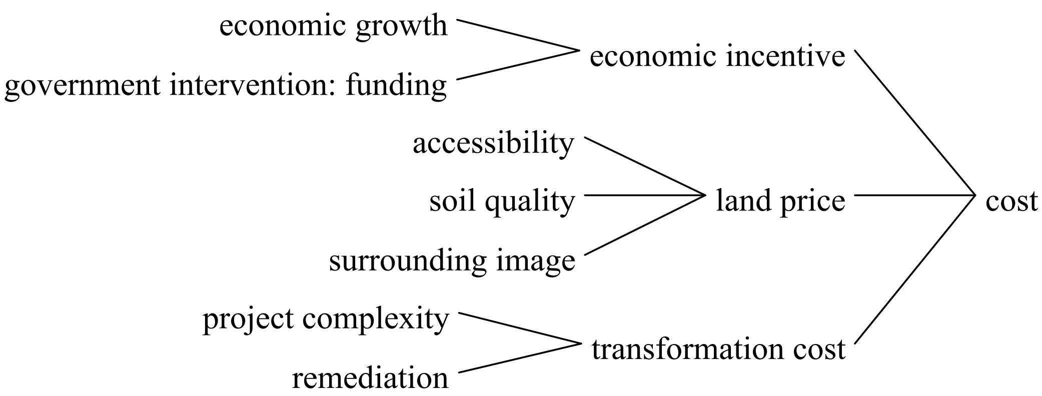
01) Acceptance chance



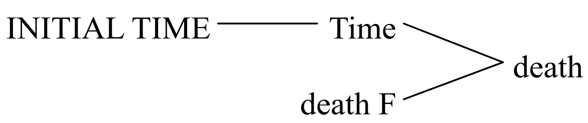
02) Birth



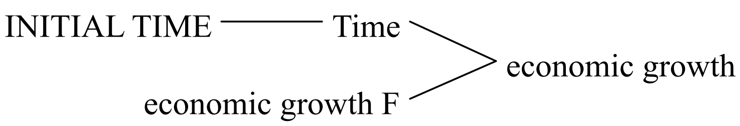
03) Cost



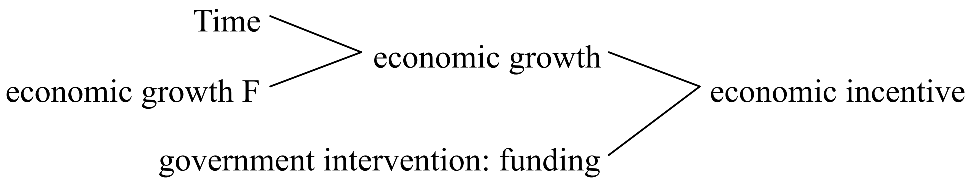
04) Death



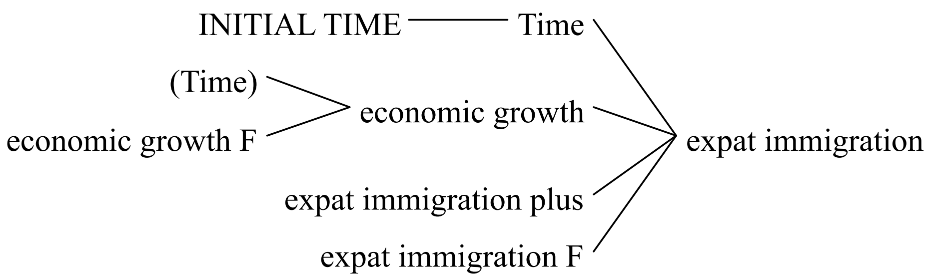
05) Economic growth



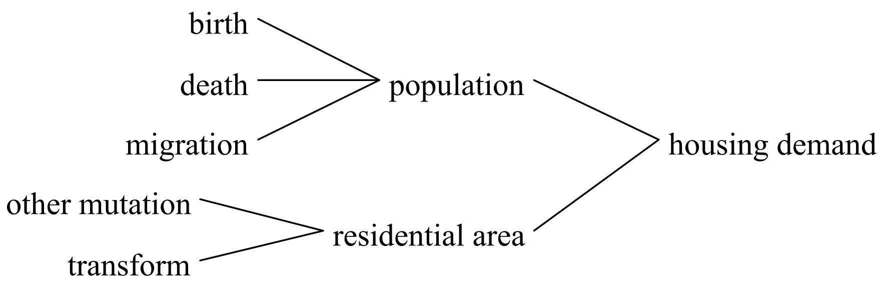
06) Economic incentive



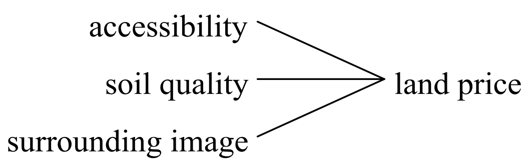
07) Expat immigration



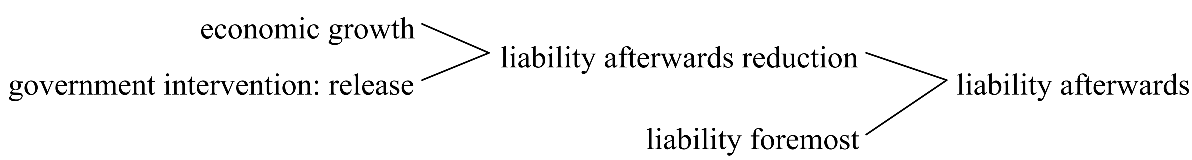
08) Housing demand



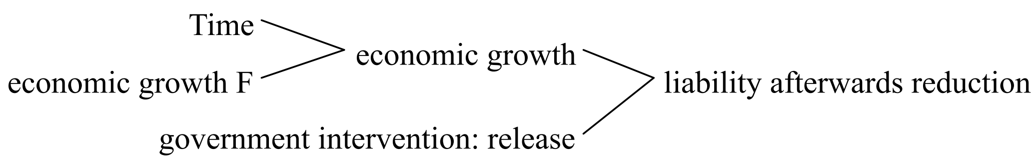
09) Land price



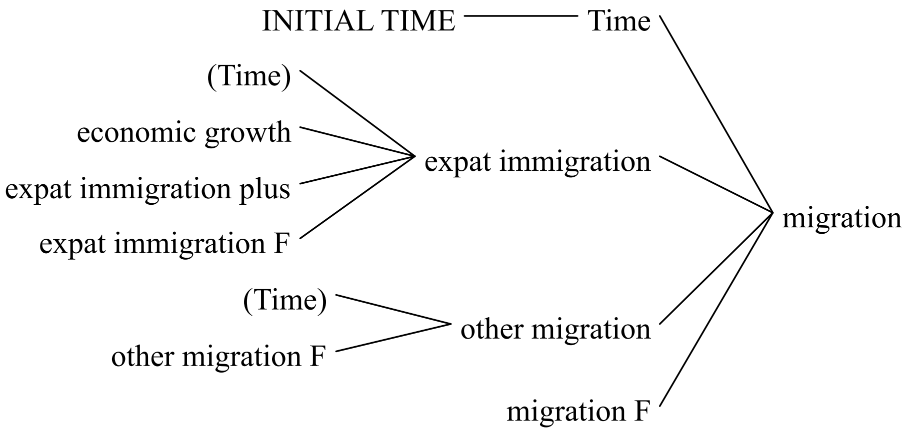
10) Liability afterwards



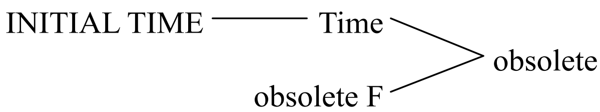
11) Liability afterwards reduction



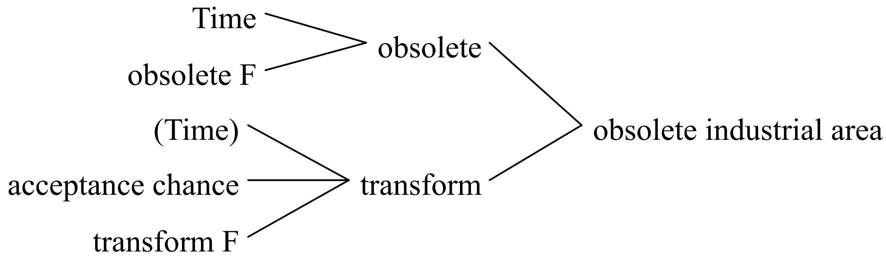
12) Migration



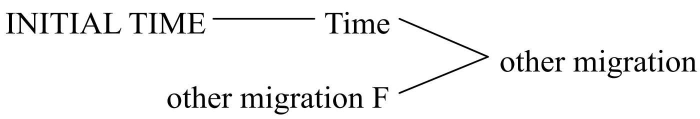
13) Obsolete



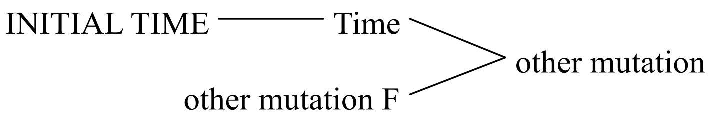
14) Obsolete industrial area



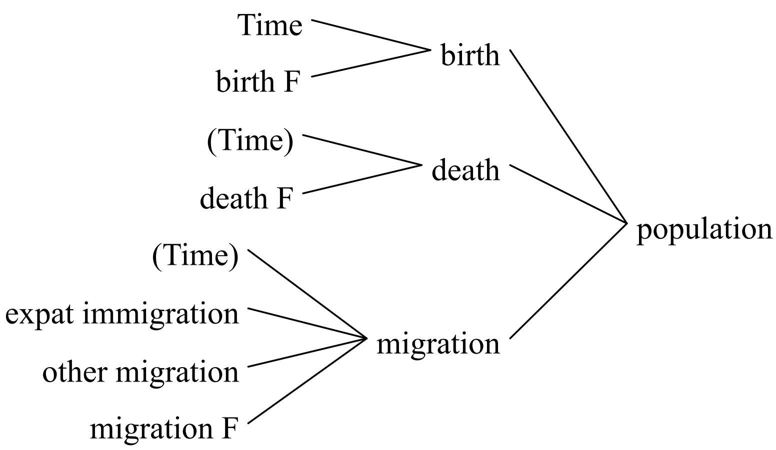
15) Other migration



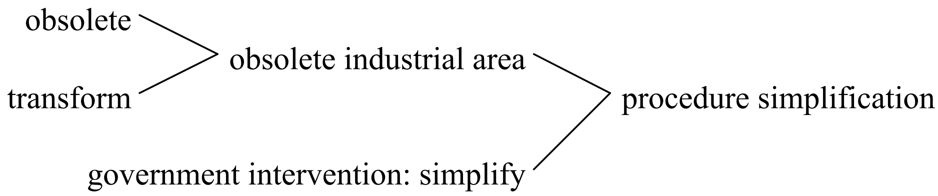
16) Other mutation



17) Population

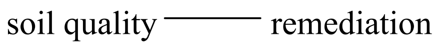


18) Procedure simplification

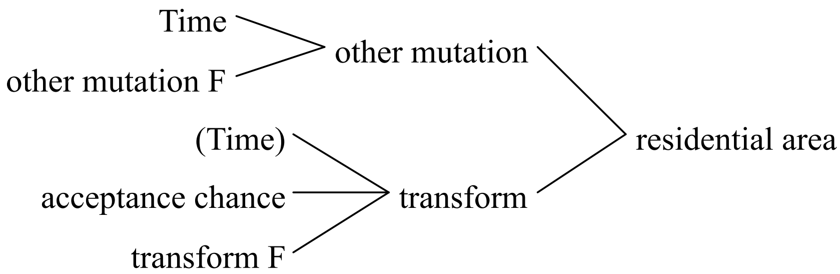


19) Project complexity

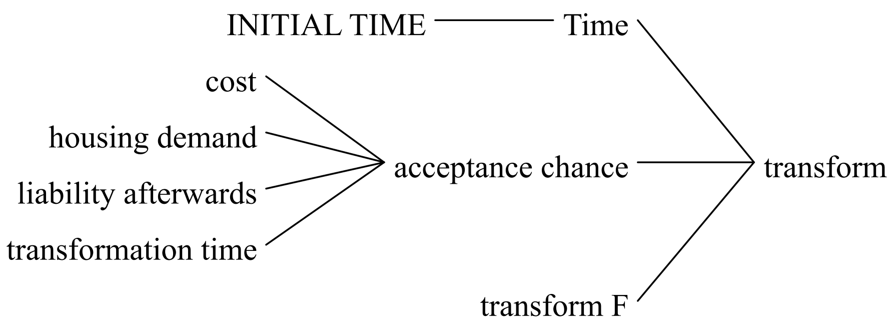
20) Remediation



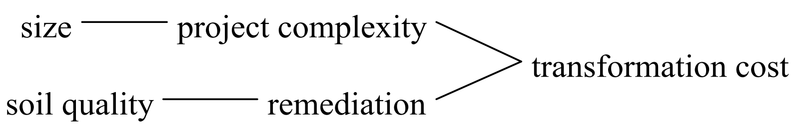
21) Residential area



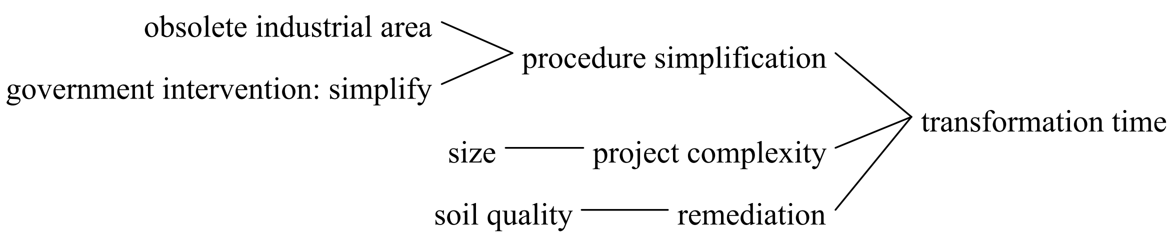
22) Transform



23) Transformation cost



24) Transformation time



Appendix III Equation

Equation List

(01) acceptance chance=

IF THEN ELSE(

cost>=31:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand<63 , 1 , IF THEN ELSE(

cost>=31:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand>=63 , 2 , IF THEN ELSE(

cost>=31:AND:liability afterwards=10:AND:transformation time<=4:AND:housing demand<63 , 2 , IF THEN ELSE(

cost>=31:AND:liability afterwards=10:AND:transformation time<=4:AND:housing demand>=63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand<63 , 2 , IF THEN ELSE(

cost>=31:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand>=63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=8:AND:transformation time<=4:AND:housing demand <63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=8:AND:transformation time<=4:AND:housing demand >=63 , 4 , IF THEN ELSE(

cost>=31:AND:liability afterwards=9:AND:transformation time>4:AND:housing demand <63 , 2 , IF THEN ELSE(

cost>=31:AND:liability afterwards=9:AND:transformation time>4:AND:housing demand >=63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=9:AND:transformation time<=4:AND:housing demand <63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=9:AND:transformation time<=4:AND:housing demand >=63 , 4 , IF THEN ELSE(

cost>=31:AND:liability afterwards=6:AND:transformation time>4:AND:housing demand <63 , 3 , IF THEN ELSE(

cost>=31:AND:liability afterwards=6:AND:transformation time>4:AND:housing demand >=63 , 4 , IF THEN ELSE(

cost>=31:AND:liability afterwards=6:AND:transformation time<=4:AND:housing demand <63 , 4 , IF THEN ELSE(

cost>=31:AND:liability afterwards=6:AND:transformation time<=4:AND:housing demand >=63 , 5 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand<63 , 2 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand>=63 , 3 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=10:AND:transformation time<= 4:AND:housing demand<63 , 3 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=10:AND:transformation time<= 4:AND:housing demand>=63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand<63 , 3 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand>=63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=8:AND:transformation time<=4:AND:housing demand<63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=8:AND:transformation time<=4:AND:housing demand>=63 , 5 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=9:AND:transformation time>4:AND:housing demand<63 , 3 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=9:AND:transformation time>4:AND:housing demand>=63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=9:AND:transformation time<=4:AND:housing demand<63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=9:AND:transformation time<=4:AND:housing demand>=63 , 5 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=6:AND:transformation time>4:AND:housing demand<63 , 4 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=6:AND:transformation time>4:AND:housing demand>=63 , 5 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=6:AND:transformation time<=4:AND:housing demand<63 , 5 , IF THEN ELSE(

cost>15:AND:cost<31:AND:liability afterwards=6:AND:transformation time<=4:AND:housing demand>=63 , 6 , IF THEN ELSE(

cost<=15:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand <63 , 3 , IF THEN ELSE(

cost<=15:AND:liability afterwards=10:AND:transformation time>4:AND:housing demand >=63 , 4 , IF THEN ELSE(

cost<=15:AND:liability afterwards=10:AND:transformation time<=4:AND:housing demand <63 , 4 , IF THEN ELSE(

cost<=15:AND:liability afterwards=10:AND:transformation time<=4:AND:housing demand >=63 , 5 , IF THEN ELSE(

cost<=15:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand <63 , 4 , IF THEN ELSE(

cost<=15:AND:liability afterwards=8:AND:transformation time>4:AND:housing demand >=63 , 5 , IF THEN ELSE(

cost<=15:AND:liability afterwards=8:AND:transformation time<=4:AND:housing demand <63 , 5 , IF THEN ELSE(

cost<=15:AND:liability afterwards=8:AND:transformation time<=4:AND:housing

demand >=63 , 6 , IF THEN ELSE(
cost<=15:AND:liability afterwards=9:AND:transformation time>4:AND:housing
demand <63 , 4 , IF THEN ELSE(
cost<=15:AND:liability afterwards=9:AND:transformation time>4:AND:housing
demand >=63 , 5 , IF THEN ELSE(
cost<=15:AND:liability afterwards=9:AND:transformation time<=4:AND:housing
demand <63 , 5 , IF THEN ELSE(
cost<=15:AND:liability afterwards=9:AND:transformation time<=4:AND:housing
demand >=63 , 6 , IF THEN ELSE(
cost<=15:AND:liability afterwards=6:AND:transformation time>4:AND:housing
demand <63 , 5 , IF THEN ELSE(
cost<=15:AND:liability afterwards=6:AND:transformation time>4:AND:housing
demand >=63 , 6 , IF THEN ELSE(
cost<=15:AND:liability afterwards=6:AND:transformation time<=4:AND:housing
demand <63 , 6 , 7)
Units: Dmnl

(02) accessibility=
20
Units: Dmnl [10,30,10]

(03) birth=
birth F(Time)
Units: Person/Year

(04) birth F(
[(2005,0)-(2029,30000)],(2005,26301),(2006,26007),(2007,25327),(2008,25987
),(2009,25599),(2010,25545),(2011,25015),(2012,24027),(2013,23558),(2014,24395
),(2015,24644),(2016,24856),(2017,25142),(2018,25366),(2019,25588),(2020,25783
),(2021,25966),(2022,26105),(2023,26235),(2024,26360),(2025,26416),(2026,26424
),(2027,26414),(2028,26383),(2029,26355))
Units: Person/Year

(05) cost=
land price+transformation cost-economic incentive
Units: Dmnl

(06) death=
death F(Time)
Units: Person/Year

(07) death F(
[(2005,0)-(2029,30000)],(2005,19178),(2006,19138),(2007,19017),(2008,19446

),(2009,19284),(2010,19503),(2011,19775),(2012,20456),(2013,20545),(2014,21340
),(2015,21770),(2016,22182),(2017,22587),(2018,22958),(2019,23332),(2020,23686
),(2021,24036),(2022,24404),(2023,24772),(2024,25145),(2025,25522),(2026,25879
),(2027,26258),(2028,26631),(2029,26995))
Units: Person/Year

(08) economic growth=
economic growth F(Time)
Units: Dmnl [-0.05,0.05,0.001]

(09) economic growth F(
[(2005,-0.06)-(2029,0.06)],(2005,0.0306),(2006,0.039),(2007,0.033),(2008,
0.011),(2009,-0.052),(2010,0.019),(2011,0.035),(2012,-0.016),(2013,-0.01),
(2014,0.017))
Units: Dmnl

(10) economic incentive=
IF THEN ELSE(
economic growth>=0.03 , "government intervention: funding"*1 , IF THEN ELSE(
economic growth<0.03:AND:economic growth>=0.01 , "government intervention: funding"*0.5 ,
0))
Units: Dmnl

(11) expat immigration=
IF THEN ELSE(
Time<=2013 , expat immigration F(Time) , IF THEN ELSE(
economic growth>=0.015 , 60000+expat immigration plus ,
30000+expat immigration plus))
Units: Person/Year

(12) expat immigration F(
[(2005,0)-(2013,60000)],(2012,56500),(2013,56600))
Units: Person/Year

(13) expat immigration plus=
0
Units: Person/Year [0,5000,2500]

(14) FINAL TIME = 2029
Units: Year
The final time for the simulation.

(15) "government intervention: funding"=
0
Units: Dmnl [0,8,4]

(16) "government intervention: release"=
0
Units: Dmnl [0,4,2]

(17) "government intervention: simplify"=
0
Units: Dmnl [0,2,1]

(18) housing demand=
population/residential area
Units: Person/Hectare

(19) INITIAL TIME = 2005
Units: Year
The initial time for the simulation.

(20) land price=
IF THEN ELSE(
surrounding image=0:AND:soil quality=0:AND:accessibility=30 , 5 , IF THEN ELSE(
surrounding image=0:AND:soil quality=0:AND:accessibility=20 , 10 , IF THEN ELSE(
surrounding image=0:AND:soil quality=0:AND:accessibility=10 , 15 , IF THEN ELSE(
surrounding image=0:AND:soil quality=1:AND:accessibility=30 , 10 , IF THEN ELSE(
surrounding image=0:AND:soil quality=1:AND:accessibility=20 , 15 , IF THEN ELSE(
surrounding image=0:AND:soil quality=1:AND:accessibility=10 , 20 , IF THEN ELSE(
surrounding image=1:AND:soil quality=0:AND:accessibility=30 , 10 , IF THEN ELSE(
surrounding image=1:AND:soil quality=0:AND:accessibility=20 , 15 , IF THEN ELSE(
surrounding image=1:AND:soil quality=0:AND:accessibility=10 , 20 , IF THEN ELSE(
surrounding image=1:AND:soil quality=1:AND:accessibility=30 , 15 , IF THEN ELSE(
surrounding image=1:AND:soil quality=1:AND:accessibility=20 , 20 ,
25)))))))))))
Units: Dmnl

(21) liability afterwards=
liability foremost-liability afterwards reduction
Units: Dmnl

(22) liability afterwards reduction=
IF THEN ELSE(
economic growth>=0.03 , "government intervention: release"*1 , IF THEN ELSE(

economic growth<0.03:AND:economic growth>=0.01 , "government intervention: release" *0.5 , 0))

Units: Dmnl

(23) liability foremost=

10

Units: Dmnl

(24) migration=

IF THEN ELSE(

Time<=2013:AND:Time>=2012 , expat immigration+other migration ,

migration F(Time))

Units: Person/Year

(25) migration F(

[(2005,-8000)-(2029,8000)],(2005,-2536),(2006,-3773),(2007,-525),(2008,3192),(2009,3283),(2010,4015),(2011,4231),(2012,3754),(2013,5250),(2014,5501), (2015,5298),(2016,5096),(2017,4901),(2018,4703),(2019,4551),(2020,4500),(2021 ,4398),(2022,4351),(2023,4398),(2024,4398),(2025,4449),(2026,4449),(2027,4449),(2028,4449),(2029,4449))

Units: Person/Year

(26) obsolete=

IF THEN ELSE(Time=2013 , obsolete F(Time) , 60)

Units: Hectare/Year [0,150]

(27) obsolete F(

[(2005,0)-(2029,100)],(2005,50),(2013,45))

Units: Hectare/Year

(28) obsolete industrial area= INTEG (

obsolete-transform,

5600)

Units: Hectare

(29) other migration=

other migration F(Time)

Units: Person/Year

(30) other migration F(

[(2005,-60000)-(2029,0)],(2012,-52746),(2013,-51350))

Units: Person/Year

(31) other mutation=
IF THEN ELSE(Time<=2009 , other mutation F(Time) , -5)
Units: Hectare/Year

(32) other mutation F(
[(2005,0)-(2029,300)],(2005,145.628),(2006,160.021),(2007,151.034),(2008, 45.2685),(2009,45.3076))
Units: Hectare/Year

(33) population= INTEG (
birth-death+migration, 2.41136e+06)
Units: Person

(34) procedure simplification=
IF THEN ELSE(
obsolete industrial area>=6300 , "government intervention: simplify"*1 , IF THEN ELSE(
obsolete industrial area<6300:AND:obsolete industrial area>5800 , "government intervention: simplify"*0.5 , 0))
Units: Dmnl [0,2,1]

(35) project complexity=
size
Units: Dmnl

(36) remediation=
soil quality
Units: Dmnl

(37) residential area=
INTEG (
other mutation+transform,
38182)
Units: Hectare

(38) SAVEPER =
TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

(39) size=
1
Units: Dmnl [0,2,1]

(40) soil quality=
1
Units: Dmnl [0,1,1]

(41) surrounding image=
1
Units: Dmnl [0,1,1]

(42) TIME STEP = 1
Units: Year
The time step for the simulation.

(43) transform=
IF THEN ELSE(
Time<=2009 , transform F(Time) , IF THEN ELSE(
acceptance chance<2 , 0 , IF THEN ELSE(
acceptance chance>=2:AND:acceptance chance<4 , 5 , IF THEN ELSE(
acceptance chance>=4:AND:acceptance chance<6 , 15 ,
25))))
Units: Hectare/Year

(44) transform F(
[(2005,0)-(2029,40)],(2005,20.372),(2006,12.9792),(2007,20.9656),(2008,4.73152
),(2009,3.69238))
Units: Hectare/Year

(45) transformation cost=
IF THEN ELSE(
project complexity=0:AND:remediation=1 , 5 , IF THEN ELSE(
project complexity=0:AND:remediation=0 , 10 , IF THEN ELSE(
project complexity=1:AND:remediation=1 , 10 , IF THEN ELSE(
project complexity=1:AND:remediation=0 , 15 , IF THEN ELSE(
project complexity=2:AND:remediation=1 , 15 ,
20)))))
Units: Dmnl

(46) transformation time=
IF THEN ELSE(
remediation=1:AND:project complexity=0:AND:procedure simplification=2 , 1
, IF THEN ELSE(
remediation=1:AND:project complexity=0:AND:procedure simplification=1 , 2
, IF THEN ELSE(

remediation=1:AND:project complexity=0:AND:procedure simplification=0 , 4
, IF THEN ELSE(
remediation=1:AND:project complexity=0:AND:procedure simplification=0.5 ,
3 , IF THEN ELSE(
remediation=1:AND:project complexity=1:AND:procedure simplification=2 , 2
, IF THEN ELSE(
remediation=1:AND:project complexity=1:AND:procedure simplification=1 , 3
, IF THEN ELSE(
remediation=1:AND:project complexity=1:AND:procedure simplification=0 , 5
, IF THEN ELSE(
remediation=1:AND:project complexity=1:AND:procedure simplification=0.5 ,
4 , IF THEN ELSE(
remediation=1:AND:project complexity=2:AND:procedure simplification=2 , 3
, IF THEN ELSE(
remediation=1:AND:project complexity=2:AND:procedure simplification=1 , 4
, IF THEN ELSE(
remediation=1:AND:project complexity=2:AND:procedure simplification=0 , 6
, IF THEN ELSE(
remediation=1:AND:project complexity=2:AND:procedure simplification=0.5 ,
5 , IF THEN ELSE(
remediation=0:AND:project complexity=0:AND:procedure simplification=2 , 2
, IF THEN ELSE(
remediation=0:AND:project complexity=0:AND:procedure simplification=1 , 3
, IF THEN ELSE(
remediation=0:AND:project complexity=0:AND:procedure simplification=0 , 5
, IF THEN ELSE(
remediation=0:AND:project complexity=0:AND:procedure simplification=0.5 ,
4 , IF THEN ELSE(
remediation=0:AND:project complexity=1:AND:procedure simplification=2 , 3
, IF THEN ELSE(
remediation=0:AND:project complexity=1:AND:procedure simplification=1 , 4
, IF THEN ELSE(
remediation=0:AND:project complexity=1:AND:procedure simplification=0 , 6
, IF THEN ELSE(
remediation=0:AND:project complexity=1:AND:procedure simplification=0.5 ,
5 , IF THEN ELSE(
remediation=0:AND:project complexity=2:AND:procedure simplification=2 , 4
, IF THEN ELSE(
remediation=0:AND:project complexity=2:AND:procedure simplification=1 , 5
, IF THEN ELSE(
remediation=0:AND:project complexity=2:AND:procedure simplification=0 , 7 ,
6)

Units: Year

Equation Table

Table 4-2 Statistics: Industrial area

Year	Gross surface [Ha]	Obsolete Yes [Numb]	Obsolete No [Numb]	Obsolete Unknown [Numb]	Obsolete [Ha]
2005	16428.93	-	-	-	
2006	16684.05	-	-	-	
2007	16768.91	-	-	-	
2008	16885.99	-	-	-	
2009	17042.65	-	-	-	2700
2013	17918.57	182	383	49	3906.538111

Table 4-3 Statistics: Residential area

Year	Residential area [Ha]	Total mutation [D]	Total mutation [Ha]	Surface per mutation [Ha]	Other Increase (transformation) [D]	Transformation [Ha]
2005	38182		166		842	20.37195744
2006	38348	6861	173	0.024194724	690	12.97923236
2007	38521	9197	172	0.018810482	1486	20.96563038
2008	38693	12191	50	0.014108769	786	4.731519384
2009	38743	8306	49	0.006019745	887	3.692379577
2010	38792	11771	0	0.004162773	410	
2011	38792	7201	0		661	
2012	38792	8348	0		-	

Table 4-4 Statistics: Population

Year	In total [person]	Change in total [person]	Natural increase [person]	Births [person]	Deaths [person]	Net migration [person]	Immigration in total [person]
2005	2411359	4587	7123	26301	19178	478	94195
2006	2415946	3096	6869	26007	19138	-406	96924
2007	2419042	5785	6310	25327	19017	2264	98749
2008	2424827	9733	6541	25987	19446	4976	102596
2009	2434560	9598	6315	25599	19284	6074	95699
2010	2444158	10057	6042	25545	19503	6678	96760
2011	2454215	9471	5240	25015	19775	7449	99732
2012	2463686	7325	3571	24027	20456	6793	102092
2013	2471011	8263	3013	23558	20545	7065	106614
2014	2479274	-	-	-	-	-	-

Table 4-5 Statistics: Forecast – Population 2014-2030, Province: Noord-Brabant

Year	Total [person]	Growth [person]	Natural growth [person]	Births [person]	Deaths [person]	Total migration [person]
2014	2479580	8556	3055	24395	21340	5501
2015	2488136	8172	2874	24644	21770	5298
2016	2496308	7770	2674	24856	22182	5096
2017	2504078	7456	2555	25142	22587	4901
2018	2511534	7111	2408	25366	22958	4703
2019	2518645	6807	2256	25588	23332	4551
2020	2525452	6597	2097	25783	23686	4500
2021	2532049	6328	1930	25966	24036	4398
2022	2538377	6052	1701	26105	24404	4351
2023	2544429	5861	1463	26235	24772	4398
2024	2550290	5613	1215	26360	25145	4398
2025	2555903	5343	894	26416	25522	4449
2026	2561246	4994	545	26424	25879	4449
2027	2566240	4605	156	26414	26258	4449
2028	2570845	4201	-248	26383	26631	4449
2029	2575046	3809	-640	26355	26995	4449
2030	2578855	3387	-1062	26296	27358	4449

Table 4-6 Statistics: Economic growth

Year	GDP, volume changes %
2005	3.06
2006	3.90
2007	3.30
2008	1.10
2009	-5.20
2010*	1.90
2011	3.50
2012**	-1.60
2013*	-1.00
2014*	1.70

Table 4-7 Levels: Surrounding image, soil quality and accessibility

Surrounding image		Soil quality		Accessibility	
Bad	0	Need remediation	0	Road network within 30 km	30
Good	1	Need no remediation	1	Road network within 20 km	20
				Road network within 10 km	10

Table 4-8 Levels: Land attributes and land price

Surrounding image, Soil quality, Accessibility	0, 0, 30	0, 0, 20	0, 0, 10	0, 1, 30	0, 1, 20	0, 1, 10	1, 0, 30	1, 0, 20	1, 0, 10	1, 1, 30	1, 1, 20	1, 1, 10
Land price	5	10	15	10	15	20	10	15	20	15	20	25

Table 4-9 Levels: Soil quality and remediation

Soil quality	Remediation
Need remediation 0	Yes 0
Need no remediation 1	No 1

Table 4-10 Levels: Size and project complexity

Size	Project complexity
Small 0	Easy 0
Medium 1	Medium 1
Large 2	Complex 2

Table 4-11 Levels: Transformation cost

Remediation	Project complexity	Transformation cost
No 1	Easy 0	5
Yes 0		10
No 1	Medium 1	10
Yes 0		15
No 1	Complex 2	15
Yes 0		20

Table 4-12 Levels: Economic growth, government intervention – funding and economic incentive

Economic growth	Government intervention: funding	Economic incentive	
<0.01	0	0	
0.01⩽growth<0.03	0	0.5*'government intervention: funding'	0
	4		2
	8		4
⩾0.03	0	1*'government intervention: funding'	0
	4		4
	8		8

Table 4-13 Levels: Cost

Land price	Transformation cost	Economic growth	Economic incentive	Cost
5	5	<0.01	0	10

Land price	Transformation cost	Economic growth	Economic incentive	Cost
		0.01⩽growth<0.03	0	10
			2	8
			4	6
		⩾0.03	0	10
			4	6
			8	2
5	10	<0.01	0	15
		0.01⩽growth<0.03	0	15
			2	13
			4	11
		⩾0.03	0	15
			4	11
			8	7
5	15	<0.01	0	20
		0.01⩽growth<0.03	0	20
			2	18
			4	16
		⩾0.03	0	20
			4	16
			8	12
5	20	<0.01	0	25
		0.01⩽growth<0.03	0	25
			2	23
			4	21
		⩾0.03	0	25
			4	21
			8	17
10	5	<0.01	0	15
		0.01⩽growth<0.03	0	15
			2	13
			4	11
		⩾0.03	0	15
			4	11
			8	7
10	10	<0.01	0	20
		0.01⩽growth<0.03	0	20
			2	18
			4	16
		⩾0.03	0	20

Land price	Transformation cost	Economic growth	Economic incentive	Cost
			4	16
			8	12
10	15	<0.01	0	25
		0.01⩽growth<0.03	0	25
			2	23
			4	21
		⩾0.03	0	25
			4	21
			8	17
10	20	<0.01	0	30
		0.01⩽growth<0.03	0	30
			2	28
			4	26
		⩾0.03	0	30
			4	26
			8	22
15	5	<0.01	0	20
		0.01⩽growth<0.03	0	20
			2	18
			4	16
		⩾0.03	0	20
			4	16
			8	12
15	10	<0.01	0	25
		0.01⩽growth<0.03	0	25
			2	23
			4	21
		⩾0.03	0	25
			4	21
			8	17
15	15	<0.01	0	30
		0.01⩽growth<0.03	0	30
			2	28
			4	26
		⩾0.03	0	30
			4	26
			8	22
15	20	<0.01	0	35
		0.01⩽growth<0.03	0	35

Land price	Transformation cost	Economic growth	Economic incentive	Cost
			2	33
			4	31
		⩾0.03	0	35
			4	31
			8	27
20	5	<0.01	0	25
		0.01⩽growth<0.03	0	25
			2	23
			4	21
		⩾0.03	0	25
			4	21
			8	17
20	10	<0.01	0	30
		0.01⩽growth<0.03	0	30
			2	28
			4	26
		⩾0.03	0	30
			4	26
			8	22
20	15	<0.01	0	35
		0.01⩽growth<0.03	0	35
			2	33
			4	31
		⩾0.03	0	35
			4	31
			8	27
20	20	<0.01	0	40
		0.01⩽growth<0.03	0	40
			2	38
			4	36
		⩾0.03	0	40
			4	36
			8	32
25	5	<0.01	0	30
		0.01⩽growth<0.03	0	30
			2	28
			4	26
		⩾0.03	0	30
			4	26

Land price	Transformation cost	Economic growth	Economic incentive	Cost
			8	22
25	10	<0.01	0	35
		0.01⩽growth<0.03	0	35
			2	33
			4	31
		⩾0.03	0	35
			4	31
			8	27
25	15	<0.01	0	40
		0.01⩽growth<0.03	0	40
			2	38
			4	36
		⩾0.03	0	40
			4	36
			8	32
25	20	<0.01	0	45
		0.01⩽growth<0.03	0	45
			2	43
			4	41
		⩾0.03	0	45
			4	41
			8	37

Table 4-14 Levels: Liability afterwards reduction and liability afterwards

Economic growth	Government intervention: release	Liability afterwards reduction		Liability foremost	Liability afterwards
<0.01	0	0		10	10
0.01⩽growth<0.03	0	0.5*'government intervention: release'	0		10
	2		1		9
	4		2		8
⩾0.03	0	1*'government intervention: release'	0		10
	2		2		8
	4		4		6

Table 4-15 Levels: Procedure simplification

Obsolete industrial area	Government intervention: simplify	Procedure simplification

Obsolete industrial area	Government intervention: simplify	Procedure simplification	
⩾6000	2	1*'government intervention: simplify'	2
	1		1
	0		0
5500<area<6000	2	0.5*'government intervention: simplify'	1
	1		0.5
	0		0
⩽5500	0	0	

Table 4-16 Levels: Transformation time

Remediation	Project complexity	Obsolete industrial area	Procedure simplification	Transformation time
No 1	Easy 0	⩾6000	2	1
			1	2
			0	4
		5500<area<6000	1	2
			0.5	3
			0	4
		⩽5500	0	4
	Medium 1	⩾6000	2	2
			1	3
			0	5
		5500<area<6000	1	3
			0.5	4
			0	5
		⩽5500	0	5
	Complex 2	⩾6000	2	3
			1	4
			0	6
		5500<area<6000	1	4
			0.5	5
			0	6
		⩽5500	0	6
Yes 0	Easy 0	⩾6000	2	2
			1	3
			0	5
		5500<area<6000	1	3
			0.5	4
			0	5

Remediation	Project complexity	Obsolete industrial area	Procedure simplification	Transformation time
		⩽5500	0	5
	Medium 1	⩾6000	2	3
			1	4
			0	6
		5500<area<6000	1	4
			0.5	5
			0	6
		⩽5500	0	6
	Complex 2	⩾6000	2	4
			1	5
			0	7
		5500<area<6000	1	5
			0.5	6
			0	7
		⩽5500	0	7

Table 4-17 Levels: Acceptance chance

Cost	Liability	Transformation time	Housing demand	Acceptance chance
≥31	10	>4	<63	1
			≥63	2
		⩽4	<63	2
			≥63	3
	8, 9	>4	<63	2
			≥63	3
		⩽4	<63	3
			≥63	4
	6	>4	<63	3
			≥63	4
		⩽4	<63	4
			≥63	5
15<cost<31	10	>4	<63	2
			≥63	3
		⩽4	<63	3
			≥63	4
	8, 9	>4	<63	3
			≥63	4
		⩽4	<63	4
			≥63	5
	6	>4	<63	4

Cost	Liability	Transformation time	Housing demand	Acceptance chance
			≥63	5
		⩽4	<63	5
			≥63	6
⩽15	10	>4	<63	3
			≥63	4
		⩽4	<63	4
			≥63	5
	8, 9	>4	<63	4
			≥63	5
		⩽4	<63	5
			≥63	6
	6	>4	<63	5
			≥63	6
		⩽4	<63	6
			≥63	7

Table 4-18 Levels: Transform rate

Acceptance chance (dmnl)	Transform (Hectare/Year)
⩽2	35
2<acceptance chance<6	85
≥6	135

Appendix IV Model Running Results

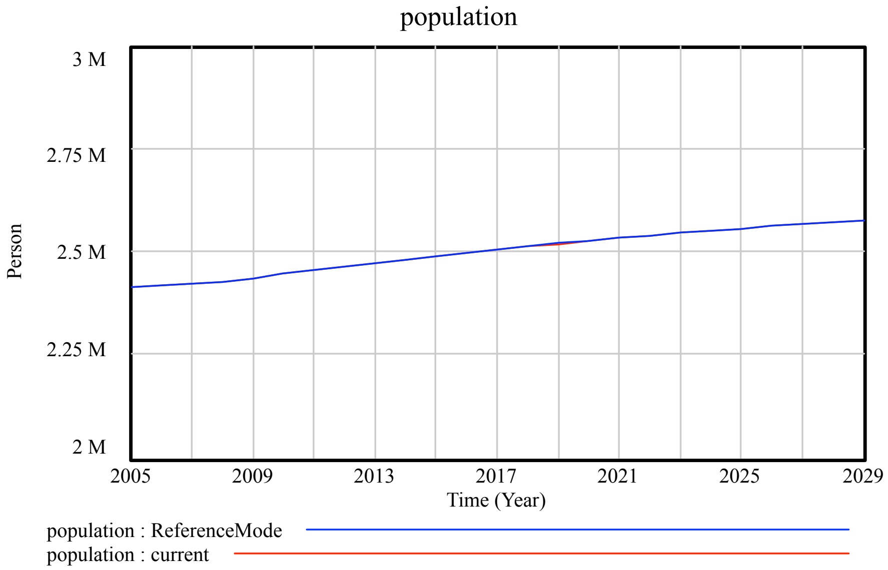


Figure 4-16 Run 'current' – population

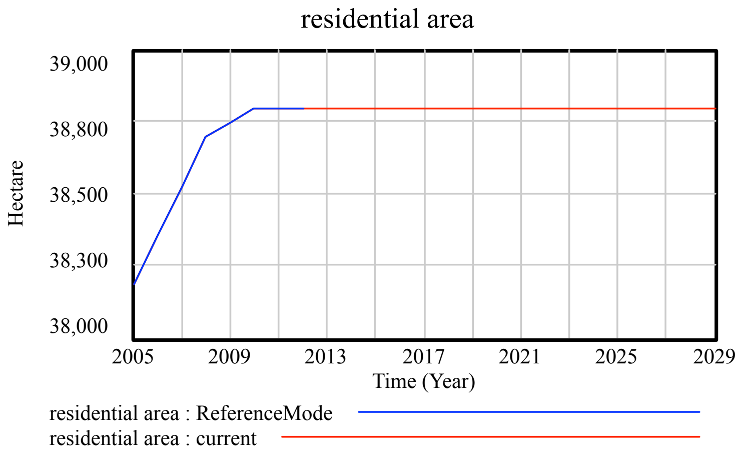


Figure 4-17 Run 'current' – residential area

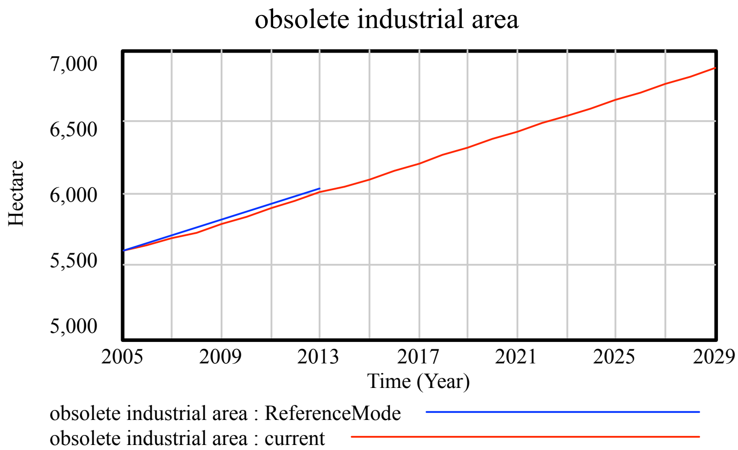


Figure 4-18 Run 'current' – obsolete industrial area

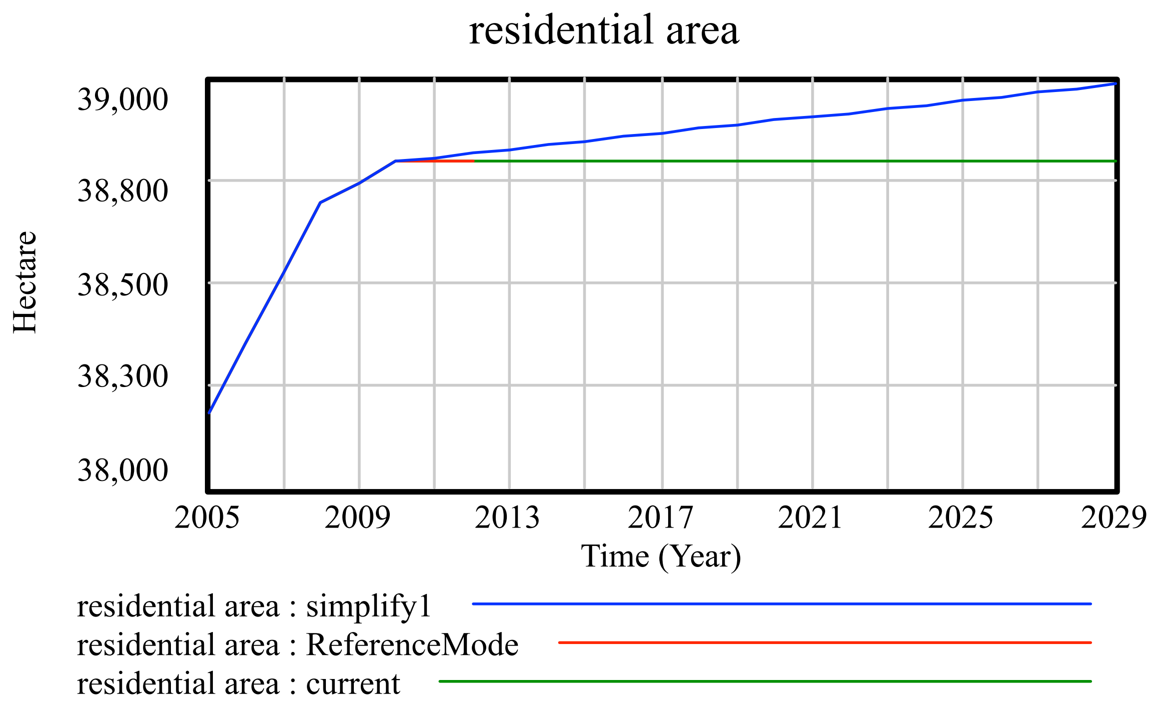


Figure 4-19 Run 'simplify1' – residential area

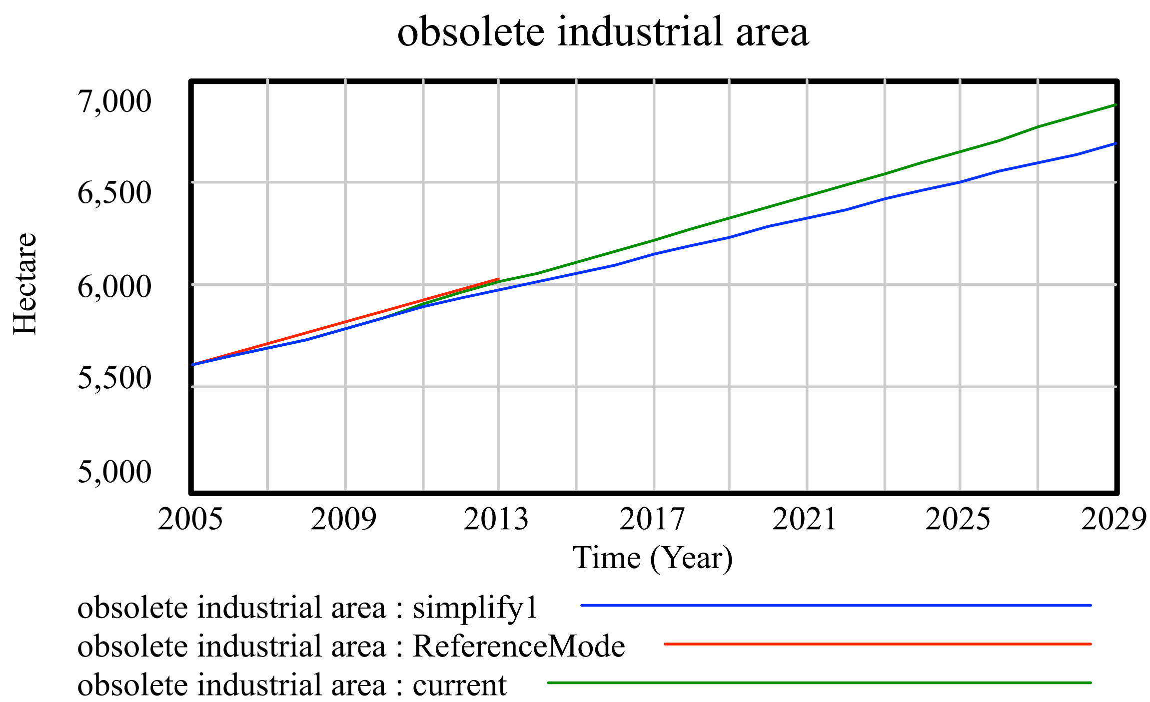


Figure 4-20 Run 'simplify1' – obsolete industrial area

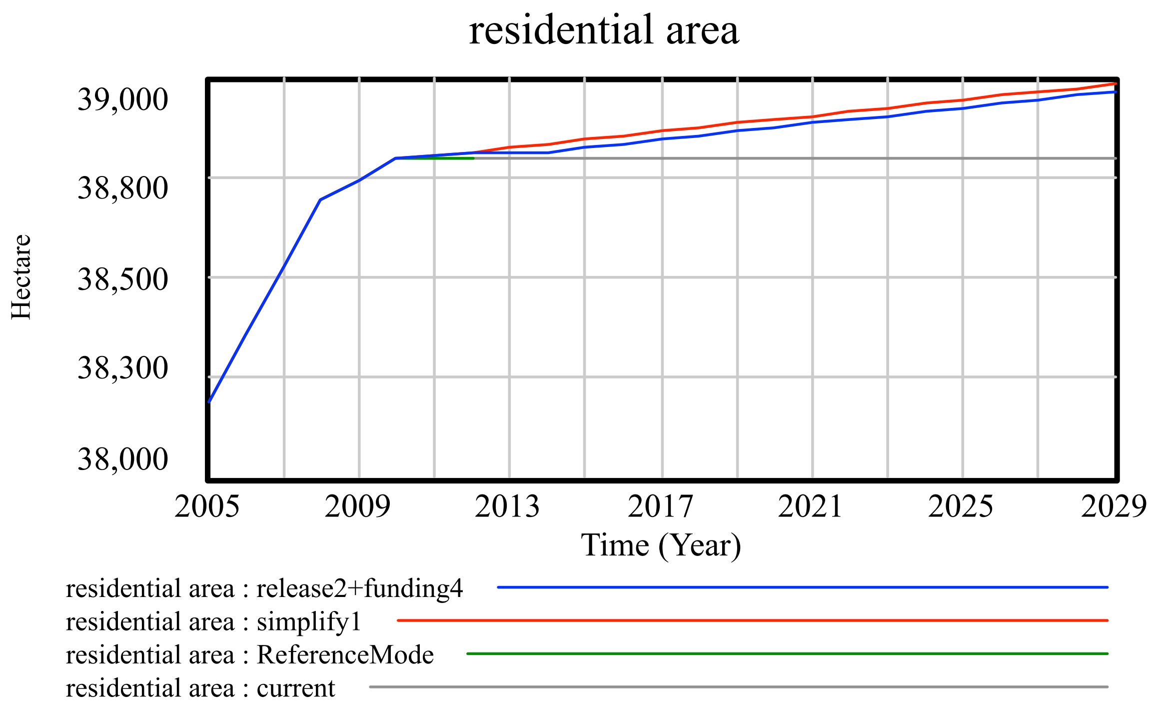


Figure 4-21 Run 'release2+funding4’ – residential area

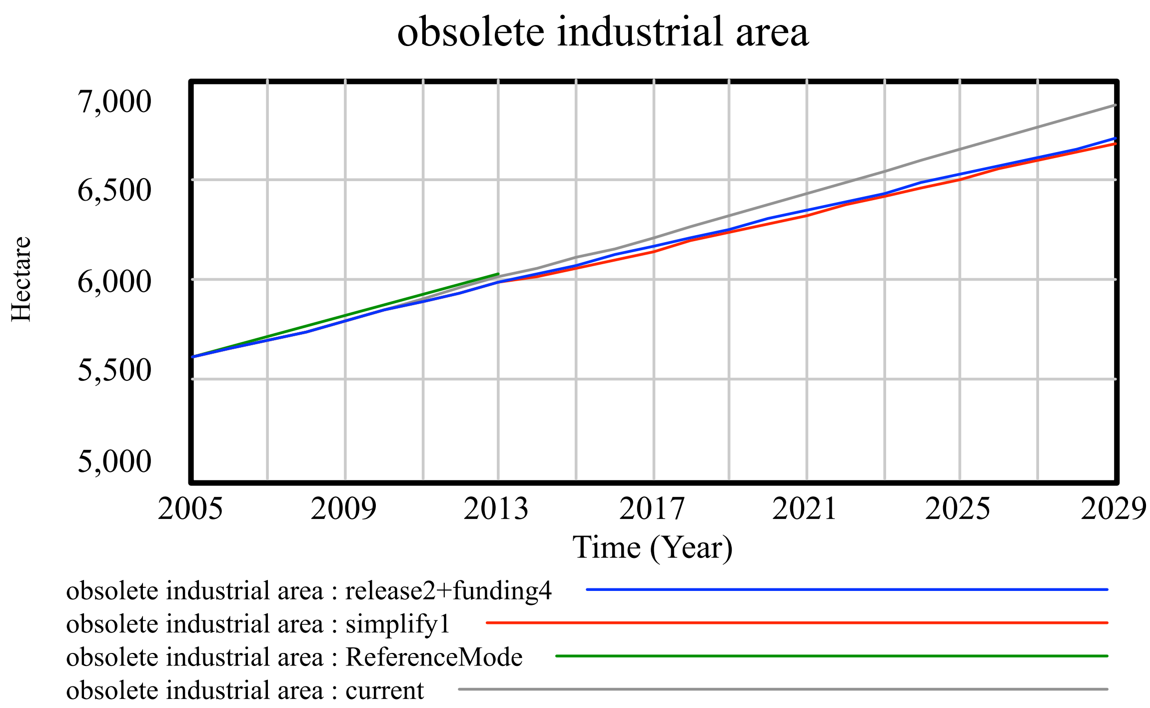


Figure 4-22 Run 'release2+funding4' – obsolete industrial area

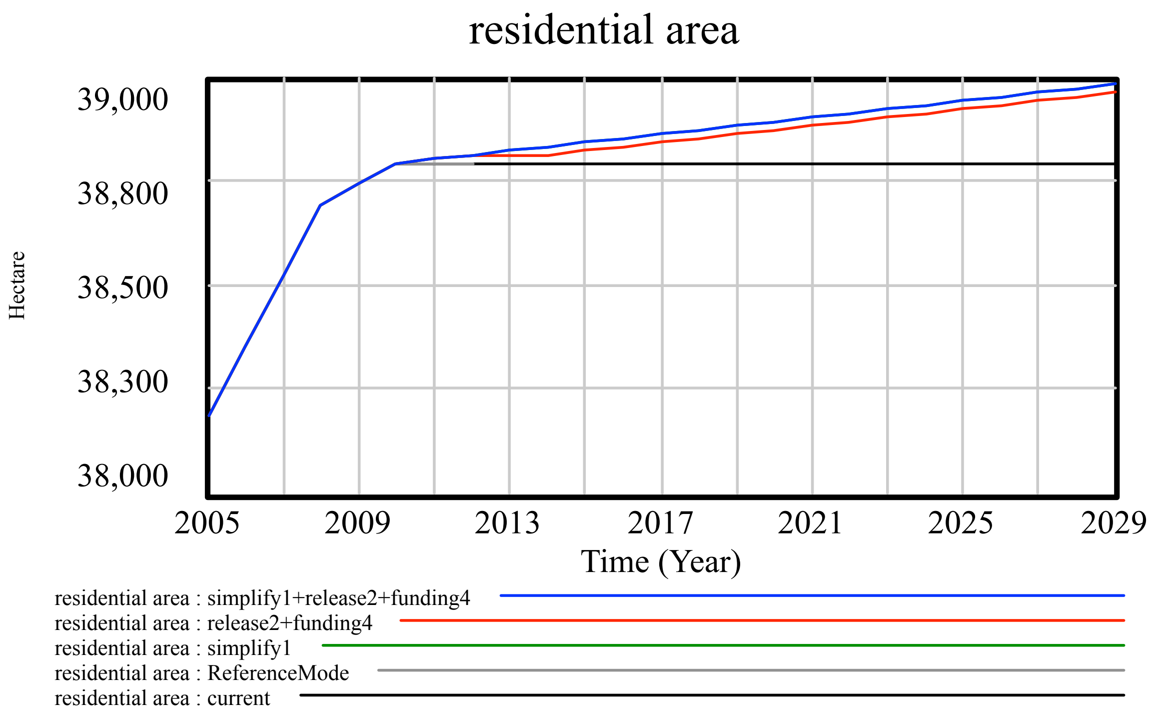


Figure 4-23 Run 'simplify1+release2+funding4' – residential area

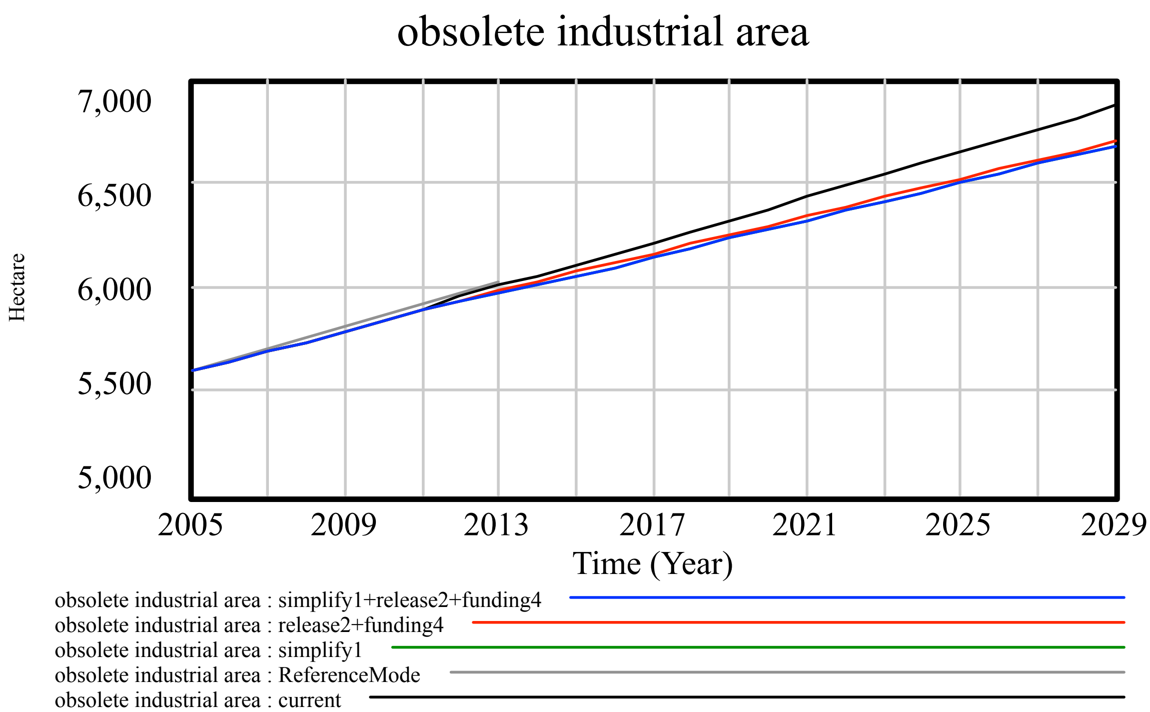


Figure 4-24 Run 'simplify1+release2+funding4' – obsolete industrial area

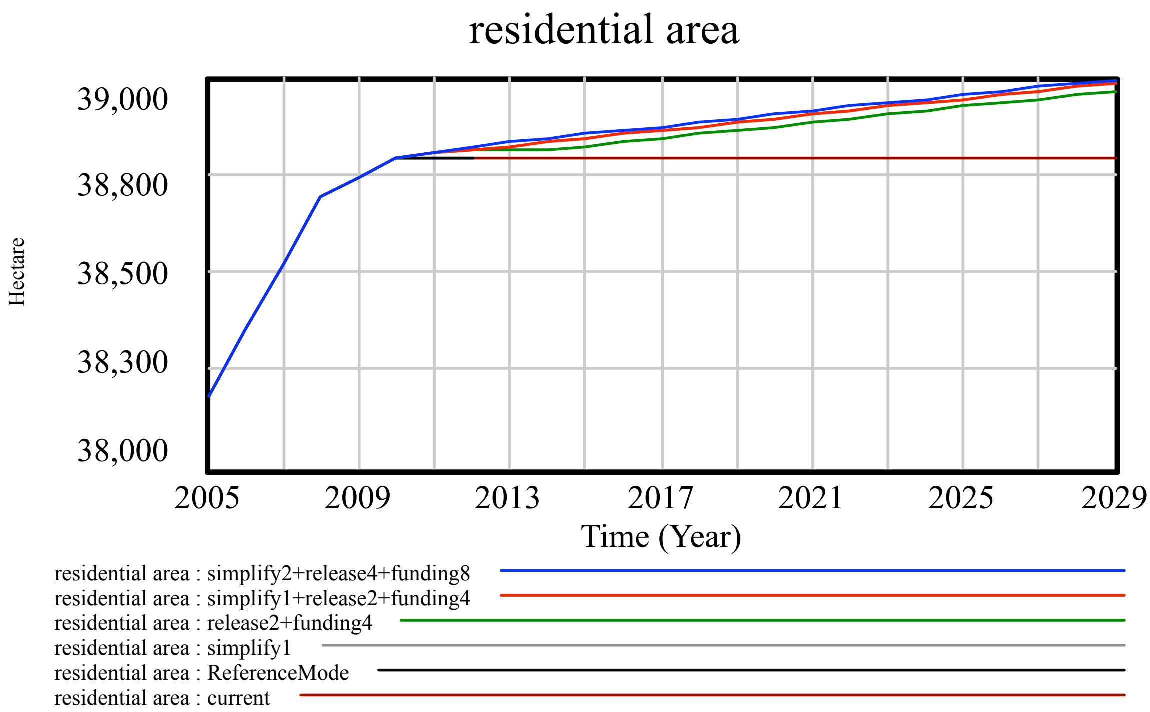


Figure 4-25 Run 'simplify2+release4+funding8' – residential area

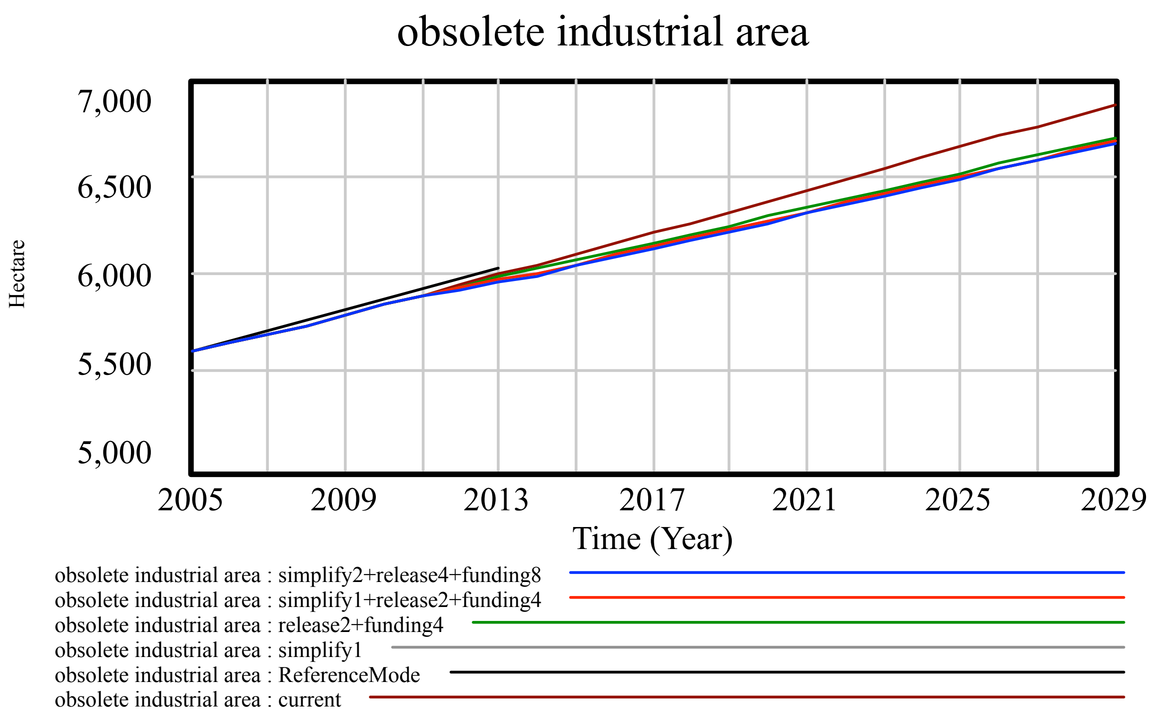


Figure 4-26 Run 'simplify2+release4+funding8' – obsolete industrial area