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a system dynamics approach

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GRADUATION THESIS

North Brabant land use change driving forces analysis and scenario simulation:

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Table of Content

1. Introduction

1.1 Context

In this section, the background, motives and research relevance of this research are discussed. Current land use change studies will be illustrated in the background part, while in the motive part several reasons why we want to do this research are explained. Furthermore, the research relevance between this study and Eindhoven University of Technology and the Royal Association MKB-Nederland are stated based on the background and motives.

1.1.1 Background

Since the origins of the mankind, land resource provides human beings with place to live, to plant, to build, to produce and so on. Without land resource, there would be no human beings at all on the earth. With the massive growth of population, land use is transiting from extensive use to intensive use, especially in some densely populated areas. Land resource use is getting more and more significance because of the limited nature of land resource. Moreover, the higher and higher price of land stimulates people trying to understand what will happen to the land in one area and predicting the future scenarios so that they can make profits and mitigate risks. For the public authorities, security of land resource has risen to the level of national security. One of the reasons behind it is the security of food. Some countries even believe that only after assuring the security of food, then the national security can be protected, especially under extreme conditions like world war. We always say that the earth is almost full. So what will happen in the future considering we will have not sufficient land supply? That kind of questions we should always ask ourselves. Doing research about this kind of issues can help people plan the future land use more scientifically.

Considering all the mentioned reasons above but not limited to, people are becoming studying land use substantially nowadays. Many studies have been practiced for simulating land use change in the cities or regions of developing countries and several models have been proposed for analyzing the driving forces behind it so that future scenarios are predictable (Bai, 2000; Wu, 2011; Luo, 2010; et al.). But this kind of study is far from enough for the capricious and widely-implicated land resource use.

What is worse, for cities or regions in developed countries, there is not much reference， especially in Europe. Generally speaking, it is because that Europe regions' spatial development speed is not that fast. Nevertheless, more researches on these issues should be carried out for a better planning in some comparatively faster developing regions. And we should also mention that even in other areas, which are not fast spatial developed, this kind of research still cannot be ignored. One thing we need to keep in mind all time is land use is a long time process. Today's plan or policy can influence ten years or twenty years' later land use situation. So we really need to be careful and more scientific based rather than emotional based. Before the planning is made, more tests and simulations need to be practiced.

It is well known that the Netherlands is one of the most populous countries with around 404 people per square kilometers, ranking as 30th in the world. Not to mention that this is after all these years polders construction to make land from the sea. That's why the usage of land should be studied substantially to support both economy and society development and sustainability. There are already several studies in this field for the whole Netherlands (Verburg et al, 2003) and the province of Overijssel (Koomen et al, 2010). But for other Dutch provinces there is no research in this field up to now.

1.1.2 Motivation

In 2008, the new national Spatial Planning Act is introduced, calling for a more pro-active role of Dutch provinces in the policy arena. It demands Regional Spatial Strategies and they are the main guiding documents in spatial planning at the regional and local level. These strategies should focus on the year 2020 with a further outlook until 2040. (Koomen et al, 2010).

With a population of approximately 2.5 million and an area of around five thousand square kilometers, North Brabant (mostly called Brabant) is one of the largest Dutch provinces (Wikipedia). Based on remote sensing imageries, North Brabant land use does change a lot in the past 30 years (USGS, Landsat TM). We want to mention that up to the case study part, we always want to know what will happen for the past 30 years. But considering the data acquisition issue, later it will change to past years from 1996 up to now.

Why did land use changes happen in the past and what will happen in the future if nothing will change? What will happen if something will do change? Is the land use sustainable and will it support the future economy development? Can the land use be better and more efficient in order to creating a more environmental friendly human society? If so, what should be changed in the current land use plan strategy? We doubt about this kind of questions continuously.

Under current economic crisis, creating an excellent spatial environment for economic and social development towards an innovative and globally competitive region is far more important than ever. Therefore, careful spatial planning and development for better accessibility and mobility for the region is one of the core tasks for the North Brabant province. That's why North Brabant is chosen for the case study for finding the driving forces behind land use change and predicting the future scenarios. After constructing the future scenarios, simulations based on the proposed systems can be done to show different possibilities.

1.1.3 Research relevance

We will first deal with the relevance to Eindhoven University of Technology and then talk about the relevance to the Royal Association MKB-Nederland.

1.1.3.1 Relevance Eindhoven University of Technology

This study is useful for the decision making and policy making analysis in different fields. By modeling and analyzing the driving forces behind land use change in North Brabant and modeling the future scenarios, people can have a better understanding of this complicated procedure. This research will benefit North Brabant where TU/e is located in and help TU/e and the region with a better land use strategy.

Moreover, coming possible future researches in this field could probably apply for PhD positions. We have applied for one position dealing with the comparison land use study between Shenyang in China and North Brabant in the Netherlands. Shenyang is the capital of Liaoning province of China. It has comparatively same level population and area as North Brabant and is also well known for its industry. However, recent years the land use in Shenyang faces difficulties like lacking of investment, agricultural land decreases sharply, environment deterioration and so on. The government has taken a lot of efforts to improve the situation, but the result is not that distinct. Revitalizing this old industrial base is one of the core goals for the government, without sacrificing environment and sustainability.

There is no comparative research in regional land use change field between developed countries and developing countries. This kind of comparison study would give policy makers insights on the differences and similarities between developed area and developing area, and stimulate the learning process between them to governance a better land use plan. Furthermore, there is no standard land use assessment framework to evaluate the land use sustainability state, which includes all kinds of spatial, temporal, economic, societal indicators that drive the regional land use change.

These two regions have been chosen for the case study for finding the driving forces behind land use change, predicting the future scenario and doing the comparative study using our proposed land use simulation framework. The output from this comparative study is an increased understanding of differences in policy and local spatial contexts so that they can learn from each other to improve their land use planning.

In addition, it is also possible for finding cooperation between TU/e and other countries' universities. Last but not least, good cooperation will give TU/e a good reputation and more chances for publishing papers.

1.1.3.2 Relevance MKB

The Royal Association MKB-Nederland is the largest entrepreneurs' organization in the Netherlands. Around 120 branch organizations and 250 regional and local entrepreneurs' fellowships are affiliated to this umbrella organization. All in all, MKB-Nederland promotes the interests of about 150.000 entrepreneurs.

The members of MKB comprise entrepreneurs in areas such as the construction, industry, retail, chain-store trade, recreation, and tourism, business services and health care and medical services. And most of the time, they represent the small or medium sized companies. Small and medium-sized companies obviously have a strong vested interest in a healthy enterprise climate and, consequently, in incentive-based government policies. Combining the strength of private enterprises is a decisive factor in promoting such a climate. And that's precisely what the Royal Association MKB-Nederland does.

Maxing existing legislation and enactments more enterprise-friendly and, above all, initiating new policies geared to changing socio-economic conditions are among the tasks MKB-Nederland has set itself. The method consists of intensive contact with Ministers, Secretaries of State, Members of Parliament and Civil Servants.

So we are also going to talk about the relevance of this study to MKB because of the policy and socio-economic conditions affect MKB a lot regarding land use change issues. (MKB web)

Knowing what will possibly happen gives people in MKB more basement for decision making in their companies, especially when things related to large scale land use projects. Good decisions will save MKB's money and prevent them from financial dangers. Moreover, new Dutch Spatial Planning Act in 2008 emphasizes the possibility of cooperation between private parties and authorities in land use. This research and the following researches can offer a basis for their cooperation in the future.

1.2 Research approach

First we will define the problems we are facing in this study, and then based on these problems research questions can be derived. We do have objectives in answering these research questions, but of course there will be research limitations like data collection problems and so on. So there will also be one part talking about research hypothesis to define the scope and reduce the limitations.

1.2.1 Problem definition

In order to make better land use strategies for accommodating or even promoting socio-economic development, firstly we need to identify the driving forces behind land use changes and to what extent they influence North Brabant land use change. Based on the obtained information we can propose a model to predict the future land use scenarios.

Knowing reasonable future land use change can offer policy makers a better understanding on this kind of issue. As stated before, Verburg et al. (2003) has already studied the determinants of land use change patterns in the Netherlands. Derived from this paper, we can have a starting point for North Brabant land use change in the past 30 years. The technology development of remote sensing offers us more intensive understanding for this region and that's one way we can add more data in the simulation to make the model more reliable if the statistics data is not sufficient or not able to be acquired.

1.2.2 Research question

After defining the problems we are facing with, here come the specific questions we would like to answer after this research.

1) How does the land use change in North Brabant in the past 30 years?(later modified as 15 years because of data acquisition issues)?
2) What are the driving forces behind these changes?
3) Can we propose a model to simulate these changes?
4) What will happen for these driving forces in the future considering different global socio-economic scenarios?
5) Can we propose or construct several scenarios including future driving forces and simulate the land use change under these possible scenarios?
6) What will be the future land use in this region without new interventions?
7) What will be the future land use in this region with new interventions?

1.2.3 Research objective and limitation

After answering all the above questions, we can understand North Brabant land use change more comprehensively and give policy makers reliable suggestions based on the predicted future scenarios and simulated results. And as mentioned above, this research can also be the start for comparison study and framework standard research.

What's more, the model we are going to propose is not only about biophysical properties, but also about accessibility, spatial policies, and human-physical interactions. In other words, a complicated system including diverse sub-systems which have several internal links would be constructed. So the influence is not direct any more, but quite complicated. People cannot determine what will happen from instinct, but from computer simulation.

The model can become a practical tool for different provinces as a reference for creating their own. But of course, they need to change the system in order to suit their own conditions.

Furthermore, the model can be used by companies to predict future possible land use policy and adjust their development correspondent strategy timely.

Considering the research limitations, we have to admit that this research can only give suggestions, not blueprint because predicted land use is based on incomplete system. We say incomplete system on the basis of limited driving forces and sub-systems in the model. We have to mention that no simulation system is perfect, but as reference for policy makers.

Another issue is probably insufficient data collection. It would lead to imperfect parameter estimation. In addition, the model we propose can only give numbers for different types of land use in the future but no specific location. For future research, location specific spatial simulation can be accomplished by using other simulation tools like agent based modeling or cellular automata. Of course there have been several studies in this field. So it won't be quite different for location specific study in the future.

At the end of this study, a SD model including all the identified driving forces of North Brabant land use change will be given. The model will explain the land use changes over the last 15 years and it will show how North Brabant land use will evolve if exogenous variables don't change and when no interventions made on the endogenous variables. Moreover the model is used to analyze different scenarios which we construct to predict the future trends of socioeconomic attributes. This insight can be used be policy makers to develop new land use policies. Also it can help people from other perspectives have a corresponding strategy regarding to authorities' decisions. After studying the future trends of policy and other variables, different future scenarios including various interventions will also be constructed for simulations and sensitivity analysis.

1.2.4 Research hypothesis

In order to do this research reasonably, we hypothesize that land use change can be analyzed by driving forces analysis and the major identified driving forces can represent the main trend of land use change. Moreover, data collecting can supply this research with sufficient information. Last but not least, different interventions can be used to construct future scenarios and their trends can be predicted.

1.2.5 Definition of scope

In order to limit the complexity of the whole system, there need to be a scope for the analysis. So we will define only several significant driving forces in huge effected sub systems like population sub system and so on.

1.3 Methodology

In methodology section, we are going to discuss the methods we want to use in this research and the reasons behind it. Then the research model will be explained. It shows how we want to combine these methods in a reasonable way and how the data and model can refer to each other.

1.3.1 Research method

In order to know to what extent North Brabant land use has changed in the past 15 years, statistical inventories will be used to find land use classifications and quantities in different time periods. This kind of statistics can be found from diverse sources like Centraal Bureau voor de Statistiek (CBS), 3TU Datacentrum, et cetera.

Literature review will help us find driving forces behind these changes and their inner connections. It includes geographical study, theoretical study, policy review, population study, economy research and so on and we will also focus on studying different methods used in the past years for analyzing land use change. Based on these theories, we can have a good view on what methods we should use for our study.

Based on the information collected, a System Dynamics (SD) model will be proposed for the purpose of predicting land use change in the coming 43 years (up to 2055). Land use change is closely related with the regional socioeconomic development which is mainly driven by human factors. The SD model has been proved to be a useful tool for analyzing the complex connection between land use and socio-economic development. Furthermore, it is easier and more flexible to use a SD model to design plausible land use scenarios (Luo. et al., 2010). By using SD, we can have a top-down view which gives us the opportunity of understanding the whole system comprehensively.

Regression will be used for finding parameters between different variables in SD model. We will use histrorical data of different driving forces to calculate the coefficients and equations behind each variable. Matlab software probably will solve regression question.

We will also focus on the "Welvaart en Leefomgeving" (WLO) scenarios for validating our SD model and finding the most influential driving forces to create our future possible scenarios for North Brabant. Among hundreds of possible scenarios in the future, we will use scenario theory to build three scenarios which will show extreme situations and most possible situation to use for predicting the future land use trends.

1.3.2 Research model

You can see the research model of our study below. We firstly do literature review both from abroad and in the Netherlands about land use change to identify driving forces. At the same time, literature study can give us clues about the methodologies we should use. In our case, we will use system dynamics (SD) to simulate the future land use trends. The reasons would be explained later in the methodology part.

After identifying the driving forces, we will create a preliminary SD model. Meanwhile, we will collect histrorical data of these identified driving forces.

In the third step, the collected historical data will be inputted into the preliminary SD model to determine the equations behind each variable. This is done by the help of Matlab software as mentioned before.

However, there is also data which is not used in determining the equations. These are new updated data. With the help of new updated data, we can see if our SD model can simulate the actual land use change successfully. This is one part of the validation of our model. This step is listed as the fourth step.

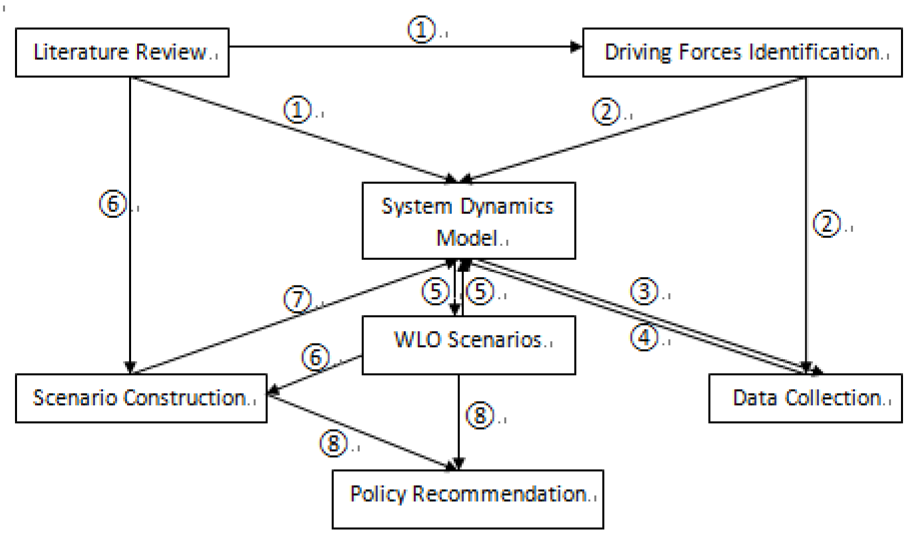


Figure 1 Research model

WLO scenarios show four possible scenarios' results from year 2002 to year 2040. With the help of this available information, we can see if the SD model we created has the similar trends as in WLO scenarios in step five. We can see from year 2002 to year 2008, if our simulated results are in the predicted range in WLO scenarios. This is another part of the validation of our model. Besides, by inputting the future trends of WLO scenarios into our model, we can use Matlab to find out the most influential driving forces for scenario construction.

With the help of the previous steps, we can formulate our scenarios for North Brabant. Also this needs literature study for practical scenario construction methods. For the determined most influencial driving forces' values, we will use WLO scenarios' predictions to define their values. Of course, we also need to connect them to our SD model.

In steps seven and eight, three scenarios will be established with the defined driving forces' values. These three scenarios will be put into SD model to see the simulation results. Comparing our scenarios results and the WLO results, we can give possible policy references to the policy makers.

2. Theory: land use change analysis method desk study

This section displays the result of the literature study. It is an extensive description to get answers of some listed questions and explaination of methodologies we are going to use. For the literature study in this section, the available scientific papers, reports, and other relevant online and offline documents are used. Since this section is all about the existing theory and methodology, the paragraphs in this section are all based on desk study.

One thing we need to mention before is that after the introduction of each method, we are also going to give several examples in which researchers use this method or their combination to deal with specific case. But all these cases or examples are not located in the Netherlands. Therefore, there is also going to be one part in section three introducing specific study about the Netherlands situation. Nevertheless, theories in this section will also help us figure something out like similar driving forces in each case study. This kind of literature study gives us baseline and starting points for our case study in section three.

2.1 Remote sensing

"Remote sensing (RS) is the acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth. " (Wikipedia: Remote Sensing) Nowadays, remote sensing imageries are commonly used in land use change analysis. With the help of satellites, people can distinguish the change spatial specifically and use the maps software generates for further scenario analysis.

However, considering the resolution ratio and other limitations in remote sensing, if all the statistical data is available it is better in our view that we only use statistical data in this research. This method can be used for sure if the data we get from statistic study is not enough. Remote sensing can be used in the future study for spatially specific research. Some examples about this method combined with other research methods will be discussed below in the combination part.

2.2 Geographic information system

"A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The acronym GIS is sometimes used for geographical information science or geospatial information studies to refer to the academic discipline or career of working with geographic information systems. " (Wikipedia: GIS) So GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. With the help of computers, people can analyze geographic data easier in GIS. A GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared. That's why lots of researches have combined remote sensing imageries and GIS together land use change analysis. You can find more details about these researches from combination part.

However, since later we found out that our required data are all listed in the central statistics for the Netherlands (in Dutch: Het Centraal Bureau voor de Statistiek, for short, CBS), there is no necessity for using GIS in short a short period. We only consider it as a possible extensive study method for the future.

2.3 System dynamics

"System dynamics (SD) is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system. What makes using system dynamics different from other approaches to studying complex systems is the use of feedback loops and stocks and flows. These elements help describe how even seemingly simple systems display baffling nonlinearity." (Wikipedia: System dynamics)

Compared with the previous mentioned geo-information based GIS and RS methods, system dynamics are more socioeconomic system based. In specific areas, geo-information and attributes are relatively stable. While for socioeconomic and other attributes related to human decisions, GIS and RS cannot fulfill the analysis efficiently. That's why in more and more researches, SD method is getting used to simulate human and environment interactions, especially in populous areas and policy-orientated areas like China.

As we have mentioned before, Dutch new policy requires a more local oriented spatial planning strategy and the populous essence of the Netherlands, using SD to simulate land use change with focus on human interactions is quite necessary.

Furthermore, SD method is based on time simulation. We can simulate the trends in the past easily and analyze the future scenarios with it simply. Under different scenarios, various policy recommendations can be made. That's why SD is getting more and more attention in the policy making processes. For more information about this method's usage, please see the coming combination part which elaborates all the mentioned methods used in land use change analysis study.

2.4 Cellular automata

"Cellular automata model is a well-known simulation model in which space and time are discrete and interactions are only local." (Wikipedia: Cellular Automata)

In fact, proximity is one of the essential geospatial elements that emphasize the dynamics of various change events. Areas expose a higher tendency to change to a class when they are located near existing areas of the same class, for example, the sprawl phenomena. So these events can be efficiently simulated by means of CA models.

From above, you can see clearly that CA is mostly used for spatial location determination according to the surrounding characteristics. Even though it is quite a useful tool for allocating various land use types, in our study it can only be the further step.

We will give several examples in the following part to show you how this method is used specifically.

2.5 Driving forces analysis method

As one of our main goals is identifying driving forces behind land use change, the methods used for determining driving forces are quite important. Normally speaking, researchers use literature study first. Then a list of different driving forces in different sectors will be established. Some researches finish at this point. While some of them even get experts in different fields to evaluate the driving forces distinguished and weigh them.

In our case study, we will adopt the major trend. Firstly studying much literature and then establishing a list with various driving forces within different sectors. Finally these driving forces are located in the SD model and some of them even become the variables we want to use to create future scenarios. For example, some policies and economic growth rate can be used for designing future trends.

2.6 Scenario analysis

Scenarios are perceptions of the future; they are stories telling what the future might look like for our projects, our organizations, our issues, our nations, or even our world. However, scenarios are not the same as predictions; they are provocative and plausible stories about diverse situations in the future including many relevant issues in your decided context. (Bood, R. et al, 1997, 2000)

For urban development projects, scenarios for private investors are the future possibilities for their willing projects, inside and outside. For example, in different scenarios, the future political environment, social attitudes, regulations, and the strength of the economy can all become a part of one scenario for them. (Georgantzas, N.C. and Acar, W., 1995)

We construct scenarios and use scenario thinking to design and grasp the opportunities and threats that might occur in the future and try to make better decisions by using this tool, not just in short-term but also in long-term.(Godet, 1996, 2000)

In general, there is no specific and certain construction method for creating scenarios. However, we can have a clear view about the construction methods by reading the reference articles. For the urban development scenario planning, the following guideline can be useful: (Khakee, A., 1991 and Veldhuisen et al., 2004)

1) Identify focal issue or decision;
2) Key forces in the local environment;
3) Driving forces;
4) Rank by importance and uncertainty;
5) Selecting the scenario logics;
6) Fleshing out the scenarios;
7) Implications for strategy;
8) Selection of leading indicators and signposts;
9) Feed the scenarios back to those consulted;
10) Discuss the strategic options;
11) Agree the implementation plan;
12) Publicize the scenarios.

In section three for creating our own scenarios about North Brabant land use change, some of these steps will be used, including driving forces identification, uncertainty and risks determination, selection of scenario logics, fleshing the possible scenarios, discussing the strategic options and so on.

Some of the main uncertainties we want to mention first in the urban development scenarios are: (Georgantzas et al., 1995)

1) Political uncertainties: political authorities have strong power in making the policies for the urban development processes. On the basis of the elections and changing of the governments, the policy for the development can be changed into completely different view. So for the urban development scenarios the political uncertainties can be really important especially for the long-term scenarios. We need to think about this issue during the construction phase of the scenario.
2) Economic uncertainties: Nowadays the economic situation of the world is changing dramatically. In recent years because of the economic crisis the investments in the urban development have had some problems and the available fund for developments is not stable. Indeed the economic downturn or growth can affect the future of the urban development processes. That is why we should think about this issue in urban development scenarios.
3) Population and employment and infrastructure uncertainties: the population growth is the other important uncertainty. Because of this issue the rate of employment is also subject to change. More demands for housing, transportation and social welfare are important aspects here. The growth in travel movements between homes and workplaces can affect the need for better transportation systems. The infrastructures should be improved to support the needs of the society and youth for making life easier for them.

2.7 Other method and combination example

Other methods like agent based approach will be explained in the combination with other above mentioned methods.

Guan, et al. demonstrates a combined Markov-Cellular Automata model can analyze temporal change and spatial distribution of land use. They firstly calculate the area change and spatial distribution of land use using GIS, and then analyze the transition matrices. At the same time, an integration evaluation procedure with natural and socioeconomic data is used to generate potential maps in the future. (Guan et al., 2011) While Yang, et al. also uses RS imageries and Markov model to simulate the land use tendency. (Yang, et al., 2011)

Arsanjani's paper emphasizes the area of Tehran, Iran. A hybrid model consisting of logistic regression model, Markov chain and cellular automata is designed to improve the standard logistic regression model. And environmental and socioeconomic attributes are added into the system to create a probability surface of spatiotemporal states of built up land use. Future land use maps are predicted by this hybrid approach. (Jokar Arsanjani, J., et al., 2012) For a more agent based orientated approach, Robinson's paper copes with data limitations of land use change in Koper, Slovenia by constructing an agent based model which integrates utility theory, logistic regression and cellular automata together. With this model, they get insights into the dynamics of land use change for local stakeholders. (Robinson, D.T., et al., 2012)

For the coming up examples, we put our focus on system dynamics and scenario analysis combined with other methods. After explaining several combinations and practices, you can get a better idea why system dynamics and scenario analysis are suitable in our case study.

Wu yuzhe and his fellows consider land use change as a dynamic system model composing of five sub-systems: urbanization, social, economic, environmental and land use sub-systems. The key attributes in these five sub-systems are interactive and they are dynamic variables. They assess the urbanization policies' impacts to land use change through this model. (Wu, Y., et al., 2011) The same combination of methods comes up in his another research about Suichang County.(Wu, Y., Peng, Y. et al., 2011) The most significant difference in this study is that they focus more on scenario creation because of the various policy options they are facing with. Yu Wanhui also has one similar research on land use cover change in the Daqing city using the similar methods. (Yu, W., Zang, S., et al.,2011)

The combination of system dynamics and scenario analysis is very valuable for policy simulation on land use change considering various sub-systems and socioeconomic attributes. However, people may also have interests in spatial allocations of newly built-up areas. That's why cellular automata and GIS are incorporated, too. Lauf's paper integrate SD and CA to incorporate household dynamics and housing decisions as driving forces of residential development. (Lauf, S., Haase, D., et al., 2011)

Of course, the combination of system dynamics and cellular automata does not only provide with spatial allocation ideas, but also with urban spatial pattern evaluation revolution. Just like in one of the researches of Han (Han Ji, et al. 2009). And Guan's research even combines GIS with scenarios and system dynamics to assess urban economy-resource-environment system. (Guan, D., et al., 2011) Another research even incorporates SD, GIS and 3D visualization in sustainability assessment of urban residential development. (Xu, Z., Coors, V., 2012)

2.8 Conclusion

After all the explanation above, we can see that there are two main directions of modeling land use change up to current studies.

One is geo-information based on spatial modeling with the help of GIS, 3D, RS and so on. The other is system based socioeconomic development scenarios simulation under the assistance of SD, scenario analysis and driving forces analysis.

The first one makes a difference in spatial aspect, while the latter has its advantages in system interactions and long term time modeling.

Above all, the combination of SD and scenario analysis could help policy makers better considering policy and future scenario simulation if all the data can be acquired from statistics data. That's why in our case study, we mainly focus on the latter direction of land use change simulation.

3. Case Study

In this section, we will first introduce North Brabant elaborately to give you a full overview about this Dutch province, especially the social economic conditions and geographic information.

In the second part, current study about this area will be explained including the land use change study, the population study, migration policy study and so on. After clarifying all the study that has been done up to now, we can identify driving forces behind North Brabant land use change effectively and efficiently.

Data collection part will need many efforts to get all the required data from literature study or all kinds of datasets. We will list some of these data in the following parts to give you a better understanding of the statistics we will deal with in the next parts, not just the land use statistics, but also driving forces statistics. For sure we still need to adjust all the data into one standard so that all of them are based on one baseline. Only after adjustment can the data help us construct the whole system.

After all the mentioned procedures for the preparation of system dynamics model, we can propose a preliminary system dynamics model which includes several sub-systems. We say preliminary system because of the coming calibration and adjustment issues. These sub-systems will be explained one by one. In each sub-system, we will introduce all the variables, stocks, flows and equations behind them. And each sub-system will be calibrated using historical data. Only in this way, we can make all these sub-systems reasonable and reliable.

Even all the sub-systems have been calibrated; it is still not efficient for the whole system. That's why we still need a long iterative calibration procedure. And of course there should always be validation part to see if our model can predict the newly updated data from year 2009 and year 2010.

Knowing only what happened in the past and why they have happened are for sure not enough. The focus should also be on the future. What will happen in the future and why is that. So in the coming part, we need to search for the current study about the variables in the system and predict their future trends. For example, what will happen to the population and what will be the consequences of the current immigration policy? But only analyzing their single change is nonsense and not substantial. We need to know their combinations to simulate the whole system.

So in the last part of this section, we will use scenario analysis to find out and construct several possible scenarios for North Brabant in about 40 years. With these constructed probably scenarios, we adjust them into the proposed land use change system dynamics model and simulate the results. Then it will be clear to all of us including the policy makers what will happen in the future and what we should do from now on to make the process more sustainable and better. From this point of view, giving suggestions to the policy makers will become possible.

3.1 North Brabant Introduction

"North Brabant (Dutch: Noord-Brabant), mostly called Brabant, is a province of the Netherlands, located in the south of the country, bordered by Belgium's Antwerp and Limburg provinces in the south, the Meuse River (Maas) in the north, and Limburg in the east and Zeeland in the west.

North Brabant is currently divided into 67 municipalities. Traditionally, almost every town was a separate municipality, but their number was reduced greatly in the 1990s by incorporating smaller towns into neighboring cities or by other mergers.

Like most of the Netherlands, North Brabant is mostly flat but nearly every part of North Brabant is above sea level, therefore there are not as many canals as in the lower parts of The Netherlands. While most of the population lives in urban areas, the province is scattered with villages around which most of the land is cultivated. Naturally raised areas, forests, heath lands and dune areas can however also be found.
The province is bordered by the Meuse River in the north. Its delta flows through the Biesbosch area, a national park.

Employment is found in the agricultural, industrial and service sectors. The main agricultural products are wheat and sugar beet, while cows and pigs are held as livestock. The chief industries are automobile production, electronics (both mainly in Eindhoven), textile and shoes.

In the twentieth century, tourism has become an important sector for North Brabant, the woods and its quiet atmosphere combined with the beauty of some of the cities having proved successful. Another big tourist attraction is theme park Efteling in Kaatsheuvel, the largest of the Benelux." (Wikipedia : North Brabant)

To give you an overview about this province, a map of North Brabant from 2012 year and a map showing its location of the whole Netherlands are listed below:

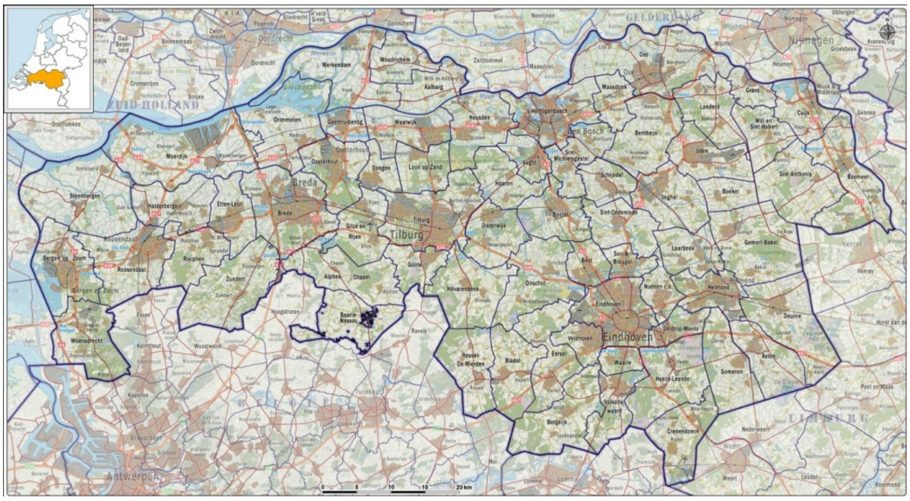


Figure 2 17: 24, 8 January 2012 North Brabant

Figure 3 North Brabant in the Netherlands

What we should have focused for North Brabant is the Eindhoven region, which is so-called Brainport area. It gives the province more energy and strength to compete in the world. And the Brainport concept will truly help stimulate the province's economic and social development. We will introduce Eindhoven and the concept of Brainport as follows.

Eindhoven is a municipality and a city located in the province of North Brabant in the south of the Netherlands. The agglomeration has some 440,000 inhabitants. The metropolitan area (which includes Helmond) has nearly 750,000 inhabitants. As of 2010, the population of

Eindhoven consisted of 213,809 persons (according to the Eindhoven city council, the city will reach the maximum population of 230,000 inhabitants around the year 2025). Of these, 28.8% or some 61,546 people are of foreign descent. Eindhoven has grown from a little village in 1232 to one of the biggest cities in the Netherlands with around 212,000 inhabitants in 2009. Much of its growth is due to Philips and DAF Trucks.

Due to its high-tech environment, Eindhoven is part of several initiatives to develop, foster and increase a knowledge economy. Chief among these are:

1) Brainport Top Technology Region: A cooperative initiate of local government, industry and the Eindhoven University of Technology to develop the local knowledge economy of the Eindhoven region.
2) Brainport Development: An extension of the Top Technology Region, Brainport Development serves commercial exploitation and advertising of the region.
3) SRE: The Samenwerkingsverband Region Eindhoven is a cooperative agreement among the municipalities in the Eindhoven metropolitan area. Although SRE is far more than just an economic agreement, it includes economic cooperation.
4) The Eindhoven-Leuven-Aachen triangle: An extensive cooperation agreement between the universities and surrounding regions of Eindhoven, Leuven (Belgium) and Aachen (Germany).
5) Within the Eindhoven region (particularly around Helmond), several parties are working together to set up an automotive testing facility of European scale, for testing and European certification of vehicles. This cooperation involves the Eindhoven University of Technology, TNO Automotive and the different automotive companies in and around Helmond.

As a result of these efforts, the Intelligent Community Forum has named the Eindhoven metro region in 2011 the Intelligent Community of the Year. (Wikipedia)

Brainport Eindhoven Region is a powerful innovative player in a European and global context. It accounts for a third of all Dutch private R&D expenditure, invests 8% of the GDP on R&D and is one of Europe’s top three regions in terms of patent density. The economic success of Brainport Eindhoven Region is the result of unique cooperation among industry, research and government. This triple helix cooperation generates a very conducive climate for business, for both internationally renowned companies and innovative small and medium-sized enterprises in the region. These companies cooperate with each other and with knowledge institutes by sharing and multiplying knowledge in an open innovation environment before bringing their products to market.

Brainport Development is the new style development agency of the Brainport foundation, which has representatives of the triple helix-structure on its governing board. The task of the organization is to drive the region forward and make the economy of the region ‘future proof’. (Brainport web)

3.2 Current study in the Netherlands

While in section two, we have already introduced many researches about land use analysis with different methods; in this part we focus on the study of land use in the Netherlands. So it maybe is true that some of the methods they use are quite similar. However, the areas are different. Since we will make a system considering the Netherlands, the study specifically about the Netherlands is of much significance for the following parts.

In the Netherlands, in 2008 a new Spatial Planning Act will come into force (Wet ruimtelijke ordening).(Spatial Planning Act, 2008) (VROM, 2007) After literature study, we can find out why some of the changes have been executed and to what extent will they change Dutch land use.

As a part of this new act, the legal instruments for cost recovery will also be changed. This part has been discussed separately in Parliament, and is also called the Land development Act (Grondexploitatiewet). The new system will change the current system fundamentally, at least on paper. With respect to the content of the system, two main adaptations will be made:

(1) The possibilities for agreements dealing with cost recovery or value capturing are enlarged and;
(2) The possibilities for enforcing a contribution from a private developer are enlarged. (Wolff, H., 2007).

In this paper, we are not going to talk about why exactly these changes have happened, but about land use change analysis under different scenarios. However, in short speaking, we can say that new Dutch spatial planning act does give more space for development. A published article from Ministry for Social Building, Regional Planning, and Environment Administration (in Dutch: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, in short: VROM) briefly explains why the new act gives space for development.

The guiding principles behind the new Spatial Planning Act are fewer rules, less central control where possible, and an implementation-oriented approach. They represent an actual simplification of the decision-making process in spatial planning, with due consideration of such important concepts as legal certainty and democracy. The new Act ensures a clear division of labor. The responsibilities and powers are distributed among municipalities, provinces and the national government in such a way that each tier of government can represent the interests entrusted to it to the best of its ability. (VROM, 2007) As we have mentioned before in the introduction part, it stimulates municipalities and provinces to make their own spatial strategies to increase their competitiveness based on their own situations.

With all the mentioned but not limited to reasons above, many researchers have been dealing with modeling Dutch land use to help policy makers for a better planning, not only the national level, but also more focus has been laid down to provincial levels. One of the most commonly used land use modeling tools is the land use modeling system (LUMOS) toolbox, which is managed by PBL Netherlands Environmental Assessment Agency. The book "Land-Use Modeling in Planning Practice" gives an elaborated overview and practice experience on this modeling method. (Koomen, E., J. Borsboom-van Beurden (eds.), 2011)

"The land use scanner uses current land use configuration as a starting point to calculate future land use change. The predicted demand for space of these aggregated land use classes is needed for these calculations. On the basis of socioeconomic scenarios for the future, the demand for space for every land use type is generated with help of sector models of specialized institutes. Attractiveness determines the spatial allocation. Suitability maps have been created for each land use type. These maps may include distance relations, policy maps and physical environment maps. " (LUMOS web)

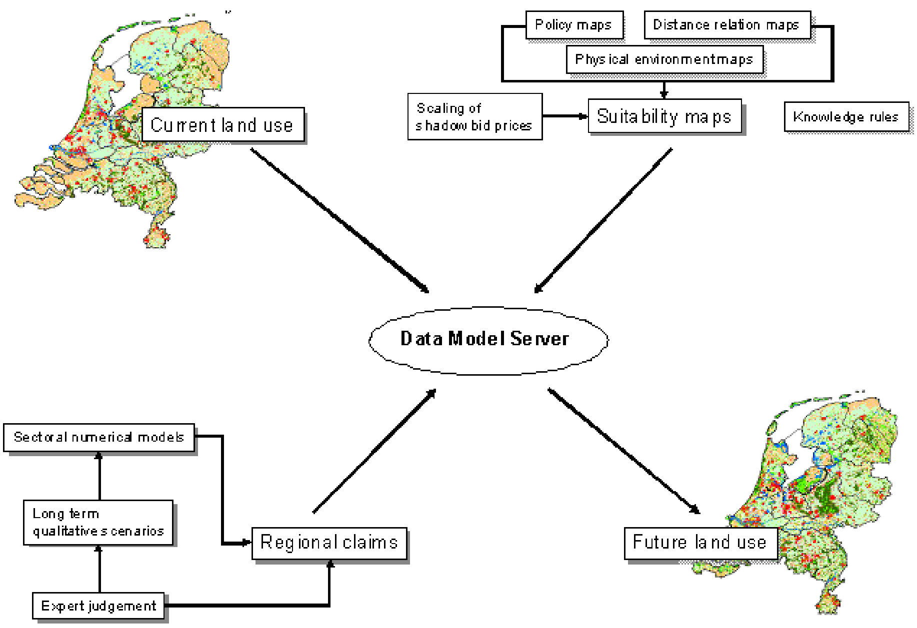


Figure 4 Flow Chart of the LUMOS model structure

In this book, there are several practiced case study by using this toolbox. For example, chapter 4 of this book highlights the comprehensive application of Land Use Scanner at the national level for the Second Sustainability Outlook on the future of the Netherlands. Comparing with the baseline scenarios, researchers try to find influences of different future land use changes to various sustainability indicators. Based on these influences, several policy references are given to optimize the sustainability in the future after the simulation of future land use change by using this toolbox. (Kuiper, R., et al., 2011)

In chapter 7 of this book, the role of different optimizations of land-use patterns and their environmental impact in a regional spatial planning process in the Province of Overijssel is evaluated. (Koomen, E., Koekoek, A. and Dijk, E. ,2011) This is the efforts corresponding to the new Dutch spatial planning act. More and more provinces will need land use modeling methods to optimize their sustainability of land use in the future.

There is also another example using this model to explain land use transition in a segmented land market. (E. Koomen, J. Borsboom-van Beurden (eds.), 2010) They present a novel analytical method for explaining how probable locations for future urban development can be identified from information on actual land prices.

Even though many practical examples and cases have been practiced by using this model and the results shows quite well when they are dealing with policy making processes, this model still needs improvement and its own disadvantages. (Borsboom, J., Zondag, B. 2009):

1) Lack of information about actors, activities and spatial objects apart from their land consumption;
2) Lack of dynamics in land-use simulation: the static approach of Land Use Scanner, which follows on from equilibrium modelling, is not in line with the usually gradual, path-dependent, changes that occur in land use. What is more, equilibrium modelling is mainly motivated by economic theory: the existence of an equilibrium in practice has not yet been proven;
3) Lack of consistency between sector models mutually and between sector models and the land-use model;
4) Insufficient elaboration and quantification of indicators.

In short, we can say that this model cannot include the dynamic process and inner connection between different sectors. So in our study, we would like to deal with some of these disadvantages by using system dynamics to simulate the dynamic process of land use change and connecting different sectors with various sub-systems. But for the spatial allocation, there is no way to calculate location-specifically. We can only simulate different sectors to predict the future trends in number under possible scenarios. The coming study with other methods like agent based modeling and cellular automata can help solve these problems.

3.3 Land use change driving forces identification

Two main reference papers give us most of the information about land use change driving forces in the Netherlands. Other studies on different countries as we have mentioned previously in section two also inspire us with possible driving forces. We will first define several driving forces based on different types and then redefine them into our own classification.

We should mention that our classification is mostly based on human interaction with environment and socioeconomic conditions rather than biophysical attributes. This is mostly because of North Brabant’s geographic condition which is somehow different with other provinces in the Netherlands. North Brabant doesn’t have land under sea level which makes the biophysical attributes not as important as other human or socioeconomic attributes. Also it is since that according to the data we can acquire, mostly they are from 1996 and from that time, biophysical conditions don't have much importance as human and socioeconomic attributes.

In "Determinants of land-use change patterns in the Netherlands", the authors define the determinants with five sections, namely biophysical constraints and potentials, economic factors, social factors, spatial interaction and neighborhood characteristics and spatial policies. Stepwise logistic regression is used to estimate the coefficients of the defined model. Other details can be found from the reference paper. (Verburg, P.H., et al., 2004)

In "Driving forces of land use change", Zondag and Borsboom (Zondag, B., Borsboom, J. 2009) present a multi-sectoral overview of the key driving forces of Dutch land use change. This study focuses on the five major land-occupying sectors in the Netherlands: housing, water, nature and employment. In addition to these five sectors, three themes were identified: transport, energy and recreation. They interact strongly with the sectors. The authors then combine the driving forces in each sector into several clusters such as: existing spatial patterns of land use, objects and activities; demography; economy; technology; societal values and trends; climate change and energy transition and policies. For each driving force, they have marked the influential degree and effect. We should mention that this kind of identification focuses more on socioeconomic driving forces, compared with the previous one which focuses more on biophysical issues. And in the coming part for our own identification, we mainly use this one as reference.

We also read other papers concerning driving forces analysis in other parts of the world. Hualou Long's paper analyzes characteristics, major driving forces and alternative management measures of land-use change in Kunshan, Jiangsu province, China. (Long, H., Tang, G., Li, X., Heilig, G., 2007) The study uses remote sensing maps and socioeconomic data to detect land-use change and analyze major driving forces triggering change through bivariate analysis. It indicates that industrialization, urbanization, population growth and China's economic reform measures are four major driving forces.

One study about a central Europe case study (Hersperger, A. M., Burgi, M. (2009) offers us with a list of 73 potentially relevant driving forces in which 52 of them are identified as primary driving forces. With all of them, urbanization and economic driving forces are very important of change, followed by political driving forces, and greening is steadily increasing its significance.

In Wu's paper, they incorporate five sub-systems into the whole system. They are urbanization policy, land use, social, economic and environment sub-system separately. The thing we want to emphasize here is that they define the economic activities based on first, second or third industry which can give us some inspiration. In his another paper, this kind of sub-systems are also listed for identifying the driving forces behind Suichang County's land use change. The issue we need to point out here is that they include scenarios into the system. This is also one of our major tasks in analyzing different circumstances under variable scenarios.

In Dongjie Guan's paper and Wanhui Yu's paper, they also do almost the same classification of driving forces sub-systems as Wu. But of course the focusing points are different. Since they have been discussed before in section two, here we will not explain it again.

S.Lauf's paper emphasizes on allocation of different land use types, so they put demography and planning in a very important place. Here we will not talk it again to prevent repeating with section two.

After all these discussions and considering North Brabant's specific conditions, we have identified North Brabant's land use change driving forces as follows:

1) Four sub-systems including population, industrial land, residential land and agricultural land;
2) In each sub-system, different driving forces in the same cluster have different effects. For example, immigration policy can affect population sub-system and subsidy policy can have an effect on residential land sub-system;
3) Different sub-systems have connections. Taken "new increase job" as an example, it not only has influence on population in North Brabant, but also is able to affect industrial and commercial land demand;
4) In order to simplify the whole system, we have limited the number of all the driving forces and the amount of sub-systems. But there is also variable in the system to limit the total land in North Brabant which will reflect other land use types like water and natural land use from sideways.

In order to give you a clearer overview on all the identified driving forces and sub-systems for North Brabant land use change analysis, tables one to four are listed below showing different categorized driving forces based on various sub-systems:

Table 1: Driving forces behind population sub-system

	Demography	Policy (Interventions)	Economy
Population sub-system	Birth rate; Death rate; Net birth rate; Immigration from other countries; Emigration to other countries; Net migration rate; Inter-municipal moves for emigration; Inter-municipal moves for immigration;	Immigration policy; Education attractiveness; Education budget effect;	Non-Dutch employee ratio; GDP; New increase Job each year;

Table 2: Driving forces behind industrial and commercial land sub-system

	Demography	Policy	Economy	ICL conditions
Industrial & Commercial Land (ICL)	Population growth (Population);	Technology investment (Brainport Concept); Financial investment (Investment budget, etc); ICL redevelopment policy;	New increase job; GDP; Treat transport hotel catering GDP growth rate; Information communication GDP growth rate; Construction GDP growth rate ; Energy industry GDP growth rate; Mining quarrying GDP growth rate; Financial institution GDP growth rate; Business services GDP growth rate;	Current ICL stock; Net increase ICL per year; Demand change into supply delay;

Table 3: Driving forces behind residential land sub-system

	Demography	Policy (Interventions)	Economy	RL conditions
Residential Land (RL)	Population growth (Population); Rent demand Living spaces per capita hectare;	Subsidy effect for buying; Loan rate effect; Subsidy effect for rent;	Full time employee; Price income ratio for tenant per month; Price income ratio for buyer per month; Income for buyer; Buy demand;	RL demand per year; Floor area ratio; Current RL stock; Rent price per hectare per month; Living spaces per capita hectare; Average purchase price; RL demand change into supply delay;

Table 4: Driving forces behind agricultural land sub-system

	Demography	Policy (Interventions)	Economy	Environment	AL Conditions
Agricultural Land (AL)	Population;	Policy like WTO effect; Technology investment on AL effect; Import effect; Export effect;	Food price effect; EU economy conditions; Bio-fuel price effect;	Change into other land; Net increase ICL; RL increase rate ; Water land from AL ratio; RL from AL ratio;	AL demand per year; AL demand per capita; AL demand change into supply delay; AL change into other land use type rate; Al demand increase rate;

More details about these driving forces interactions and descriptions are in sub-system description parts.

3.4 Data collection

After determining related land use driving forces in each sector, we collect their data from several sources. Centraal Bureau voor de Statistiek (CBS) provides us the most needed data, namely land use types numbers, population dynamics, provincial GDP in total and different industries GDP growth rate and so on.

Other information like agricultural land per capita is found in various papers and researches. For some of them, there is no specific research or data. In this case, we use studies in Europe or the National level data of the Netherlands. For example, we adopt European standard agricultural land per capita in hectares data to simulate North Brabant's data. This kind of explanation can be found in each sub-system.

3.4.1 Land use statistics

Land use statistics are most from CBS and they can only be traced back to the year 1996. That's why after data collection, we change our model from the previous one to this one. In the previous model, the starting point is year 1980, which means back to 30 years and looking forward for another 30 year from now on. But now, in the current model, as the change of starting year, we will use the past 15 years' historical data to generate the relationships between different variables. Then use the proposed model to predict future 43 years trends.

Land use statistics are based on different land use types. In CBS research, land use is divided into many sections. Detailed data and each section's description can be found from Appendix 7.1. In the main text, we only want to mention several significant points about how we specifically combine and use these data to define our land use types:

1) We use the "Woonterrein" data to stand for "Residential land" amount;
2) "Bedrijventerrein" under "Bebouwd terrain" column and "Bouwterrein" under "Semi-bebouwd terrain" column are used to calculate "Industrial and Commercial land" sub-system;
3) "Totaal agrarisch terrain" is used to simulate agricultural land sub-system;

Of course there are other columns stating various land use types. We have simplified the SD system and that's why not all these data are used in the system. But most of these unused land use types haven't changed a lot in the past 14 years, except the total water areas. As the total land in North Brabant is certain, we make a reasonable guess that the increase water area are from the decrease of agricultural land.

One thing for sure is that we do these changes and adoptions all based on the descriptions and classifications of CBS researches. Since almost all of our data are from CBS report, the baselines are the same.

3.4.2 Driving forces statistics

For the population sub-system, data are also available, including total population, birth rate, death rate, immigration, inter-municipal moves, and emigration and so on. This not only offers us with statistical data, but also gives us refreshment about how to simulate and define population sub-system. More of the descriptions of various attributes are stated in in the sub-system parts.

For economy sub-system which most connected to industrial and commercial land use, data is not easy to be obtained. There is many national accounts about GDP amounts but not on much on provincial level. We can only get market prices of GDP from year 1996 for North Brabant up to year 2008. The thing we surely could acquire is GDP growth rate for different economy activities in different parts of North Brabant. In order to find a specific method to give the whole North Brabant's different economy activities a GDP growth rate, we use average method.

As the result of very limited and not sufficient data, economy attributes that we use to define most parts of industrial and commercial land use are not very predictable. However, for now the simulation results are quite good. For the future expanded study, this sector needs to been redeveloped with more data.

Considering the residential land use sub-system, most of the economic attributes are about income, house price, rent price, and so on. These kinds of data can all be found in CBS database. Of course some of these data still ask for recalculation. And more resources are essential to complete our model. This will be explained further in the SD part.

All the above mentioned rest data and descriptions are listed in Appendix 7.2 and 7.3.

3.4.3 Data adjustment

As stated before, we do have made several adjustments to make the CBS data more suitable for our research and our SD model. Just name a few:

1) We change the starting point from 1980 to 1996 and extend the future trend prediction up to 2055. This is because of the data acquisition in practice;
2) Many data's weights and measures are changed to make them standard and understandable. For example, the house price per square meters are changed into hectares in order to be correspondent to living space per capita in hectares;
3) When data are not sufficient, we do try to use our own ideas to reasonably get the data from existing research. For example, we use the European standard living space per

capita in hectares to simulate North Brabant's situation. Another example could be the average calculation of North Brabant GDP growth rate in different sectors. This kind of data is generated from lots of insufficient data from different areas in North Brabant;

4) Last but not least, for some variables like GDP, the amount is quite large. It is not convenient for using in the system. So we have kept the current "Million" metrology instead of * 10^6 Euros for simplification in the calculation.

3.5 System dynamics

After dealing with all kinds of data and identifying all the related driving forces specifically in socioeconomic fields, we can now use these previous preparations to come up with our system dynamics model. We will introduce each of the four sub-systems in our model and then do the verification and validation for the whole system.

3.5.1 Population and economy sub-system

Normally we call this sub-system as population sub-system. But since there also are several variables related to economy, we also call this sub-system as population and economy sub-system. However, we use population sub-system for short in the following parts.

The coming sections about different sub-systems are all organized in the following ways: firstly introduce the sub-system structure by defining variables, stocks and flows; then state the identification processes of equations behind different variables; the last calibrate the sub-system.

3.5.1.1 Variable, stock and flow

We incorporate the identified driving forces from demography, economy and policy (interventions) categories to make this sub-system. For details, please see table one.

You can see the sub-system in figure 5:

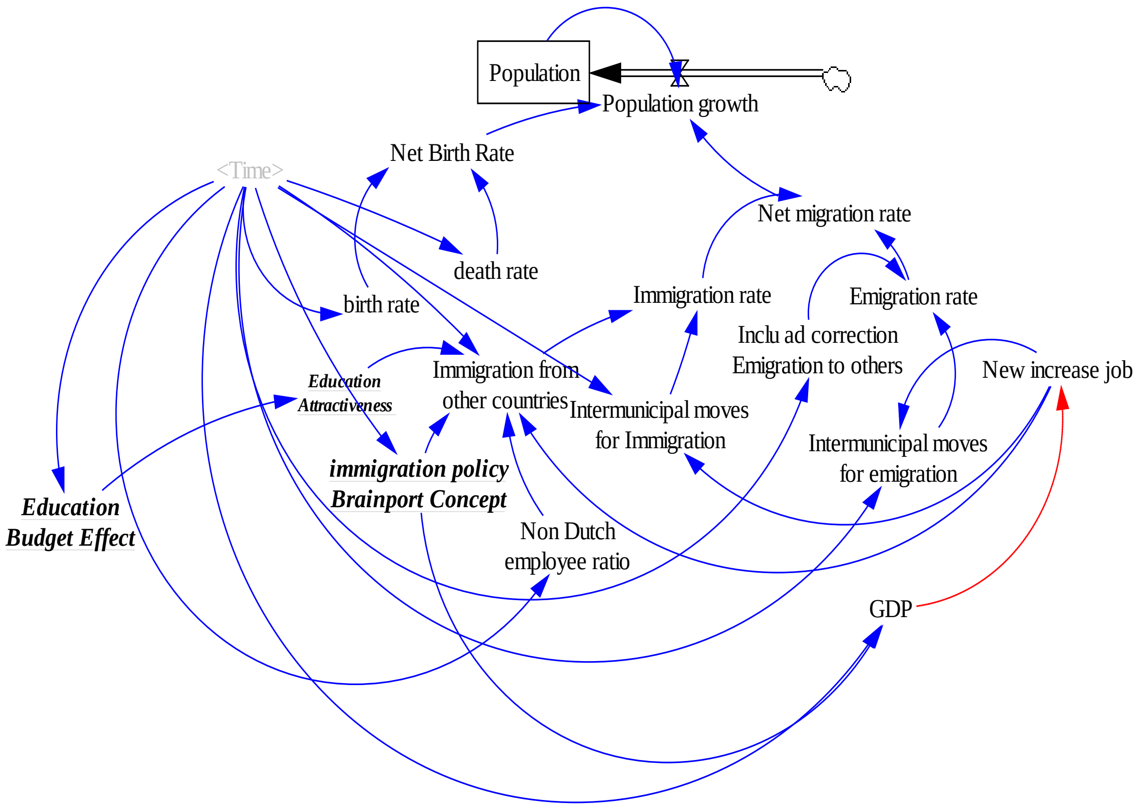


Figure 5: Population sub-system

Maybe you have recognized some of the variables are marked bold, italic and underline. Those are the policy interventions that maybe changed in the scenario analysis. For now, we keep them as 0. As you can see from the sub-system, we define population as a stock which is determined by the inflow of population growth. We need to understand that population growth can be plus or minus. And the population growth is the result of net migrate rate and net birth rate. Net birth rate is the differences between birth rate and death rate. These two rates, with other variables in the system, are only time related or without. We call this kind of variables as fundamental driving forces.

For net migration rate, the situation is a little bit more complicated. It is the differences between immigration rate and emigration rate. Two main reasons of migration are migration from or to other countries and inter-municipal movements.

One thing we want to mention is that for emigration to other countries, we include administration corrections to make the data more reasonable since many Dutch people only go outside for a short time for work reasons. New increase job each year will have positive effects on immigration from other countries and inter-municipal movements for immigration and negative effects on inter-municipal movements for emigration. Considering the work issues, non Dutch ratio of employment in North Brabant is also an important factor of immigration from other countries. So the immigration policy and concept of Brainport are quite important possible policy interventions at present and in the future to change the situation of population sub-system which finally changes the whole system.

We cannot ignore the power of education. Every year, many people from other countries come to North Brabant to study. The Education attractiveness increase North Brabant's population, too. One of the top issues we are discussing nowadays is the cut of education budget. The shortage of education budget will lead to international students' decrease. Later in the scenario analysis part, we will make emphasizes on it. And we have assumed that new increase job does have relationship with GDP. However, the real data shows there is no apparent connection. So we use red broken line to mark their connection. It is deleted in the total system.

3.5.1.2 Equation identification

After the briefly introduction of the relationships between different variables, stocks and flows in population sub-system, we give a table which shows the equations between them. For not obvious relationships, we give remarks behind the equations, showing how we come up with the coefficients. Talking about the connections that are not quite apparent like new increase job each year and GDP we use historical data to analyze the consistency. If they are consistent, we use historical data to do linear regression just like what we do for fundamental driving forces. If they are not consistent, we delete the connections between them in the system.

Table 5 Attributes relationships in population sub-system

Numbers	**Attributes**	**Equations**	**Remarks**
1	Population	Integ(Population growth, 2.29042e+006)	Integration of Population growth, initial value is 2.20042e+006
2	Population growth	Net Birth Rate* Population+ Net migration rate	
3	Net Birth Rate	birth rate-death rate	
4	Net migration rate	Immigration rate-Emigration rate	
5	Emigration rate	Included correction Emigration to others + Inter-municipal moves for emigration	
6	Immigration rate	Immigration from other countries + Inter-municipal moves for Immigration	
7	Immigration from other countries	155.198*Time+ 0.535885*New increase job*Non Dutch employee ratio + Education	Matlab to calculate historical data and determine coefficients for

		Attractiveness +Immigration policy(Brainport Concept) +11955.5	each variable
8	Inter-municipal moves for Immigration	201.789*Time + 0.131025*New increase job+78560.5	Matlab to calculate historical data and determine coefficients for each variable
9	Education Attractiveness	1*Education Budget Effect	Assumption as the same effect of Education budget effect
10	Education Budget Effect	0*Time	In the initial case, we set it as 0 effect, later in the scenario analysis, settings are changed
11	birth rate	(-0.183*Time + 13.07)/1000	Using linear regression to determine coefficients
12	death rate	(0*Time + 8)/1000	Using linear regression to determine coefficients
13	immigration policy Brainport Concept	0*Time	In the initial case, we set it as 0 effect, later in the scenario analysis, settings are changed
14	Non Dutch employee ratio	0.004*Time + 0.139	Using linear regression to determine coefficients
15	GDP	3226*Time+ 44708+immigration policy Brainport Concept	Matlab to calculate historical data and determine coefficients for each variable
16	New increase job	14000+GDP*0	This variable is mostly related to GDP growth rate in different sectors, here without other sub-systems, we use average number of it to stand for new increase job
17	Inter-municipal moves for emigration	502.254*Time + 0.095474*New increase job+76229.3	Matlab to calculate historical data and determine coefficients for each variable

18	Included correction Emigration to others	2646*ln(Time) + 8756	Using regression to determine coefficients

3.5.1.3 Sub system calibration and validation

During the process of running this sub-system, all the equations need to be calibrated again and again to make the simulated results closer to the actual data. For example, “included correction Emigration to other countries” and time’s relationship is calculated and calibrated in the whole system many times. Finally we decide that non-linear equation is more suitable for this attribute other than the normal linear regression. After running this calibrated sub-model, we can see the historical data are quite well simulated. See the coming figure showing population trends in the past and future (starting point is year 1996, showed in figures as year 1).

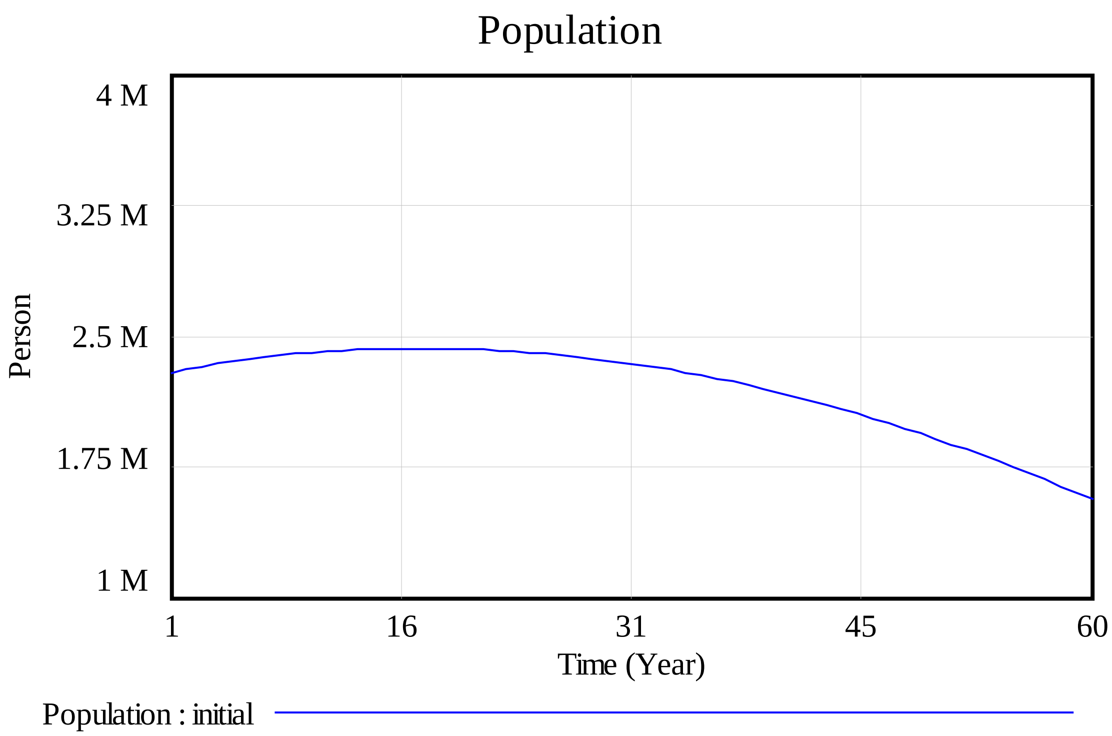


Figure 6: initial population sub-system simulation result

We can validate the system by comparing historical actual data and simulation data. In the table below, you can see one example of the validation processes showing the differences and the rate of change about population data. For other variables, the same validation processes repeat and the results show the simulation reasonable and acceptable.

Table 6: Validation example of population sub-system

Year	**Actual historical data**	**Simulated result**	**Change rate**
1996	2290424	2290420	0.00%
1997	2304094	2308569.25	0.19%
1998	2319262	2324435.5	0.22%
1999	2337709	2338762.75	0.05%
2000	2356004	2351850.5	-0.18%
2001	2375116	2363858.75	-0.47%
2002	2391123	2374886.75	-0.68%
2003	2400198	2385000.75	-0.63%
2004	2406994	2394248	-0.53%
2005	2411359	2402663.5	-0.36%
2006	2415946	2410274.25	-0.23%
2007	2419042	2417101	-0.08%
2008	2424827	2423160.75	-0.07%

From this example, you can see clearly that the absolute value of change rates are all below 3% which means the simulation results are quite correspondent to the historical data.

3.5.2 Industrial and commercial land sub-system

For industrial and commercial land sub-system, conditions are much more complicated. It is because that there is not enough data showing GDP growth rate. However, GDP growth rate in different industrial and commercial sectors are quite important for predicting trends of industrial and commercial land use. So we have made some adjustments to make the sub-system work. Brief introduction about these changes have been discussed in the data adjustment part. In the following part, you can have clearer understanding about the adjustments after understanding the relationships between different variables, stocks and flows.

3.5.2.1 Variable, stock and flow

In this sub-system, we put the identified driving forces from demography, economy and policy (interventions) categories together. Detailed information is listed in table two.
Firstly you can see the sub-system for better understanding in figure 7:

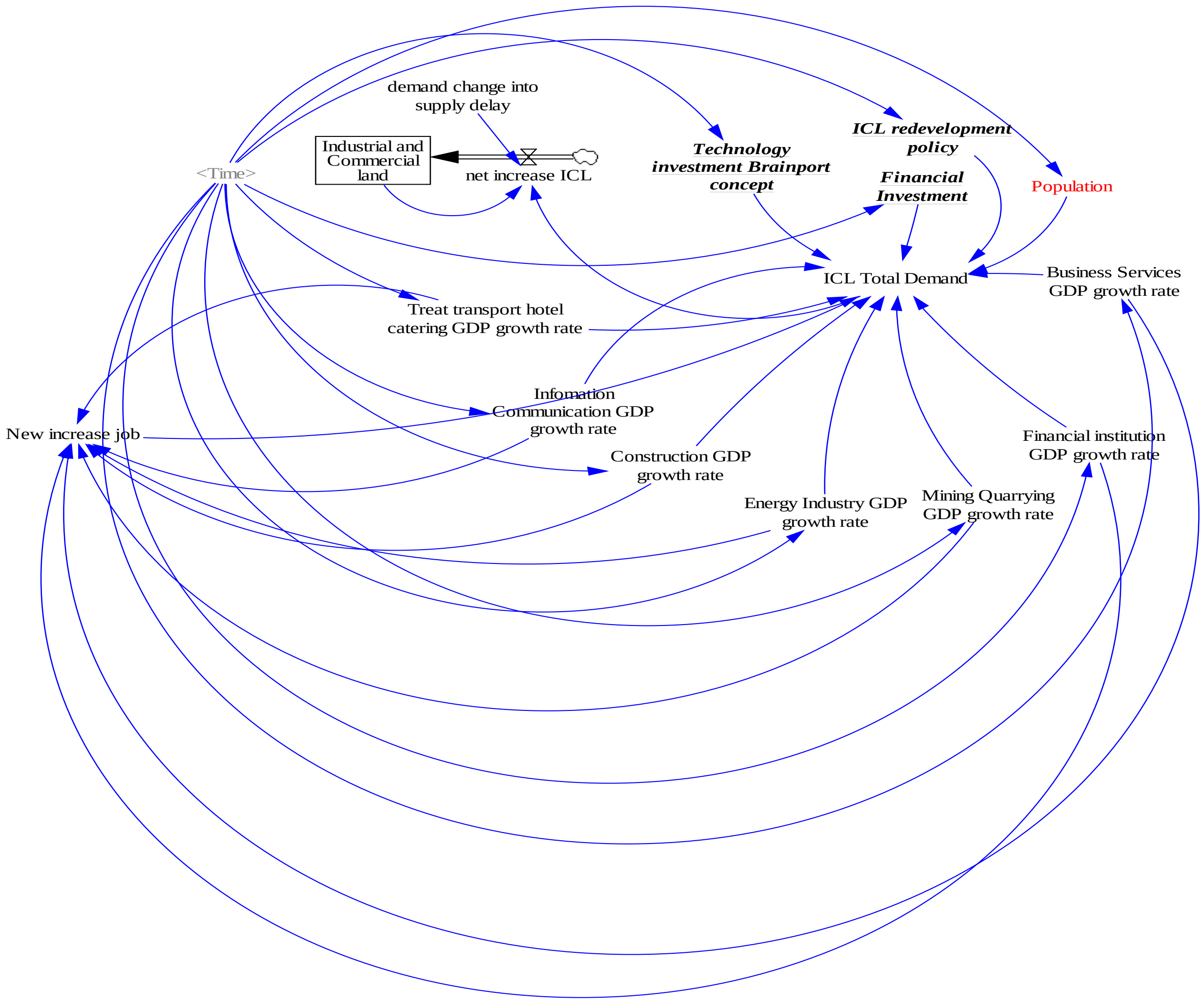


Figure 7: Industrial and Commercial land sub-system

Again the variables marked as bold, italic and underline are main interventions from policy makers point of view that later can be changed and will probably have huge effects on industrial and commercial land use. For now, we keep the effects of them as 0. The population variable is marked in red because it is the stock of population sub-system. Here we can only use linear regression method to predict its trend. Later the whole system, "population" stock connects "ICL total demand" directly. So the results may have slight difference. But both methods are correct and reasonable.

As you can see from the sub-system, we define "Industrial and commercial land (ICL)" as a stock which is determined by the inflow of "net increase of ICL". One thing we need mention is that industrial land in North Brabant is facing serious abandonment and redevelopment problems. That's more significant other than other provinces because North Brabant's position in Dutch even Europe industry.

In my previous study about Dutch industrial land, several current studies have been deeply researched. And one possible solution of these problems could be SER tools to limit the buying of new industrial land but redevelop the existing ones. (Blokhuis, E.G.J. et al. 2010, 2011). In our current study about North Brabant land use change, this possible solution is also included in the system. We call it "ICL redevelopment policy". For now the setting is 0, but later it might be changed to simulate different scenarios. Considering the current stagnating situation of industrial land redevelopment, we assume the stock of industrial land can only increase or stay stable but not decrease. And since commercial land is always connected with industrial land, we assume the stock of industrial and commercial land cannot decrease, either. So we need to keep in mind and set limitations to make sure that "net increase ICL" can never be minus. You can see the detailed settings in the equations table.

And the "net increase ICL" is the consequence of "ICL total demand", the current stock of "ICL" and the "delay of demand changing into supply". "ICL total demand" is mostly affected by different sectors GDP growth rates. We classify these different sectors of industry and commerce based on the data acquisition situation. So now in the system, "treat, transport, hotel catering GDP growth", "Information Communication GDP growth rate", "Construction GDP growth rate", "Energy industry GDP growth rate", "Mining Quarrying GDP growth rate", "Financial institution GDP growth rate" and "Business Services GDP growth rate" are simulated. Their coefficients are calculated in Matlab software with the help of historical data. This kind of GDP growth rates are only affected by time in our current system. For the further study, it can be a choice of making connections between total GDP and these separate GDP growth rates.

However, these various GDP growth rates have influences on "New increase job each year". In calculating the effects of each of them on "New increase job each year", we also use Matlab by analyzing historical data relationships.

In another hand, ICL total demand can also be affected by "Population", "New increase job each year” and several policies like what have listed in the system: “Technology investment Brainport Concept”, “ICL redevelopment policy (SER tools)”, “Financial Investment policy”, etc.

3.5.2.2 Equation identification

After the briefly introduction of the relationships between different variables, stocks and flows in “Industrial and Commercial land” sub-system, we now can give a table which shows the equations behind them. We have talked about several methods we use to calculate the coefficients in the previous sub-system like linear regression and with the help of Matlab for sophisticated situations. So here we only list their calculation methods in the remarks.

Table 7 Attributes relationships in industrial and commercial land sub-system

Numbers	**Attributes**	**Equations**	**Remarks**
1	Industrial and Commercial land	Integ (net increase ICL, 14500)	Integration of net increase ICL, initial value is 14500
2	net increase ICL	IF THEN ELSE((ICL Total Demand-Industrial and Commercial land)/demand change into supply delay>=0 , (ICL Total Demand-Industrial and Commercial land)/demand change into supply delay , 0)	Limit "net increase ICL" more or equal than 0 because of the stagnating industrial land redevelopment
3	demand change into supply delay	1 year	A reasonable hypothesis
4	Technology investment Brainport concept	0*Time	In the initial case, we set it as 0 effect, later in the scenario analysis, settings are changed
5	ICL redevelopment policy	0	In the initial case, we set it as 0 effects, later in the scenario analysis; settings might be changed as one policy intervention for redevelopment of ICL. For example, SRE tools.

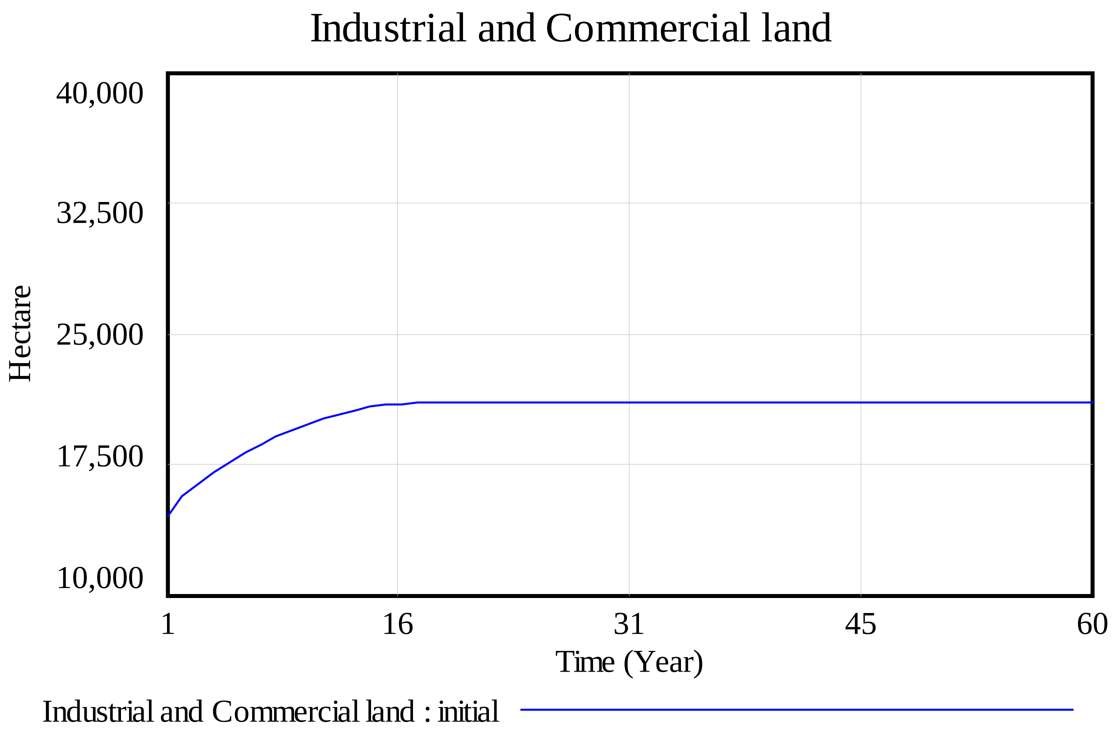
6	Financial Investment	0*Time	In the initial case, we set it as 0 effects, later in the scenario analysis; settings are changed as one policy intervention.
7	Population	10644*Time + 2e+006	Marked in red because it is the stock of population sub-system, here use actual data to calculate linear regression equation to simplify ICL sub-system
8	Business Services GDP growth rate	7.632-2.27*ln(Time)	Using regression to determine coefficients
9	Financial institution GDP growth rate	0.026*Time + 6.745	Using linear regression to determine coefficients
10	Mining Quarrying GDP growth rate	0.755*Time - 6.021	Using linear regression to determine coefficients
11	Energy Industry GDP growth rate	2.966-0.006*Time	Using linear regression to determine coefficients
12	Constructio n GDP growth rate	1.84-0.161*Time	Using linear regression to determine coefficients
13	Information Communica tion GDP growth rate	10.42-0.857*Time	Using linear regression to determine coefficients
14	Treat transport hotel catering GDP growth rate	3.774-0.367*Time	Using linear regression to determine coefficients

15	ICL Total Demand	Business Services GDP growth rate*110+Construction GDP growth rate*109.002-Financial institution GDP growth rate*14.8704+Financial Investment-Energy Industry GDP growth rate*101.805+Infomation Communication GDP growth rate*19.5784+Mining Quarrying GDP growth rate*0.73525-New increase job*0.0143272+Population*0.0453056+Technology investment Brainport concept+32.1251*Treat transport hotel catering GDP growth rate+ ICL redevelopment policy-88652.1	Matlab to calculate historical data and determine coefficients for each variable
16	New increase job	1004.61*Treat transport hotel catering GDP growth rate+820.568*Information Communication GDP growth rat+2359.73*Construction GDP growth rate+85.972*Mining Quarrying GDP growth rate-2043.96*Energy Industry GDP growth rate+103.773*Financial institution GDP growth rate+1255.93*Business Services GDP growth rate+6623.42	Matlab to calculate historical data and determine coefficients for each variable

3.5.2.3 Sub system calibration and validation

This sub-system also requires many calibration procedures. One of the main reasons behind it is the lack of sufficient data. With the help of Matlab, we can first have reasonable coefficients for each variable. This gives us the starting point for doing calibration process.

After running this sub-model, we can see the historical data are quite well simulated in the calibrated system. See the coming figure showing ICL stock trends in the past and future (starting point is year 1996, showed in figures as year 1). Also we can see another picture showing the “ICL total demand”, it gives a more complete understanding of ICL use change.



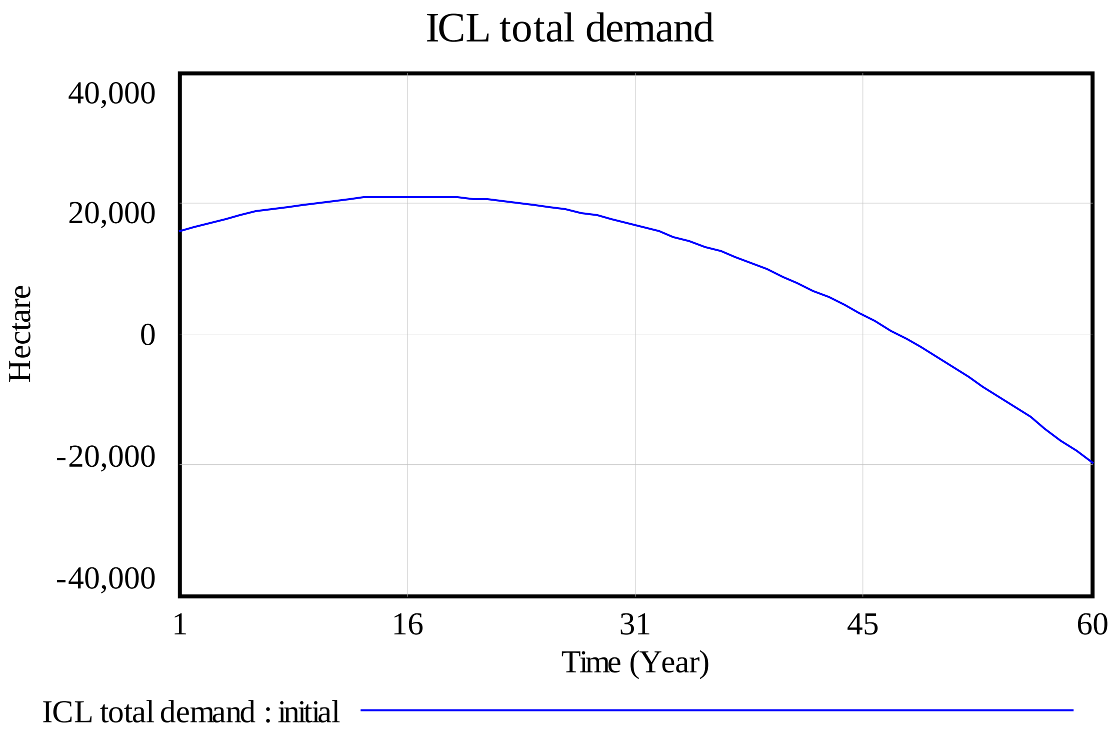


Figure 8: initial ICL sub-system simulation result

The stock first increases and then keeps at the same level after around year 15. It is mainly because of the stock cannot decrease after it reach its highest point. But this is based on no interventions scenario. In the coming parts, several scenarios will be established. Then we can see the differences between their simulation results.

We can validate the system by comparing historical actual data and simulation data, too. In the table below, you can see one example of the validation processes showing the differences and the rate of change about the stock of industrial and commercial land. For other variables, the same validation processes repeat and the results show the simulation reasonable and acceptable. What we want to mention here is that variable here “Population” influences the “ICL total demand” so much that the simplified sub-system cannot be as accurate as the whole system without the help of population sub-system. So we put the validation of this stock in the whole system. Here comes the result which shows the simulation also acceptable.

Table 8: Validation example of ICL sub-system

Year	**Historical data**	**Simulated result**	**Change rate**
1996	14788	14500	-1.95%
2000	17767	17619.5957	-0.83%
2003	19143	19090.07031	-0.28%
2006	20289	20131.2168	-0.78%
2008	21491	20889.6582	-2.80%

From this validation example, you can see clearly that the absolute value of change rates are all below 3% which means the simulation results are quite correspondent to the historical data.

3.5.3 Residential land sub-system

Residential land sub-system is influenced by renting demand and buying demand. For this sub-system, many attributes’ statistics are not available from CBS statistics data. So we also find other sources. Take this as an example. We want to get information about “Living space per capita hectare”. This attribute regulates how much space or hectares one person in North Brabant requires average for living. We cannot find specific data for North Brabant or the Netherlands. So we find a publication which shows this kind of information to help us. More details about other attributes and their relationships are as follows.

3.5.3.1 Variable, stock and flow

In this sub-system, besides dividing driving forces into demography, economy and policy (interventions) categories, we also add another category of driving forces. This category is about the Residential Land conditions, namely RL demand per year, floor area ratio, buy demand, current RL stock, rent price per hectare per month, living spaces per capita hectare, average purchase price, RL demand change into supply delay and so on. Detailed information is listed in table three.

You can see this sub-system for better understanding in figure 9:

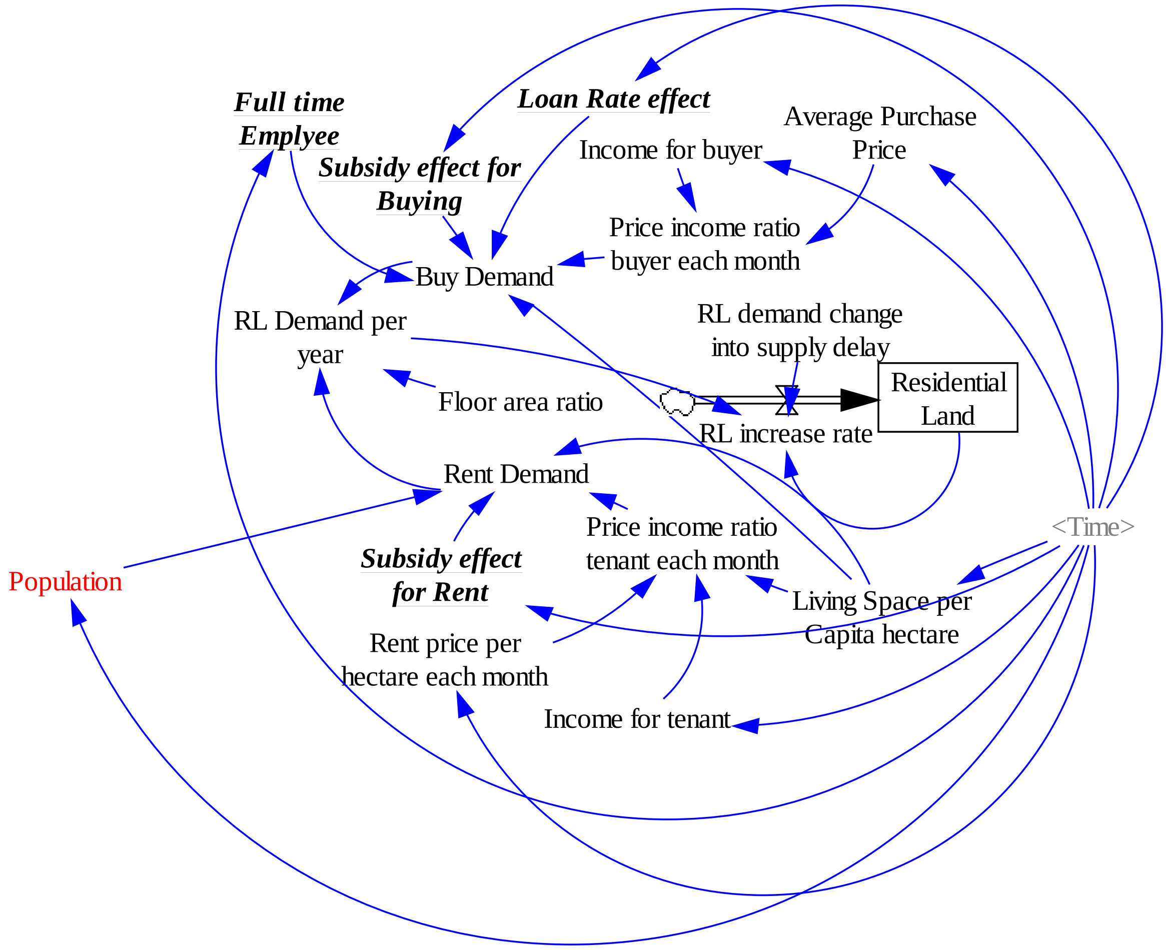


Figure 9: Industrial and Commercial land sub-system

Again the variables marked as bold, italic and underline are main interventions related to policy and might be changed later for scenario analysis. For now, we keep the effects of them as 0. The population variable is marked in red because it is the stock of population sub-system. Here we can only use linear regression method to predict its trend. Later the whole system, “population” stock connects “Rent demand” directly because we believe as long as there is human being, there will always be renting demand since every needs space to live. But population doesn’t have a straight relation with “Buy demand” because not all the people can afford the high price of housing.

As you can see from the sub-system, we define “Residential land (RL)” as a stock which is determined by the inflow of “RL increase rate”. There is also a “RL demand change into supply delay” which could affect the “RL stock”.

"RL demand per year" is the total amount of demands from buying and renting. "Floor area ratio" is the ratio between living space and basement space. We define this attribute in the thought of the differences between land use and tier buildings.

"Buy demand" are related to "Full time employee number", "Income for buyer", "Average purchase price", "Living Space per capita hectare" which means how much hectares (will be changed into square meters in calculation), "Price income ratio buyer each month" which is the ratio between housing prices per month and the buyer's income, and policy effects like "Loan rate effect" and "Subsidy effect for buying".

"Rent demand" is mostly connected with "population" because of human being's nature demand of space. Similar with "Buy demand", policy like "Subsidy effect for Rent", "Rent price per hectare each month", "Income for tenant" and "Living space per Capita hectare" are also influential attributes.

3.5.3.2 Equation identification

We now can give the table which shows the equations behind different variables, stock and flow with the remarks about calculation methods and other information.

Table 9 Attributes relationships in residential land sub-system

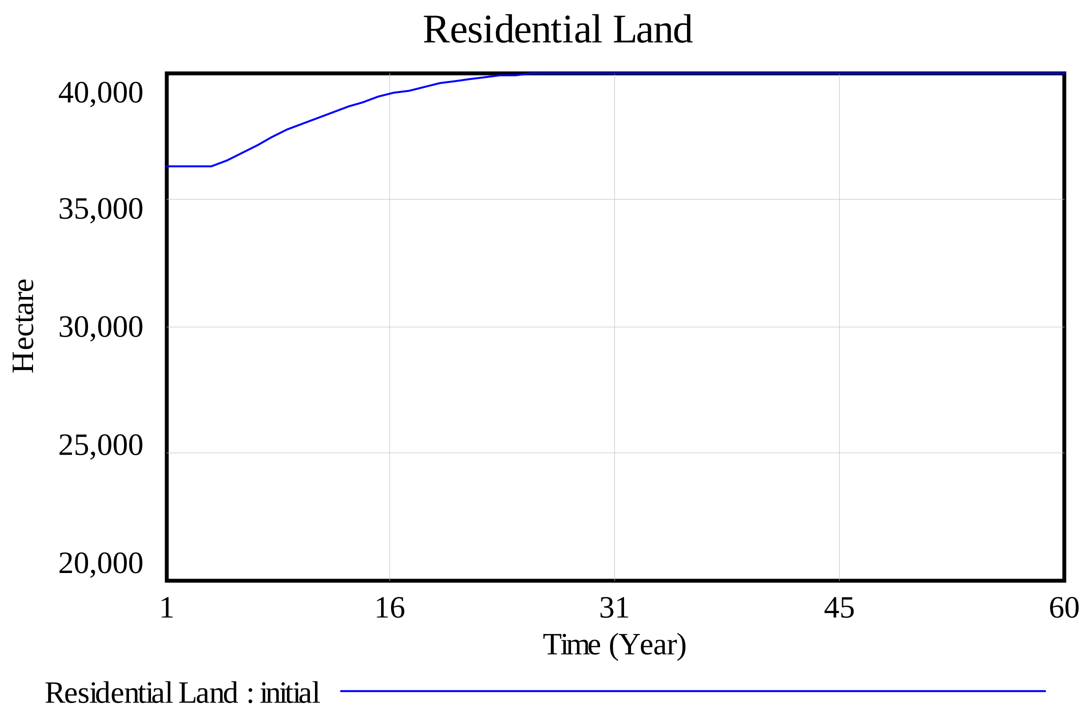
Numbers	Attributes	Equations	Remarks
1	Residential land	Integ (RL increase rate, 36323)	Integration of RL increase rate, initial value is 36323
2	RL increase rate	IF THEN ELSE((RL Demand per year-Residential land)>=0, (RL Demand per year-Residential land)/RL demand change into supply delay , 0)	This limitation is similar with the Industrial and Commercial land use sub-system. Once a residential area is developed, it will get no demolishment in the period we are going to look forward (43 years).
3	RL demand change into supply delay	1.5 years	Reasonable hypothesis
4	RL Demand per year	(Buy Demand +Rent Demand)/Floor area ratio	
5	Floor area ratio	1.4	Reasonable hypothesis for North Brabant compared with Randstad
6	Buy Demand	IF THEN ELSE(Price income ratio buyer each month<0.5, Living Space per Capita hectare*Full time Employee *(1-Loan Rate effect +Subsidy effect for Buying) , 0)	Careful calibration and reasonable hypothesis, limited buy demand related to Price income ratio, living space per capita, full time employee, loan rate, subsidy policy effects.
7	Full time Emplyee	(54.59*ln(Time) + 764)*1000	Using regression to determine coefficients
8	Subsidy effect for Buying	0*Time	In the initial case, we set it as 0 effect, later in the scenario analysis, settings are changed
9	Loan Rate effect	0.0001+0*Time	In the initial case, we set it as 0.0001 effect after the calibration processes, later in the scenario analysis, settings are changed
10	Income for buyer	1517*Time + 28909	Using linear regression to determine coefficients

11	Average Purchase Price	IF THEN ELSE(Time<=13,14360*Time + 10400,71850*ln(Time) + 79878)	Using linear regression to determine coefficients, combined with limitations. This are all because of the calibration process shows we need to give some limitations in order to better simulate the historical data.
12	Price income ratio buyer each month	(Average Purchase Price/180)/(Income for buyer/12)	After weighs recalculation
13	Rent Demand	IF THEN ELSE(Price income ratio renter each month>=0.5, Living Space per Capita hectare*Population*(1+Subsidy effect for Rent) , Population*Living Space per Capita hectare)	After calibration, this limitation and equation suits the best.
14	Subsidy effect for Rent	0*Time	In the initial case, we set it as 0 effect, later in the scenario analysis, settings are changed
15	Price income ratio renter each month	Living Space per Capita hectare*Rent price per hectare each month/(Income for renter/12)	After weighs recalculation
16	Living Space per Capita hectare	0.016+Time*3e-005	Based on the data found in a website, see reference; and use regression to find coefficients with time
17	Rent price per hectare each month	300000+5000*Time/12	Using linear regression to determine coefficients
18	Income for renter	1517*Time + 28909	Using linear regression to determine coefficients

3.5.3.3 Sub system calibration and validation

This sub-system also requires many calibration procedures. We have mentioned several of them in the previous equations table. One of the main reasons behind it is the lack of sufficient data from CBS.

After running this sub-model, we can see the historical data are quite well simulated in the calibrated system. See the coming figure showing RL stock trends in the past and future (starting point is year 1996, showed in figures as year 1). Also we can see another picture showing the "RL total demand per year", it gives a more complete understanding of RL use change. This sub-system has many similarities with ICL sub-system.



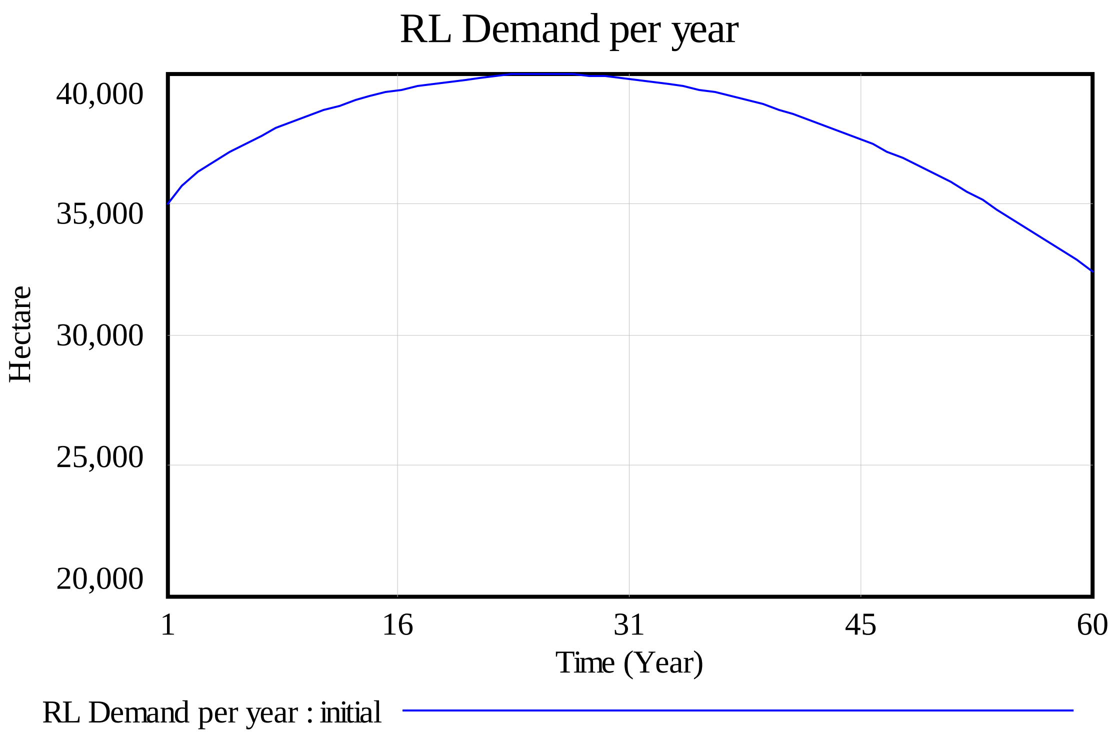


Figure 10: initial RL sub-system simulation results

The stock first keeps at the same level in the first around 4 years, then increases stably. Finally after year 24 it stops increasing. It is also because of the stock are quite enough and they cannot be demolished in a short period of time. The “RL demand per year” means in each year how much RL demand in total North Brabant needs. So firstly it increases and this causes the increasement of RL stock. However, after around year 24, it goes down stably and this doesn’t make the RL stock go down because of the previous setting that RL stock in a short period cannot be demolished.

In the table below, you can see the validation process of “Residential land”. For other variables, the same validation processes repeat and the results show the simulation reasonable and acceptable. What we want to mention here is that variable here “Population” influences the “ICL total demand” so much that the simplified sub-system cannot be as accurate as the whole system without the help of population sub-system. So we put the validation of this stock in the whole system. Here comes the result which shows the simulation also acceptable.

Table 10: Validation example of RL sub-system

Year	**Historial data**	**Simulated result**	**Change rate**
1996	36323	36323	0.00%
2000	37713	36528	-3.14%
2003	38849	37463	-3.57%
2006	38346	38237	-0.28%
2008	38691	38657	-0.09%

From this validation example, you can see clearly that even though two absolute values of change rates are above 3%, they are just slightly over 3% and it is mostly related to the not sufficient data. But we should focus on the trends. We think this simulated sub-system is still acceptable based on the simulation trends.

3.5.4 Agricultural land sub-system

Agricultural land sub-system has small differences with other land use sub-systems. It has not only one inflow, but also an outflow. The inflow is for sure because of the demand of AL, while the outflow is mostly because of many AL has been changed into other land use types because of the development, economy, and environment reasons. For example, most of the increase of ICL is from the decrease of AL. Parts of the increase of water area is also from previous AL. With all the historical data, we can have a clearer view about these kinds of changes. For all the historical data, please see the appendix 7.1.

3.5.4.1 Variable, stock and flow

In this sub-system, we combine the identified driving forces into demography, economy and policy (interventions) categories together. Even more, we also have a category of environmental driving forces for AL sub-system. These driving forces are mostly related to the decrease of AL such as “change into other land”, “Net increase ICL”, “Water land from al ratio”, “ICL from AL ratio” and so on. Detailed information is listed in table two. Firstly you can see the sub-system for better understanding in figure 11:

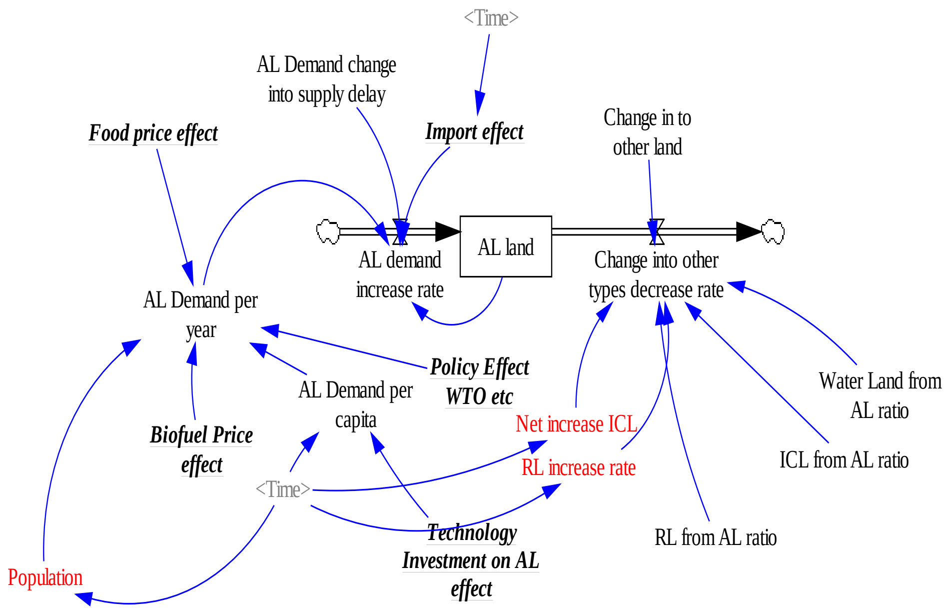


Figure 11: Agricultural land sub-system

Again the variables marked as bold, italic and underline are main interventions later with current zero effects. The three red variables are calculated from other sub-system. Here we can only use linear regression method to predict its trend. So in the validation part later, we are also going to use the whole system to validate this sub-system.

As you can see from the sub-system, “Agricultural land (AL)” is determined by the net inflow. And the net inflow is the difference between “AL demand increase rate” and “Change into other land use types’ rate”.

“Technology investment on AL effect” decreases the “AL demand per capita” sharply. That’s why people don’t need so much AL as before. However, “WTO effect” “Milk and other agricultural products export effect”, “Food price effect”, ”Biofuel price effect” can also have influences on “AL demand”.

Other land use types’ increase causes the outflow of AL. So we use historical data to simulate these type changing trends.

3.5.4.2 Equation identification

Equations behind AL sub-system are listed below with different remarks:

Table 11 Attributes relationships in agricultural land sub-system

Numbers	Attributes	Equations	Remarks
1	AL land	Integ (AL demand increase rate-Change into other types decrease rate, 322640)	Integraion of (AL demand increase rate-Change into other types decrease rate), initial value is 322640
2	AL demand increase rate	IF THEN ELSE((AL Demand per year*(1-Import effect)-AL land)>=0 , (AL Demand per year*(1-Import effect)-AL land)/AL Demand change into supply delay , 0)	Limitation because of food security. If after import, AL stock still cannot fulfill all AL needed for the whole country, then the increase rate cannot be less than 0.
3	Change into other types decrease rate	IF THEN ELSE((ICL from AL ratio*Net increase ICL+RL from AL ratio*RL increase rate +Water Land from AL ratio +Change in to other land)>=0, ICL from AL ratio *Net increase ICL+RL from AL ratio*RL increase rate +Water Land from AL ratio+Change in to other land , 0)	A reasonable limitation
4	AL Demand change into supply delay	1 year	Reasonable hypothesis
5	AL Demand per year	AL Demand per capita*Population*(1+Biofuel Price effect +Food price effect +Policy Effect WTO etc)	Determined by all processes of calibration of historical data.
6	AL Demand per capita	IF THEN ELSE(-0.001*Time + 0.14-Technology Investment on AL effect>0.1 , -0.001*Time + 0.14-Technology Investment on AL effect , 0.1)	Determined by all processes of calibration of historical data.
7	Food price effect	0	Initial setting
8	Bio-fuel Price effect	0	Initial setting

9	Policy Effect WTO etc	0	Initial setting
10	Technology Investment on AL effect	0	Initial setting
11	Import effect	0*Time	Initial setting
12	Change in to other land	530	Historical data review finding
13	RL from AL ratio	1	Historical data review finding
14	ICL from AL ratio	1	Historical data review finding
15	Water Land from AL ratio	75	Historical data review finding

3.5.4.3 Sub system calibration and validation

This sub-system requires lots of calibration procedures because of the uncertain technology investment effects and other effects.

After running this sub-model, we can see the historical data are quite well simulated in the calibrated system. See the coming figures showing AL stock trends and demand increase rate and change into other types decrease rates.

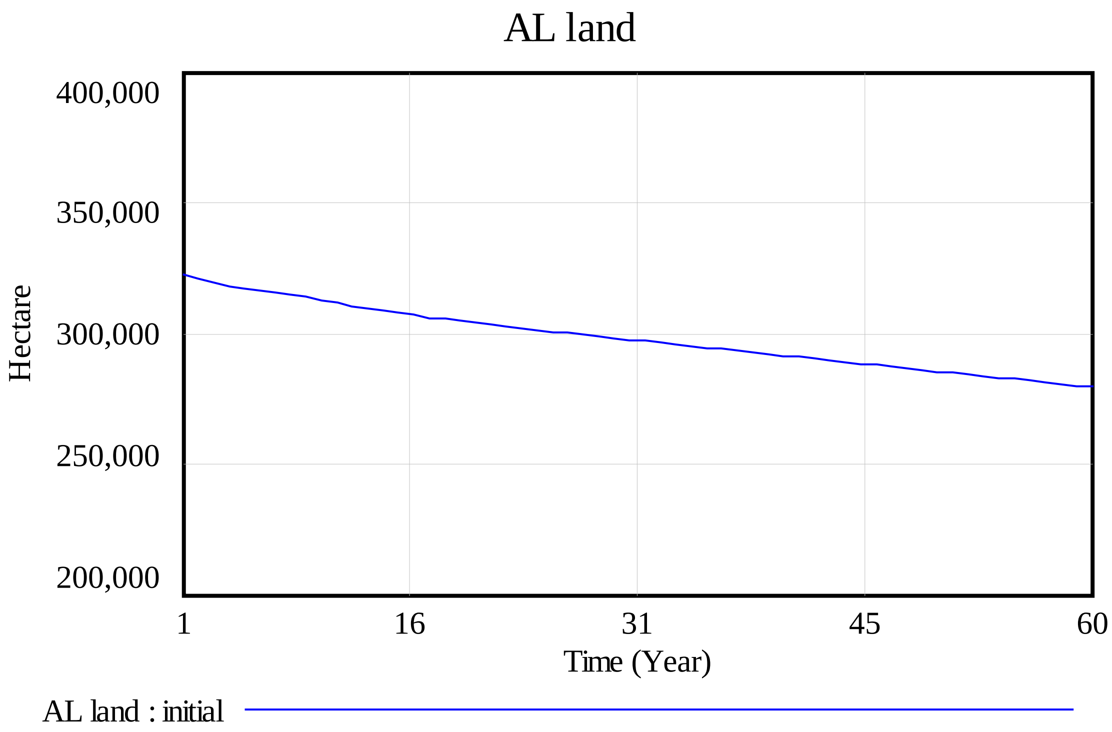


Figure 12: initial AL sub-system simulation result

This picture makes it clear that AL is decreasing smoothly.

In the validation part, “Population”, “New increase jobs”, “Net increase ICL” and “RL increase rate” affect AL so much that the simplified sub-system cannot be as accurate as the whole system. So we put the validation of this stock in the whole system. Here comes the result which shows the simulation also acceptable.

Table 12: Validation example of AL sub-system

Year	**Historical data**	**Simulated result**	**Change rate**
1996	322640	322640	0.00%
2000	316958	317068	-3.14%
2003	314204	314984	-3.57%
2006	312302	311663	-0.28%
2008	310522	309566	-0.09%

From this validation example, you can see clearly that the absolute value of change rates trends are becoming below 3% which means the simulation results are correspondent to the historical data.

3.5.5 Verification and Validation

Verification is doing things correct, and validation is doing right things. We have analyzed each sub-system and validated them separately. So we can say in simply way, the verification process has been practiced. For now, we need to validate the whole system. For the whole system's structure, you can see appendix 6.4.

Here we add one variable called "Rest Land" to limit North Brabant's different land use types. "Rest land" includes forests, recreational land and other land use types, so it could never be too little. You can see the simulation results for different land use types and the rest land below:

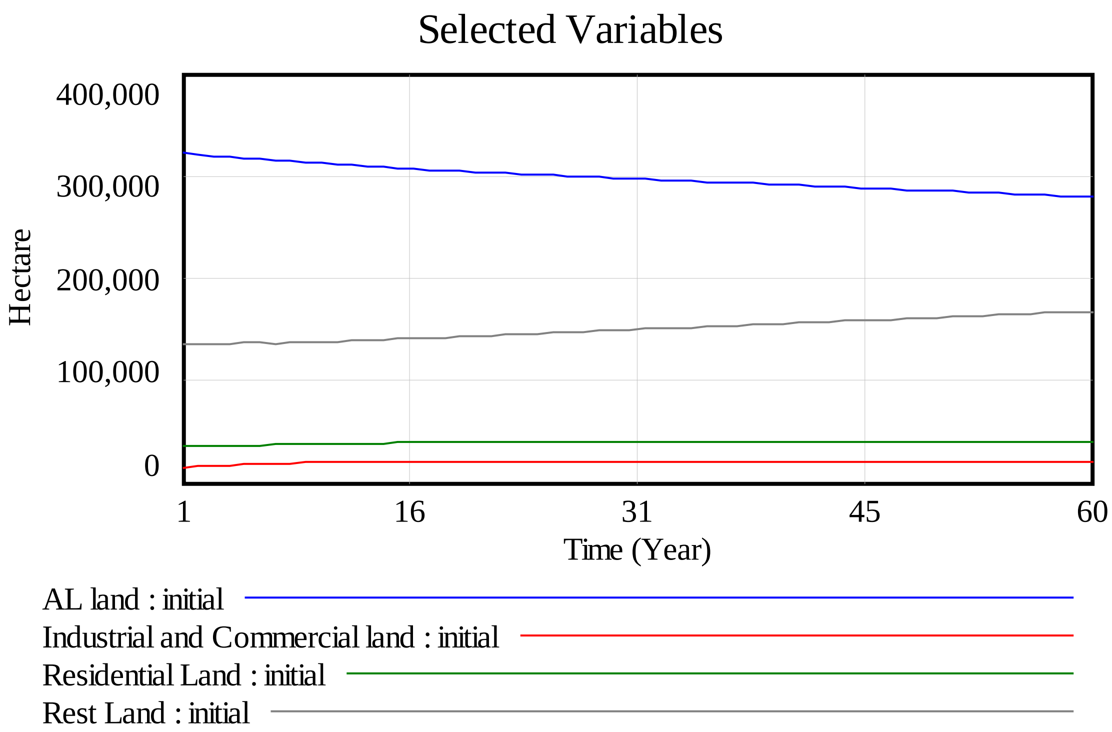


Figure 13 Whole system initial run result of different land use types

In this picture, you see that with the decrease of AL, rest land is keeping increasing. ICL and RL firstly increases then come to a stable status.

And we have validated each sub-system already. Here with the new updated data from 2009 and 2010 for population, we can simply validate the whole system to see if our model can simulate the future trends from the population perspective.

Population simulation result in graph, this displays the trends clearer than just numbers.

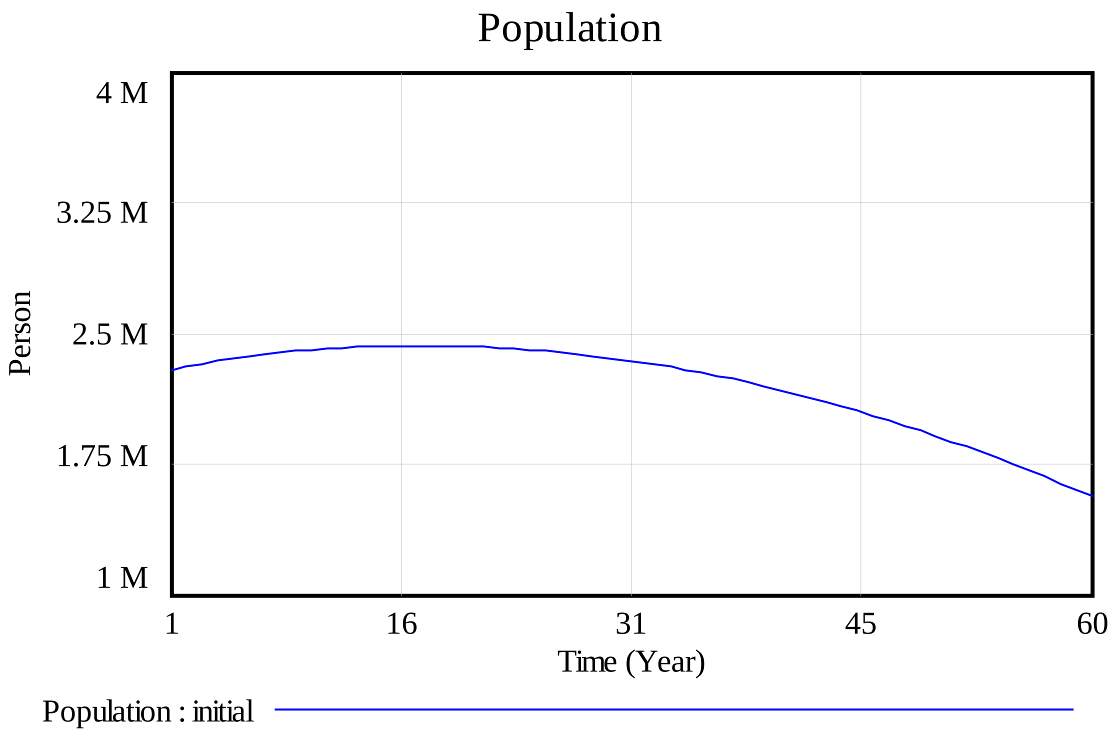


Figure 14 Whole system initial run result of population

From it, we know that population will come to its peak in around year 16 (which is year 2011). Then population keeps going down. Some changes need to be done to prevent too many population losing.

The predicted data for population in 2009 and 2010 are 2,425,330 and 2,427,960 respectively. The updated actual statistical data are 2,434,560 and 2,444,158. Together with the data from 2008, we can see that the trends are correctly predicted. However, from this trend you can also see that our simulated result's will have more and more differences with histortical data later if this trends of change rate continues. So later in the scenario part, we will try to change this condition by combining the WLO scenario settings. In short, our simulation results are quite similar in their "Regional Community" scenario, so we will based on this scenario to adjust our model for the scenario analysis.

Table 13: Validation of whole system from population perspective

Year	**Historical data**	**Simulated result**	**Change rate**
2008	2424827	2423161	0.07%
2009	2434560	2425330	0.39%
2010	2444158	2427960	0.67%

In "Welvaart en Leefomgeving (WLO)", four scenarios in 2040 have been created and several studies executed by using LUMOS to simulate regional spatial strategies. Moreover, we will also have some baselines for the whole system's validation. As we have validated the population part, now we only use the available baselines to validate the land use variables in the whole system.

There are four scenarios in WLO study, namely “Global economy”, “Strong Europe”, “Transatlantic market” and “Regional communities”. For the specific description, we will do that in the next part about scenario construction. For validating the whole system, now we only show some results for four scenarios from different perspectives.
Firstly we can validate the “Full time employee” in the RL use sub-system. It is a very important variable later in the scenario analysis because it can determine the demand of residential land in a high level. From our simulated resulte, we can calculate that from year 2002 to year 2020, the “Full time employee” increases 0.5% per year. And in the WLO scenarios, the “Transatlantic market” does have an increase rate for this variable. Moreover, for year 2020 to year 2055, our simulated result shows a 0.1% increase rate, while the highest increase rate in the four WLO scenarios from year 2020 to year 2040 is 0.1% per year. We use different time range because in our model we simulate up to the 60th year from year 1996 (year 2055), but in WLO study they only predict up to year 2040. In the following part about scenarios analysis and construction, we will always compare our simulation results from a 60 year range with their 40 year range prediction. As long as the average increase or decrease rate is the same scope as they do, we can say the simulation can be validated. Also from this comparison, we can see that in the short run, the state of our model is in “Transatlantic market”.

Table 14: Validation of whole system from full time employee perspective

	Global economy		**Strong europe**		**Transatlantic market**		**Regional communities**		**Initial SD**	
	2002 to 2020	2021 to 2040	2002 to 2020	2021 to 2040	2002 to 2020	2021 to 2040	2002 to 2020	2021 to 2040	2002 to 2020	2021 to 2055
	Average growth per year (%)									
Overgangszone(Including North Brabant)	0.9	0.1	0.3	-0.1	0.5	-0.3	-0.1	-0.7	0.5	0.1

Considering the RL land, we would not validate it now because we find out that the current stock of North Brabant’s RL is quite high. So the new increase demand ratio (New demand increase per year/ RL stock) is 0.02% in our simulated result, while in WLO scenarios, the lowest increase rate is 0.2% per year. From here we can recognize that North Brabant’s RL market is not that efficient which needs policy interventions in the future.

Now come to the ICL sub-system. You could see another table shows the comparison results.

Table 15: Validation of whole system from ICL growth rate perspective

	Global economy	Strong europe	Transatlantic market	Regional communities	Initial SD
	2002 to 2040	2002 to 2040	2002 to 2040	2002 to 2040	2002 to 2055
	Average growth per year (%)				
Overgangszone(Including North Brabant)	1.0	0.55	0.54	0.03	0.3

From the comparison, you can see that our simulated result is also within the scope of these four scenarios. Our model shows a ICL state in between "Transatlantic market" and "Regional communities".

Talking about the AL, please see that following table. From it, you can also see that our SD model's simulation result is in the range of these four scenarios and the state of AL is somewhat related to "Strong Europe" and "Transatlantic market" scenarios.

Table 16: Validation of whole system from AL growth rate perspective

	Global economy	Strong europe	Transatlantic market	Regional communities	Initial SD
	2002 to 2040	2002 to 2040	2002 to 2040	2002 to 2040	2002 to 2055
	Average growth per year (%)				
Overgangszone(Including North Brabant)	0.42	-0.58	-0.13	-0.8	-0.22

After all these validation procedures, we should say that our model can simulate the past experiences quite well and also can simulate the future trends reasonably. Now we are going to do scenario analysis.

3.6 Scenario analysis

In this part, we will first explain each of driving force in our SD model and also the interventions. During the explanation, we will identify the unpredictability and the inner connections between them. Then we can find the most fundamental and unpredicted driving force or intervention.

WLO scenarios will offer us the actual data of their prediction from year 2002 to year 2040.

So after analyzing each of their four scenarios, we will find out the most related two scenarios to our SD model and put their prediction results into our model. In that way, we can use methmatical method to calculate the coefficients or equations behind each intervention or driving force. After all the calculation procedures, we can find out which ones are the most important.

Based on the unpredictability and impact of each driving force or intervention, we can have a matrix. The most unpredicted and important ones would be chosen to make our own scenarios. Note that some of these can be combined together into one new variable.

Then we can create our own scenarios. Basicly we will have four scenarios. However, after analyzing, we can only choose three of them to do the model test, namely the worst case, the best case and the most possible case. For the future trend determination of these variables in each scenario, we will use adjusted WLO settings.

3.6.1 Intervention and influential driving force identification

From all the mentioned driving forces and possible policy interventions, we choose the most important and influential ones now. And explain their explicit information and discuss about their effects to the whole system or a specific sub-system.

All the variables in the system are identified driving forces, but only several of them will be used to construct the scenarios later. They are the most influential and important ones in our point view considering the current economy and policy situations. We discuss their importance and uncertainty now. After this discussion, we will find out the most unpredictable driving forces or interventions. Of course, we can also use commen sense to figure out which ones are the most important ones. However, for the accurate study, we also need the coming step to find out the most influencial ones with the help of WLO scenarios.

In the population sub-system, we think the followings are important ones:

1) Birth rate: for this driving force, we check the historical data from 1960 up to now. It shows that in 1960 the birth rate is 23.8 per 1000 persons; while it is currently 10.4 per 1000 persons with smoothly decrease during all these years. This trend makes the population increase from new-born children decrease sharply. We could say that this variable is very easy to predict but would have high impact.
2) Death rate: we also look back to year 1960 and track the trend up to now of death rate. It shows that during all these years, the death rate has a smaller increase rate compared with the decrease rate of birth rate. In 1960, the death rate is 6.7 per 1000 persons and now it is around 8.0 per 1000 persons each year. So the trend of this variable is also predictable. Of course, this one is also very influencial.
3) Net birth rate: from the above analysis, we can say that up to now the birth rate is bigger than death rate, but the difference between them is becoming smaller and smaller and it will turns in to negative in the future if this trend keeps. We should say that these first

three driving forces are mostly kind of certain without too much uncertainty.

4) Immigration policy (Brainport concept): North Brabant is a big province for industry. And Eindhoven which is the fifth biggest cities in the Netherlands is chosen as the smartest area of the world. Many immigrants come to North Brabant because of its strategy to compete with other areas in the world. The immigrants make up a large part of the provincial society. The immigrant number from other countries in this area keeps increasing from the year with some fluctuation in between, from 4312 in 1960 up to 18856 in 2010. However, because of the political reasons, Dutch government has announced several policies against new immigrants. It is becoming harder and harder for people to come to this country for migration. What's worse, many people will be sent back to their own countries like Iraq, Iran and so on. Even for the high knowledge immigrants, the salary requirements have arisen so much that probably many high tech immigrants cannot live here anymore. Since the previous government just fell down and the new election will be in this September, we do have much uncertainty about the actual policy against immigration. However, we hold a pessimistic attitude on this issue. And we think this driving force has a huge impact on population system in North Brabant. Later we will prove this by using the WLO scenario data.
5) Education budget effect:
   Because of the bad economy situation in Europe, not only migration becomes harder and harder, but also the education budget has been cut down quite a lot. This influences the Dutch and international students a lot. There will be much less scholarships and allowances for students. For Eindhoven, Tilburg and other high tech and knowledge based cities in North Brabant; this is definitely not good news. It does avoid people from outside to come for studying and education. And the policies have been set down which we believe it for sure would last for many years. So this driving force is kind of certain. However, the impact could be quite high considering the population system's huge effects on other land use sub-systems.

In ICL sub-system, important driving forces are as follows:

1) Technology investment (Brainport concept): more money investment for technology would stimulate the area and even the whole country's development. However, considering the current economy situation and the stagnating state of the Dutch industrial areas, this would not have too much effect on the near future. And it is kind of certain because the current stock is almost enough for the coming years and cannot be demolished or redeveloped based on the loose policy restrictions.
2) Financial investment: this is the same as the technology investment. But for both of them, we should mention that the government has tries to establish more and more public private partnerships considering the development of construction, infrastructures and so on. So it is also possible that in around 30 years later, this kind of technology and financial private investment would have their effects.

The RL sub-system is mostly defined by population trends which we have already defined before. But it does have other interventions like "subsidy effect for buying and renting". The increase of them would definitely increase the demand of buying and renting, vice versa. Also for the buying demand, the full time employee level would also have positive effect on it.

1) Subsidy effect for buying: in the previous time, the government used many friendly policies to stimulate people buying a new house. For example, people with high income even can get almost the same amount of the tax they paid back. This kind of policy had quite a huge influence on the house market which makes people buying more than two houses and many houses have been left unused. Now the government is trying to change this situation with fewer subsidies for buying. Since in the current initial whole system, we give the subsidy for buying a zero effect. Later in the scenario analysis, we will make this effect as minus to be correspondent with the new trend of buying house subsidy.
2) Subsidy effect for rent: people would always need a place to live. With less buying, more renting houses are needed. However, subsidy effect for renting is not that important considering the rigid demand of housing. And the trend of it is some kind of certain because of the low economy growth rate.
3) Full time employee:
   We consider it as the most effectible driving force for new migrations in North Brabant because it can somehow connect to the new increase job in population sub-system. The effects are so huge that we cannot ignore. So we should say this driving force is quite effectible but the trend of it is also not certain in the future.
4) Loan rate effect:
   This is used to simulate the trend of loan rate effect. We assume this as not that important driving force in the whole system. Later in the scenario case, we can prove this. The predictability is somehow high because the policy doesn't change a lot.

As you can see from the previous sub-system of AL, it is mostly affected by the other land use types. So we only need several sentences to explain the influential variables:

1) Policy like WTO effect, Import effect and export effect: the Netherlands has been in WTO for a long time, so big differences from now on.
2) Technology Investment on AL effect: without big breakthrough in AL technology, this also would not affect a lot.
3) Food Price and bio-fuel price effect: this is mostly related to the agricultural products. However in a short period of time, this would not change the situation because of more profits from other land types than agricultural land.
4) Import effect: this is bit important for the AL. And the trend is still not quite clear.

As we have mentioned before, AL is mostly decreased because of the changing into other land use types. So in our coming scenario analysis, these variables would not be used to formulate the scenarios. We focus more on the most profitable land use types like RL and ICL and the variables that would affect them.

Now after analyzing the driving forces and interventions, we can now have a clear view that the most unpredictable ones are “Immigration policy (Brainport concept)”, “Full time employee”, “Education budget effect”, and “Subsidy for buying”.

And based on our commen senses, we would like to assume the most effective variables are “Immigration policy (Brainport concept)”, “Full time employee”, “Subsity for buying”, “Net birth rate” and “Education budget effect”. For the most convicable proofs please see the following part which introduces the application of WLO scenarios in our SD model.

Based on WLO scenario study and the system we have proposed, we can have some basic understanding about the scenarios we are going to create, along with extra information. In this part, we want to explain the four scenarios WLO has proposed to predict the future trends from year 2002 to year 2040.

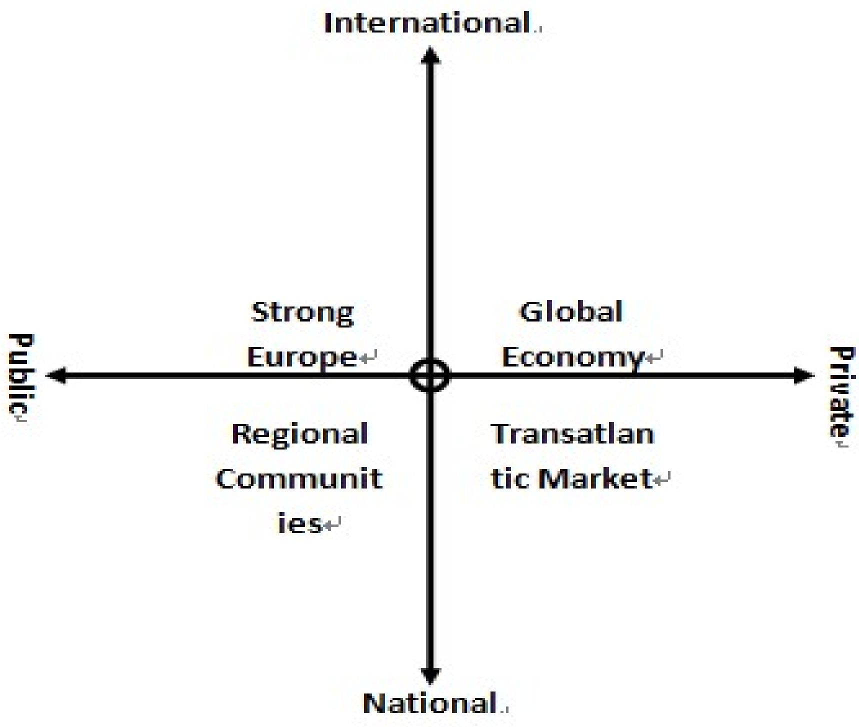


Figure 15 WLO scenarios

They create these four scenarios based on two key uncertainties: sovereignty versus co-operation and public versus private approaches to problems. Now we explain each of their characteristics one by one.

In the scenario “Global Economy”, the EU expands further eastwards. Besides Turkey, countries like Ukraine will also come as a member. The WTO negotiations are successful, and there is momentum in international trade. However, the participating countries do not integrate in politics. International cooperation in other areas beyond trade issues fail. Like in “Transatlantic Market”, government highlights the responsibility of citizens. Compared with “Transatlantic Market” scenario, the growth in labor productivity in this scenario is even more caused by the strong global economic integration. The growth of both the material prosperity and the population (mainly by immigrants) in this scenario is therefore the highest.

In the “Strong Europe” scenario, there is much attention to international cooperation. The European institutions are reformed and successful countries give some of their sovereignty. This makes Europe an influential player in the economic and political world stage, and international environmental issues can be coordinated addressed. Turkey will join the European Union. The socio-economic policy is like in the scenario “Regional Communities” focused on solidarity and a steady income, through increased investment in education and research, and by the larger labor market growing more than in “Regional Communities”. The economic growth and population growth, especially by immigration are higher in this scenario.

In the scenario “Transatlantic Market”, the enlargement of the European Union does not succeed. Countries solve problems rather at national level. However, trade between the United States and Europe is extensively liberalized, so that eventually a new internal market comes out. This scenario is characterized by a government that emphasizes the personal responsibility of citizens. The welfare state is reduced and public facilities are going to be retrenched. Because the power of unions decreases, the labor market becomes more flexible. The retrenchment of the social security employment grows, the international competition increases the incentive to innovate, and the larger income differences make study attractive. The growth of labor productivity and economic growth are higher than in the Strong Europe scenario, while the population only hamoderate increases.

In the scenario “Regional Communities”, countries adhere strongly to their own sovereignty. Also, global trade liberalization is not from the ground, making the world falls apart into a number of trading blocs. However, the relatively low pressures make population and economic growth modest. Due to lower incentives in social security and the high tax and premium rates, the employment rate is relatively low and unemployment high. Less competition inhibits the need for businesses to innovate. By the small differences in income, the incentive to invest in education is limited. Labour increasing every year and little economic growth is low.

After the description of all these four scenarios and the validation process of the whole system, we can say that the current North Brabant land use and human interaction SD system based on our point of view is either in “Regional Communities” or “Transatlantic Market” or between. Some of the obvious characters can be high tax, low employment increase, low education investment and so on.

Only knowing the most related and connected scenarios in their study is not enough. In order to find the most influential driving forces or saying prove most significant interventions in our system as we assumed before, we would like to use their two scenarios’ prediction results to calculate the coefficients for each intervention. Then we can compare the changing rate of each variable after the whole system comes to their predicted results. The most effective driving forces are the ones with lowest changing rates.

Based on the WLO “Transatlantic market” scenario, population sub-system would have a yearly 0.3% increase since year 2002. After putting all the other predicted increase rate of this scenario into the system, we can find out the previous marked interventions or variables’ new equations. In “Regional communities” scenario, population would have a yearly 0% increase since year 2002. By calibrating method, we can also find another equation for each of the marked variables. Now only the equations need to be listed, but also the changing rate of these variables should be mentioned. With these changing rates, the variables can have influences on the system as WLO has predicted. Based on these changing rates of the variables, we can find the most effective ones. Combined with the previous assumed influencial variables and the identified most unpredictable ones, we can make the final matrix of all the variables. You can see the results of this sub-system below:

Table 17 Influenticlal driving forces in population sub-system and their equations in two WLO scenarios

	immigration policy Brainport Concept	Education Budget effect
Initial Settings	0*Time	0*Time
Transatlantic Market: 0.3% per year increase for population	IF THEN ELSE(Time<=7, 0 , 20500)	IF THEN ELSE(Time<=7, 0 , 4600)
Regional Communities: 0% per year increase for population	IF THEN ELSE(Time<=7, 0 , 14000)	IF THEN ELSE(Time<=7, 0 , 2500)
Variables changing rates from TM to RC	0.3	0.46

For other driving forces in population sub-system, they are not fundamental driving forces like “Education attractiveness” which in our model is determined by “Education budget effect”. So we will not calculate the importance of them. Also ther is other driving forces which cannot be well intervened in the current days like the natural birth rate and death rate. So also not include them for analysis. We only focus on the ones with high unpredictability.

For other sub-systems, the procedures of finding the most effective variables are the same. So we only list all the other tables for these sub-systems now. Since the “Technology investment effect” and “Financial investment effect” on ICL have been identifies as not so influential in our case, we will only list the equations behind them in each scenario.

Table 18 Influenticlal driving forces in ICL sub-system and their equations in two WLO scenarios

	Technology Investment effect	Financial investment effect
Initial Settings	0*Time	0*Time
Transatlantic Market: 0.5% per year increase for ICL	IF THEN ELSE(Time<=7, 0 , -8300)	IF THEN ELSE(Time<=7, 0 , -13000)
Regional Communities: 0.04% per year increase for ICL	IF THEN ELSE(Time<=7, 0 , -6000)	IF THEN ELSE(Time<=7, 0 , -10000)
Variables changing rates from TM to RC	0.3	0.23

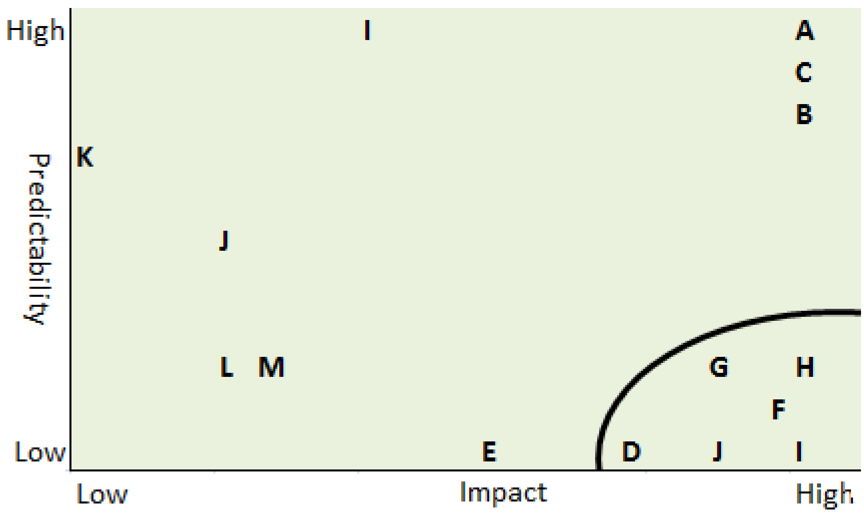
Table 19 Influenticlal driving forces in RL sub-system and their equations in two WLO scenarios

	Full time Emplyee	Subsidy effect for Buying	Subsidy effect for Rent
Initial Settings	0*Time	0*Time	0*Time
Transatlantic Market: 0.6% per year increase for RL	IF THEN ELSE(Time<=7,(54.59*ln(Time) + 764)*1000 , (54.59*ln(Time) + 680)*1000)	IF THEN ELSE(Time<=7, 0 , 0.2)	IF THEN ELSE(Time<= 7, 0 , 0.06)
Regional Communities: 0.2% per year increase for RL	IF THEN ELSE(Time<=7,(54.59*ln(Time) + 764)*1000 , (54.59*ln(Time) + 390)*1000)	IF THEN ELSE(Time<=7, 0 , 0.19)	IF THEN ELSE(Time<= 7, 0 , 0.07)
Variables changing rates from TM to RC	0.42	0.05	0.14

However, in this sub-system, we should mention that the Full time employee ratio changes a little bit high because of the new settings in another scenario applies the trend of it. If we keep the first scenarios' settings for it, then the RL would never change into 0.04% per year no matter what values we will give to subsidies' effects. In other way, the subsidy effects can only persome a good influence on RL on the basis of "Full time employee" changes. So we also consider "Full time Employee" as a very important and quite influential driving force.

For other interventions like "Loan rate effect", there would be much influence on the whole system after the calibration of the new equations. So we consider them as not most influential.

Above all the descriptions, we can give a matrix now.



A: Birth rate; B: Death rate; C: Net birth rate; D: Immigration policy; E: Education budget effect; F: New increase job each year; G: Technology investment; H: Financial investment; I: Subsidy for buying; J: Subsidy for renting; K: WTO, import and export effect; L: Food and bio-fuel price; M: Import effect

Figure 16: most influential driving forces' predictability and impact

So up to now, we have proved that the most influencial attributes in our SD model are: "Full time employee", "Subsidy effect for renting and buying", "Financial inverstment on ICL", "Technolgy investment" and "Immigration policy". As they already are the most unpredictable variables, we will combine them into two new categories to construct our own model.

After all the above discussion, we think all the significant driving attributes or policy interventions in the darker area of the matrix can be put into two categories, namely "policy interventions effect" and "Economy situation". We now give a general introduction of these two categories of driving forces. Later we will use these two categories to construct the future scenarios.

1) Policy interventions: it is the combination of immigration policy effect and subsidy effects for renting and buying;
2) Economy situation: this is related to ful time employee in RL sub-system, financial and technology investment in ICL sub-system.

Choose we use these two new categories to make four scenarios. We will explain each created scenario separately. And finally we will choose three scenarios from them to do the simulation analysis. In each of these scenarios, future trends of these identified driving forces will be analyzed using current study and conditions.

3.6.2 Scenario construction

In the previous part we have described that, from our point of view, the state of the economy and the policy of immigration and education are the two main uncertainties. So we would like to use them for making the scenarios.

First of all, in the following figure, you can see the two most important and most unpredictable (uncertain) clusters/factors in two axes which have a high and a low amount.

Considering the "Economy situation", when the state of the economy is good, consequently the housing market, and the industrial and commercial land will be influenced. On the other hand, when the state of the economy is bad, we face with a kind of economic crisis and the financial situation of the buyers and investors would be bad.

Regarding the "Policy intervention", when this issue is high, the restriction of policy is big. Immigration policy is quite strict that the population would be less than the initial case. When the issue of policy intervention is low, then the migration would become easier in the future. For subsidies there will be fewer subsidies for renting and buying.

So we could make four scenarios in the four specific areas of the figure below:

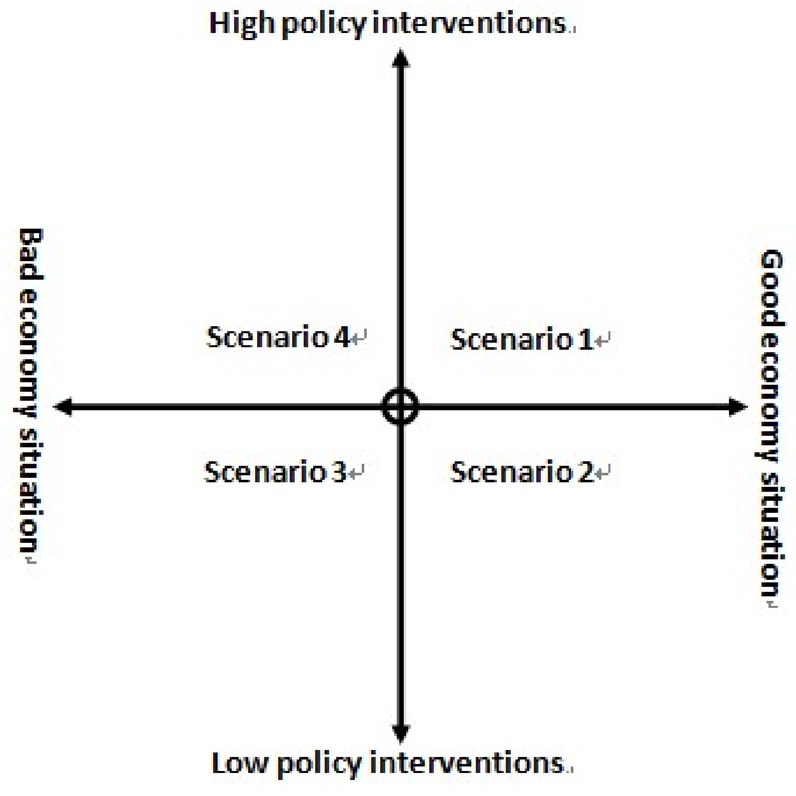


Figure 17: Scenario matrix

1) Scenario 1 (contradictory scenario)

In this scenario, as it could be seen from the figure, both the state of the economy is good and the policy intervention level is high. So there will be high restriction for migration and we think in the long run it is not good for more qualified employee. It is a little strange situation that government cut the budget when economy is good. So this scenario is not actually practical in our opinions.

2) Scenario 2 (best scenario)

In this scenario, as it could be seen from the figure, the state of the economy is good and the policy intervention level is low. In this case, more investors, buyers and visitors like students can come to North Brabant and it has a good influence on economy, too. Also there will be more subsidies for RL sub-system. And the investment on ICL is also high. This is the best case in our scenario construction.

3) Scenario 3 (possible scenario)

In this scenario, as it could be seen from the figure, the state of the economy is bad and the policy intervention level is low. In our meaning, the government will still spend lot money on subsidies and more people can also come to North Brabant. This may stimulate the economy and make the situation better again. It could also be that more and more competition in finding job and more people live with government allowance which makes the situation even worse. So this is an interesting scenario that we would also want to simulate in our model.

4) Scenario 4 (worst scenario)

In this scenario, as it could be seen from the figure, the state of the economy is bad and the policy intervention level is high. In this case, population becomes less because of the strict policy and less budget for education. In this case, the government would like to spend less money on housing market and there will be less money on ICL market. It could have a really bad reinforcing loop for economy. We consider it as the worst case.

3.6.3 Chosen scenario's

The difficulty of urban redevelopment is the long time span that is needed from the initiative to the realization phase. In this time span a lot of circumstances can change because there are a lot of uncertainties that can influence the process. To make sure that the development will be profitable policy makers should take into account the most extreme situations and think of measures to take to still ensure the profitability under these extreme circumstances.

It makes sense that we will further develop three draft designs; one for the Worst case scenario, one for the Best case scenario and one for the likely interesting scenario. They are scenario 2, 3 and 4 respectively.

3.6.4 Variable and intervention's future trends prediction

Based on the chosen scenarios' description, we make a list of all the changed variables under each scenario. Also we want to mention that since now it is already 2012, so we would like to simulate the change from year 17 in the system.

In order to determine the new equations of these most important and unpredictable interventions, we would like to apply the most related two scenarios from WLO, namely TM and RC scenarios. We already put their results into our model to calculate the possible equations for each of the intervention under their assumptions. So for now, in our own model, we can use them as baseline to set values. Just give you an example, as we know that in the RC scenario, the trends of population is the closest to our simulation results. So we may propose that in our worst scenario, the immigration policy effect would make the population decrease in stead of the initial setting 0. In our best case, we may propose it has an average value of the RC settings and our initial settings. Other variables' new settings are also determined in this way. In the best case, there could be more or less than the WLO scenarios. For the worst case, the new settings they are going to be set as minus in stead of the initial 0. Then the possible case's settings will be the average of the best case and worst.

Table 20 New trends in different scenarios of interventions

	immigration policy Brainport Concept	Technology Investment effect	Financial investment effect	Full time Emplyee	Subsidy effect for Buying	Subsidy effect for Rent
Initial Settings	0*Time	0*Time	0*Time	(54.59*ln(Time) + 764)*1000	0*Time	0*Time
Best scenario	IF THEN ELSE(Time<=16, 0 , 7000)	IF THEN ELSE(Time<=16, 0 , 2000)	IF THEN ELSE(Time<=16, 0 , 3000)	IF THEN ELSE(Time<=16,(54.59*ln(Time) + 764)*1000 , (54.59*ln(Time) + 722)*1000)	IF THEN ELSE(Time<=16, 0 , 0.3)	IF THEN ELSE(Time<=16, 0 , 0.03)
Possible scenario	IF THEN ELSE(Time<=16, 0 , 1000)	IF THEN ELSE(Time<=16, 0 , -1000)	IF THEN ELSE(Time<=16, 0 , -1000)	IF THEN ELSE(Time<=16,(54.59*ln(Time) + 764)*1000 , (54.59*ln(Time) + 650)*1000)	IF THEN ELSE(Time<=16, 0 , 0.2)	IF THEN ELSE(Time<=16, 0 , 0.02)
Worst scenario	IF THEN ELSE(Time<=16, 0 ,-5000)	IF THEN ELSE(Time<=16, 0 , -4000)	IF THEN ELSE(Time<=16, 0 , -5000)	IF THEN ELSE(Time<=16,(54.59*ln(Time) + 764)*1000 , (54.59*ln(Time) + 570)*1000)	IF THEN ELSE(Time<=16, 0 , 0.1)	IF THEN ELSE(Time<=16, 0 , 0.01)

3.6.5 Scenario simulation in system dynamics

We will show you the results one by one sub-system.
In population sub-system, different results for population are as follows:

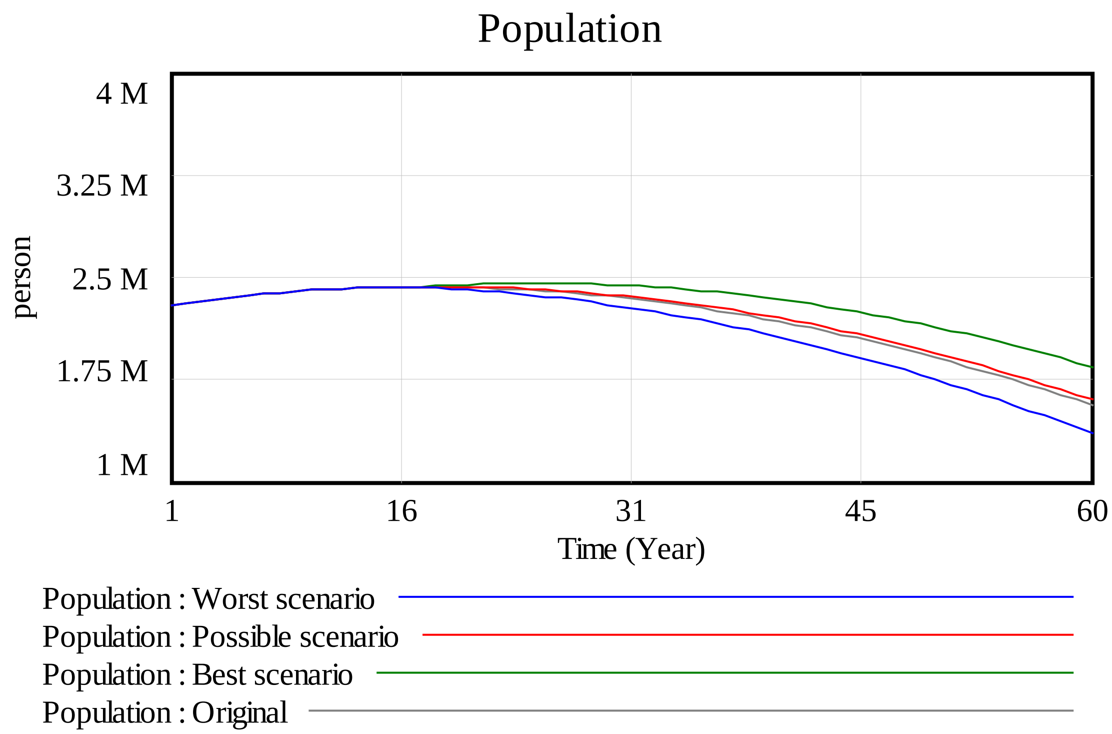


Figure 18: Population simulation results contrast

From the simulation results, we can see that in the best scenario, North Brabant's population can reach its peak than other scenarios. And in the worst scenario, population decreases more easily. Compared with the initial settings, the possible and most interesting scenario shows a higher population result. No matter which scenario would happen, we should always say that the population trend is not good because it keeps decreasing. So we would like to give some possible policy recommendations to the policy makers to change this situation.

What's worse, the current new education budget reduction policy and the more restricted migration policy are causing the trend worse. So we should really have some measures to prevent the situation from being too bad.

For the industrial and commercial land simulation contrast, you can see the following picture:

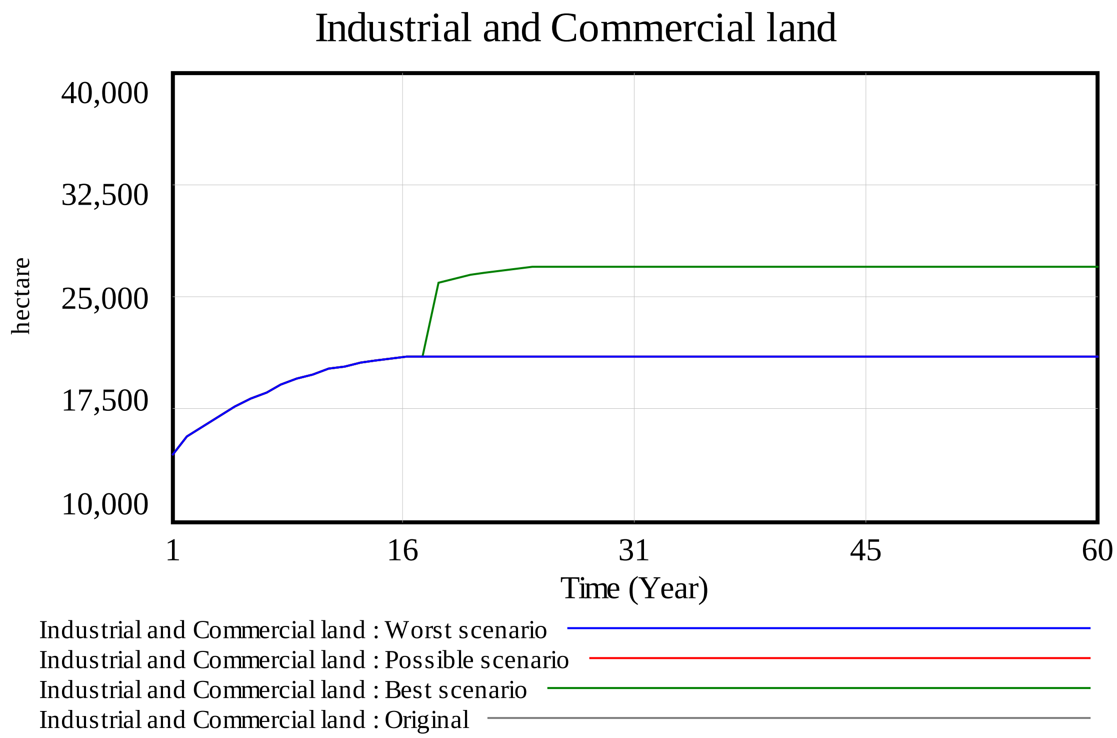


Figure 19 ICL simulation results contrast

From the simulation results, we can see that only in the best scenario, North Brabant's ICL stock can reach its peak than other scenarios. And in other scenarios, it can only achieve a quite low level of stock compared with the best scenario. Together with the initial settings, the possible and most interesting scenario ad also the worst scenario show the same ICL stock result. From this we can say that the North Brabant's current ICL stock is really high and needs policies like SER tools to make use of this kind of land for redevelopment and other uses. However, if the economy does go well, then there is still a large amount of requirement of new ICL.

For the agricultural land simulation contrast, you can see the following picture:

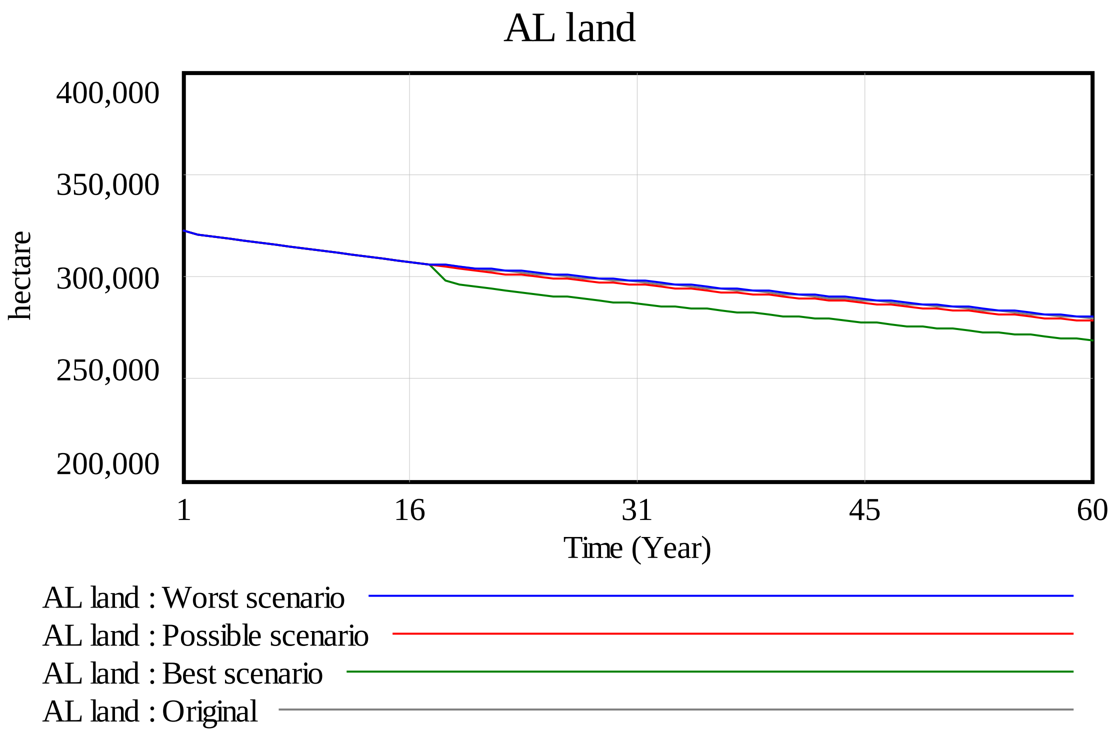


Figure 20 AL simulation results contrast

From the simulation results, you can see that the attributes that we choose to create scenarios do have much influence on AL because of the other land use types' changes. In the best case, economy goes well and also there is low policy intervention, so the ICL and RL stock would increase, so that's why AL land would decrease. While in the worst case, the stock of AL land is a little smaller than the original case; it is because of the less population needs less AL to feed on. In this case, more land would be transferred into other land use types like nature land. In the possible case, the AL stock would be slight lower than the original simulation result.

For the residential land simulation contrast, you can see the following picture:

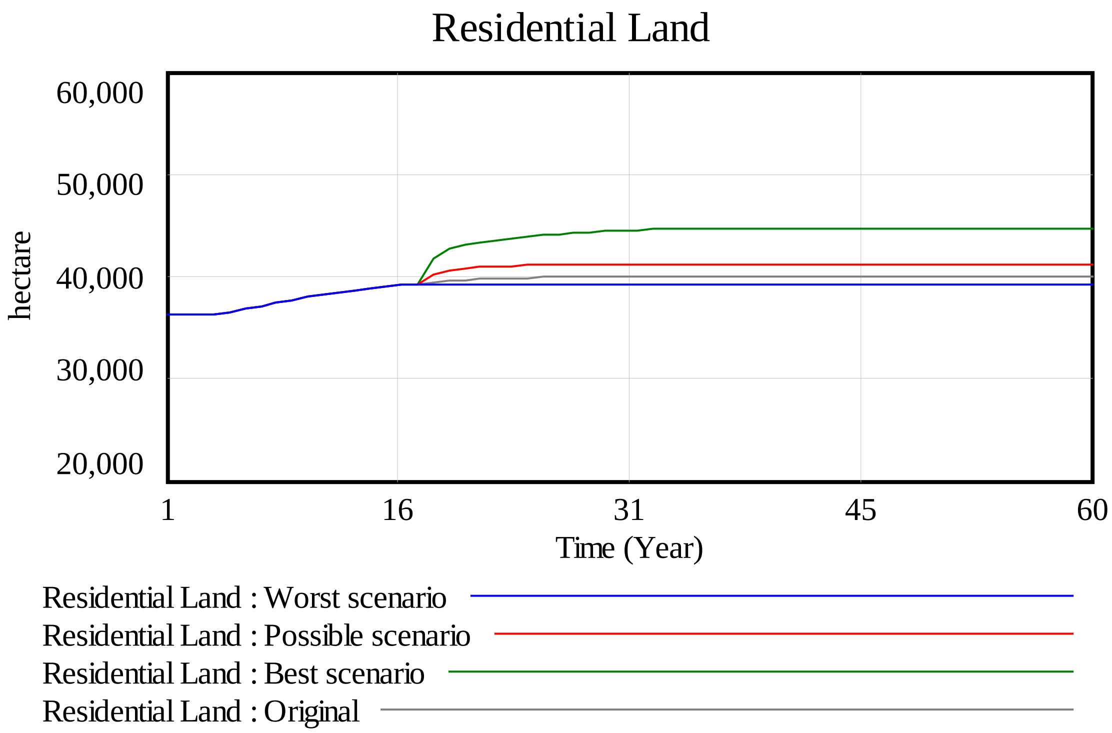


Figure 21 RL simulation results contrast

From the simulation results, we can see that in the best scenario, North Brabant's RL stock can reach its peak after year 34. And in the worst scenario, it can only achieve a quite low level of highest stock in around year 17 compared with other scenarios, even less than the original case. Compared with the initial settings, the possible and most interesting scenario shows a higher RL stock result.

3.7 Policy recommendation

From all the simulation processes and results, we can have a clearer view on North Brabant's land use. For the population, new migrants will have a major impact on new land use, in particular for housing, infrastructure, and industrial land use. Demographic and economic growth is mostly determined by future immigration flows. However, even after several different settings about immigration policy, there is still no solution not letting the population goes down and down. So if the government would like to change this situation, it is better that they have some specific policies to stimulate people having babies and offer better health care which could reduce the death rate.

For residential land and industrial or commercial land, the biggest problem now is the stagnating redevelopment of the vacant areas. Municipalities can give some benefits to the private parties to fully utilize this kind of areas. In another saying, it is also possible to find a way to create more jobs and stimulate the economy development. But even in this case, new industrial areas or residential areas would be developed; the existing vacant areas still cannot be fully utilized.

For the agricultural land, food price and other bio-fuel price still cannot compete with the profits from industry and commerce. But for the national security reason, it is better to protect the agricultural land from now on preventing so much agricultural land from changing to other land use types. There could be more creative methods of using agricultural land, such as visiting agricultural, more vacation villages. It is another way of creating jobs and stimulating the economy.

Regarding to the whole system, we should say that more limitations on migration policy would probably harm the economy development here because of the elimination of foreign investment. However, there are already some laws that allow rich foreigners to come here. That's just a start point, more human-friendly laws should come up that can encourage people to come. And for the education effect, cutting budget is definitely not a good choice for North Brabant. For one thing, it is a knowledge based province. For another, technologies need to be innovated by scientists and researcher. But the current laws prevent people pursuing higher degrees. If it cannot be changed about the cutting of budget, it is better that government can collaborate with private investors to set up funding for researchers or scholars. Or it is also available to find other ways out.

This study does not intend to make policy choices. Instead it presents an approach that may support policy makers in developing robust policies and setting priorities. As we have mentioned before, the population of North Brabant really needs the government to take care. Also the migration has becoming a quite important source of population increase, so the current new restricted policies for migration are not beneficial to North Brabant in our point of view. Other priorities of policies could be the settings of SER tools to make the stagnating state of ICL and RL improve. In such a populous country, the vacant areas are quite wasteful and not profitable.

Some trends are relatively certain, such as the demographic change, the proportional increase of the ageing population, for example requires the priority of policies for health care. Other trends, such as the effects of immigration, economic growth and EU policy, are more difficult to predict. Policy makers are challenged to apply flexible and robust strategies that allow for such uncertainty.

4. Conclusion and Discussion

In this research, we firstly read lots of papers regarding to land use change analysis methods, like GIS, RS, and so on. Secondly we study the current researches about North Brabant region and about the whole Netherlands. After reading all these papers, we think the study about North Brabant is not sufficient, so we have carried out this study.

We compare all kinds of methods nowadays people use to do this kind of research. It turns out that there are two ways. One is geographic allocation way, and the other is system analysis way. We choose the latter one because of the objectives of this research. It is going to find out what has happened in the past and why did it happen. It is more like finding out the reasons rather than wanting to know where some land types should locate. Moreover, we would like to see whether the current changed policies like immigration restriction and education budget cut would affect the whole land use system. Even so, what can we do from now on to keep things going right? All of our objectives require us to do more system thinking researches. That’s why we choose to use system dynamics and scenario analysis to do this research.

After listing all the possible driving forces behind North Brabant land use change and categorizing them, we have a better overview. By referring to other researches, we finally have our own driving forces list for North Brabant. There are four main sub-systems, namely population sub-system, agricultural land sub-system, industrial and commercial land sub-system and residential land sub-system.

We calibrate the sub-system by using all the available historical data. After all the equations have been filled in the system, we also validate them to make sure it works. For the whole system, we also use the new updated data from year 2009 and 2010 to see if the model works well. The result shows it can simulate the real trend.

Then we also use WLO scenarios prediction to see if our model can have the same level of increasement for each sub-system land use. In our validation part, this kind of comparison gives us the positive feedback that our model is consistent with the WLO prediction.

So we start to work on finding the most influential and unpredictable driving forces. Firstly we explain all the interventions we think are the most unpredictable. Meanwhile, we use commen sense to evaluate their impact on the whole system. In order to prove our assumptions are correct, we put the WLO scenarios’ prediction results into our model and try to calibrate out the interventions’ new settings under different scenarios. In this way, we can find out which ones are the most influential variables. After making a matrix, we find out four most influential and unpredictable driving forces from our point of view and we combine them into two new variables: economy condition and policy intervention.

With these two new variables, we create a scenario matrix which would help us construct four possible future scenarios. For each scenario, we have explained quite a lot about what they mean and what should change to simulate these scenarios from the initial settings. We should also mention that by determining the new settings we use the baselines of WLO scenarios. This makes our new settings reasonable.

At last we choose three scenarios to do the simulation contrast. One is the best scenario we think with low policy restriction, and good economy condition. The other is the worst scenario which is just on the contrast with the best scenario. The last scenario is the one that we think very interesting and challenging for the current Dutch government. In this case, government would still offer relatively loose restriction of immigration, but the economy is not good. After running all the simulations, we give come conclusions about each scenario and also some policy recommendations to the government based on the simulated results.

This is all about the current study up to now. However, there are several points we want to say that may be improved in the future.

For one thing, in the current model, GDP is not connected with different sectors' GDP growth rates. And it could be changed in the future to make the model more reasonable and practical after getting more historical data.

For another, we first assume that there is connection between GDP and new increase job. However, the data shows that they are not consistent. In our point of view, it is because of the insufficient dataset. So in the future, it is also possible that we find other variables which could fill in the gap between GDP and new increase jobs.

In the industrial and commercial land sub-system, it is not quite stable because the data are so little. We need to do a lot of calibration to make the model work. In order to make the model stronger, it is better to find other resources of data.

Up to now, there are only three land use types in the system. However, more land use types can be added into the system like water system, wood system and so on. But we need to mention that in order to add more systems into the current model, it is better to make this model work better first.

In the following studies, more special specific objectives can be added. For example, where would the new increased industrial land locate in North Brabant? These kinds of questions need to be answered with the help of GIS, RS and cellular automata or even agent based modeling.

There is also one other option to expand this study. We can also build up a land use sustainability assessment framework and do some comparison studies between different areas.

Last but not least, for the scenarios construction, it is also possible to build up different scenarios based on various study needs.

5. Reference

[1] *Act of 20 October 2006 containing new rules for spatial planning (Spatial Planning Act)*, (2008).

[2] Amsalu, A., Stroosnijder, L., Graaff, J. (2007) Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia, *Journal of Environmental Management*, 83(4), 448-459.

[3] Blokhuis, E.G.J. (2010) Governing Multi-Actor Decision Processes in Dutch Industrial Area Redevelopment, Ph.D. thesis, Eindhoven University of Technology.

[4] Blokhuis, E.G.J., Han., Q., Schaefer, W.F. (2011) Understanding the Dutch market for Industrial Areas with System Dynamics modeling, proceedings of the 2011 ERES conference, Eindhoven.

[5] Bood, R. and Postma, T. (1997) Strategic learning with scenarios, *European Management Journal*, Vol. 15, pp. 633-647.

[6] Bood, R.P. and Postma, T.J.B.M. (2000) *Scenario analysis as a strategic management tool*, University of Groningen.

[7]Borsboom, J., Zondag, B. (2009) Visiedocument modelontwikkeling voor ruimtegebruiksmodellering bij het PBL, Bilthoven: Internal note, PBL.

[8] CPB, MNP and RPB (2006) *Welvaart en Leefomgeving, Een scenariostudie voor Nederland in 2040*, Den Haag: Centraal Planbureau, Milieu-en Natuurplanbureau en Ruimtelijk Planbureau.

[9] E. Koomen, J. Borsboom-van Beurden (eds.), *Land-Use Modelling in Planning Practice,* The GeoJournal Library 101, DOI 10.1007/978-94-007-1822-7_9.

[10] Georgantzas, N.C. and Acar, W. (1995) *Scenario-driven planning: learning to manage strategic uncertainty*, Quorom, London.

[11] Godet (2000) *The art of scenarios and strategic planning: tools and pitfalls, Technological Forecasting and Social Change*, Vol. 65, nr. 1, pp. 3-22.

[12] Godet, M. and Roubelat, F. (1996) *Creating the future: The use and misuse of scenarios, Long Range Planning*, Vol. 29, pp. 164-171.

[13] Guan, D., Gao, W., Su, W., Li, H., Hokao, K. (2011) Modeling and dynamic assessment of urban economy-resource-environment system with a coupled system dynamics-geographic information system model, *Ecological Indicator*s, 11(5), 1333-1344.

[14] Han, J., Hayashi, Y., Cao, X., Imura, H. (2009) Application of an integrated system dynamics and cellular automata model for urban growth assessment: A case study of Shanghai, China, *Landscape and Urban Planning*, 91 (2009) 133-141.

[15] Hersperger, A. M., Burgi, M. (2009) Going beyond landscape change description: Quantifying the importance of driving forces of landscape change in a Central Europe case study, *Land Use Policy* 26(2009), 640-648.

[16] Hjorth, P., Bagheri, A. (2006) Navigating towards sustainable development: A system dynamics approach, *Futures*, 38(1), 75-92.

[17] Jokar Arsanjani, J., et al., (2012) Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion, *Int. J. Appl. Earth Observ. Geoinf.*, doi:10.1016/j.jag.2011.12.014.

[18] Khakee, A. (1991) *Scenario Construction for Urban Planning Omega*, Vol. 19, pp. 459-469.

[19] Koomen, E., Koekboek, A., Dijk, E. (2011) Simulating Land-use Change in a Regional Planning Context, *Applied Spatial Analysis*, 4, 223-247.

[20] Koomen, E., J. Borsboom-van Beurden (eds.). (2011) *Land-Use Modeling in Planning Practice,* The GeoJournal Library.

[21] Koomen, E., Koekoek, A. and Dijk, E. (2011) Simulating land-use change in a regional planning context. *Applied Spatial Analysis and Planning*, doi: 10.1007/s12061-010-9053-5.

[22] Kuiper, R., Kuijpers-Linde, M., Bouwman, A. (2011) A Sustainable Outlook on the Future of the Netherlands, *Land-Use Modeling in Planning Practice*, the GeoJournal Library 101, doi 10.1007/978-94-007-1822-7_4.

[23] Lauf, S., Haase, D., Hostert, P., Lakes, T., Kleinschmit, B. (2011) Uncovering land-use dynamics driven by human decision-making – A combined model approach using cellular automata and system dynamics, *Environmental Modelling & Software* 27 -28, 71-82.

[24] Long, H., Tang, G., Li, X., Heilig, G. (2007) Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China, *Journal of Environmental Management*, 83(5), 351-364.

[25] Luo, G., Yin, C., Chen, X., Xu, W., Lu, L. (2010) Combing system dynamics model and CLUE-S model to improve land use scenario analyses at regional scale: A case study of Sangong watershed in Xinjiang, China, *Ecological Complexity*, 7(2), 198-207.

[26] Needham, B. (2004) The new Dutch spatial planning act: Continuity and change in the

way in which the Dutch regulate the practice of spatial planning, *Research group Governance and Places*, working paper series 2004/12.

[27] Robinson, D.T., Murray-Rust, D., Rieser, V., Milicic, V., Rounsevell, M. (2012) Modeling the impacts of land system dynamics on human well-being: using an agent- based approach to cope with data limitations in Koper, Slovenia, *Computers, Environment and Urban Systems* (2012), doi: 10.1016/j.compenvurbsys.2011.10.002.2.

[28] The new Spatial Planning Act gives space (2007) The Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM).

[29] Veldhuisen, K.J., Timmermans, H.J.P. and Kapoen, L.L. (2004) Application of Ramblas to Amsterdam North-Wing Urban Development Scenarios, *Progress in Activity-Based Analysis*, 28-31 May 2004, Maastricht, The Netherlands, Maastricht: EIRASS Workshop.

[30] Verburg, P.H., Eck, J.R.R., Nijs, T.C.M., Dijst,M.J., Schot, P. (2004) Determinants of land-use change patterns in the Netherlands, *Environment and Planning B: Planning and Design*, 31(1), 125-150.

[31] Wolff, H. (2007) The new Dutch Land development Act as a tool for value capturing, *ENHR 2007 International Conference 'Sustainable Urban Areas'*.

[32] Wu, Y., Zhang, X., Shen, L. (2011) The impacts of urbanization policy on land use change: A scenario analysis, *Cities*, 28(2), 147-159.

[33] Wu, Y., Peng, Y., Zhang, X., Skitmore, M., Song, Y. (2011) Development priority zoning (DPZ)-led scenario simulation for regional land use change: The case of Suichang County, China, *Habitat international*, doi:10.1016/j.habitatint.2011.10.011.

[34] Xu, Z., Coors, V. (2012) Combing system dynamics model, GIS and 3D visualization in sustainability assessment of urban residential development, *Building and Environment*, 47, 272-287.

[35] Yang, H., Du, L., Guo, H., Zhang, J. (2011) Tai'an land use analysis and prediction based on RS and Markov Model, *Procedia Environmental Sciences* 10 (2011) 2625-2630.

[36] Yu, W., Zang, S., Wu, C., Liu, W., Na, X. (2011) Analyzing and modeling land use land cover change(LUCC)in the Daqing City, China, *Applied Geography*, 31(2), 600-608.

[37] Zondag, B., Borsboom, J. (2009) Driving forces of land use change, the 49th ERSA conference, Lodz, Poland.

[38] http://www.mkb.nl/

[39] http://upload.wikimedia.org/wikipedia/commons/e/e2/2012-P10-NB-basis.jpg

[40] http://en.wikipedia.org/wiki/North_Brabant

[41] http://en.wikipedia.org/wiki/Eindhoven

[42] http://www.brainport.nl/en/high-tech-systems-materials/brainport-eindhoven-region

[43] http://en.wikipedia.org/wiki/File:Noord-Brabant_in_the_Netherlands.svg#file

[44] http://www.lumos.info/landusescanner.php.

[45] http://en.wikipedia.org/wiki/Remote_sensing.

[46] http://en.wikipedia.org/wiki/Geographic_information_system.

[47] http://en.wikipedia.org/wiki/System_dynamics.

[48]http://www.cbs.nl/en-GB/menu/themas/bouwen-wonen/publicaties/artikelen/archief/2010/2010-3086-wm.htm.

[49] http://www.welvaartenleefomgeving.nl/references_UK.html

[50] http://www.pbl.nl/sites/default/files/cms/publicaties/500082001.pdf

6. Appendix

6.1 Land use data and description

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Totale oppervlakte	Verkeersterrein	
			Totaal verkeersterrein	Spoorterrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	508 185	16 923	1 015
	2000	508 176	17 057	1 001
	2003	508 176	16 895	931
	2006	508 176	17 574	1 022
	2008	508 176	17 746	1 035
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Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Verkeersterrein		Bebouwd terrein
		Wegverkeersterrein	Vliegveld	Totaal bebouwd terrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	15 147	760	52 739
	2000	15 279	777	55 450
	2003	15 487	478	56 979
	2006	15 933	619	57 978
	2008	16 091	620	58 718
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Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Bebouwd terrein		
		Woonterrein	Terrein voor detailhandel en horeca	Terrein voor openbare voorzieningen
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	36 323	678	2 459
	2000	37 713	701	2 450
	2003	37 849	932	2 349
	2006	38 346	1 001	2 183

	2008	38 691	1 051	2 129

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Bebouwd terrein		Semi-bebouwd terrein
		Terrein voor sociaal-culturele voorz.	Bedrijventerrein	Totaal semi-bebouwd terrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	2 427	10 852	4 654
	2000	2 413	12 172	6 118
	2003	2 628	13 220	6 295
	2006	2 635	13 813	6 737
	2008	2 571	14 275	7 328

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Semi-bebouwd terrein		
		Stortplaats	Wrakkenopslagplaats	Begraafplaats
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	457	103	407
	2000	385	102	419
	2003	402	93	438
	2006	417	92	441
	2008	386	93	438

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Semi-bebouwd terrein		
		Delfstofwinplaats	Bouwterrein	Semi-verhard overig terrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	190	3 068	428
	2000	282	4 612	316
	2003	295	4 696	370
	2006	224	5 251	313
	2008	218	5 947	245

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Recreatieterrein		
		Totaal recreatieterrein	Park en plantsoen	Sportterrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	11 534	2 843	5 001
	2000	12 066	3 186	5 066
	2003	12 942	3 650	5 328
	2006	13 187	3 772	5 461
	2008	13 300	3 745	5 582

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Recreatieterrein		
		Volkstuin	Dagrecreatief terrein	Verblijfsrecreatief terrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	352	1 071	2 267
	2000	345	1 168	2 301
	2003	346	1 221	2 397
	2006	338	1 203	2 413
	2008	330	1 176	2 467

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Agrarisch terrein		
		Totaal agrarisch terrein	Terrein voor glastuinbouw	Overig agrarisch terrein
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	322 640	946	321 695
	2000	316 958	1 135	315 823
	2003	314 204	1 393	312 811
	2006	312 302	1 640	310 662
	2008	310 522	1 724	308 798

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Bos en open natuurlijk terrein		
		Totaal bos en open natuurlijk terrein	Bos	Open droog natuurlijk terrein
Regio's	Perioden	*ha*		

Noord-Brabant (PV)	1996	83 753	72 221	6 695
	2000	84 281	73 183	6 550
	2003	84 334	72 606	6 059
	2006	83 787	71 866	6 069
	2008	83 827	71 856	6 207

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Bos en open natuurlijk terrein	Binnenwater	
		Open nat natuurlijk terrein	Totaal binnenwater	IJsselmeer / Markermeer
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	4 837	15 943	
	2000	4 548	16 246	
	2003	5 669	16 526	
	2006	5 852	16 611	
	2008	5 764	16 735	

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Binnenwater		
		Afgesloten zeearm	Rijn en Maas	Randmeer
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	2 948	2 826	
	2000	2 948	2 826	
	2003	2 949	2 804	
	2006	2 942	2 806	
	2008	2 851	2 808	

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Binnenwater		
		Spaarbekken	Recreatief binnenwater	Binnenwater voor delfstofwinning
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	619	1 208	391
	2000	619	1 230	449

	2003	619	1 302	572
	2006	619	1 303	537
	2008	619	1 352	552

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Binnenwater		Buitenwater
		Vloei- en/of slibveld	Overig binnenwater	Totaal buitenwater
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996	152	7 798	
	2000	151	8 023	
	2003	64	8 216	
	2006	64	8 340	
	2008	66	8 486	

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Buitenwater		
		Waddenzee, Eems, Dollard	Oosterschelde	Westerschelde
Regio's	Perioden	*ha*		
Noord-Brabant (PV)	1996			
	2000			
	2003			
	2006			
	2008			

Bodemgebruik; naar gebruiksvorm en gemeente

	Onderwerpen	Buitenwater
		Noordzee
Regio's	Perioden	*ha*
Noord-Brabant (PV)	1996	
	2000	
	2003	
	2006	
	2008	

Totale oppervlakte

Totale oppervlakte van Nederland.

Verkeersterrein

Terrein in gebruik voor spoor-, weg- en luchtverkeer.

Totaal verkeersterrein

Totale oppervlakte van de hoofdgroep 'Verkeersterrein'.

Spoorterrein

Terrein in gebruik voor vervoer en transport per rail.

Tot spoorterrein wordt gerekend:

- spoorweg, tot de voet van de spoordijk, bij een ingesneden baan inclusief de taluds;
- doodlopend zijspoor naar bedrijfsterrein;
- rangeerterrein;
- spoorwegemplacement inclusief stationsgebouwen en bijbehorende parkeerterreinen.

Niet tot spoorterrein wordt gerekend:

- smalspoor, dit wordt gerekend tot de aangrenzende vorm van grondgebruik

Wegverkeersterrein

Terrein in gebruik voor vervoer en transport over het hoofdwegennetwerk.

Tot wegverkeersterrein wordt gerekend:

- wegen die volgens de TOP10vector specificatie de functie van vervoers-ader hebben (aaneensluitingen van de TOP10Vectorcodes: 200, 208, 210, 220, 230, 234, 240, 244, 250, 280, 287, 290, 300, 310, 314, 320, 324, 330, 334);
- groen in aansluitingen van wegen en binnen klaverbladen;
- parkeerplaats;
- busstation;
- benzinestation;
- opslagplaats van onder andere Rijks- en Provinciale Waterstaat voor onderhoud.

Niet tot wegverkeersterrein wordt gerekend:

- ingesloten groen groter dan 1 ha in gebruik als landbouwgrond of bos;
- ingesloten water groter dan 1 ha;
- hoofdweg in aanbouw.

Ondergrens: Geen, moet echter wel deel uitmaken van het wegennetwerk.

Vliegveld

Terrein in gebruik voor vervoer en transport door de lucht.

Tot vliegveld wordt gerekend:

- Verharde en onverharde start- en rolbanen;
- bijbehorende gebouwen en parkeerterreinen.

Niet tot vliegveld wordt gerekend:

- onverharde grond binnen de omheining van het vliegveld (geen start- of rolbaan);
- bij het vliegveld gelegen terrein(en) met dienstverlenende bedrijven.

Bebouwd terrein

Terrein in gebruik voor wonen, werken, winkelen, uitgaan, cultuur en openbare voorzieningen.

Totaal bebouwd terrein

Totale oppervlakte van de hoofdgroep 'Bebouwd terrein'.

Woonterrein

Terrein dat voornamelijk voor het wonen bestemd is, inclusief primaire woonvoorzieningen.

Tot woonterrein worden gerekend:

- terrein met bestemming wonen;
- primaire voorzieningen als (buurt)winkels, scholen voor kleuter- en basisonderwijs;
- bijkantoren van onder andere banken;
- groenvoorziening kleiner dan 1 hectare;
- straten en parkeerplaatsen;
- erven, tuinen;
- trapveldjes en speelplaatsen;
- woonwagenkamp (exclusief wrakkenopslagplaatsen > 0,1 hectare).

Wanneer woonwijken in bos zijn gelegen, wordt het gehele terrein als woongebied aangemerkt indien er van een stratenpatroon sprake is.

Terrein voor detailhandel en horeca

Terrein in gebruik voor geconcentreerde detailhandel en horeca-activiteiten.

Tot terrein voor detailhandel en horeca wordt gerekend:

- winkelcentrum, veelal gelegen in en/of aan voetgangersgebied (ook al wordt daarboven gewoond);
- goederenmarkt;
- terrein met bedrijven in de horecasector;
- bijbehorende parkeerterreinen

Door nieuwe en betere bronnen zijn de cijfers voor deze categorie per 2003 verbeterd. Dit heeft wel gevolgen voor de vergelijkbaarheid in de tijd.

Terrein voor openbare voorzieningen

Terrein in gebruik voor het algemeen nut, zoals gemeentehuizen, politiebureaus en nutsbedrijven.

Tot terrein voor openbare voorziening wordt gerekend:

- ministerie;
- gemeentehuis (stadskantoor), kantoor openbare werken enzovoort;
- grenskantoor (douane enzovoort);
- provinciehuis;
- politiebureau, brandweerkazerne, rechtbank, gevangenis;
- nutsbedrijf (gas, water, elektriciteit, stadsverwarming en centrale antenne-inrichtingen) inclusief het daarbij behorende terrein;
- waterzuiveringsinstallatie en vuilverbrandingsinstallatie, evenals de

opslagplaatsen;
- opslagterrein ten behoeve van Rijk, Provincie en Gemeente, met uitzondering van opslagterrein voor het onderhoud van wegen;
- militair object, zoals munitiedepot, kazerne, mobilisatiecomplex, radarpost en schietbaan;
- fort (voormalig)
- bijbehorende parkeerterreinen en bos- of heesterstroken.

Openbare voorzieningen worden in de topografische kaart in de regel met een afrastering afgebakend. Als begrenzing van een object wordt dan de afrastering aangehouden.

Terrein voor sociaal-culturele voorz.

Terrein in gebruik voor sociale en culturele voorzieningen zoals ziekenhuizen, universiteiten en musea.

Tot terrein voor sociaal-culturele voorziening wordt gerekend:
- onderwijsinstelling voor het voortgezet en hoger onderwijs;
- internaat;
- conferentieoord;
- ziekenhuis, sanatorium, verpleeghuis, psychiatrisch ziekenhuis, inrichting voor zwakzinnigen en dergelijke;
- kerk, klooster, museum (ook voor het publiek toegankelijke kastelen), exclusief openluchtmuseum;
- schouwburg, bioscoop, concert- en congresgebouw;
- cultureel centrum;
- wijkgebouw, verenigingsgebouw, jeugdsociëteit;
- sociale werkplaats;
- bijbehorende parkeerplaatsen, tuinen en bos- of heesterstroken.

Sociaal-culturele voorzieningen worden in de topografische kaart soms met een afrastering afgebakend. Als begrenzing van een object wordt dan de afrastering aangehouden.

Bedrijventerrein

Terrein in gebruik voor nijverheid, handel en zakelijke dienstverlening.

Tot bedrijfsterrein wordt gerekend:
- fabrieksterrein;
- haventerrein;
- veilingterrein;
- tentoonstellingsterrein;
- veemarkt (al dan niet overdekt);
- groothandelscomplex;
- terrein met banken en verzekeringsmaatschappijen en dergelijke;
- bijbehorend opslagterrein en parkeergelegenheid;
- garage (inclusief parkeergarage);
- garage van busmaatschappij;
- kantoorgebouw;
- bijbehorende parkeerterreinen;

Niet tot deze categorie behoren ingesloten braak-, en/of niet bouwrijpe bedrijfsterreinen, deze worden tot bouwterrein gerekend.

Semi-bebouwd terrein

Terrein met een zekere mate van verharding dat niet in gebruik is als verkeersterrein of bebouwd terrein.

Totaal semi-bebouwd terrein

Totale oppervlakte van de hoofdgroep 'Semi-bebouwd terrein'.

Stortplaats

Terrein voor opslag van afval.
Tot stortplaats wordt gerekend:
- Stortplaats;
- Bijbehorende gebouwen, parkeerterreinen en bos- of heesterstroken.

Wrakkenopslagplaats

Terrein voor de opslag en/of sloop van autowrakken.
Tot wrakkenopslagplaats wordt gerekend:
- terrein voor opslag van autowrakken;
- sloperij;
- bijbehorende gebouwen, parkeerterreinen en bos- of heesterstroken.

Niet tot wrakkenopslagplaats wordt gerekend:
- terrein in gebruik voor de schrootverwerkende industrie.

Ondergrens 0,1 hectare.

Begraafplaats

Terrein in gebruik voor begraven en cremeren.
Tot begraafplaats wordt gerekend:
- terrein voor het begraven van mensen of dieren;
- crematorium;
- bijbehorende gebouwen, parken, tuinen, parkeerterreinen en bos- of heesterstroken.

Ondergrens 0,1 hectare.

Delfstofwinplaats

Terrein voor het winnen van grondstoffen uit de bodem.
Tot delfstofwinplaats wordt gerekend:
- Terrein voor diepte- en oppervlakwinning van grondstoffen;
- de tot dat terrein behorende gebouwen, parkeergelegenheden, opslagplaatsen van winningsproducten en afvalstoffen;
- bijbehorende parkeerterreinen.

Tot grondstoffen worden gerekend:
- aardgas;
- aardolie;
- gesteente;
- grind;
- klei;
- leem;
- mergel;

- veen;
- zand;
- zout.

Winplaatsen van aardgas en aardolie zijn op de topografische kaart in de regel met een afrastering afgebakend. Als begrenzing van een object wordt dan de afrastering aangehouden.

Ondergrens 0,5 hectare.

Bouwterrein

Terrein in gebruik als bouwlocatie.

Tot bouwterrein wordt gerekend:

- terrein waarop wordt gebouwd of voorbereidende bouwsporen voorkomen;
- braakliggende grond in bedrijfsterrein.

Semi-verhard overig terrein

Overig semi-bebouwd terrein met een zekere mate van verharding.

Tot semi-verhard overig terrein wordt gerekend:

- niet met gras begroeide dijk;
- in zee lopende pier;
- braakliggend terrein voor zover dit niet als bouwterrein kan worden beschouwd;
- niet meer in gebruik zijnde spoorbaan.

Voor aan land vastzittende, in water gelegen pieren en strekdammen geldt een ondergrens van 0,1 hectare.

Recreatieterrein

Terrein bestemd voor recreatief gebruik.

Totaal recreatieterrein

Totale oppervlakte van de hoofdgroep 'Recreatieterrein'.

Park en plantsoen

Terrein met groenvoorziening in gebruik voor ontspanning.

Tot park en plantsoen wordt gerekend:

- terrein voor het publiek opengesteld bestaande uit gazons, speel- en ligweiden, paden, bosschages, bloemperken, heesterbeplanting en waterpartijen;
- groenstroken

Delen van het park die zijn te typeren als bos (ook indien groter dan 1 hectare) worden als park of plantsoen geclassificeerd.

Bij de inventarisatie van 2003 is extra nadruk gelegd bij het in kaart brengen van parken en plantsoenen. Dit heeft geresulteerd in kwalitatief betere cijfers.

Sportterrein

Terrein in gebruik voor sportactiviteiten.

Tot sportterrein wordt gerekend:

- terrein voor veldsport inclusief draf- en rensport, golfterrein;
- zwembad, (kunst)ijsbaan;

- sporthal en manege;
- permanente motorcrossbaan (ook provisorisch ingericht);
- bijbehorende tribunes, parkeerterreinen en bos- of heesterstroken;
- bos voor zover gelegen in het sportterrein.

Ondergrens 0,5 hectare.

Volkstuin

Terrein voor niet-commerciële sier- en groenteteelt.

Tot volkstuin wordt gerekend:

- in complexen gelegen volkstuinen;
- veelal langgerekte complexen pal langs de spoorwegen;
- schooltuinen;
- bijbehorende parkeerterreinen en bos- of heesterstroken.

Ondergrens 0,1 hectare.

Dagrecreatief terrein

Terrein in gebruik voor dagrecreatie zoals dierentuinen, openluchtmusea en pretparken.

Tot dagrecreatief terrein wordt gerekend:

- dagcamping;
- dierentuin en safaripark;
- sprookjestuin;
- pretpark;
- openluchtmuseum;
- jachthavens exclusief het water, maar inclusief terrein voor aanverwante bedrijvigheid, met een minimale oppervlakte van 0,1 hectare;
- bijbehorende parkeerterreinen en bos- of heesterstroken.

De volgende terreinen worden eveneens tot deze categorie gerekend als ze geen deel uitmaken van park en plantsoen:

- speeltuinen;
- picknickplaatsen;
- hertenkampen;
- kinderboerderijen;
- midgetgolfterreinen;
- speelweiden.

Ondergrens: Voor jachthavens geldt een ondergrens van 0,1 hectare voor het landgedeelte.

Verblijfsrecreatief terrein

Terrein in gebruik voor een meerdaags recreatief verblijf, zoals camping, bungalowparken en jeugdherbergen.

Tot verblijfsrecreatief terrein wordt gerekend:

- kampeer- en caravanterrein, kampeerboerderij;
- camping;
- terrein met tweede woningen;
- bungalowpark en vakantiehuizen;
- jeugdherberg;

- bijbehorende parkeerterreinen en bos- of heesterstroken .

Verblijfsrecreatieve terreinen worden in de topografische kaart soms met een afrastering afgebakend. Als begrenzing van een object wordt dan de afrastering aangehouden.

Agrarisch terrein

Terrein bestemd voor agrarisch gebruik.

Totaal agrarisch terrein

Totale oppervlakte van de hoofdgroep 'Agrarisch terrein'.

Terrein voor glastuinbouw

Terrein in gebruik voor agrarische bedrijfsvoering onder staand glas.

Tot terrein voor glastuinbouw wordt gerekend:

- terrein in gebruik voor de teelt van gewassen onder staand glas;
- in- en aanliggende waterbassins.

Overig agrarisch terrein

Agrarisch terrein niet in gebruik voor glastuinbouw, zoals grasland, tuinland, bouwland of boomgaard.

Tot overig agrarisch terrein wordt gerekend:

- grasland (hooi- en weiland) inclusief de met gras begroeide dijken en uiterwaarden;
- terrein bestemd voor veehouderij;
- hoogstam- zowel als laagstamboomgaard, inclusief onderteelt, verzorgingspaden en windsingels;
- terrein beteeld met akkerbouw- en tuinbouwgewassen;
- terrein in gebruik voor de teelt van kleinfruit;
- verspreide bebouwing met bijbehorende erven en tuinen, voor zover die te midden van of langs een terrein voor landbouwactiviteiten liggen;
- natuurlijk grasland.

Bos en open natuurlijk terrein

Terrein in gebruik als bos of open natuurlijk terrein.

Totaal bos en open natuurlijk terrein

Totale oppervlakte van de hoofdgroep 'Bos en open natuurlijk terrein'.

Bos

Terrein begroeid met bomen bestemd voor houtproductie en/of natuurbeheer.

Tot bos wordt gerekend:

- terrein zodanig begroeid met bomen, dat de kruinen een min of meer gesloten geheel vormen dan wel zullen gaan vormen;
- kapvlakte;
- brandgang;
- bospad;
- boomkwekerij;
- houtopslagplaats;
- verspreide bebouwing, voor zover die in het bos ligt;
- populierenweide.

Niet tot bos worden gerekend:
- beboste delen van parken;
- niet in het bos gelegen boomkwekerijen;
- woongebieden (met stratenpatroon) en terreinen voor verblijfsrecreatie die in bos gelegen zijn.

Open droog natuurlijk terrein

Open terrein met een droge ondergrond, met als belangrijkste functie natuur.
Tot open droog natuurlijk terrein wordt gerekend:
- droog heideterrein;
- met grasachtig gewas begroeid natuurlijk terrein (niet voor agrarisch gebruik);
- duin;
- zandverstuiving;
- zandplaat;
- strand.

Open nat natuurlijk terrein

Open terrein met een natte ondergrond met als belangrijkste functie natuur.
Tot open nat natuurlijk terrein wordt gerekend:
- nat heideterrein;
- riet en biezen (ook indien in cultuur);
- kwelder, schor of gors (bij gemiddeld hoogwater niet onderlopend);
- drooggevallen grond, mits onbegroeid;
- blauwgrasland.

Niet tot open nat natuurlijk terrein wordt gerekend:
- griend;
- nat bos

Binnenwater

Inlandig water in gebruik als vaarweg, recreatiewater, delfstofwinplaats, vloei en/of slibveld, of als spaarbekken, inclusief het IJsselmeer.

Totaal binnenwater

Totale oppervlakte van de hoofdgroep 'Binnenwater'.

IJsselmeer / Markermeer

Het water begrensd door de Afsluitdijk, de Ketelbrug, de Hollandsebrug bij Muiderberg en de Oranje Sluizen bij Amsterdam.

Afgesloten zeearm

Van de zee afgesloten inham, te weten Haringvliet en Hollands Diep (tot aan de Moerdijkspoorbrug), Volkerak, Krammer, Grevelingenmeer, Veerse meer en Lauwersmeer.

Rijn en Maas

Wateren voortkomend uit de rivier de Rijn en de rivier de Maas, dus inclusief hun benedenrivieren.
Als begrenzing geldt het Keteldiep (IJssel), de pieren van Hoek van

Holland (Nieuwe Waterweg) en het spoorgedeelte van de Moerdijkbruggen (Amer), evenals de overgangen van de Dordtse Kil en het Spui in het Haringvliet.

Randmeer

Het water begrensd door de Hollandsebrug bij Muiderberg, de Ketelbrug tussen de Noordoostpolder en Oostelijk Flevoland, het Kattendiep en het Keteldiep.

Per 2003 is het Zwarte Meer toegevoegd.

Spaarbekken

Terrein in gebruik voor wateropslag.

Tot spaarbekken wordt gerekend:

- wateropslag voor drinkwater;
- wateropslag voor de industrie.

Recreatief binnenwater

Binnenwater in gebruik voor recreatieve doeleinden, zoals water in golfterreinen en parken, roeibanen en recreatieplassen.

Tot recreatief binnenwater wordt gerekend:

- water in park en plantsoen;
- strandbad/spartelvijver;
- recreatieplas (surfen, zwemmen en dergelijke);
- water in golfterrein;
- water in jachthavens;
- roeibaan, waterskibaan.

De oevers van deze terreinen bestaan voor ten minste driekwart tot een sportterrein of een terrein voor dag- of verblijfsrecreatie, park en plantsoen. Uitzondering hierop vormen roeibanen en waterskibanen.

Ondergrens: Voor jachthavens geldt een ondergrens van 0,5 hectare voor het watergedeelte.

Binnenwater voor delfstofwinning

Water in gebruik voor de winning van delfstoffen.

Het water behoort tot deze categorie zolang er zandzuigers aanwezig zijn.

Vloei- en/of slibveld

Opslagterrein voor het scheiden van water en bezinksel, of voor opslag van (vervuild) havenslib.

Tot vloei- en slibveld wordt gerekend:

- opslagterrein voor het scheiden van water en bezinksel;
- opslagterrein voor (vervuild) havenslib.

Overig binnenwater

Binnenwater, breder dan zes meter, dat niet onder een andere categorie van bodemgebruik valt.

Tot overig binnenwater wordt gerekend:

- vaarwegen (rivieren, kanalen, grachten, vaarten en dergelijke);
- meren en plassen;
- sloten;

- havens, voor zover geen jachthavens.
Vanaf 2003 wordt het Zwarte Meer niet langer als 'Overig binnenwater' maar als Randmeer aangemerkt.

Buitenwater

Water buiten de gemiddelde hoogwaterlijn.

Totaal buitenwater

Totale oppervlakte van de hoofdgroep 'Buitenwater'.

Waddenzee, Eems, Dollard

Het water gelegen tussen de Waddeneilanden, de Afsluitdijk en de kust van Noord-Holland, Friesland en Groningen.
Per 2003 is er een nieuwe grens getrokken tussen de Waddenzee en de Noordzee.

Oosterschelde

Het water gelegen tussen de Oosterscheldekering, de Grevelingendam, de Philipsdam en de Oesterdam .

Westerschelde

Het water gelegen landinwaarts van de denkbeeldige lijn tussen Vlissingen en Breskens.

Noordzee

Het water dat is gelegen aan de zeezijde van de kust van Zeeland, Holland en van de Waddeneilanden.
Het gaat hierbij alleen om dat deel van de Noordzee dat gemeentelijk ingedeeld is. Bij de Nieuwe Waterweg, een vrij in zee uitstromende rivier, wordt de scheidingslijn tussen binnen- en buitenwater bepaald door een denkbeeldige verbinding tussen de uiteinden van de havenhoofden.
Per 2003 is er een nieuwe grens getrokken tussen de Waddenzee en de Noordzee.

Noord-Brabant (PV)

PV = Provincie
Bestuurlijke onderverdeling van het Nederlands grondgebied. Sinds het instellen van de provincie Flevoland per 1 januari 1986 telt Nederland 12 provincies.

6.2 Population dynamics data and description

Population dynamics; birth, death and migration per region

		Subjects	Population on 1 January	Live born children
				Live born children, ratio
Sex	Regions	Periods	*aantal*	*per 1,000*
Males and	Noord-Brabant	1960	1 484 671	23.8

females	(PV)	1961	1 512 787	24.3
		1962	1 543 395	23.7
		1963	1 575 211	23.4
		1964	1 605 864	23.3
		1965	1 638 795	22.4
		1966	1 670 632	21.4
		1967	1 700 866	20.8
		1968	1 725 292	20.3
		1969	1 753 934	20.7
		1970	1 787 783	19.6
		1971	1 819 459	18.1
		1972	1 850 495	17.0
		1973	1 879 848	15.3
		1974	1 910 347	14.7
		1975	1 940 817	13.7
		1976	1 967 261	13.6
		1977	1 991 176	13.1
		1978	2 011 578	13.1
		1979	2 030 920	13.0
		1980	2 051 195	13.1
		1981	2 071 885	12.7
		1982	2 085 420	12.0
		1983	2 093 969	11.6
		1984	2 103 003	12.0
		1985	2 112 971	12.2
		1986	2 124 656	12.5
		1987	2 139 626	12.7
		1988	2 156 280	12.4
		1989	2 172 604	12.7
		1990	2 189 481	13.2
		1991	2 209 047	13.1
		1992	2 225 331	13.1

		1993	2 243 546	12.7
		1994	2 259 779	12.8
		1995	2 276 207	12.4
		1996	2 290 424	12.2
		1997	2 304 094	12.3

Population dynamics; birth, death and migration per region

		Subjects	Population on 1 January	Live born children
				Live born children, ratio
Sex	Regions	Periods	*aantal*	*per 1,000*
Males and females	Noord-Brabant (PV)	1998	2 319 262	12.6
		1999	2 337 709	12.5
		2000	2 356 004	12.9
		2001	2 375 116	12.3
		2002	2 391 123	12.2
		2003	2 400 198	12.0
		2004	2 406 994	11.4
		2005	2 411 359	10.9
		2006	2 415 946	10.8
		2007	2 419 042	10.5
		2008	2 424 827	10.7
		2009	2 434 560	10.5
		2010	2 444 158	10.4
		2011*	2 454 215	10.1

Population dynamics; birth, death and migration per region

		Subjects	Deaths	Natural increase
			Deaths, ratio	
Sex	Regions	Periods	*per 1,000*	*aantal*
Males and females	Noord-Brabant (PV)	1960	6.7	25 650
		1961	6.4	27 290
		1962	6.7	26 377
		1963	6.8	26 426

		1964	6.5	27 208
		1965	6.7	25 941
		1966	6.8	24 604
		1967	6.6	24 227
		1968	6.8	23 364
		1969	6.9	24 406
		1970	6.9	22 920
		1971	6.8	20 689
		1972	6.9	18 826
		1973	6.8	16 136
		1974	6.6	15 544
		1975	6.8	13 496
		1976	6.7	13 492
		1977	6.6	13 117
		1978	6.9	12 671
		1979	6.6	12 909
		1980	6.7	13 109
		1981	6.8	12 269
		1982	6.9	10 743
		1983	6.9	9 889
		1984	7.0	10 476
		1985	7.1	10 837
		1986	7.3	11 222
		1987	7.2	11 908
		1988	7.2	11 340
		1989	7.5	11 222
		1990	7.4	12 767
		1991	7.6	12 155
		1992	7.6	12 354
		1993	7.9	10 975
		1994	7.8	11 496
		1995	8.0	9 884

		1996	8.0	9 663
		1997	7.8	10 281

Population dynamics; birth, death and migration per region

		Subjects	Deaths	Natural increase
			Deaths, ratio	
Sex	Regions	Periods	*per 1,000*	*aantal*
Males and females	Noord-Brabant (PV)	1998	7.9	10 869
		1999	8.2	10 246
		2000	8.1	11 320
		2001	8.1	10 120
		2002	8.3	9 400
		2003	8.2	9 091
		2004	7.9	8 313
		2005	7.9	7 123
		2006	7.9	6 869
		2007	7.9	6 310
		2008	8.0	6 541
		2009	7.9	6 315
		2010	8.0	6 042
		2011*	8.0	5 186

Population dynamics; birth, death and migration per region

		Subjects	Arrivals in municipality	
			Total arrivals	Due to immigration
Sex	Regions	Periods	*number*	
Males and females	Noord-Brabant (PV)	1960	70 040	4 312
		1961	70 187	5 278
		1962	73 975	6 415
		1963	74 988	5 051
		1964	79 189	6 681
		1965	80 299	8 049
		1966	87 113	9 713

		1967	85 356	6 015
		1968	88 555	7 403
		1969	95 778	10 019
		1970	98 246	12 767
		1971	107 198	12 253
		1972	110 602	10 785
		1973	116 662	10 462
		1974	112 342	11 124
		1975	107 449	12 677
		1976	103 386	9 767
		1977	95 851	10 079
		1978	88 441	10 539
		1979	82 690	11 866
		1980	85 008	13 314
		1981	76 491	9 684
		1982	75 601	7 901
		1983	78 038	7 793
		1984	78 707	7 621
		1985	83 753	8 654
		1986	91 845	9 890
		1987	92 369	10 088
		1988	92 618	10 253
		1989	95 259	10 911
		1990	91 202	12 293
		1991	88 382	11 948
		1992	91 684	12 579
		1993	93 644	13 130
		1994	92 702	12 600
		1995	95 783	11 777
		1996	96 714	12 798
		1997	94 346	12 560
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Population dynamics; birth, death and migration per region

		Subjects	Arrivals in municipality	
			Total arrivals	Due to immigration
Sex	Regions	Periods	*number*	
Males and females	Noord-Brabant (PV)	1998	101 478	15 051
		1999	97 667	15 131
		2000	95 701	16 378
		2001	94 029	16 597
		2002	93 977	14 341
		2003	90 965	12 293
		2004	89 863	11 180
		2005	94 396	12 081
		2006	97 094	13 284
		2007	98 945	14 848
		2008	102 807	18 324
		2009	95 878	18 539
		2010	96 886	18 886
		2011*	99 303	19 623

Population dynamics; birth, death and migration per region

		Subjects	Arrivals in municipality	Departures from municipality
			Due to intermunicipal moves	Total departures including administra...
Sex	Regions	Periods	*number*	
Males and females	Noord-Brabant (PV)	1960	65 728	.
		1961	64 909	.
		1962	67 560	.
		1963	69 937	.
		1964	72 508	.
		1965	72 250	.
		1966	77 400	.
		1967	79 341	.
		1968	81 152	.

		1969	85 759	.
		1970	85 479	.
		1971	94 945	.
		1972	99 817	.
		1973	106 200	.
		1974	101 218	.
		1975	94 772	.
		1976	93 619	.
		1977	85 772	.
		1978	77 902	.
		1979	70 824	.
		1980	71 694	.
		1981	66 807	.
		1982	67 700	.
		1983	70 245	.
		1984	71 086	.
		1985	75 099	.
		1986	81 955	.
		1987	82 281	.
		1988	82 365	87 703
		1989	84 348	89 700
		1990	78 909	84 513
		1991	76 434	84 306
		1992	79 105	85 790
		1993	80 514	88 399
		1994	80 102	87 991
		1995	84 006	91 657
		1996	83 916	93 291
		1997	81 786	89 601

Population dynamics; birth, death and migration per region

	Subjects	Arrivals in municipality	Departures from municipality

			Due to intermunicipal moves	Total departures including administra...
Sex	Regions	Periods	*number*	
Males and females	Noord-Brabant (PV)	1998	86 427	93 464
		1999	82 536	90 008
		2000	79 323	88 481
		2001	77 432	88 814
		2002	79 636	95 017
		2003	78 672	94 367
		2004	78 683	94 781
		2005	82 315	97 590
		2006	83 810	101 497
		2007	84 097	100 217
		2008	84 483	100 183
		2009	77 339	93 001
		2010	78 000	92 816
		2011*	79 680	95 149

Population dynamics; birth, death and migration per region

		Subjects	Departures from municipality	
			Due to emigration including administr...	Due to intermunicipal moves
Sex	Regions	Periods	*number*	
Males and females	Noord-Brabant (PV)	1960	.	62 426
		1961	.	62 186
		1962	.	63 682
		1963	.	65 896
		1964	.	67 710
		1965	.	67 308
		1966	.	74 061
		1967	.	76 908
		1968	.	76 712
		1969	.	79 827
		1970	.	81 635

		1971	.	88 449
		1972	.	91 340
		1973	.	93 237
		1974	.	89 325
		1975	.	87 048
		1976	.	84 923
		1977	.	80 717
		1978	.	73 801
		1979	.	67 546
		1980	.	69 610
		1981	.	66 947
		1982	.	69 289
		1983	.	70 771
		1984	.	71 499
		1985	.	75 256
		1986	.	80 839
		1987	.	80 556
		1988	8 219	79 484
		1989	8 932	80 768
		1990	8 946	75 567
		1991	9 239	75 067
		1992	9 206	76 584
		1993	9 452	78 947
		1994	9 470	78 521
		1995	10 374	81 283
		1996	11 226	82 065
		1997	10 094	79 507

Population dynamics; birth, death and migration per region

		Subjects	Departures from municipality	
			Due to emigration including administr...	Due to intermunicipal moves
Sex	Regions	Periods	*number*	

Males and females	Noord-Brabant (PV)	1998	9 398	84 066
		1999	10 328	79 680
		2000	12 026	76 455
		2001	12 925	75 889
		2002	15 170	79 847
		2003	15 055	79 312
		2004	15 148	79 633
		2005	15 394	82 196
		2006	16 513	84 984
		2007	15 645	84 572
		2008	14 604	85 579
		2009	14 509	78 492
		2010	13 871	78 945
		2011*	15 955	79 194

Population dynamics; birth, death and migration per region

		Subjects	Net migration
			Net migration including administrative..
Sex	Regions	Periods	*number*
Males and females	Noord-Brabant (PV)	1960	.
		1961	.
		1962	.
		1963	.
		1964	.
		1965	.
		1966	.
		1967	.
		1968	.
		1969	.
		1970	.
		1971	.
		1972	.
		1973	.

		1974	.
		1975	.
		1976	.
		1977	.
		1978	.
		1979	.
		1980	.
		1981	.
		1982	.
		1983	.
		1984	.
		1985	.
		1986	.
		1987	.
		1988	4 915
		1989	5 559
		1990	6 689
		1991	4 076
		1992	5 894
		1993	5 245
		1994	4 711
		1995	4 126
		1996	3 423
		1997	4 745

Population dynamics; birth, death and migration per region

		Subjects	Net migration
			Net migration including administrative..
Sex	Regions	Periods	*number*
Males and females	Noord-Brabant (PV)	1998	8 014
		1999	7 659
		2000	7 220
		2001	5 215

		2002	-1 040
		2003	-3 402
		2004	-4 918
		2005	-3 194
		2006	-4 403
		2007	-1 272
		2008	2 624
		2009	2 877
		2010	4 070
		2011*	4 154
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Population on 1 January

Population:
The total number of people residing in a given area.
In the population statistics compiled by Statistics Netherlands the inhabitants are the people registered in the population register of a Dutch municipality.

Live born children

Live born child:
A baby showing some sign of life after birth, regardless of the duration of pregnancy.
Live born children are recorded in the municipality of residence of the baby's mother (or occasionally the father). It is, therefore, not necessarily the municipality where the birth occurred.
.
On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

.
1960-1962: excluding live born children after a pregnancy lasting less than 26 weeks deceased before registration of birth.

Live born children, ratio

Live born children per 1,000 of the average population.
Not available by sex.
.
Population:

The total number of people residing in a given area.
In the population statistics compiled by Statistics Netherlands the inhabitants are the people registered in the population register of a Dutch municipality.

Deaths

Death:
Person declared dead by an authorized doctor.
Deaths represent the number of deaths in the 'de jure' population of the municipality of residence of the deceased, not the municipality where the death occurred.

.

On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

.

1960-1962: excluding live born children after a pregnancy lasting less than 26 weeks deceased before registration of birth.

Deaths, ratio

Deaths per 1,000 of the average population.
Not available by sex.

.

Population:
The total number of people residing in a given area.
In the population statistics compiled by Statistics Netherlands the inhabitants are the people registered in the population register of a Dutch municipality.

Natural increase

The number of live births minus the number of deaths.

.

Live born child:
A baby showing some sign of life after birth, regardless of the duration of pregnancy.
Live born children are recorded in the municipality of residence of the baby's mother (or occasionally the father). It is, therefore, not necessarily the municipality where the birth occurred.
1960-1962: excluding live born children after a pregnancy lasting less than 26 weeks deceased before registration of birth.

.

Death:
Person declared dead by an authorized doctor.

Deaths represent the number of deaths in the 'de jure' population of the municipality of residence of the deceased, not the municipality where the death occurred.
1960-1962: excluding live born children after a pregnancy lasting less than 26 weeks deceased before registration of birth.
.
On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

Arrivals in municipality

Arrivals in the municipality due to immigration or intermunicipal move.
.
Immigration:
People moving to the Netherlands from another country.
.
Intermunicipal move:
A move from one municipality to another.
.
On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

Total arrivals

Up to 1987 data may differ from other published data on StatLine. This is due to differences between the data files used by Statistics Netherlands and the official data as published in 'Loop van de bevolking per gemeente'.

Due to immigration

Immigration:
People moving to the Netherlands from another country.
Until October 1994, with a few exeptions, persons with the Dutch nationality were registered if they planned to stay for more than 30 days.
For persons who did not have a Dutch passport the corresponding period was 180 days.
From October 1994, the requirements for registration are met, both for Dutch residents and non-Dutch residents, if the anticipated length of stay in the first six months after settlement is at least four months.
.

Up to 1987 data may differ from other published data on StatLine. This is due to differences between the data files used by Statistics Netherlands and the official data as published in 'Loop van de bevolking per gemeente'.

.

Break in series external migration

As a result of an improved production process, a small shift has occurred in the figures on external migration.

From 2010 the following changes have been implemented.

- previously missed reports are now included;
- administrative entries preceding emigration are now considered as immigration;
- administrative removals followed by immigration are now considered as emigration

Due to intermunicipal moves

Intermunicipal move:

A move from one municipality to another, excluding changes caused by an adjustment of municipal borders.

Departures from municipality

Departures from the municipality due to emigration or intermunicipal move.

.

Emigration:

People leaving for another country.

.

Intermunicipal move:

A move from one municipality to another, excluding changes caused by an adjustment of municipal borders.

.

On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

Total departures including administra...

Total departures including net administrative corrections.

Data on departures including net administrative corrections give a better impression of the true level of departures than data excluding net administrative corrections.

Up to 1987 data may differ from other published data on StatLine. This is due to differences between the data files used by Statistics Netherlands and the official data as published in 'Loop van de bevolking per gemeente'.

.

Administrative correction:
Entry in and removal from the municipal population register for reasons other than birth, death, arrival, departure or municipal boundary change. The majority of administrative corrections refer to persons who are no longer living in their former place of residence, usually because they have settled in a foreign country. Administrative corrections resulting in registration usually concern persons who have been found (in their former place of residence or elsewhere) and are entered into the municipal population registers. This explains why the net administrative corrections are included in emigration (and net migration) but not in immigration.

.

Net administrative corrections:
Administrative entries minus administrative removals.

.

Administrative entry:
Decision by a municipality, at the request of the person concerned, to include that person in its population while it has no knowledge of birth, immigration or establishment of that person from another municipality in the Netherlands.

.

Administrative removal:
Decision by a municipality no longer to include a person in its population, once it has established that the address of the person is unknown, the person cannot be contacted and probably no longer resides in a municipality in the Netherlands.

Due to emigration including administr...

Emigration including net administrative corrections.
Data on emigration including net administrative corrections give a better impression of the true level of emigration than data excluding net administrative corrections.
Up to 1987 data may differ from other published data on StatLine. This is due to differences between the data files used by Statistics Netherlands and the official data as published in 'Loop van de bevolking per gemeente'.

.

Emigration:
People leaving for another country.
Until October 1994, persons who had the intention to leave the Netherlands for a period exceeding 360 days were deregistered.
From October 1994, the anticipated length of stay abroad in the year after settlement in another country is at least eight months.

.

Administrative correction:
Entry in and removal from the municipal population register for reasons

other than birth, death, arrival, departure or municipal boundary change.
The majority of administrative corrections refer to persons who are no longer living in their former place of residence, usually because they have settled in a foreign country. Administrative corrections resulting in registration usually concern persons who have been found (in their former place of residence or elsewhere) and are entered into the municipal population registers. This explains why the net administrative corrections are included in emigration (and net migration) but not in immigration.

.

Net administrative corrections:
Administrative entries minus administrative removals.

.

Administrative entry:
Decision by a municipality, at the request of the person concerned, to include that person in its population while it has no knowledge of birth, immigration or establishment of that person from another municipality in the Netherlands.

.

Administrative removal:
Decision by a municipality no longer to include a person in its population, once it has established that the address of the person is unknown, the person cannot be contacted and probably no longer resides in a municipality in the Netherlands.

.

Break in series external migration
As a result of an improved production process, a small shift has occurred in the figures on external migration.
From 2010 the following changes have been implemented.
- previously missed reports are now included;
- administrative entries preceding emigration are now considered as immigration;
- administrative removals followed by immigration are now considered as emigration

Net migration

The number of people moving in minus the number of people moving out.

.

On 18 March 2010 the municipality Rozenburg was abolished and incorporated in the municipality of Rotterdam.For the purpose of clarity, all figures for births, mortality, external migration and intra-municipal migration in Rozenburg in 2010 have been included in those for Rotterdam. No data are available for population developments in Rozenburg in 2010.Population growth of Rotterdam refers to Rotterdam and Rozenburg together.

.

Up to 1987 data may differ from other published data on StatLine. This is due to differences between the data files used by Statistics Netherlands and the official data as published in 'Loop van de bevolking per gemeente'.

Net migration including administrative..

Net migration including net administrative corrections.
Data on net migration including net administrative corrections give a better impression of the true level of net migration than data excluding net administrative corrections.
.
Administrative correction:
Entry in and removal from the municipal population register for reasons other than birth, death, arrival, departure or municipal boundary change. The majority of administrative corrections refer to persons who are no longer living in their former place of residence, usually because they have settled in a foreign country. Administrative corrections resulting in registration usually concern persons who have been found (in their former place of residence or elsewhere) and are entered into the municipal population registers. This explains why the net administrative corrections are included in emigration (and net migration) but not in immigration.
.
Net administrative corrections:
Administrative entries minus administrative removals.
.
Administrative entry:
Decision by a municipality, at the request of the person concerned, to include that person in its population while it has no knowledge of birth, immigration or establishment of that person from another municipality in the Netherlands.
.
Administrative removal:
Decision by a municipality no longer to include a person in its population, once it has established that the address of the person is unknown, the person cannot be contacted and probably no longer resides in a municipality in the Netherlands.

Noord-Brabant (PV)

PV = Province

Administrative classification of the Dutch territory. The Netherlands has had 12 provinces since the creation of the province Flevoland on 1 January 1986.

6.3 Economy statistics and description

Key figures

	Subjects	GDP (market prices)	Compensation of employees	Labour input of employed persons
Regions	Periods	*mln euro*		*1000 full-time equivalent jobs*
Noord-Brabant (PV)	1995	44 530	22 773	.
	1996	46 954	23 720	.
	1997	50 501	25 099	.
	1998	53 210	26 993	.
	1999	57 720	29 032	.
	2000	62 960	31 348	.
	2001	66 722	33 603	1 003.8
	2002	68 563	35 383	1 001.8
	2003	70 034	36 580	989.8
	2004	72 259	37 484	983.3
	2005	75 615	37 961	982.2
	2006	79 624	40 009	1 006.1
	2007	83 872	42 154	1 028.8
	2008	86 817	44 597	1 048.0
	2009*	84 650	44 877	1 032.8

GDP (market prices)

Gross domestic product (GDP), value added at market prices of the total economy is calculated as follows:
total value added at basic prices of industries
plus: balance of taxes and subsidies on products
plus: difference imputed and paid VAT.
VAT, taxes on imports and subsidies on re-exports cannot be attributed to individual industries. Therefore, GDP at market prices cannot be broken down completely by industry.
Value added can be valued gross (including consumption of fixed capital) or net (excluding consumption of fixed capital).

Compensation of employees

Compensation of employees is the total renumeration paid by employers to their employees in return for work done.
Employees are all residents and non-residents working in a paid job. Managing directors of limited companies are considered to be employees; therefore their salaries are also included in the compensation of employees. The same holds for people working in sheltered workshops.
Compensation of employees is distinguished between wages and salaries and employers' social contributions.
Wages and salaries include income taxes and employees' social contributions even if they are actually withheld by the employer and paid directly to tax authorities, social security schemes and pension schemes.
Wages include payments that are periodically and directly paid to employees. Besides they contain extra's (such as bonuses, overtime pay, tips, commission), wages in kind (such as free housing, free food, 'company car', day nursery, lower interest rates on mortgages, free travel (or at reduced prices) and holiday allowances. Furthermore, certain refunds for costs made by the employee, such as travel expenses to and from work, are included as well.
Employers' social contributions consist of payments to insurers made by employers for the benefit of their employees. They can be classified in employers' social security contributions, employers' private social contributions (o.w. pension schemes) and the imputed social contributions.
In most cases the employers directly pay the employers' social contributions to the insurers. However, to show that these contributions are paid for the benefit of employees, these payments are recorded as two transactions: a) employers pay employers' social contributions to their employees, and b) employees pay the same contributions to social insurance funds.

Labour input of employed persons

Labour input of employed persons is defined as the number of full-time equivalent jobs. Part-time jobs are converted to full-time jobs.
For employees a full-time equivalent job is the annual contractual hours considered full-time in that branch of industry.
For self-employed a full-time equivalent job is the quotient of the usual weekly work hours of that job and the average weekly work hours of self-employed with 37 or more normal weekly hours in the same branch of industry.

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
A-U All economic	Noord-Brabant (PV)	2008	44 597	704

activities		2009*	44 877	983
	West-Noord-Brabant (CR)	2008	10 986	182
		2009*	11 060	266
	Midden-Noord-Brabant (CR)	2008	7 447	100
		2009*	7 520	125
	Noordoost-Noord-Brabant (CR)	2008	11 567	197
		2009*	11 699	258
	Zuidoost-Noord-Brabant (CR)	2008	14 598	225
		2009*	14 598	334
A Agriculture, forestry and fishing	Noord-Brabant (PV)	2008	423	171
		2009*	441	175
	West-Noord-Brabant (CR)	2008	126	31
		2009*	130	32
	Midden-Noord-Brabant (CR)	2008	57	25
		2009*	58	25
	Noordoost-Noord-Brabant (CR)	2008	131	59
		2009*	138	61
	Zuidoost-Noord-Brabant (CR)	2008	109	56
		2009*	115	58
B-F Industry and energy	Noord-Brabant (PV)	2008	12 879	157
		2009*	12 646	348
	West-Noord-Brabant (CR)	2008	3 238	57
		2009*	3 212	117
	Midden-Noord-Brabant (CR)	2008	1 742	12
		2009*	1 720	24
	Noordoost-Noord-Brabant (CR)	2008	3 359	43
		2009*	3 298	82
	Zuidoost-Noord-Brabant (CR)	2008	4 540	45
		2009*	4 416	125
B-E Industry (no construction), energy	Noord-Brabant (PV)	2008	9 880	130
		2009*	9 670	313
	West-Noord-Brabant (CR)	2008	2 476	50

		2009*	2 454	108
	Midden-Noord-Brabant (CR)	2008	1 296	8
		2009*	1 275	19
	Noordoost-Noord-Brabant (CR)	2008	2 469	34
		2009*	2 390	71
	Zuidoost-Noord-Brabant (CR)	2008	3 640	36

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
B-E Industry (no construction), energy	Zuidoost-Noord-Brabant (CR)	2009*	3 548	115
B Mining and quarrying	Noord-Brabant (PV)	2008	22	0
		2009*	21	0
	West-Noord-Brabant (CR)	2008	10	0
		2009*	13	0
	Midden-Noord-Brabant (CR)	2008	2	0
		2009*	0	0
	Noordoost-Noord-Brabant (CR)	2008	5	0
		2009*	4	0
	Zuidoost-Noord-Brabant (CR)	2008	5	0
		2009*	3	0
C Manufacturing	Noord-Brabant (PV)	2008	9 350	59
		2009*	9 061	184
	West-Noord-Brabant (CR)	2008	2 294	11
		2009*	2 237	32
	Midden-Noord-Brabant (CR)	2008	1 245	6
		2009*	1 218	15
	Noordoost-Noord-Brabant (CR)	2008	2 281	14
		2009*	2 177	36

	Zuidoost-Noord-Brabant (CR)	2008	3 530	28
		2009*	3 429	100
D Electricity and gas supply	Noord-Brabant (PV)	2008	220	70
		2009*	289	127
	West-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
	Midden-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
	Noordoost-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
	Zuidoost-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
E Water supply and waste management	Noord-Brabant (PV)	2008	288	1
		2009*	299	2
	West-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
	Midden-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
	Noordoost-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
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Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
E Water supply and waste management	Zuidoost-Noord-Brabant (CR)	2008	x	x
		2009*	x	x
F Construction	Noord-Brabant (PV)	2008	2 998	27
		2009*	2 978	34
	West-Noord-Brabant (CR)	2008	762	7
		2009*	758	9
	Midden-Noord-Brabant	2008	446	4

	(CR)	2009*	445	5
	Noordoost-Noord-Brabant (CR)	2008	890	8
		2009*	909	11
	Zuidoost-Noord-Brabant (CR)	2008	899	8
		2009*	866	10
G-N Commercial services	Noord-Brabant (PV)	2008	19 564	175
		2009*	19 417	241
	West-Noord-Brabant (CR)	2008	4 620	42
		2009*	4 574	61
	Midden-Noord-Brabant (CR)	2008	3 467	27
		2009*	3 428	37
	Noordoost-Noord-Brabant (CR)	2008	5 037	45
		2009*	5 084	62
	Zuidoost-Noord-Brabant (CR)	2008	6 439	60
		2009*	6 331	81
G-I Trade, transport, hotels, catering	Noord-Brabant (PV)	2008	8 891	66
		2009*	8 914	90
	West-Noord-Brabant (CR)	2008	2 486	19
		2009*	2 492	28
	Midden-Noord-Brabant (CR)	2008	1 591	11
		2009*	1 667	17
	Noordoost-Noord-Brabant (CR)	2008	2 314	16
		2009*	2 323	22
	Zuidoost-Noord-Brabant (CR)	2008	2 499	17
		2009*	2 431	24
G Wholesale and retail trade	Noord-Brabant (PV)	2008	6 219	53
		2009*	.	.
	West-Noord-Brabant (CR)	2008	1 720	16
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	1 118	9
		2009*	.	.
	Noordoost-Noord-Brabant	2008	1 643	13

	(CR)			

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
G Wholesale and retail trade	Noordoost-Noord-Brabant (CR)	2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	1 738	14
		2009*	.	.
H Transportation and storage	Noord-Brabant (PV)	2008	2 013	6
		2009*	.	.
	West-Noord-Brabant (CR)	2008	623	2
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	378	1
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	483	1
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	529	1
		2009*	.	.
I Accommodation and food serving	Noord-Brabant (PV)	2008	659	7
		2009*	.	.
	West-Noord-Brabant (CR)	2008	143	1
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	95	1
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	188	2
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	232	2
		2009*	.	.
J Information and communication	Noord-Brabant (PV)	2008	1 593	6
		2009*	1 554	9

	West-Noord-Brabant (CR)	2008	184	1
		2009*	183	1
	Midden-Noord-Brabant (CR)	2008	250	1
		2009*	133	1
	Noordoost-Noord-Brabant (CR)	2008	451	2
		2009*	465	3
	Zuidoost-Noord-Brabant (CR)	2008	709	3
		2009*	773	4
K Financial institutions	Noord-Brabant (PV)	2008	2 155	10
		2009*	2 173	11
	West-Noord-Brabant (CR)	2008	419	2
		2009*	426	2
	Midden-Noord-Brabant (CR)	2008	443	1
		2009*	429	1

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
K Financial institutions	Noordoost-Noord-Brabant (CR)	2008	589	3
		2009*	600	4
	Zuidoost-Noord-Brabant (CR)	2008	704	4
		2009*	718	4
L Renting, buying, selling real estate	Noord-Brabant (PV)	2008	488	1
		2009*	500	1
	West-Noord-Brabant (CR)	2008	127	0
		2009*	133	0
	Midden-Noord-Brabant (CR)	2008	97	0
		2009*	101	0
	Noordoost-Noord-Brabant (CR)	2008	118	0
		2009*	124	0

	Zuidoost-Noord-Brabant (CR)	2008	146	0
		2009*	142	0
M-N Business services	Noord-Brabant (PV)	2008	6 437	91
		2009*	6 276	130
	West-Noord-Brabant (CR)	2008	1 403	19
		2009*	1 341	30
	Midden-Noord-Brabant (CR)	2008	1 085	13
		2009*	1 098	19
	Noordoost-Noord-Brabant (CR)	2008	1 567	24
		2009*	1 571	34
	Zuidoost-Noord-Brabant (CR)	2008	2 381	36
		2009*	2 266	48
M Other specialised business services	Noord-Brabant (PV)	2008	3 204	51
		2009*	.	.
	West-Noord-Brabant (CR)	2008	772	10
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	493	5
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	773	14
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	1 165	22
		2009*	.	.
N Renting and other business support	Noord-Brabant (PV)	2008	3 233	40
		2009*	.	.
	West-Noord-Brabant (CR)	2008	631	9
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	592	8

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors	Regions	Periods	*mln euro*	

(SIC 2008)				
N Renting and other business support	Midden-Noord-Brabant (CR)	2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	794	10
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	1 216	14
		2009*	.	.
O-U Noncommercial services	Noord-Brabant (PV)	2008	11 732	202
		2009*	12 373	219
	West-Noord-Brabant (CR)	2008	3 001	52
		2009*	3 143	57
	Midden-Noord-Brabant (CR)	2008	2 181	37
		2009*	2 314	38
	Noordoost-Noord-Brabant (CR)	2008	3 040	49
		2009*	3 179	53
	Zuidoost-Noord-Brabant (CR)	2008	3 509	64
		2009*	3 736	70
O-Q Government and care	Noord-Brabant (PV)	2008	10 773	194
		2009*	11 393	208
	West-Noord-Brabant (CR)	2008	2 772	50
		2009*	2 908	54
	Midden-Noord-Brabant (CR)	2008	1 985	35
		2009*	2 111	37
	Noordoost-Noord-Brabant (CR)	2008	2 791	48
		2009*	2 934	51
	Zuidoost-Noord-Brabant (CR)	2008	3 224	61
		2009*	3 439	67
O Public administration and services	Noord-Brabant (PV)	2008	3 144	30
		2009*	.	.
	West-Noord-Brabant (CR)	2008	873	8
		2009*	.	.
	Midden-Noord-Brabant	2008	540	5

	(CR)	2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	904	9
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	828	8
		2009*	.	.
P Education	Noord-Brabant (PV)	2008	2 877	3
		2009*	.	.
	West-Noord-Brabant (CR)	2008	670	1
		2009*	.	.

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
P Education	Midden-Noord-Brabant (CR)	2008	582	1
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	684	1
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	940	1
		2009*	.	.
Q Health and social work activities	Noord-Brabant (PV)	2008	4 752	161
		2009*	.	.
	West-Noord-Brabant (CR)	2008	1 229	41
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	863	29
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	1 203	38
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	1 456	52
		2009*	.	.
R-U Culture,	Noord-Brabant (PV)	2008	958	8

recreation, other services		2009*	981	11
	West-Noord-Brabant (CR)	2008	230	2
		2009*	235	3
	Midden-Noord-Brabant (CR)	2008	196	1
		2009*	203	3
	Noordoost-Noord-Brabant (CR)	2008	248	2
		2009*	246	3
	Zuidoost-Noord-Brabant (CR)	2008	285	2
		2009*	296	4
R Culture, sports and recreation	Noord-Brabant (PV)	2008	452	5
		2009*	.	.
	West-Noord-Brabant (CR)	2008	108	1
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	109	1
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	109	1
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	126	1
		2009*	.	.
S Other service activities	Noord-Brabant (PV)	2008	500	3
		2009*	.	.
	West-Noord-Brabant (CR)	2008	120	1

Regional accounts; production structure

		Subjects	Compensation of employees	Subsidies, not product-related
Economic sectors (SIC 2008)	Regions	Periods	*mln euro*	
S Other service activities	West-Noord-Brabant (CR)	2009*	.	.
	Midden-Noord-Brabant (CR)	2008	86	0
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	137	1
		2009*	.	.

	Zuidoost-Noord-Brabant (CR)	2008	157	1
		2009*	.	.
T Activities of households	Noord-Brabant (PV)	2008	6	0
		2009*	.	.
	West-Noord-Brabant (CR)	2008	2	0
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	1	0
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	2	0
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	2	0
		2009*	.	.
U Extraterritorial organisations	Noord-Brabant (PV)	2008	.	.
		2009*	.	.
	West-Noord-Brabant (CR)	2008	.	.
		2009*	.	.
	Midden-Noord-Brabant (CR)	2008	.	.
		2009*	.	.
	Noordoost-Noord-Brabant (CR)	2008	.	.
		2009*	.	.
	Zuidoost-Noord-Brabant (CR)	2008	.	.
		2009*	.	.

Compensation of employees

Compensation of employees is the total renumeration paid by employers to their employees in return for work done.
Employees are all residents and non-residents working in a paid job. Managing directors of limited companies are considered to be employees; therefore their salaries are also included in the compensation of employees. The same holds for people working in sheltered workshops. Compensation of employees is distinguished between wages and salaries and employers' social contributions.

Subsidies, not product-related

Subsidies on production paid to producers, not related to the value or volume of products domestically produced or transacted. These are mainly wage subsidies.

A-U All economic activities

A Agriculture, forestry and fishing
B Mining and quarrying
C Manufacturing
D Electricity, gas, steam and air conditioning supply
E Water supply; sewerage, waste management and remediation activities
F Construction
G Wholesale and retail trade; repair of motor vehicles and motorcycles
H Transportation and storage
I Accommodation and food service activities
J Information and communication
K Financial institutions
L Renting, buying and selling of real estate
M Consultancy, research and other specialised business services
N Renting and leasing of tangible goods and other business support services
O Public administration, public services and compulsory social security
P Education
Q Human health and social work activities
R Culture, sports and recreation
S Other service activities
T Activities of households as employers; undifferentiated goods- and service- producing activities of households for own use
U Extraterritorial organisations and bodies

A Agriculture, forestry and fishing

A Agriculture, forestry and fishing

B-F Industry and energy

B Mining and quarrying
C Manufacturing
D Electricity, gas, steam and air conditioning supply
E Water supply; sewerage, waste management and remediation activities
F Construction

B-E Industry (no construction), energy

B Mining and quarrying
C Manufacturing
D Electricity, gas, steam and air conditioning supply
E Water supply; sewerage, waste management and remediation activities

B Mining and quarrying

B Mining and quarrying

C Manufacturing

C Manufacturing

D Electricity and gas supply

D Electricity, gas, steam and air conditioning supply

E Water supply and waste management

E Water supply; sewerage, waste management and remediation activities

F Construction

F Construction

G-N Commercial services

G Wholesale and retail trade; repair of motor vehicles and motorcycles

H Transportation and storage

I Accommodation and food service activities

J Information and communication

K Financial institutions

L Renting, buying and selling of real estate

M Consultancy, research and other specialised business services

N Renting and leasing of tangible goods and other business support services

G-I Trade, transport, hotels, catering

G Wholesale and retail trade; repair of motor vehicles and motorcycles

H Transportation and storage

I Accommodation and food service activities

G Wholesale and retail trade

G Wholesale and retail trade; repair of motor vehicles and motorcycles

H Transportation and storage

H Transportation and storage

I Accommodation and food serving

I Accommodation and food service activities

J Information and communication

J Information and communication

K Financial institutions

K Financial institutions

L Renting, buying, selling real estate

L Renting, buying and selling of real estate

M-N Business services

M Consultancy, research and other specialised business services

N Renting and leasing of tangible goods and other business support services

M Other specialised business services

M Consultancy, research and other specialised business services

N Renting and other business support

N Renting and leasing of tangible goods and other business support services

O-U Noncommercial services

O Public administration, public services and compulsory social security

P Education

Q Human health and social work activities

R Culture, sports and recreation

S Other service activities

T Activities of households as employers; undifferentiated goods- and service- producing activities of households for own use

U Extraterritorial organisations and bodies

O-Q Government and care

O Public administration, public services and compulsory social security
P Education
Q Human health and social work activities

O Public administration and services

O Public administration, public services and compulsory social security

P Education

P Education

Q Health and social work activities

Q Human health and social work activities

R-U Culture, recreation, other services

R Culture, sports and recreation
S Other service activities
T Activities of households as employers; undifferentiated goods- and service- producing activities of households for own use
U Extraterritorial organisations and bodies

R Culture, sports and recreation

R Culture, sports and recreation

S Other service activities

S Other service activities

T Activities of households

T Activities of households as employers; undifferentiated goods- and service- producing activities of households for own use

U Extraterritorial organisations

U Extraterritorial organisations and bodies

Noord-Brabant (PV)

Comprises the COROP regions West-Noord-Brabant, Midden-Noord-Brabant, Noordoost-Noord-Brabant and Zuidoost-Noord-Brabant.

West-Noord-Brabant (CR)

Is included in the province of Noord-Brabant.

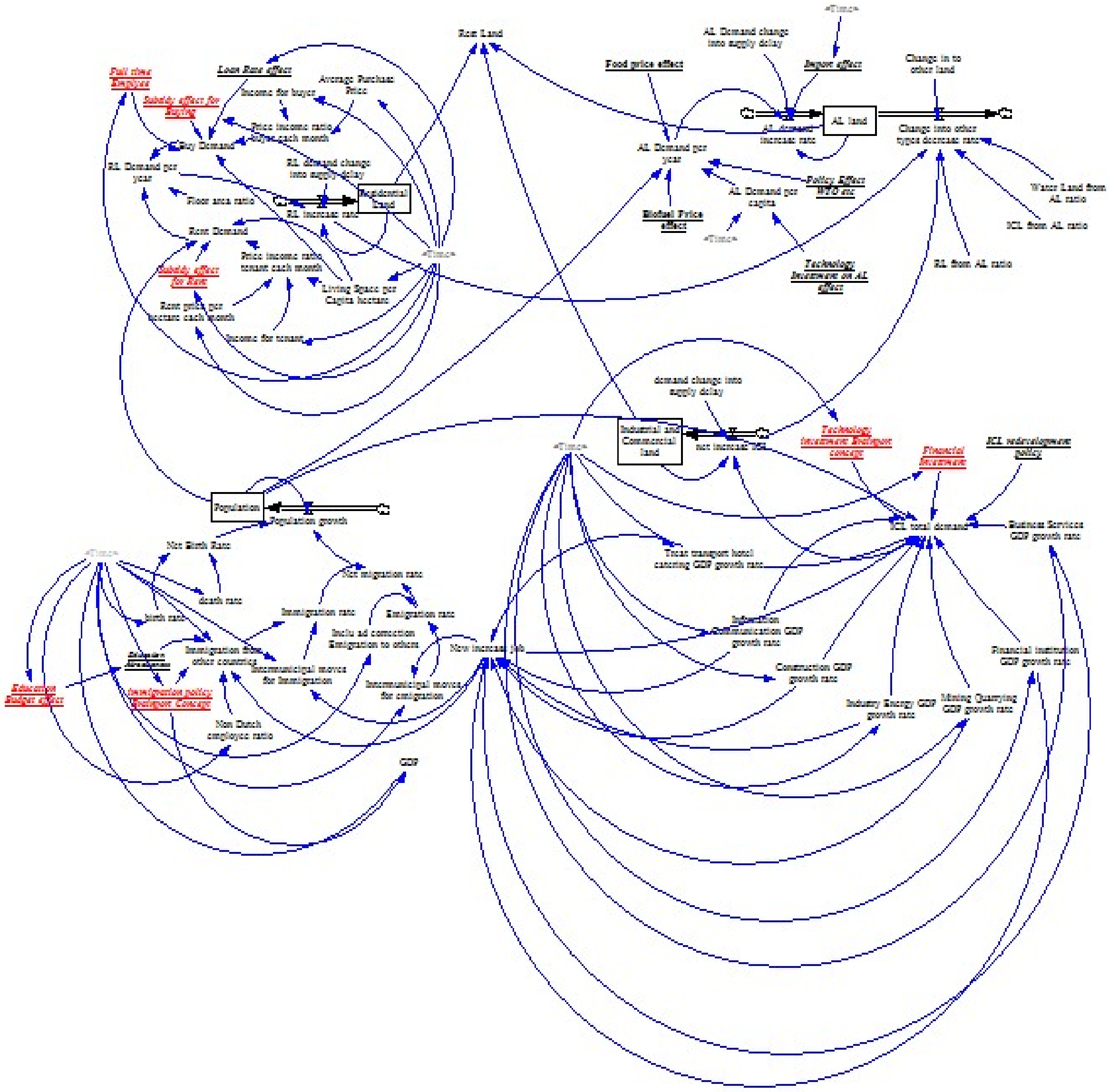
Noordoost-Noord-Brabant (CR)

Is included in the province of Noord-Brabant.
The region is subdivided into (see detailed COROP regions):
- Stadsgewest 's-Hertogenbosch
- Overig Noordoost-Noord-Brabant.

2009*

Preliminary figures.

6.4 Whole system dynamics system



7. Summary

NORTH BRABANT LAND USE CHANGE DRIVING FORCES ANALYSIS AND SCENARIO SIMULATION: A SYSTEM DYNAMICS APPROACH

Construction Management and Urban Development 2010-2012

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02-07-12

ABSTRACT

Land use is of much significance for human beings. This paper combines system dynamic (SD) and scenario analysis (SA) together for simulating North Brabant land use change from the system top-down approach. After studying all the current researches in and outside the Netherlands with various research methods, we define our research as system-orientated socioeconomic driving forces land use simulation. We first make a list of driving forces in four sub-systems. Then calibrate the system and create possible future scenarios. Based on these scenarios, we have simulation results which can give policy makers suggestions. Further spatial location orientated research can also be done with other methods.

Keywords: land use change driving forces, North Brabant, system dynamics, scenario analysis

INTRODUCTION

Since the origin of human beings, land resource offers us place to live, to produce and to build. Without land resource, there would be no human beings at all on the earth. With the massive growth of population, land use is transiting from extensive use to intensive use, especially in some densely populated areas. Land resource use is getting more and more significance because of the limited nature of land resource. Moreover, the higher and higher price of land stimulates people trying to understand what will happen to the land in one area and predicting the future scenarios so that they can make profits and mitigate risks.

However, there is not much reference about developed countries in Europe. As the Netherlands is one of the most populous countries in the world, we believe it is very essential for us to do Dutch land use change analysis research. A land use study about the whole Netherlands has been executed in which different kinds of land use change driving forces, especially biographic attributes, have been identified. Nevertheless, there is still no provincial level research in the Netherlands.

In 2008, the new national Spatial Planning Act is introduced, calling for a more pro-active role of Dutch provinces in the policy arena. It demands Regional Spatial Strategies and they are the main guiding documents in spatial planning at the regional and local level. These strategies should focus on the year 2020 with a further outlook until 2040. (Koomen et al, 2010).

With a population of approximately 2.5 million and an area of around five thousand square kilometers, North Brabant (mostly called Brabant) is one of the largest Dutch provinces (Wikipedia). Under current economic crisis, creating an excellent spatial environment for economic and social development towards an innovative and globally competitive region is far more important than ever. Therefore, careful spatial planning and development for better accessibility and mobility for the region is one of the core tasks for the North Brabant province. That's why North Brabant is chosen for the case study for finding the driving forces behind land use change and predicting the future scenarios.

GOALS AND QUESTIONS

Goals

Based on our motivations, there are several goals we want to achieve:

- Understanding the current state about land use change study;
- Identifying driving forces behind North Brabant land use change;
- Proposing a system dynamics model to simulate these changes with the identified driving forces;
- Constructing future scenarios to predict the future trends of these driving forces;
- Simulating land use change in the future under the constructed future scenarios;
- And give possible solutions to the policy makers.

Questions

- Based on these goals, several question we need to answer:
- How does the land use change in North Brabant in the past 15 years?
- What are the driving forces behind these changes?
- Can we propose a model to simulate these changes?
- What will happen for these driving forces in the future considering different socio-economic scenarios?
- Can we propose or construct several scenarios including future driving forces and simulate the land use change under these possible scenarios?
- What will be the future land use in this region without new interventions?
- What will be the future land use in this region with new interventions?

METHODOLOGY

In order to know to what extent North Brabant land use has changed in the past 15 years, statistical inventories will be searched. Most of our data are from central bureau of statistics, including land use dynamics, population dynamics, and economy dynamics for North Brabant and so on.

Literature review can help us find driving forces behind these changes and their inner connections. It includes geographical study, theoretical study, policy review, population study, economy research and so on.

Based on the information collected, a System Dynamics (SD) model is proposed. Land use change is closely related with the regional socioeconomic development which is mainly driven by human factors. The SD model has been proved to be a useful tool for analyzing the complex connection between land use and socio-economic development. Furthermore, it is easier and more flexible to use a SD model to design plausible land use scenarios (Luo. et al., 2010). By using SD, we can have a top-down view which gives us the opportunity of understanding the whole system comprehensively.

Regression will be used for finding parameters between different variables in SD model. Matlab software solves regression questions. For future land use scenario analysis, trends for different driving forces are going to be analyzed to create several possible scenarios for model test. Among hundreds of possible scenarios in the future, we will use scenario theory to build three scenarios which will show extreme situations and most possible situation to use for predicting the future land use scenarios.

Then we use commen sense to find out the most unpredictable variables in our SD model. At the same time, we can have assumptions on which ones are the most influencial ones. Also in this part we use WLO scenarios to put into our SD model to find the most influencital variables to create our own scenarios. This procedure also offers us with reasonable setting method of the new intervention values in our scenarios.

Calibration and validation process would make the system reliable. Based on simulated results under different scenarios, we can give policy advices with high value of reference. And these recommendations will be given based on the model testing results from government policy makers' point of view.

RESULTS

Identified land use change driving forces

We combine all the most influential driving forces into several categories under different sub-systems. For more information, you can see the following tables.

	Demography	Policy (Interventions)	Economy
Population sub-system	Birth rate; Death rate; Net birth rate; Immigration from other countries; Immigration rate; Emigration rate; Net migration rate; Inter-municipal moves for emigration; Inter-municipal moves for immigration;	Immigration policy; Education attractiveness; Education budget effect;	Non-Dutch employee ratio; GDP;

Table 1: Driving forces behind population sub-system

	Demography	Policy	Economy	ICL conditions
Industrial & Commercial Land (ICL)	Population growth (Population);	Technology investment (Brainport Concept); Financial investment (Investment budget, etc); ICL redevelopment policy;	New increase job; GDP; Treat transport hotel catering GDP growth rate; Information communication GDP growth rate; Construction GDP growth rate ; Energy industry GDP growth rate; Mining quarrying GDP growth rate; Financial institution GDP growth rate; Business services GDP growth rate;	Current ICL stock; Net increase ICL per year; Demand change into supply delay;

Table 2: Driving forces behind Industrial and Commercial land sub-system

	Demography	Policy (Interventions)	Economy	ICL conditions
Residential Land (RL)	Population growth (Population); Rent demand Living spaces per capita hectare;	Subsidy effect for buying; Loan rate effect; Subsidy effect for rent;	Full time employee; Price income ratio for tenant per month; Price income ratio for buyer per month; Income for buyer;	RL demand per year; Floor area ratio; Buy demand; Current RL stock; Rent price per hectare per month; Living spaces per capita hectare; Average purchase price; RL demand change into supply delay;

Table 3: Driving forces behind Residential land sub-system

	Demography	Policy (Interventions)	Economy	Environment	AL Conditions
Agricultural Land (AL)	Population;	Policy like WTO effect; Technology investment on AL effect; Import effect; Export effect;	Food price effect; EU economy conditions; Bio-fuel price effect;	Change into other land; Net increase ICL; RL increase rate ; Water land from AL ratio; RL from AL ratio;	AL demand per year; AL demand per capita; AL demand change into supply delay; AL change in to other land use type rate; Al demand increase rate;

Table 4: Driving forces behind Agricultural land sub-system

System dynamics model

After identifying all the most influential driving forces in different sub-systems, we can propose our system dynamics model. All the equations behind these variables are calculated by regression method and each of these sub-systems are calibrated before the validation process so that all of these sub-systems are reasonable.

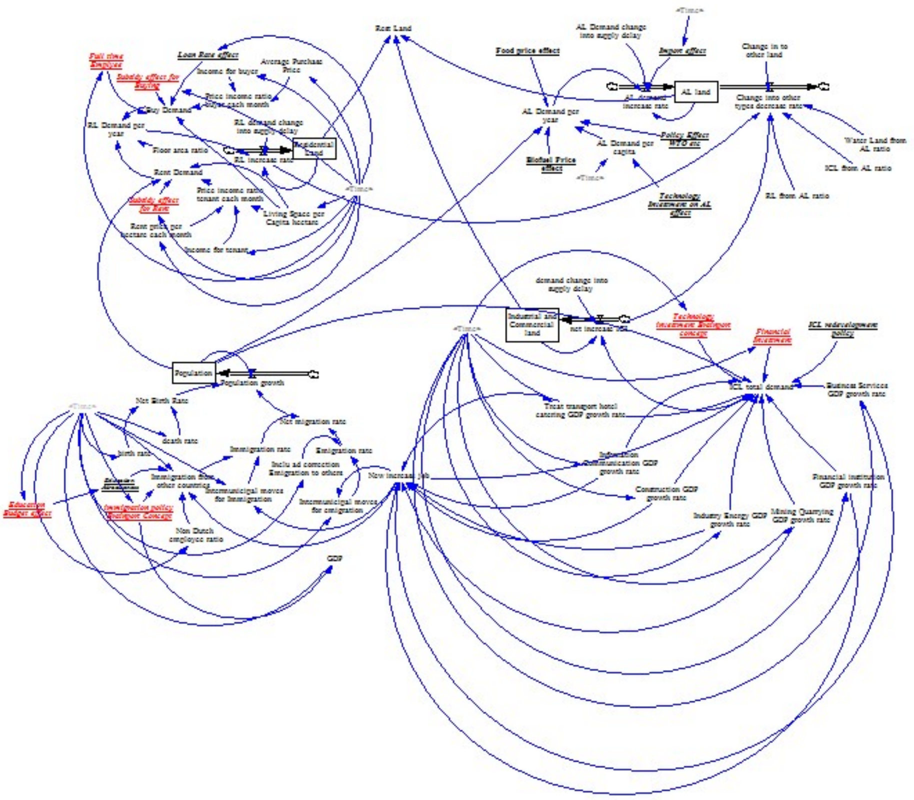


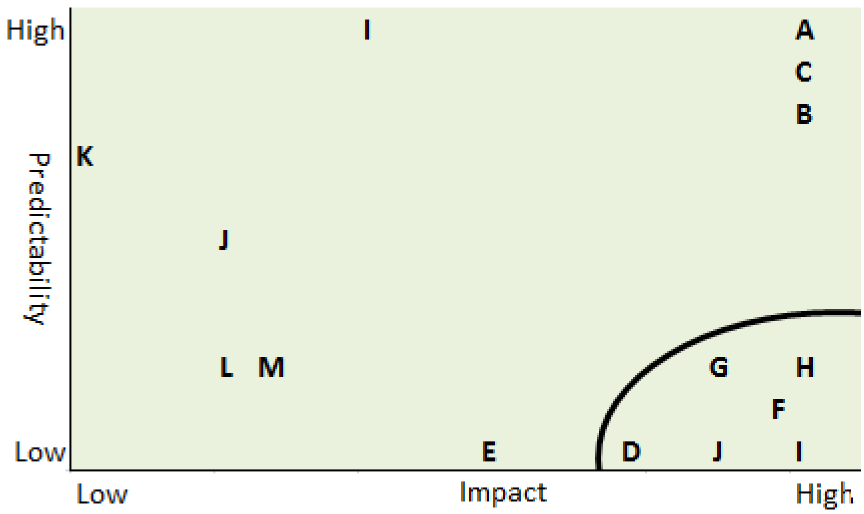
Figure 1: System dynamics model

Initial simulation results

When all the interventions are set as 0, we call the model at initial state. After running the initial model, we can see the simulation results for each sub-system. After comparing current available newly updated actual data with the simulation results like the population stock in 2009 and 2010, we can see that the model works well. For example, the predicted data for population in 2009 and 2010 are 2,425,330 and 2,427,960 respectively. The updated actual statistical data are 2,434,560 and 2,444,158. We can see that the trends are well predicted.

Scenario construction

In this part, as we mentioned before, we first determine the unpredictability of each interventions. Then use put WLO scenario settings into our SD model to find out the most influencial interventions. Then we can have an impact versus predictability matrix. In the black arc, the ones are the interventions we will use to construct our own scenarios. They are immigration policy, full time employeement, subsidies for rent and buying, technology and financial investment on ICL.



A: Birth rate; B: Death rate; C: Net birth rate; D: Immigration policy; E: Education budget effect; F: New increase job each year; G: Technology investment; H: Financial investment; I: Subsidy for buying; J: Subsidy for renting; K: WTO, import and export effect; L: Food and bio-fuel price; M: Import effect

Figure 2: Impact and predictability matrix

We combine these four into two new attributes, namely economy condition and policy intervention. Using these two new attributes, we create the scenario matrix for defining scenarios.

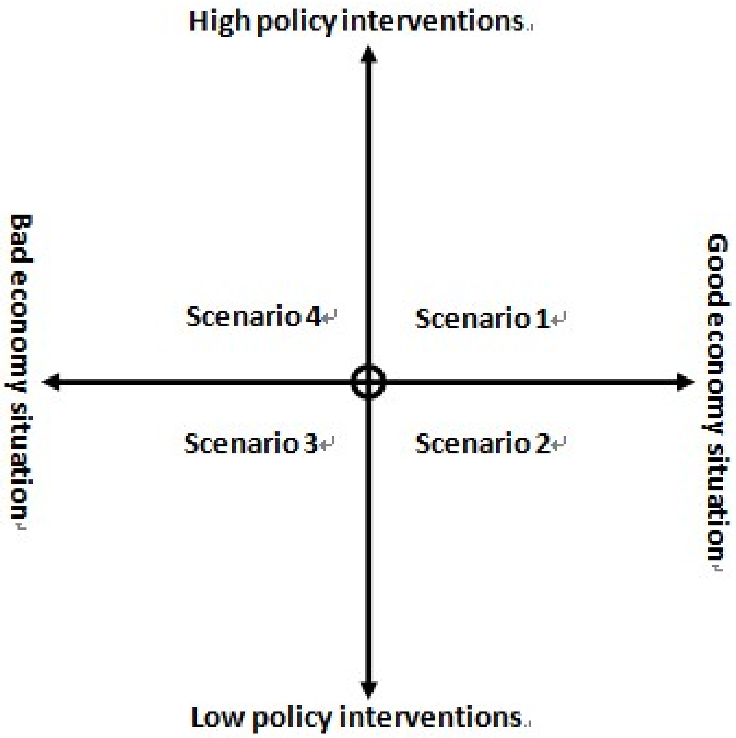


Figure 3: Scenario matrix

Scenario 1 (contradictory scenario)
In this scenario, as it could be seen from the figure, both the state of the economy is good and the policy intervention level is high. So there will be high restriction for migration and we think in the long run it is not good for more qualified employee. It is a little strange situation that government cut the budget when economy is good. So this scenario is not actually practical in our opinions.

Scenario 2 (best scenario)
The state of the economy is good and the policy intervention level is low. In this case, more investors, buyers and visitors like students can come to North Brabant and it has a good influence on economy, too. This is the best case in our scenario construction.

Scenario 3 (possible scenario)
The state of the economy is bad and the policy intervention level is low. In this case, more people still can come for finding jobs here and students can also come. It will be a quite possible scenario. It reflects that without more policy restrictions, what will happen to the land use or the economy. Maybe more people's coming would stimulate the economy which makes the situation better again.

Scenario 4 (worst scenario)
In this case, population becomes less becuase of the strict policy. And the economy is not good. It could have a really bad reinforcing loop for economy. We consider it as the worst case.

Scenario simulation
As said above, we choose scenario 2, 3 and 4 for the simulation. The following figures show one example sub-systems under these three scenarios.

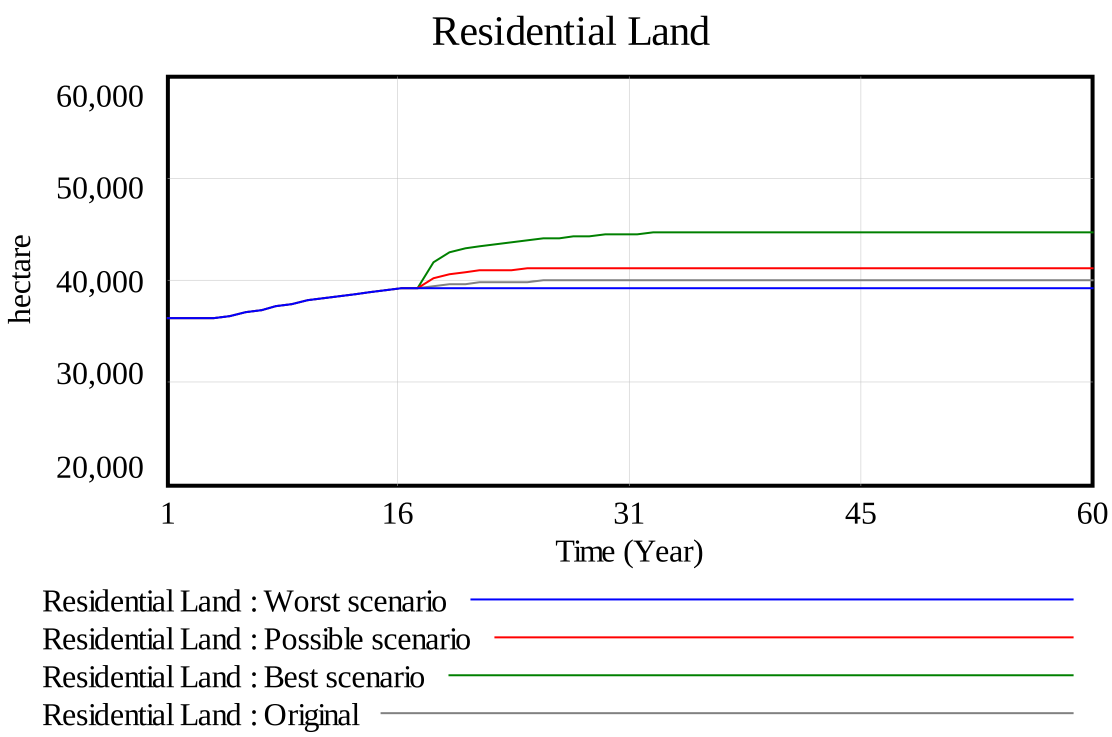


Figure 4 RL simulation results contrast

From the simulation results, we can see that in the best scenario, North Brabant's RL stock can reach its peak after year 34. And in the worst scenario, it can only achieve a quite low level of highest stock in around year 17 compared with other scenarios, even less than the original case. Compared with the initial settings, the possible and most interesting scenario shows a higher RL stock result.

Policy recommendation
Regarding to the whole system, we should say that more limitations on migration policy would probably harm the economy development here because of the elimination of foreign investment. And for the education effect, cutting budget is definitely not a good choice for North Brabant. it is better that government can collaborate with private investors to set up funding for researchers or scholars. Or it is also available to find other ways out.

CONCLUSION AND DISCUSSION
In this study, we try to make a list of land use driving forces and propose a system dynamics model to simulate the past land use change trend. After validating the past trend, we believe our model works well to predict the future trend. So we find the most influential and unpredictable attributes in our opinions to create future scenarios. We predict and contrast the differences of simulation results based on these three scenarios. Then we can give policy makers some recommendation on the basis of the contrast.

There are some points we need to mention for further improvements.

In the current model, GDP is not connected with different sectors' GDP growth rates. And we first assume that there is connection between GDP and new increase job. However, the data shows that they are not consistent. In the future, it is also possible that we find other variables which could fill in the gap between these variables. Up to now, there are only three land use types in the system. However, more land use types can be added into the system like water system, wood system and so on. More special specific objectives can be added. There is also one other option to expand this study. We can also build up a land use sustainability assessment framework and do some comparison studies between different areas. Last but not least, for the scenarios construction, it is also possible to build up different scenarios based on various study needs.

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REFERENCE
[1] Act of 20 October 2006 containing new rules for spatial planning (Spatial Planning Act), (2008).
[2] Blokhuis, E.G.J., Han., Q., Schaefer, W.F. (2011) Understanding the Dutch market for Industrial Areas with System Dynamics modeling, proceedings of the 2011 ERES conference, Eindhoven.
[3] Bood, R.P. and Postma, T.J.B.M. (2000) Scenario analysis as a strategic management tool, University of Groningen.
[4]Borsboom, J., Zondag, B. (2009) Visiedocument modelontwikkeling voor ruimtegebruiksmodellering bij het PBL, Bilthoven: Internal note, PBL.
[5] CPB, MNP and RPB (2006) Welvaart en Leefomgeving, Een scenariostudie voor Nederland in 2040, Den Haag: Centraal Planbureau, Milieu-en Natuurplanbureau en Ruimtelijk Planbureau.
[6] E. Koomen, J. Borsboom-van Beurden (eds.), Land-Use Modelling in Planning Practice, The GeoJournal Library 101, DOI 10.1007/978-94-007-1822-7_9.
[7] Georgantzas, N.C. and Acar, W. (1995) Scenario-driven planning: learning to manage strategic uncertainty, Quorom, London.
[8] Godet (2000) The art of scenarios and strategic planning: tools and pitfalls, Technological Forecasting and Social Change, Vol. 65, nr. 1, pp. 3-22.
[9] Guan, D., Gao, W., Su, W., Li, H., Hokao, K. (2011) Modeling and dynamic assessment of urban economy-resource-environment system with a coupled system dynamics-geographic information system model, Ecological Indicators, 11(5), 1333-1344.
[10] Hersperger, A. M., Burgi, M. (2009) Going beyond landscape change description: Quantifying the importance of driving forces of landscape change in a Central Europe case study, Land Use Policy 26(2009), 640-648.
[11] Koomen, E., J. Borsboom-van Beurden (eds.). (2011) Land-Use Modeling in Planning

Practice, The GeoJournal Library.
[12] Lauf, S., Haase, D., Hostert, P., Lakes, T., Kleinschmit, B. (2011) Uncovering land-use dynamics driven by human decision-making – A combined model approach using cellular automata and system dynamics, Environmental Modelling & Software 27 -28, 71-82.
[13] Long, H., Tang, G., Li, X., Heilig, G. (2007) Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China, Journal of Environmental Management, 83(5), 351-364.
[14] Needham, B. (2004) The new Dutch spatial planning act: Continuity and change in the way in which the Dutch regulate the practice of spatial planning, Research group Governance and Places, working paper series 2004/12.
[15] The new Spatial Planning Act gives space (2007) The Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM).
[16] Verburg, P.H., Eck, J.R.R., Nijs, T.C.M., Dijst,M.J., Schot, P. (2004) Determinants of land-use change patterns in the Netherlands, Environment and Planning B: Planning and Design, 31(1), 125-150.
[17] Wu, Y., Peng, Y., Zhang, X., Skitmore, M., Song, Y. (2011) Development priority zoning (DPZ)-led scenario simulation for regional land use change: The case of Suichang County, China, Habitat international, doi:10.1016/j.habitatint.2011.10.011.
[18] Xu, Z., Coors, V. (2012) Combing system dynamics model, GIS and 3D visualization in sustainability assessment of urban residential development, Building and Environment, 47, 272-287.
[19] http://www.welvaartenleefomgeving.nl/references_UK.html

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