Land use change modeling and calibration through transformation potential analysis

Citation for published version (APA):

Document status and date:
Published: 01/01/2014

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.
Land use change modeling with a focus on industrial land redevelopment: A Case Study

Tong Wang, Qi Han, Bauke de Vries*

*Built Environment Department, Eindhoven University of Technology

Abstract

Due to overoptimistic land use planning and economic crisis, a lot of abandoned or not fully used industrial areas appear these years in the Netherlands. Thorough study should be performed for these areas in order to achieve sustainable development goal. This paper presents a constrained cellular automata modeling approach to simulate land use changes with a focus on industrial land redevelopment. Moreover, a detailed calibration procedure is described together with several tools we have developed for more efficient and better calibration process. This provides a guideline for other studies using this approach.

© 2014 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the Eindhoven University of Technology, Faculty of the Built Environment, Urban Planning Group.

Keywords: land use change modelling; industrial land use; case study; Metronamica; calibration; scenario analysis

1. Introduction

Many industrial areas are not fully used in the Netherlands partially because of the economic crisis and partially because of overoptimistic land use planning\(^1\). In order to fulfil sustainable development goal, research is necessary for industrial land redevelopment. This study attempts to simulate land use changes with a focus on industrial land use on a regional level. The simulation is performed by Metronamica\(^2\), which is a software developed by RIKS\(^3\). There are several studies have been performed by researchers using this software\(^4\)\(^5\). However, in none of them the calibration process is explained specifically. This process is crucial for further study and prediction of future land use changes. It is also a very tedious and time consuming process and it would take you much more time than you can imagine if you don’t get clear instructions what to do in which order. That is why in this paper we also present step by step procedures to perform the calibration of the system. North Brabant region in the Netherlands is chosen for the case study. Several steps are taken to fulfil the goal. In the second Section, methodology is explained for this research. In Section three, North Brabant region is introduced with an overall understanding of the situation as the start of case study. Land use reclassification and data collection issues are discussed later followed by some illustrations of land use change modelling procedures. Main calibration activities and steps are included later which contains several tools that are used for improving and accelerating the speed of calibration process. In the following paragraphs, methods to construct future scenarios are discussed. The last section deals with conclusions, further steps, recommendations and acknowledgements.
2. Methodology

In this study, we use constrained cellular automata approach to model land use change for North Brabant. The reason behind it is that it requires less data than agent based modelling approach and is relatively easier to calibrate and validate. Another reason is that at this moment we don’t consider too much detailed information for land use change like human behavior, social networks. Currently, the main concern is land use itself. In this regards, constrained cellular automata approach is well recognized as being sufficient for this kind of study.

Calibration is always very crucial for this approach. So we have also developed several tools to make this process much easier and quicker. In the following calibration part, a comprehensive description is provided.

Scenario analysis is used for constructing future scenarios and predicting possible trends for further analysis and planning activities. These scenarios will be constructed later using unpredictability and importance matrix.

3. Case study

3.1. North Brabant

North Brabant region is a province of the Netherlands which is one of the most innovative regions of the European Union. Also DAF, VDL, Ciber, Atos Origin, NXP Semiconductors, ASML, FEI Company, Thales Cryogenetics and TNO Industrial Technology are located in this region. Other industries also exist like automobile, electronics, textile and shoes. However, there are plenty of abandoned industrial areas need to be redeveloped at this moment because of the previous overoptimistic land use planning and economic crisis.

In 2008, the new national land use act is introduced calling for a more proactive role for regional government in planning policy arena. One of the main goals for North Brabant region is to fulfill sustainable development and gaining more competitiveness in global world in the regard of technology, industry and research. Considering the strong connection between industry and research in this region and actual existing industrial problems, we consider this region as a good example for case study.

3.2. Land use reclassification and data collection

Land use reclassification for North Brabant is based on Kadaster data from DANS. The reason for using this dataset instead of CORINE data is that Kadaster data separate industrial areas from retail land use which is beneficial for us.

Since Metronamica requires land uses to be classified into three types, namely function, vacant and feature, the reclassified land uses are also categorized into these three types. To be more specific, function land use is the land use that are actively simulated while vacant land use are the ones that only change because of function land use changes. Feature land use is the one that does not change during the simulation period. After examining the land use maps from 2003 and 2010, we identify that forest and water body are more or less static in this region (less than 2% change). So they are defined as features. Table 1 shows the land use change rate from 2003 to 2010.

<table>
<thead>
<tr>
<th>Value</th>
<th>Class name</th>
<th>2003</th>
<th>2010</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Agricultural</td>
<td>325588</td>
<td>319491</td>
<td>1.87%</td>
</tr>
<tr>
<td>1</td>
<td>Housing</td>
<td>39937</td>
<td>40975</td>
<td>2.60%</td>
</tr>
<tr>
<td>2</td>
<td>Retails and hospitality</td>
<td>940</td>
<td>1570</td>
<td>67.02%</td>
</tr>
<tr>
<td>3</td>
<td>Public and social-cultural services</td>
<td>5331</td>
<td>5156</td>
<td>3.28%</td>
</tr>
<tr>
<td>4</td>
<td>Industrial areas</td>
<td>13806</td>
<td>15553</td>
<td>12.65%</td>
</tr>
<tr>
<td>5</td>
<td>Dump, extraction and other abandoned sites</td>
<td>824</td>
<td>748</td>
<td>9.22%</td>
</tr>
<tr>
<td>6</td>
<td>Construction sites</td>
<td>4747</td>
<td>5464</td>
<td>15.10%</td>
</tr>
<tr>
<td>7</td>
<td>Recreation</td>
<td>12812</td>
<td>13523</td>
<td>5.55%</td>
</tr>
</tbody>
</table>

Table 1. Land use change rate from 2003 to 2010.
Normally in the Dutch case, agricultural land is considered as vacant. Therefore, currently land uses are reclassified in Table 2.

<table>
<thead>
<tr>
<th>Class name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>Vacant</td>
</tr>
<tr>
<td>Housing</td>
<td>Function</td>
</tr>
<tr>
<td>Retails and hospitality</td>
<td>Function</td>
</tr>
<tr>
<td>Public and social-cultural services</td>
<td>Function</td>
</tr>
<tr>
<td>Industrial areas</td>
<td>Function</td>
</tr>
<tr>
<td>Dump, extraction and other abandoned sites</td>
<td>Function</td>
</tr>
<tr>
<td>Construction sites</td>
<td>Function</td>
</tr>
<tr>
<td>Recreation</td>
<td>Function</td>
</tr>
<tr>
<td>Road and rail networks and associated land</td>
<td>Function</td>
</tr>
<tr>
<td>Airport</td>
<td>Function</td>
</tr>
<tr>
<td>Forest</td>
<td>Feature</td>
</tr>
<tr>
<td>Water bodies</td>
<td>Feature</td>
</tr>
<tr>
<td>Outside area</td>
<td>Feature</td>
</tr>
</tbody>
</table>

After the reclassification, GIS software is used for making the maps of land use, suitability, zoning and regional boundary. Suitability map is from CORINE dataset and includes DEM map and zoning maps include Natura2000 map at this moment. More maps can be added later. Regional boundary map is from OpenStreetMap.

3.3. Land use change modelling

Metronamica, which is developed by RIKS is used for land use change simulation and calibration. The calibration part is performed firstly by neighborhood rules calibration and then by suitability and zoning rules. The calibration is based on kappa statistics\(^\text{11}\). More detailed information about the steps for calibration is in the next part.

In the land use change modelling part, a crucial thing to consider is the resolution of the maps. This is a trial and error process. Generally speaking, 200 meters to 500 meters resolution is used for regional level land use change modelling. We first try the resolution of 200 meters, and find out that land use change is not that severe, especially for industrial areas. The reason is that 200 meters is too large for an individual industrial site. Therefore, 100 meter resolution is chosen for our case study.

The original data we get from DANS is vector data. In order to rasterize them to fulfil the requirements of Metronamica, we also try several methods including FME, Quantum GIS and ArcGIS. It turns out that FME and Quantum GIS can only rasterize them in an ascending or descending order based on different values of one attribute and this is not the way we want the vector maps to be rasterized. And only ArcGIS can offer us another algorithm to rasterize the data. To be specific, this algorithm we choose at last is “MAXIMUM\_COMBINED\_AREA” in which features with common attributes are combined to produce a single area within the cell in question for consideration when determining the largest area.
3.4. Calibration and validation

In this part, the detailed calibration procedures are described. As in the Dutch case, especially in North Brabant region, land is very flat, so the suitability map actually is not quite influential. For zoning plans, only Natura2000 map is introduced in this region at this moment. For accessibility rules, since road networks are already included in the land use maps, we don’t specifically set rules for them either. Therefore, the main focus is for calibrating the neighborhood rules. There are several steps we follow to gain more insights on how to set these neighborhood rules.

White et al. provide a thorough study on neighborhood rules setting based on theoretical research and several case studies in Western countries which can be used as baseline reference for our research. For example, in their study, it shows clearly that existing industry plots are very attractive for further industrial land development, while in the contrast, repulsing housing in a short distance but attractive in a longer distance. By using two land use maps from two different years, which in our case is land use map from 2003 and 2010, we can use an excel script to generate a Pivot chart. It is an amount chart showing what land use appears from which initial land use at what distance. And this is quite similar like the neighborhood rules’ settings trends in Metronamica. Figure 1 shows the result of our Pivot chart analysis revealing the average changes from other land uses to industry at different distances. One thing needs to be noticed is that this Pivot chart cannot reveal inertia from the same land use well because of data limitation. For inertia settings, we mainly use White’s suggestions by making it very high, so do other land uses.

Fig. 1. Other land use change to industry from 2003 to 2010 at different distance.

![Fig. 1. Other land use change to industry from 2003 to 2010 at different distance.](image)

Fig. 2. Other land uses change to industry from 2003 to 2010 map.
Combining these two methods, namely literature study and real data analysis, some important settings can be generated. But it is not exactly the same as what has been generated or suggested since other factors also have influence like zoning plans and suitability issues. Therefore, we also create another tool using FME software for analyzing different changes happen in which place. Thus, this is not only the amount of changes, but also adding spatial attribute in the data analysis process. Figure 2 shows a first step analysis for the result. It shows where other land uses change to industry. The grey background shows places where stay the same land use as initial map. And then we overlay this result with transportation networks and google street map, which provide more insights into the land use change driving forces.

After experiencing calibration processes, it is well recognized that for calibrating the neighborhood rules it's best to focus on one or two of the land uses that are most important for use case and first try to improve the results of that. Change one or a few rules (using the theory of why things would attract/repulse and the results from the neighborhood analyzer as guidelines) and try to get better results for those land uses. Don't make it 'perfect' - just some improvement over the baseline, for example, constant share or the benchmark settings only including inertia for each land use type.

After this, we move on to the next land use and work the way down all other functions. When some land uses are 'related' like low and high density, or to a lesser degree, residential and commerce, we sometimes need to take them together to avoid improving one but worsening the other, then the other way around.

Until we have gotten 'better' results for all land uses, check them all again and verify that the first ones haven't gotten much worse by the next ones.

Finally start from the beginning and work our way down again. After a few iterations like this, improvements will be plateau and then we are ready to consider diagonal influences which refers to the land use change influences on itself. These are quite important and significant rules that can only be set after the other rules are set properly.

To conclude the calibration process, don't change 'all' of rules at once since we don't know what caused what; but also don't always need to change just one rule, either (just one is not enough, usually even). Experiment with changing small groups of related interactions is always important.

The checking software for calibration process is called MCK (Map Comparison Kit) which is also developed by RIKS. Using that, we could compare the simulated map with real land use map. By applying different algorithms, we could see the correctness and also other indicators like Moran statistics. But in this study, we mainly focus on neighborhood rules calibration. And the main algorithm we use for the first round is kappa algorithm. This algorithm does not consider the fuzziness of location and mixed land uses, neither corrects the amount of changes from the initial map to the final map. Therefore, it is more advanced later to use other algorithms than just normally used kappa statistics which only corrects for changes happen by chance. For example, later we could also check the kappa simulation and fuzzy kappa to see whether they are all increased after the calibration. Kappa simulation only corrects the amount of change while fuzzy kappa only considers the fuzziness of changes from location and categories. But currently we only consider neighborhood rules which doesn’t include zoning plans and planning maps, using the other algorithms is not realistic. That's why we simply use kappa statistics at this moment.

After the calibration, the kappa statistics is significantly increased from benchmark which is the case for just setting the inertia of one land use change to exactly the same land use. You can see the comparison table below.

<table>
<thead>
<tr>
<th>Class name</th>
<th>Benchmark</th>
<th>Calibrated results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>Housing</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>Retails and hospitality</td>
<td>0.48</td>
<td>0.76</td>
</tr>
<tr>
<td>Public and social-cultural services</td>
<td>0.83</td>
<td>0.84</td>
</tr>
<tr>
<td>Industrial areas</td>
<td>0.83</td>
<td>0.86</td>
</tr>
<tr>
<td>Dump, extraction and other abandoned sites</td>
<td>0.73</td>
<td>0.73</td>
</tr>
<tr>
<td>Construction sites</td>
<td>0.25</td>
<td>0.31</td>
</tr>
</tbody>
</table>
A lot of attempts have been made trying to improve the results, however, it turns out that the others stay plateau while still cannot improve retails and construction sites. The reason behind it is because of the zoning plans for the region or development plans for the region. These are not automatically generated from neighborhood rules and we need extra maps to simulate this special changes. Therefore, further calibration including zoning maps and planning maps is essential.

Furthermore, Natura2000 maps from CORINE dataset is included in the calibration process. However, it doesn’t improve the results. Probable reason is because in the neighborhood rules, we already set that industry and other functions that are not good to the environment and forest should not be located near the protected areas.

One important issue to be noticed is that no matter how we set the neighborhood rules, the construction site is impossible to get higher number for the calibration because it is more spatial planning orientated. Therefore, planning maps for construction site is very crucial for our calibration. We get all the planning maps from NieuweKaart Nederland. After overlaying these planning maps with existing land use maps, we find out that most of the construction sites that do not match are because of water body expansion, especially from the Revitaliseringsgebied Wijde Biesbosch plan. Since water bodies are considered as feature in our research, this change is neglected.

Generally speaking, there are two ways to calibrate our calibrated land use simulation system, namely using another dataset or using the same dataset but for another year. Since land use map after 2010 has not yet been updated by the government, we can only use the first path. In order to create a new dataset including land use information, we have tried to look for different sources and currently we are considering using detailed building level information from De Basisregistraties Adressen en Gebouwen (BAG) data to validate the model. So the first thing will be get the data from the server and rasterize it. And then we can compare the simulated results with the actual data we get.

3.5. Scenario analysis

Scenario analysis will be achieved firstly by constructing of several plausible scenarios. This will be done by consulting Dutch scenarios for the future after the model has been validated. The calibrated and validated system shall be tested by the scenarios and possible outcomes will be given. Several possible interventions will be provided based on the analysis. This system can be used for other regions and larger scale areas as well.

4. Conclusions and discussions

The stagnating problem of industrial and redevelopment requires careful planning for future sustainable development. This study applies constrained cellular automata approach to model land use change with a focus on industrial land use. North Brabant region is chosen as case study. Calibration procedures are explicitly explained together with several tools that we have developed for better and faster calibration process. In this way, we fill the gap that no specific calibration process is mentioned in previous study. Thus, we provide clues or a framework for future users to perform the same or similar study for other regions. The tools we have developed can also be adjusted to other uses.
Up to now, the calibration process is mainly manually. Although it could become less time consuming if you follow the procedures that have been proposed in this paper, it is still a very tedious work. Some future development could be useful for calibrating the system automatically or partially automatically.

The validation part is still on going because of data collection issue. Therefore, how to construct a new dataset from different sources is worth researching in the future. Some public available services offer great opportunity for further study like using remote sensing technique to detect different characteristics of features and generate detailed and tailored land use maps from google earth imagery or aerial pictures or satellite data.

Last but not least, regions could be classified into different groups and some panel study could give guidelines on how to set rules for each of this group. For example, big regions in fast developing countries probably would have different rule settings than relatively small regions in developed countries because of policy issues, economic growth, and different focus on development. This kind of comparative study could be beneficial for policy makers and researches from different background.

Acknowledgements

This project is supported by Chinese Scholarship Council and supervised by Design Systems Group from Built Environment Department of Eindhoven University of Technology. Sincere thanks to their support for this research.

References