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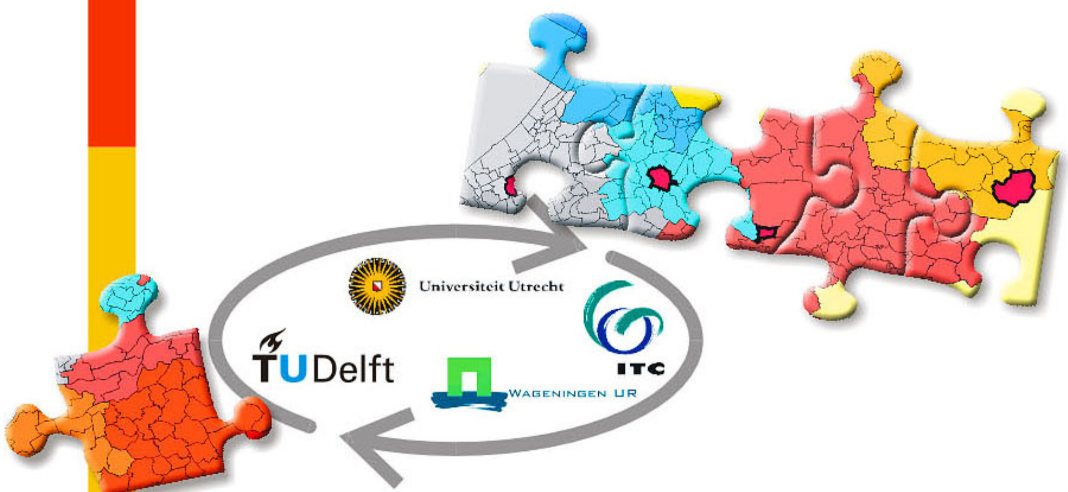
Geographical Information Management and Applications

3D Visualization of Zoning Plans

Christiaan Bos



3D Visualization of Zoning Plans

Master Thesis

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Abstract

Traditionally, zoning plans have been represented on a 2D map. However, visualizing a zoning plan in 2D has several limitations, such as visualizing heights of buildings. Furthermore, a zoning plan is abstract, which for citizens can be hard to interpret. Therefore, the goal of this research is to explore how a zoning plan can be visualized in 3D and how it can be visualized it is understandable for the public. The 3D visualization of a zoning plan is applied in a case study, presented in Google Earth, and a survey is executed to verify how the respondents perceive the zoning plan from the case study.

An important factor of zoning plans is interpretation, since it determines if the public is able to understand what is visualized by the zoning plan. This is challenging, since a zoning plan is abstract and consists of many detailed information and difficult terms. In the case study several techniques are used to visualize the zoning plan in 3D. The survey shows that visualizing heights in 3D gives a good impression of the maximum heights and is considered as an important advantage in comparison to 2D. The survey also made clear including existing buildings is useful, which can help that the public can recognize the area easier.

Another important factor is interactivity. Interactivity can range from letting people navigate through a zoning plan area and in the case study users can click on a certain area or object in the plan and subsequently a menu pops up showing more detailed information of a certain object. The survey made clear that using a popup menu is useful, but this technique did not optimally work. Navigating in Google Earth was also being positively judged.

Information intensity is also an important factor Information intensity concerns the level of detail of a 3D representation of an object. Zoning plans are generally not meant to be visualized in a high level of detail, but should be represented abstract. The survey could not implicitly point out that the zoning plan shows too much or too less detail, but it could point out that the majority of the respondents answered that the zoning plan does not show too much information.

The interface used for the case study, Google Earth, has a substantial influence on the interpretation of the zoning plan. The legend in Google Earth is unclear and an explanation of the zoning plan is lacking, which is required to make the zoning plan more understandable.

This research has shown that 3D can stimulate the interpretation of zoning plans, because users can get a better impression of the plan and is clearer than a current 2D zoning plan. However, the interpretation of a zoning plan, even in 3D, still is complex.

Preface

When I started my research period at the department of geo information at the municipality of Groningen I did not have clear idea of a topic for my research. However, rather quickly I found an interesting topic. The department of geo information is being active in 3D and one of the goal is to develop a database of 3D information and to use 3D in projects. I became more interested in 3D and I wanted to specify on a certain application of 3D. I found an article on 3D zoning plans and I was immediately enthusiastic about this topic. I have a background in spatial planning, therefore the combination of 3D geo information and zoning plans was very interesting for me. Accidently, a councilor from the one the political parties of the municipality of Groningen came with the idea to present the municipal zoning plans in a 3D environment. By presenting zoning plans in 3D, the councilor argued, it would be much clearer for the public what the allowed heights of buildings are. For me this was interesting how 3D can be used in zoning plans and this research gained me a lot of knowledge.

I would like to thank everyone who assisted me during my research. First of all I would like to thank Jelte Duister for giving me the opportunity to execute the research at the department of geo information at the Municipality of Groningen. Second of all I would like to thank all the members at the department of geo information and other members of the municipality which were involved in zoning plans for their support and cooperation. From the GIMA programma I would like to thank my supervisors Ron van Lammeren en Arend Ligtenberg for their valuable supervision and feedback during this research.

Groningen, The Netherlands

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Christiaan Bos

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1. Introduction

In the Netherlands, space is a scarce commodity, which makes it vital to be careful with the use of space. Therefore, the government sees it as its responsibility to act as a regulation body when the use and development of land is in matter (Van Zundert, 2006). One of the instruments to regulate space is the municipal zoning plan (bestemmingsplan in Dutch). It is the most important planning instrument in the Dutch spatial planning. The current zoning plans are represented on a 2D map. However, a 2D zoning plan has its limitations, mainly because the heights of buildings are not visualized (Stoter and Bijl, 2006). In addition, many developments of 3D visualizations (*Virtual Cities, Second Life, Google Earth*) are taking place and there is also a growing interest of 3D in the field of spatial planning (Batty, 2007). The interest in 3D zoning plans was also made clear when one of the main political parties in the municipality of Groningen came with a proposition to represent a 3D zoning plan on the internet (PvdA Groningen, 2010). The motive for this proposition was a complaint from citizens which had no good idea of the allowed heights of buildings. In a traditional zoning plan, these heights are not visualized. In these kinds of situations 3D visualization could offer an added value. The use of visualizations, especially in 3D, is interesting for citizens as they can get a good impression of an area and can be easier to understand than policy documents (Sieber, 2006). Furthermore, 3D can offer more and better opportunities to visualize objects. A challenge is to create visualizations in such as way it is interpretable by the user. This will be an aspect in this research. In the next section a background on zoning plans will be given.

1.1 Zoning plans in the Netherlands

1.1.1 Spatial planning in the Netherlands

In the Netherlands the government system exists of three levels: central government, provincial government and municipal government. The three-tiers are autonomous, except for certain statutory powers reserved for provinces and central government (Van der Valk, 2002). The administrative system is based on a constitution and implementing acts and the process of communication between the tiers of government is characterized by consensus building (Faludi and van der Valk, 1994). Each of these authorities has a role in spatial planning. National and provincial governments use broad framework visions and policy guidelines. Integration plans are equal to zoning plans and can be developed when national or provincial interests are at stake. Municipalities make use of both framework visions (structuurvisies in Dutch) as well as binding zoning plans. Framework visions are made to develop visions for desired spatial developments for the long-term future. The municipal zoning plan is the most important instrument in the spatial planning. The zoning plan is the only instrument where binding requirements are given for the allowed use of land. The zoning plan describes what the purposes are (development or other use) of land (Van Zundert, 2006).

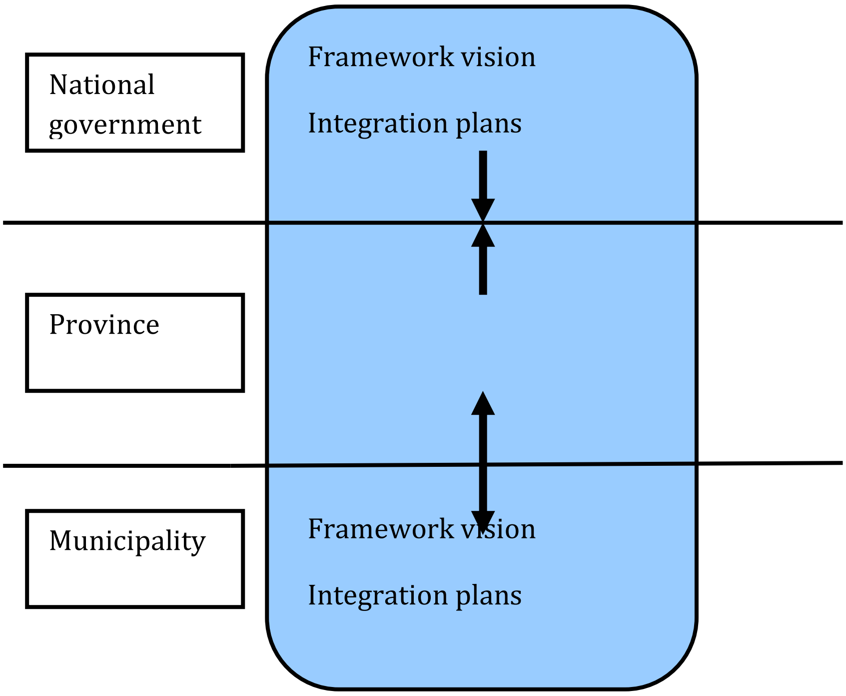


Figure 1. *A framework of Dutch spatial plans (derived from Voogd, Woltjer, 2009).*

1.1.2. Zoning plans

The municipal zoning plan is the most important instrument in the spatial planning. The zoning plan is the only instrument where binding requirements are given for the allowed use of land. The zoning plan describes what the purposes are (development or other use) of land (Van Zundert, 2006). The zoning plan consists of the regulations of the building development, like the type of development, building regulations and use regulations. Zoning plans are developed to have a 'proper spatial planning' (Wro, 2008). This for example implies that next to a housing area an industrial area can not be developed without any problems, since the environment should be taken into account for new developments. Therefore, zoning is used to prevent new development from interfering with existing residents or businesses and to preserve the 'character' of an area. A 'proper spatial planning' also implies that the interests in the involved area which play a role should be taken into account and need to be weighted. This integral weighting should result in clear and motivated choices in relation to the vision of the municipality and should be laid down in a zoning plan (Struiksma, 2008).

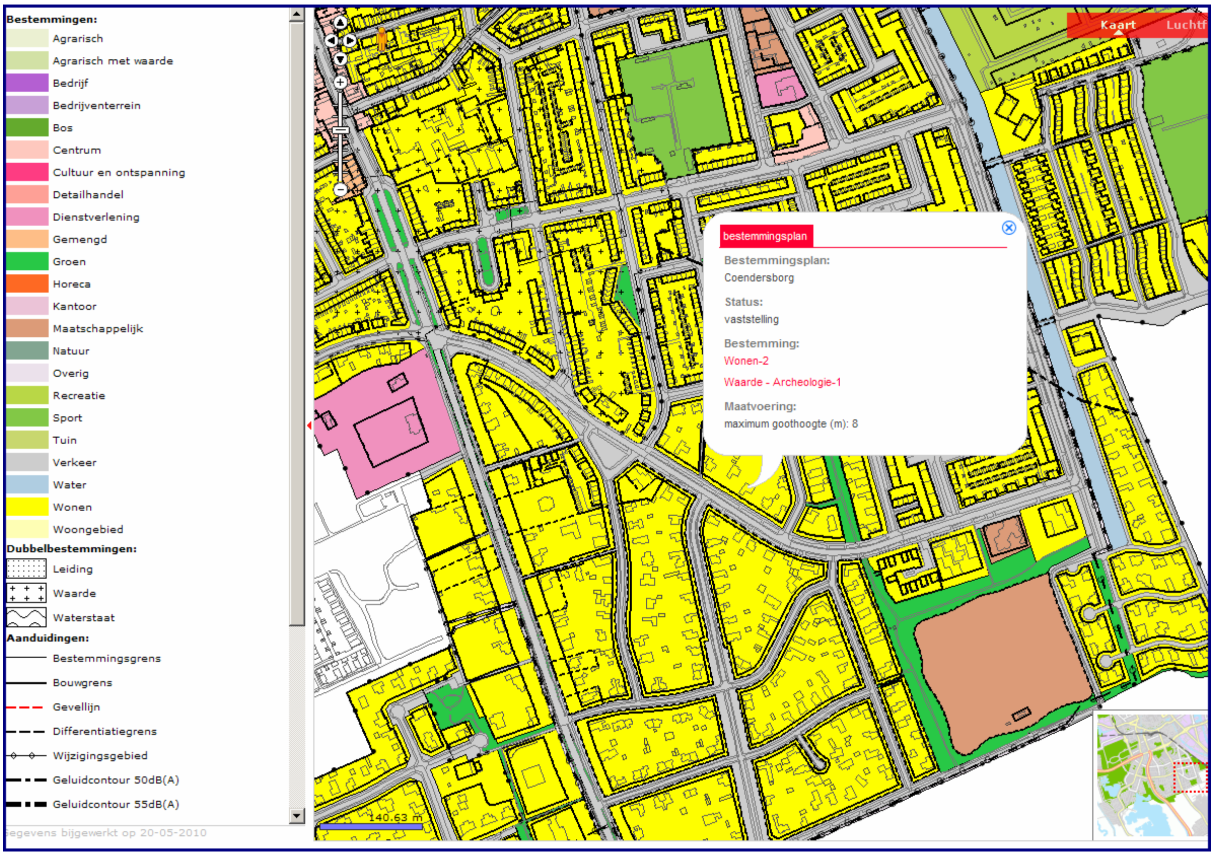


Figure 2. *Zoning plan of municipality of Groningen*

In the map belonging to the zoning plan, the different types of zones are represented. This is represented on a 2D map (see figure 2). By assigning a function to an area, it is described what is allowed and what kind of regulations exists in that area. The regulations of each function concerning the construction and land-use are related. The boundaries of each zone on the map have to be very accurate, because an incorrect boundary could make undesirable developments possible or can frustrate desired developments (Tunnissen, 2009). Here, it is not only important that the boundaries are correct, but that a user can extract this information from the map. The aspect of visualization is vital, since it should enhance the usability and understanding of the plan (Langenorf, 1992, cited in Bulmer, 2001).

1.1.3 3D zoning plans

Currently there is no municipality in the Netherlands which uses a 3D zoning plan. However, as part of a program of VROM two pilots have been done to build prototypes to find out the possibilities of a 3D zoning plan

One of the main conclusions from the pilots is that a 3D zoning plan can offer an added value in visualizing heights however, a transformation from a 2D map to 3D is a challenge, since the addition of the third dimension makes a zoning plan fundamentally different. To establish a complete 3D zoning plan, many aspects should be considered, such as data capturing, data modelling, data management, dissemination and visualization.

1.2. Problem definition

Traditionally, zoning plans have been represented on a 2D map. However, a 2D zoning plan has several limitations, such as the visualization of the heights of a building (Bijl and Stoter, 2006) and a zoning plan is abstract, which for citizens can be hard to interpret. In the last couple of years 3D have been through many developments and is being used for a wide variety of disciplines like spatial planning, geology, hydrology, environmental monitoring and real estate (Nielsen, 2005). In spatial planning, municipalities have developed 3D models of their city and begin using 3D for planning processes (Zlatanova et al. 2008). 3D visualization offers several advantages, for example the 3D visualization of spatial plans can result in better communication with citizens, thereby involving them more in the planning process (Al-Kodmany, 2002). 3D visualization of a zoning plan is fundamentally different than a 2D zoning plan, since the third dimension is added to map, which results in a different visualization of the plan. In the IMRO2008 standard, which is the Dutch standard for the representation of zoning plan, the objects and the attributes are described for the 2D visualization of zoning plan. One of challenges is how the zoning plan objects of a zoning plan can be visualized in 3D and how it can be visualized in a way it is understandable for the public. Furthermore, 3D offers several methods and techniques to visualize the zoning plan and which can help in the understanding of the zoning plan.

1.3 Research objectives

The main objective of this research is to explore how a zoning plan can be visualized in 3D and in such a way it can be made understandable for the public and improve the communication with the public.

1.4 Research questions

Based on the stated research objective, which is defined in the previous section, a main question with some sub-questions are formulated.

Main research question:

How can a zoning plan be visualized in 3D and how can it be visualized such that it is understandable?

Sub-questions:

- What are developments in zoning plans?
- What is the role of 3D geovisualization in zoning plans?
- What are the visual requirements for the 3D visualization of a zoning plan?
- How can a 2D zoning plan of Groningen be visualized in 3D which can be understandable for the users?

1.5 Scope

The research will be limited to research to the 3D visualization of a zoning plan and how it can be visualized it is clear to the public. To develop a 3D zoning plan more aspects should be taken into account, though some of them might be mentioned during this research, they will not be researched in detail. One of the aspects deals with the design of an interface. This research will make use of an existing interface, Google Earth, to visualize the zoning plan. It is not a goal to design an interface specifically for a 3D zoning plan. In addition, current zoning plans are presented on the internet, however this research will not research possibilities to design a web service for a 3D zoning plan.

3D offers new opportunities to visualize objects which are suitable to visualize in 3D and which are complex to visualize in 2D. Examples of these new opportunities are parking garages, basements, thermal energy storage etcetera. The aim of this research is not to investigate if and how these objects can be visualized in 3D in a zoning plan. This research will only visualize objects of a current zoning plan.

Another aspect deals with the juridical conditions of a zoning plan. A zoning plan is a binding plan which should be juridical correct. Visualizing a zoning plan in 3D has consequences for the juridical part of a zoning plan, since the current zoning plan regulations do not in every case fit to visualization in 3D, it fits to 2D visualization. This research will not aim to explore how the regulations should be made suitable for 3D visualization. Related to this issue is the IMRO model. This research will not develop a new data model for 3D zoning plans, but will use the zoning plan objects from the current IMRO2008 model. Though the IMRO2008 model will be discussed, no new IMRO model will be developed.

2. Methodology

This chapter deals with the methodology where the research is based on. It consists out of two parts: a scientific methodology and a thesis outline.

2.1 Scientific Methodology

In this section the methodology to give answers to the research questions will be outlined. The methodology is split up resulting into a methodology for each of the four research questions.

2.1.1. Sub-question 1

The first sub-question will discuss the developments in 3D zoning plans. This question will be divided into three sections. The first section will discuss the limitations of a traditional 2D zoning plan. It will start with explaining the traditional zoning plan and the developments which have been taken in place in the last couple of years. Subsequently it will discuss the limitations of representing a zoning plan in 2D. The second section will discuss the development of 3D zoning plans. In 2007 a pilot of VROM has been done to design a prototype of a 3D zoning plan. The outcome of this pilot will be described and discussed. Also a report about the development of a 3D zoning plan from three consultancy agencies will be described. In addition, interviews with persons from municipalities will be done which were involved in this pilot. This chapter ends with conclusions.

2.1.2 Sub-question 2

The second sub-question will consist of a literature study on 3D visualization, spatial interpretation of visualizations and an analysis of the role of 3D visualization in the planning process of a zoning plan. First an introduction on (3D) geovisualization and frameworks will be discussed to position this research and zoning plans in the framework of 3D visualization. Then general principles for visualization will be discussed to determine what is necessary for understandable visualizations. Furthermore, 3D visualization will be put into perspective of the planning process of a zoning plan by making a conceptual model and some examples of 3D visualization in spatial planning will be discussed.

2.1.3 Sub-question 3

The first step of this sub-question will be to distinguish the planning objects of a zoning plan. In the IMRO standards the planning objects are described for zoning plans which will be used for the representation in 3D. These planning objects will be used for the implementation for the 3D visualization. Furthermore, in IMRO regulations are described, for example regulations for the maximum height of buildings, which are described in the regulations of a zoning plan. These regulations have to be taken into account for the visualization of planning objects in 3D.

The second step will deal with the requirements to represent the identified planning objects in 3D. Several techniques are available to visualize the objects in 3D, this will be discussed. A conceptual model will be presented and for each object in the zoning plan, the visual requirements will be described.

2.1.3 Sub question 4

The goal of is sub question is to visualize a zoning plan in 3D as part of a case study.

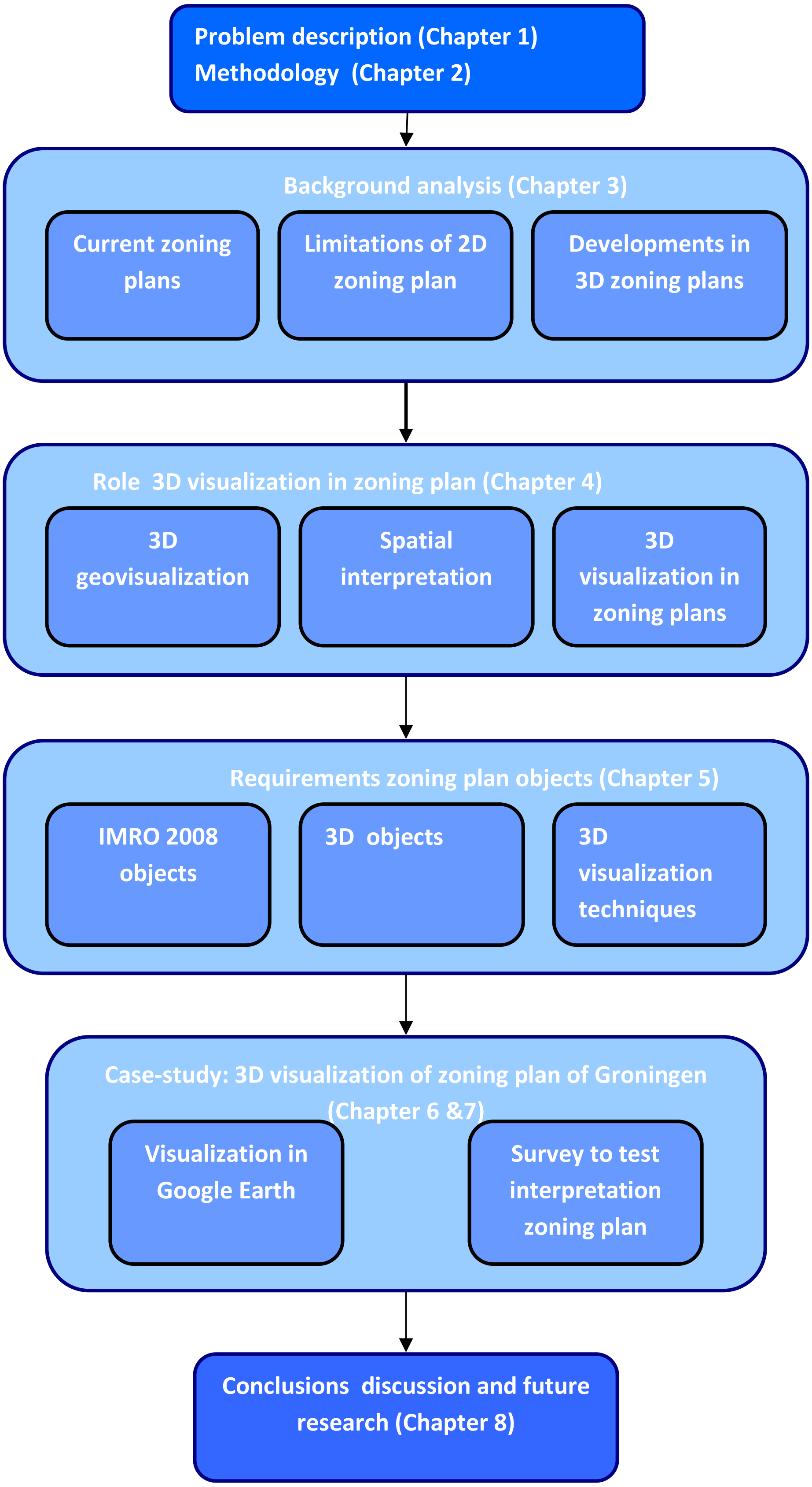
The method which will be used for this case study will be based on the Rapid Applications Development, in which prototyping is an important element. RAD is a term used by James Martin (1991) to describe a set of procedures and approaches which, as the name describes, aim to produce system designs quickly. Prototyping is an essential element of RAD allowing users to see early attempts by designers and provide concrete, positive responses. A definition of a prototype is ‘a working model of a system or part of a system which may emphasize some specific aspects of it (Reeve and Petch, 1999). The established idea of prototyping is to spend a limited amount of time and money on producing something in the small before producing something in the large. This sub-question can be considered as design prototyping, where the goal is to show how a zoning plan can be visualized in 3D.

The case study area will be a neighbourhood in Groningen, named Coendersborg. The current 2D zoning plan of Coendersborg will be used for the visualization of the zoning plan in 3D. The requirements to represent the objects based on IMRO2008, which are described in the sub-question 3 will be applied in this case study. Google Earth will be used as a viewer to represent the zoning plan. The development of the zoning plan will be done by a combination of software, such as ArcScene en Sketchup.

The developed zoning plan will be validated based on a survey. The goal of the survey is to verify if the zoning plan is clear and how the interface is perceived by the respondents. The population of the survey consists of people with and without experience in geovisualizations. A number of the respondents are civil servants from the municipality of Groningen and most of the other are citizens of the municipality of Groningen. The survey results will be analysed and discussed.

Finally, this research ends with conclusions, a discussion and some future research directions will be proposed.

2.2. Thesis outline



3. Zoning plans in the Netherlands

This chapter will discuss the developments in zoning plans and can be considered as a context for this research. First, an overview of developments in zoning plans will be given. Thereafter, limitations concerning the representation of the current zoning plan will be discussed. The last section will discuss pilots of 3D zoning plans.

3.1 Developments in zoning plans

The last couple of years, the zoning plan went through a number of developments. This will be described below.

At the end of 2000 the project DURP (Digitale Uitwisselbare Ruimtelijke Plannen, since 2005 Digitale Uitwisseling in Ruimtelijke Processen) which stands for digital exchange in spatial processes was introduced by the Ministry of Housing, Spatial Planning and the Environment (VROM), which is responsible for spatial planning. The objective of this project was to make the spatial planning process more effective and efficient through the digitalizing of the development, use and exchange of spatial plans. Furthermore, it was setup to increase the involvement of citizens and make the spatial planning process more transparent (Mettau and Verschuur, 2001).

Part of DURP was that from July 2009, municipalities, provinces and national governments are obligated to make their new spatial plans digitally. This obligation is part of the new Law on spatial planning (Wro). The law arranges the accessibility of spatial plans by two related instruments: Spatial Planning Standards 2008 (RO Standaarden 2008) and Spatial Planning Online (RO-Online). The first is a set of agreements and rules which provide that spatial plans are exchangeable, comparable and object oriented (VROM, 2008). Next to the digitization and improved exchangeability of the plans is the importance of standardization. Digitized and standardized zoning plans contribute to better uniform, up-to-date and exchange of plans. In the new Wro the requirements for standards of the instruments are described (VROM, 2007). These standards are called Spatial Planning standards 2008 (RO standaarden 2008) which are the basis for the representation, planning and accessibility of spatial plans. One of these standards is IMRO2008, which is the information model for the formulation and exchange of structure visions, zoning plans, decisions and commandments of the new Wro on every governmental level. It is a model for standardized encoding of object-based spatial plans. The different zoning functions are standardized and must be used in the plans (Janssen and Jekel, 2006). The standard for the exchange format is the Geography Markup Language (GML) (OGC), an open standard. For the application of IMRO a set of practical guidelines are defined for zoning plans. The guidelines promote an object-based approach in which objects in the map are linked with text about the type of use and regulations. Guidelines for 3D modelling are not described in the guidelines, which will be necessary when 3D land-use plans will be implemented nationally. However, GML does support 3D.

From the first January of 2010 all of the municipalities, provinces and national departments are required to make new digital spatial plans (like the zoning plan) available via internet (Van Scherpenzeel, 2010). Citizens, companies and organizations are getting easier access to information on regulations of spatial plans this should improve the services of the municipalities to its public. The website RO-Online (www.ruimtelijkeplannen.nl) shows digital zoning plans from municipalities (see figure 3). These zoning plans are captured via a web service in the municipal GIS viewer to RO-Online. Zoning plans are available on the internet via OGC (OpenGIS) standards WMS and WFS webservices.

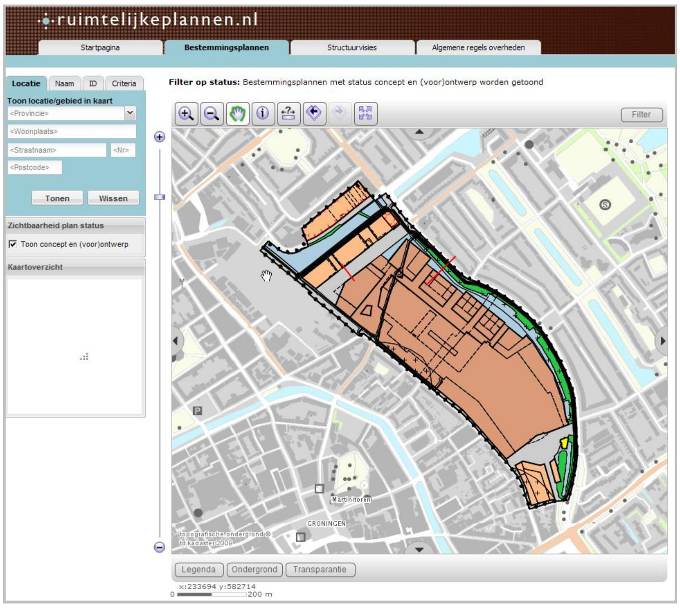


Figure 3. *Example of a digital zoning plan on www.ruimtelijkeplannen.nl*

The zoning plans have gone through several developments, which improved the accessibility, transparency and exchange of the plan. However, the current zoning plan, visualized in 2D, has limitations, where new technologies, such as 3D could offer a benefit in the visualization of the plan. 3D, therefore, could be the next step in the process of development of zoning plans. In the next section, several limitations of 2D visualization of zoning plans will be discussed.

3.2. Limitations of 2D visualization of zoning plans

The current zoning plans have a number of limitations related to the visualisation of the plan. In comparison to 3D, the 2D visualization of a zoning plan has several disadvantages. The main limitations will be discussed in this section.

3.2.1. Interpretation of height

Another important limitation of the current zoning plan is the interpretation of the plan, in particular the interpretation of the maximum heights of buildings. On the map it is not visualized what the allowed maximum building height is, but maximum heights are described in the zoning plan regulations and are not visualized on the map. Therefore for citizens a map does not give a clear view what maximum height is allowed and what the impact is on the environment (PvdA, 2010), which is important for citizens to understand the plans better. 2D maps are abstract and can be hard to understand. In 3D, people can get a better impression of the plan and people can easier recognize the study area (Al-Kodmany, 2001). In addition, in 3D it is possible to visualize the maximum heights. By visualizing the heights of buildings in 3D, citizens can get a better overview of the allowed heights of buildings. When citizens can easier understand the zoning plan, they become more involved in the planning process (Al-Kodmany, 2002). In the next chapter, the issue of interpretation of visualization will be discussed in more detail.

3.2.2 Mixed zoning

When areas have one type of zoning function (bestemming), a 2D visualization of a zoning plan is suitable and is clear. However, when more than one zoning function is assigned on a zoning plane, the current 2D maps are not suitable to give a clear view. A mixed (in Dutch: 'gemengd') zoning type is part of the main zoning functions like housing, retail, culture, service and recreation. In a zoning plan a mixed (gemengd) zoning label is assigned to a zoning plane when it contains at least two zoning types, such as housing and retail. This implies that the map does not visualize which zoning types are allowed, it only states that a certain zoning plane is meant for mixed zoning (see figure 1). Where these zoning function should be exactly located is not described in the regulations, therefore, within a mixed zone the allowed zoning types are exchangeable within the area. If one would like to know the allowed zoning types, one have to look into the zoning plan regulations to know what is allowed on the different building levels and/or on the zoning plane (Buro Vijn et al. 2006). This is a disadvantage of current zoning plans, since it is not clearly visible on which level which zoning type exactly is allowed ('t Erve, 2010).

An example of a mixed zoning type is when a zoning plane can have the zoning function housing and retail and/or service. When a zoning plane exist of a building with many building levels, it is possible to have mixed zoning with for example retail on the ground level and housing on the upper levels.

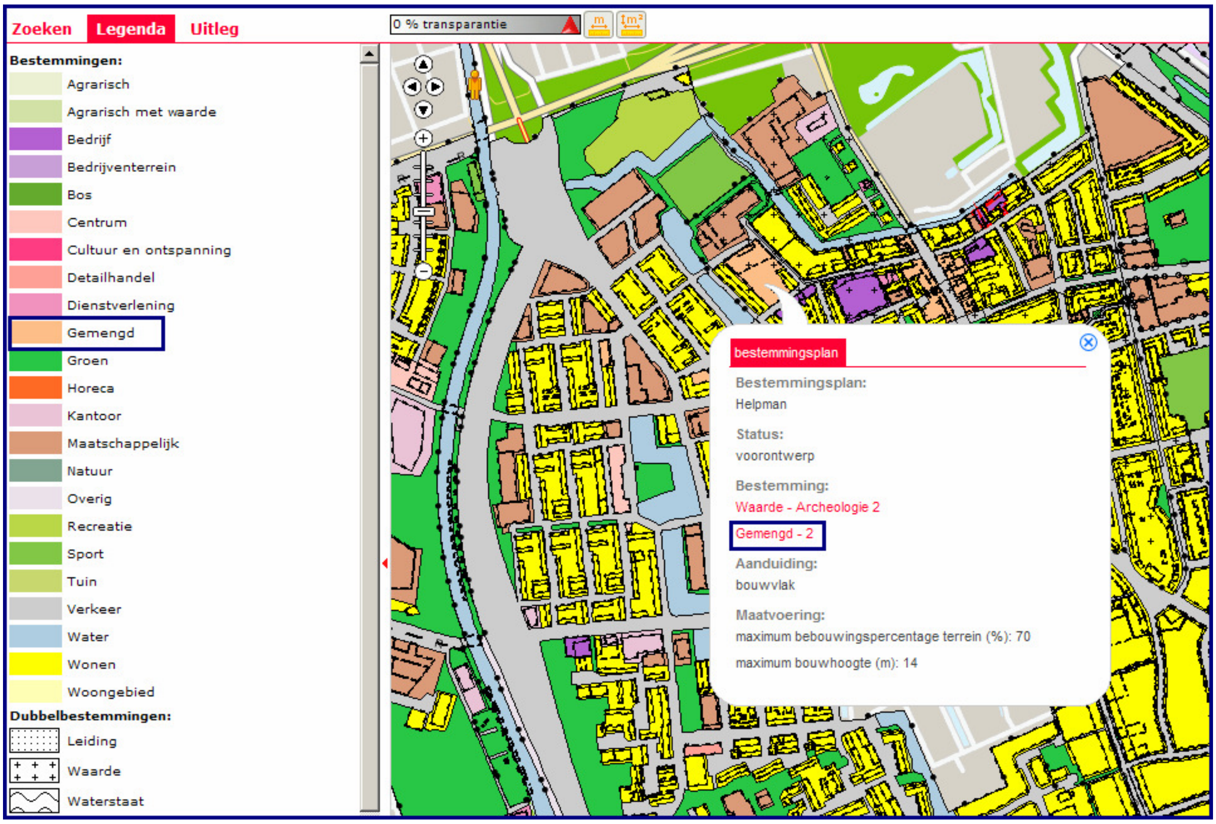


Figure 4. *Mixed zoning (source: website municipality of Groningen)*

3.2.3. Underground

Zoning in the underground is another aspect which is hard to visualize in a current zoning plan, such as the visualization of archaeological values and transport pipelines. As already shown in figure x zoning functions can be either single- or double zoning. Double zoning (in Dutch: 'dubbelbestemming') means that there are always at least zoning functions independent from each other, for example 'agriculture use' and 'gas pipeline', and one of them is overlapping more than one other zoning function. A building with two different zoning functions (eg housing and retail) is not independent. Three main groups of double zoning can be distinguished: 1. transport pipelines (eg. gas, oil, water, sewer); 2. values (eg. archaeological, culture historical, ecological); 3. water management (eg water embankment, water storage). These zoning functions overlap more than other zoning function.

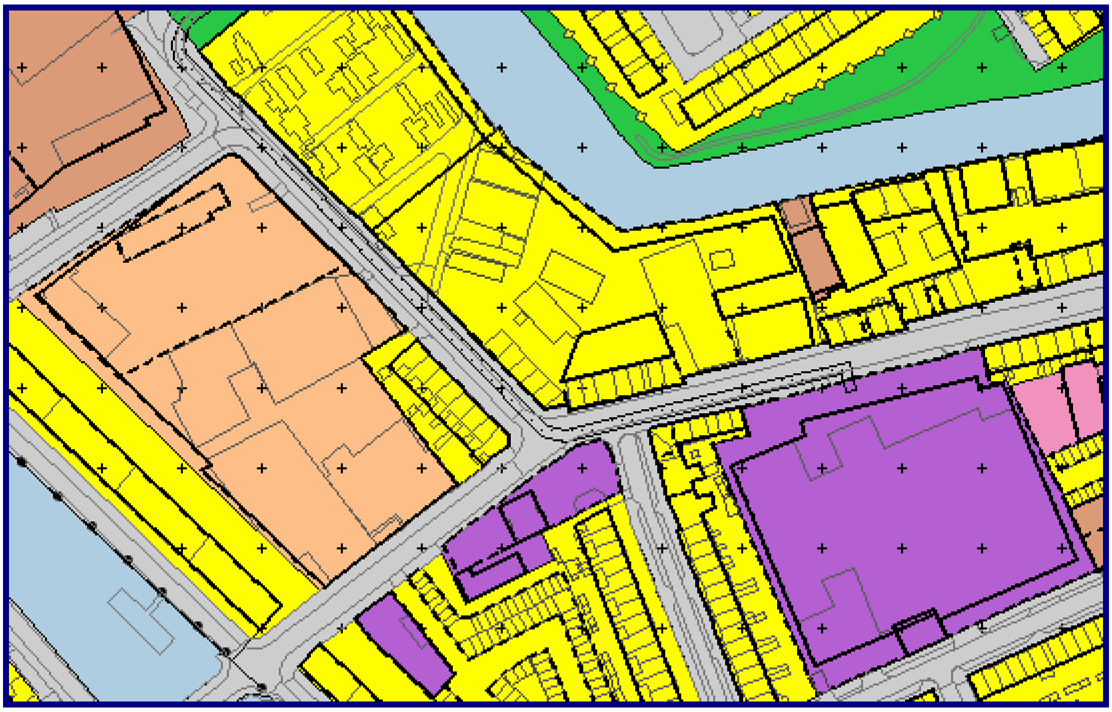


Figure 5. *Double zoning functions shown by a"+" symbol*

These zoning functions are visualized through symbols on the map (see figure 5), however it is not clear how deep these archaeological values or transport pipelines are situated. On a 2D map, only the boundaries on the surface are described in the regulations, so the third component is not taken into account. However, the third dimension is important, for knowing how deep below the base level the pipelines and cables are located and how deep they are allowed to be located, in case one wants to build constructions in the underground. In current zoning plan maps, the most important cables and pipelines are depicted, only the depths cannot be extracted from the map.

The underground could be an interesting aspect for zoning plans, since the underground is being used more intensively and therefore becoming more important. The importance of the underground is also stressed in the policy document Spatial Planning Underground (VROM, 2004). It was stated that in the Netherlands the pressure on space is increasing. Due to growing use of the underground, more and more private parties are becoming involved in the construction and management of several functions of the underground. Furthermore, the underground is being planned without a clear vision and without a vision on the consequences of spatial plans (COB, 2004).

Bijl and Stoter (2006) show an example of a zoning plan with double zoning, where visualization in 3D would give an added value. The example is the zoning plan 'HSL Rijnwoude' where the

‘Groene Hart’ tunnel of the HSL-Zuid train is visualized. By making use of a 2D map this can not be visualized, since no distinction between the levels of the zoning functions can be visualized. Areas which have been zoned through a 3D approach on different levels are still made suitable for 2D visualization. Another example is the zoning plan of the North-South metro line in Amsterdam. The tunnel is partly situated below housing and shops, partly under water and partly under public space. The areas are labelled as a sort of stacked areas and the regulation of these stacks (for example: ‘underground railway track with water above’) is settled in the regulations and mentioned in the legend. The disadvantage of this is that the space of the tunnel is not or very difficult to recognize on the map. The examples makes clear that developments with different levels, like double zoning require a 3D visualization to get a better and more understandable overview of a certain area.

Next to the already existing objects in the underground, described in a zoning plan, there are more objects which can be named which are situated in the underground. For example the underground consists of many underground parking lots, cinemas, tunnels, stations and projects like the Noord/Zuidlijn in Amsterdam. Furthermore, research is being done in the underground for archaeological findings and new types of use in the underground, like thermal energy storage, are growing. In addition, the economic feasibility plays an important role, due to an increasing pressure on space on ground level, the underground is become a more interesting alternative when looking to the increase of prices of land (Paul et al. 2002).

The underground is especially very suitable to represent in 3D, since the underground consists of several levels, making the z component necessary. Furthermore, a 2D map is too limited to visualize the underground properly. In 3D, a good overview of all the objects can be given and in 3D this could be done in more detail than in 2D.

3.2.4 Conclusions

The current visualization of a zoning plan in 2D has several clear limitations. 2D visualization of a zoning plan is abstract and therefore can be difficult to interpret by its users, such as citizens. For citizens it can be hard to get an impression of the heights of buildings when it is only described as text. In addition, the limitations make it necessary to keep many regulations described in the zoning plan documents, rather than be able to visualize them on a map, such as the maximum allowed building height.

The limitations of representing a zoning map in 2D ask for a 3D visualization, which should result in 3D visualization offering an added value in comparison to 2D visualization of zoning plans.

3.3 3D zoning plan pilots

As part of the program of VROM concerning the spatial planning of the underground a number of pilots have been done with the goal to become experienced with the spatial planning of the underground. Part of this pilot was a study concerning the representation of zoning plans in 3D, where the focus was especially laid on the 3D visualization of the underground for zoning plans. These pilots will be discussed in this chapter.

In this section two pilots initiated by VROM will be discussed, the first pilot from 2006 and the other pilot from 2007.

3.3.1. Pilot 2006

In 2006 three consultancy companies conducted an exploratory research for the possibilities of setting up a 3D zoning plan (Buro Vijn et al. 2006). The goal was to develop a prototype which should be considered as a start for the development of 3D zoning plans. The three consultancy companies developed a 3D zoning plan for three different areas. They made zoning plans for a central station area, an underground museum and an outlying area. All these locations were fictitious.

In one of the developed prototypes it became clear zoning on the ground level surface can have consequences for the underground. For example it is stated in the document that it is necessary to reserve space for foundations for housing. This makes it also clear that the zoning above ground level is often related to zoning in the underground. 3D makes it possible to visualize the functions in the underground clearly.

In figure 6 the 3D visualization of the station area is represented. In this zoning plan space is explicitly reserved for thermal energy storage, the foundations of the situated buildings and a planned tunnel. In the current zoning plan regulations, these objects are not described. A question is, whether these objects should be included in a 3D zoning plan. The same counts for thermal heating storage. This discussion will not explicitly be part of this research, since this deals more with the definition of objects of zoning plans then the discussion how to visualize the zoning plan it can be understood by the various users.

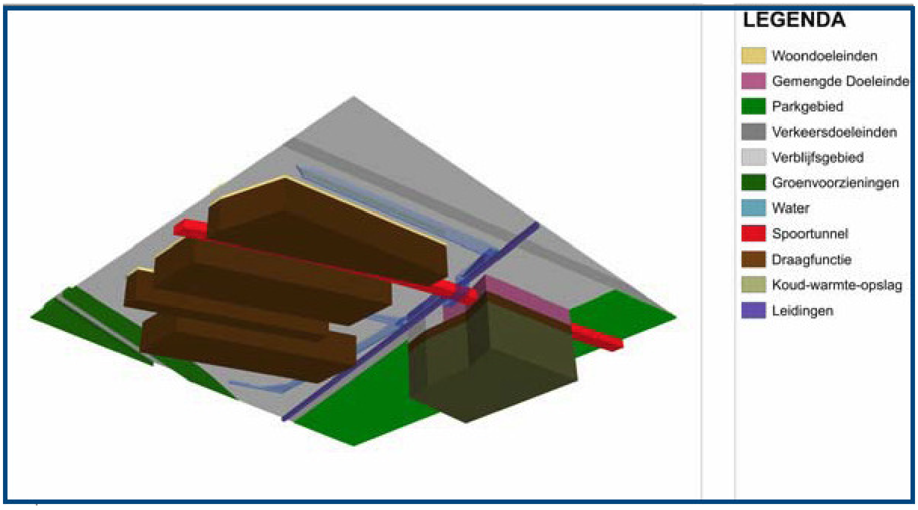


Figure 6. *3D zoning plan from below*

A number of issues came forward from the pilot. One of the issues was the height of the earth surface level. In the regulations it is described what the maximum drain- (goothoogte) and building height (bouwhoogte) is. The ground surface level is important, since from this level the maximum heights are measured.

However, it is not always clear what this earth surface level exactly is. Especially in landscapes with differences in heights this has influence on the maximum heights of buildings. The question is thus if a relative height to the terrain heights should be used or absolute height levels. In the report it is advised to use the Normaal Amsterdams Peil (NAP), which is the Dutch Ground Level, as the ground level for zoning plans. This means that for every location an exact terrain height is needed.

Another point made from the pilot concerned the planning and zoning volume. A planning volume is the complete volume of the area for which a 3D zoning plan is developed. A planning volume consists of zoning volumes and empty volumes. Empty volumes have no function and are not zones. Zoning volumes are volumes for which a zoning type is assigned. As a result planning volume consists of zoning volumes and empty volumes, making it a closed system (see figure 7).

An issue is here what the boundaries are of a planning volume. Therefore, these boundaries of should be defined for the height and how depth of the planning volume.

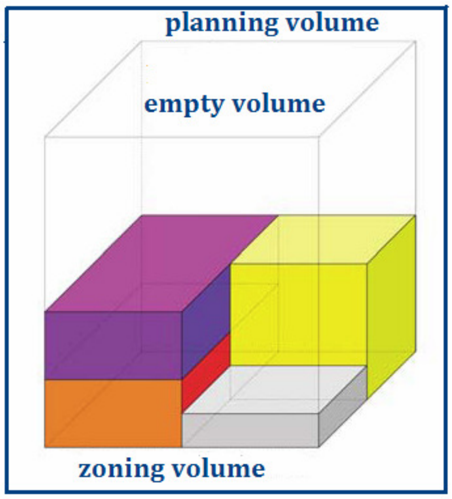


Figure 7. *Planning volume*

Another issue was made concerning splitting up of volumes. It can be complex when a volume consists of two zoning types, for example parking underground and archaeological values which intersect in the volume. An option is to make a separate volume for the intersecting volume or as a volume where both zoning types count (see figure 8).

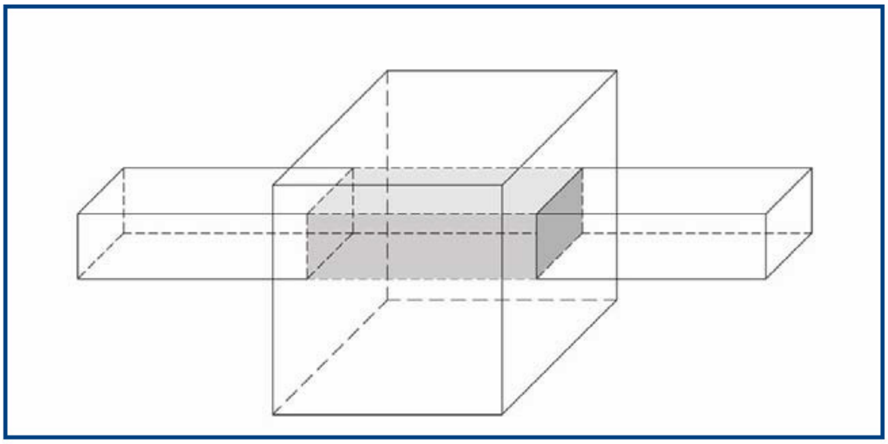


Figure 8. *Overlapping of zoning volumes.*

Furthermore, the report made recommendations concerning standards are made which should fit in the existing IMRO2008 standards as well as developing an UML scheme for 3D which should be added to IMRO2008. Also when 3D zoning plans are implemented nationally, custom software applications are needed. These issues will not be part of this research, however should be acknowledged when implementing a 3D zoning plan nationally.

3.3.2 Enschede case

As 2007 as part of the VROM program for spatial planning of the underground, another pilot has been done. Two case studies have been done, the Usseler Es in Enschede and the project Stadshavens in Rotterdam, where the goal was to design a 3D zoning plan.

In the Enschede pilot mainly the possibilities of zoning above the surface in the underground in 3D were the main goals to research. In order to translate from 2D to 3D, the existing zoning method and regulations have been maintained as much as possible. In pilot, first the 2D zoning plan was converted into 3D elements. However, the ground level is defined as a flat plane, which in reality is a convex plane. This was done, because the municipality had no sufficient data available to develop a terrain model. In figure 9 an impression of the plan is shown.

A number of difficulties came forward from the pilot. One of the difficulties was in how much detail the zoning plan should be visualized. If a lot of detail is put into the zoning plan, it will likely be harder to understand the plan. The large amount of objects can make the plan less visible. In the pilot the 3D topography of the current buildings with rooftops was included, however a question is whether these buildings should be included in the plan. A disadvantage of showing buildings with rooftops is that a suggestion can be made how buildings should look like.

Another difficulty concerns the visibility of the plan. In the pilot the allowed building volumes are showed with the existing buildings. Therefore, transparency is needed to keep the buildings visible. Next to buildings also zones like safety and noise zones should be visualized. However, including this in the zoning plan, makes the plan less visible, since several zoning objects are built up on each other. Transparency is a method to deal with this issue.

Another difficulty is how zoning objects such as noise zones should be bounded. A noise zone has a third dimension and can therefore be visualized in 3D. In the zoning plan regulations no rules for the height of the zones is determined, therefore additional information is needed for the visualization of these kinds of zones. Another issue of boundaries is how deep in the underground a planning object such as a building is allowed to be zoned. Is it allowed to build a basement as deep if one wants or are there boundaries? In current zoning plan regulation little is stated concerning zoning in the underground. However, in 3D the underground can be visualized much better and also therefore can be more included in zoning plans.

In the section 4.4.3 issues concerning the visualization in 3D will be discussed in more detail.

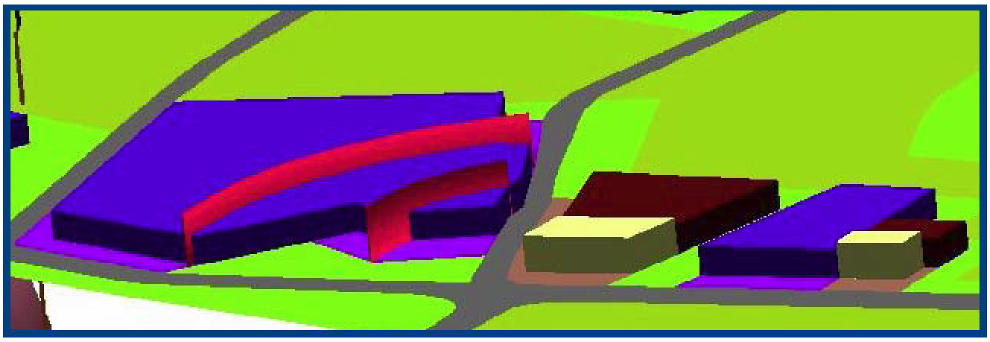


Figure 9. *Usseler Es, Enschede*

3.3.3 Rotterdam case

In the pilot of Rotterdam the emphasis was especially on the 3D modelling of the underground rather than the design of a 3D zoning plan. The idea was to model the underground in 3D to get a good overview of the spatial, technical and financial consequences of a new tunnel. By modelling the underground in 3D it became clear that the underground is complex, due to the existence many objects such as old walls, piles and remainders of explosives of World War 2. This makes it clear that a spatial policy for the underground is necessary. An advantage of Rotterdam was that the municipality owns a large amount of data of the underground which could be used for the pilot. However, it must be said that not every municipality has this kind of extensive amount of data in its database.

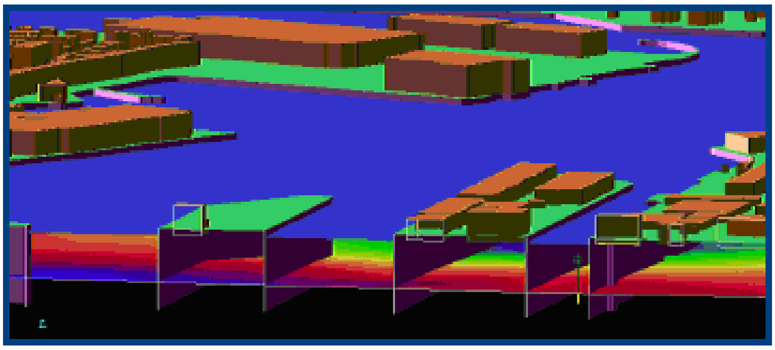


Figure 10. *Stadshavens Rotterdam*

The municipality of Rotterdam possesses data about drillings, cables and pipelines, sewers, archaeological findings, foundations, geo-hydrological data, World War II findings etcetera. By modelling the underground in 3D a good overview of the objects which are situated in the underground can be visualized. By visualizing the underground in 3D it became clear which objects would intersect with a planned tunnel (see figure 11).

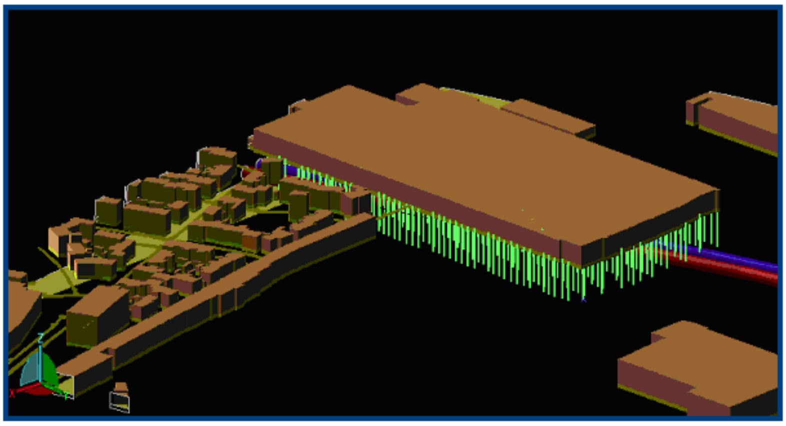


Figure 11. *Visualization of piles in the underground*

3.3.4 3D visualization issues

A number of issues came forward from this pilots making clear visualizing a zoning plan in 3D is challenging.

A first issue concerns the visibility of the plan, which is a result of the addition of the third dimension in a zoning plan. In the Enschede pilot zones, like noise zones and environmental zones are visualized in 3D. These zones mostly intersect with buildings, which make the plan less clear. In the pilot transparency is used for those zones. It is also possible that zones are crossing each other, which also gives visibility problems. Another issue with transparency is how buildings should be visualized. In the pilot of Enschede the buildings, based on the GBKN are visualized in 3D with on top the building volumes showing the maximum building heights. To make a distinction between the building and the building volumes transparency is used.

A second issue concerns the amount of information and the level of detail to be visualized in 3D. A 3D zoning plan can be visualized very basic with simple block volumes on a flat surface. Another option is to visualize a zoning plan completely in 3D, including a 3D terrain with a detailed 3D visualization of buildings. More detail will be more complex, but will also lead to more realistic models, which for citizens might be easier to recognize. Detail of buildings is another issue. Buildings can be visualized as simple block models (LoD1) or with roofs (LoD2). LoD2 shows more detail, but is more time consuming to construct. LoD1 is easy to construct, however gives very little detail on buildings and results in the surface layer (GBKN) become invisible. LoD3 or LoD4 seem less suitable, since in a zoning plan not many details concerning the architecture are described, like windows and door regulations are regulations. To choose the right level of detail it is important to study the zoning plan regulations of buildings. However, it is a question whether existing buildings should be represented in the zoning plan, since regulations are made concerning the building plane with rules such as the maximum building height and not about the existing buildings itself.

A third main issue is that 3D main data (cadastral map, 3D topography, 3D modelling of pipelines) is only very limited available. 3D topography of buildings is not available, which therefore have to be constructed from scratch based on 2D data, such as the GBKN. To zone the underground, additional data is needed which not every municipality has in its possession.. For example, when zones like noise zones have to be modelled in 3D, data is needed to construct the boundaries of the zone. For noise zones this would probably mean that fieldwork has to be done to get data of the noise levels.

A fourth issue concerns the navigation through a zoning plan. Navigating in a 3D environment could lead to a lack of overview on the map and one could get dizzy. Therefore, navigating through the map has to be convenient for a citizen. This can be done for example with a small 2D map on the screen, like Google Street View, to have a better understanding of the position in the map. Another issue concerning navigating is how text and semantics should be included in a 3D zoning plan to keep it visible and readable for the user of the zoning plan.

3.4 Conclusions

The current visualization of a zoning plan in 2D has several clear limitations. 2D visualization of a zoning plan is abstract and therefore can be difficult to interpret by its users, such as citizens. For citizens it can be hard to get an impression of the heights of buildings when it is only described as text. Furthermore, underground zoning and mixed zoning are aspects which are more suitable to visualize in 3D.

The limitations of representing a zoning map in 2D ask for a 3D visualization, which should result in 3D visualization offering an added value in comparison to 2D visualization of zoning plans.

From the pilots several conclusions can be drawn.

The first conclusion is that 3D visualization of a zoning plan offers an added value in visualizing the allowed height levels zoning plan objects, which will be easier for citizens to interpret in comparison to a traditional zoning plan, which shows ‘flat’ buildings. In addition, more detail of buildings and multiple zoning of one building can be visualized. However, 3D visualization can lead to visibility problems, because objects can overlap each other, like buildings and safety zones, which makes it challenge to visualize it clearly for the user. Also navigating through the map is complex in 3D.

The second conclusion is that visualization of the zoning plan objects in 3D is much more complex and different than in 2D. Visualizing objects in 3D is more complex to design due to the addition of the third dimension and the more realistic modelling of the real world. The levels of detail of the objects, 3D topography of buildings, ways to visualize different types of zones are examples of aspects which raise new questions.

The third conclusion is that 3D data is hardly available. For example 3D topography of buildings and 3D data of the underground is hardly or not available in 3D, especially municipalities do not possess much 3D data. This makes it more time-consuming to construct the data before developing a 3D zoning plan.

A final conclusion is that the pilots show that technically the 3D visualization of a zoning plan offers many possibilities, but that the transformation from these techniques to the regulations of a zoning plan is a challenge and especially to make it understandable for the users. 3D visualization asks for different and visualization techniques than for 2D visualization and in 3D other aspects are important, like the level and realism.

In the next chapter a literature study will be done on 3D visualization and the understanding of visualizations and the role of 3D visualization in spatial planning and especially in zoning plans will be analyzed.

4. 3D geovisualization in spatial planning and the role in zoning plans

This chapter will discuss important aspects of 3D geovisualization, the role of 3D geovisualization in the planning process and especially how it can be related to zoning plans. . First, the role of communication in the planning process will be discussed and the growing importance of e-participation. Secondly, geovisualization will be defined and important factors for geovisualizations will be explained. Thirdly, spatial interpretation of visualization will be discussed and how it can be relevant for this research. The fourth part deals with the role of 3D geovisualization in the planning process and some examples will be discussed. This chapter ends with conclusions.

4.1 Role of communication in the planning process

4.1.1 Communicative planning

Communication has become more important in the planning process in the last decades. In the last 20 years in the Netherlands the role of governments are changing on how spatial planning is implemented (Louw et al. 2003). Since the 1990s, a 'communicative turn' in planning can be observed (Healey, 1993). Governments have taken a different position in planning and this can be characterized by interactions with different governments and other actors. This situation is different from a central government making plans and taking decisions through blueprint planning. According to Van den Brink et al. (2007) the changing role of the government to governance and the trend of communicative planning make it necessary to reconsider the role of participation in planning. Citizens increasingly want to have more influence in the decision making process. Citizens become more and more critical and emancipated in defining their needs and wishes. The trend of participatory planning and governance asks for a more interaction process with different actors. In an interactive process citizens are encouraged to play a more active role in the spatial planning process. This does not mean that citizens only criticize existing plans, but that they deliver ideas to contribute to the planning process. In that sense, citizens are a source of knowledge and they become responsible for the interactive process (Edelenbos and Monnikhof, 2001). Involvement of citizens will rise when they have the feeling their (different) opinions are acknowledged in the process.

4.1.2 E-participation

In the current context of IT development, internet is becoming an important part of the process of communication and use of planning models. Traditional methods of involving the public in the planning process are usually limited in their scope and effect and are often determined by the organisational structures within a local planning authority (Forester, 1999). Internet developments, like Web 2.0 make it possible for governments to use their decision-making processes for citizens to participate over the internet, called e-participation. E-participation has the potential to establish more transparency by the government by allowing citizens to use new channels of influence that reduce barriers to public participation in policy making (UN 2008). Advantages of e-participation tools over traditional participation tools are that communication no longer is bound to a specific location and a specific time. According to a study of Koekoek et al. (2009) e-participation has the potential to involve more citizens than traditional participation meetings do and seems to attract a different public. A user-friendly application that offers typical normative and instrumental participation functions can be seen as a precondition for an effective e-participation project. In spatial planning geovisualization can be used to support the communication and participation in the planning process, such as in the planning process of zoning plans. In a survey of Burger@Overheid.nl (2003) to stimulate the digital government from the perspective of citizens, 97% of the respondents mention municipalities should place the zoning plans on the internet. Furthermore, 70% would like to have a voice in the zoning plan via the internet. In 2003 zoning plans were not yet required to be presented on the internet, this is the case from 2010 (see chapter 3). By offering the zoning plans on the internet, people can get access to zoning plans from their home and can view the zoning plan at every time they would like.

It can be concluded from this section that communication has become an important issue in the planning process and could as well be for zoning plans. Geovisualizations can be effective tools to communicate information to citizens, therefore the next section will focus on the topic of geovisualization.

4.2 Geovisualization

In this section geovisualization will be defined and important factors of geovisualization will be explained. Furthermore some frameworks of geovisualizations will be discussed and zoning plans will be positioned in the frameworks.

4.2.1 Geovisualization defined

Geovisualization is concerned with the visualization of geographical information. Geovisualization provides theory, methods and tools for the visual exploration, analysis, synthesis and presentation of geospatial data (MacEachren and Kraak, 2001). It is a relatively new and multidisciplinary field that combines human visual potential and technology in order to make spatial contexts and/or problems visible (MacEachren et al. 1999). A commonly used definition for geovisualization is made by Kraak (2003):

"Geo-visualizations are visual geospatial displays designed to explore data and through that exploration to generate hypotheses, develop problem solutions and construct knowledge. Maps and other linked graphics play a key role in this process."

Dykes state that geovisualization is about people, maps, process and the acquisition of information and knowledge. It can lead to enlightenment, thought, decision-making and information satisfaction, but can also result in frustration (Dykes et al 2005). The emphasis is on information insight for the further use in spatial models upon which decisions can be based.

In the next section important factors in geovisualization will be discussed.

4.2.2 The 'I' factors of geovisualization

To create and use geovisualizations four important factors can be named. These factors are:, interaction, intelligence, information intensity, and immersion of objects (MacEachren, 1999).

The first factor is interaction. Interaction has a broad meaning and can simple be panning and zooming on a static map, use of animations with a temporal dimension or more complicated interaction such as the ability of manipulating data in a 3D environment, for example picking up objects (Slocum, 2001). Van Lammeren and Hoogerwerf (2003) make a distinction between geovisualizations which can support interaction in the virtual environment and of the virtual environment. Interactions in the environment can be subdivided into: orientation, movement, navigation, manipulation, explanation and elaboration. Interaction of the environment means that the user is able to define the viewer settings to influence the way the environment is experienced by the user (Brink et al. 2007). Animations can be part of interaction and can be very useful in clarifying trends and processes as well as in explaining insight into spatial relationships (Kraak and Ormeling, 2003). Animations can be interactive by moving a slider to show for example spatial patterns Animations can be divided into temporal and non-temporal animations. When dealing with temporal animations, a direct relation exists between display time and world time, for example visualizing spatial patterns of migrations over a certain period of time. Display time in non-temporal animations is not directly linked to world time, and is used to explain spatial relations by presenting individual map images in a logical sequence (Kraak and Ormeling, 2003).

The second factor, intelligent objects, is about the extent to which components in the environment with a certain behaviour, which can be characterized as 'intelligence' (MacEachren, 1999). Batty et al. (1998) performed a study where computational agents were used to model individual behaviour in urban landscapes and how it coincide with the behaviour of users in the same environment. Other examples can be agents assisting in navigating through and understanding virtual landscapes (Cartwright, 1999). Intelligent objects can also be in the form of avatars, moving cars, walking behaviour of tourists in a city centre.

Information intensity deals with the level of detail of objects which are represented in geovisualizations (MacEachren, 1999). Information intensity is related to three factors: the software used, which determines the level of detail the objects are visualized, the geographical data used, which can differ in quality, extent and/or resolution and thirdly the person designing the visualization and the design is done, depending on the person's knowledge, skills and experience (van Lammeren et al. 2007). Several levels of detail can be defined (see figure 12). LoD1 defines a building as a simple block model and the most detailed LoD4 allows for representation of the interior of buildings. Naturally resolution level is increase from LoD0 to LoD4. LoD0 is the 2.5D level, over which an aerial image or a map may be draped (Gröger et al., 2006). LoD1 is a block model without any roof structures. A building in LoD2 has a distinctive roof structure and larger building installations like balconies and stairs. LoD3 contains architectural models with detailed wall and roof structures, doors and windows. LoD4 adds more detail to an object by adding interior structures, like rooms, stairs and furniture.

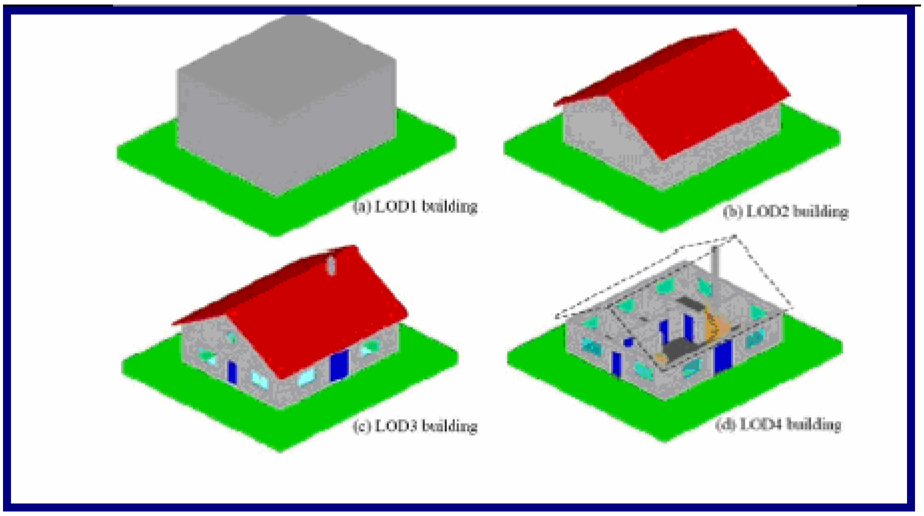


Figure 12. *Level of Detail (source CityGML, 2010*

The fourth factor is immersion. Immersion can be defined as '…a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continous stimuli and experiences" (Witmer and Singer 1998). MacEachren (1999) describes it as 'being in' the virtual environment. Immersion can be physical (full) or mental (partial) immersion. Mental immersion is the state in which the human mind feels the presence of being in the virtual world. Examples of mental immersions are high resolution CRT screens and an example of physical immersion is the CAVE where the user steps into a physical room with digital screens which provides a strong sense of immersion. Though a stronger sense of immersion could lead to better perceived and more effective geovisualizations, cartography has been successful, especially since abstraction is helpful to understand the complexity of the world (Slocum et al., 2001).

4.2.3 Geovisualization frameworks

MacEachren (2004) proposes a conceptual cube for analysing uses and types of visual media that could also be applicable for 3D visualization of zoning plans (see figure 13). Map use is defined continuously along the three axes of the three-dimensional space of the cube:

The dimensions of the interaction space are defined by three continua:

- from map use that is private (for individual needs) to public (designed for a group of users);
- map use that is directed towards revealing unknowns (exploration) versus presenting knowns (presentation);
- from map use that has high interaction versus low interaction. There are no clear boundaries in this human–map interaction space. All visualisation with maps involves some communication and all communication with maps involves some visualisation. The distinction made is in emphasis. Geographic visualisation is exemplified by map use in the private, exploratory, and high interaction corner. Cartographic communication is exemplified by the opposite corner.

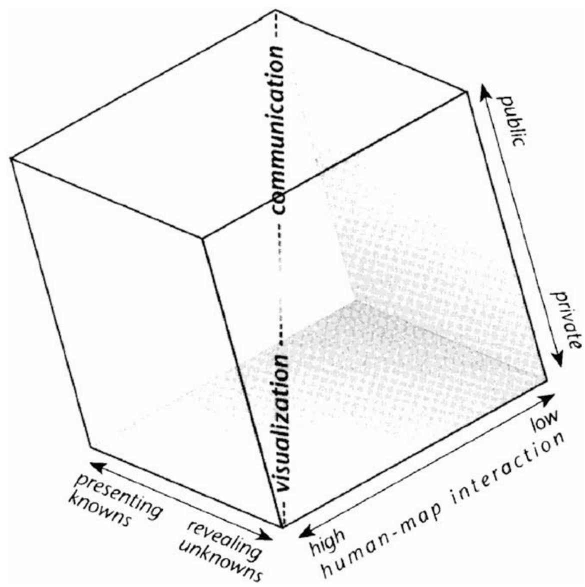


Figure 13. *MacEachren's cube representing key dimensions related to visualizaton and communication. Source: (MacEachren (2004).*

The E-Interaction Communication Protocol (ECP) cube (van Lammeren et al, 2007) continues on the framework of MacEachren (2004). In this framework, communication technology offers several options in certain space and time slots. Several space and time slots are mentioned which are fitted in the framework: same place and time (SP/ST); same place and different time (SP/DT); different place and same time (DP/ST) and; different place and different time (DP/DT). (see figure 14). An example of different place and same time is Second Life where users can meet each other virtually, but being on different places. In the ECP cube the place time components are divided into an immersive and a non-immersive half, in the framework represented as blue planes. The framework also includes different communication relationships: many to many (M-M), one to many (I-M) and many-to-one (M-N).

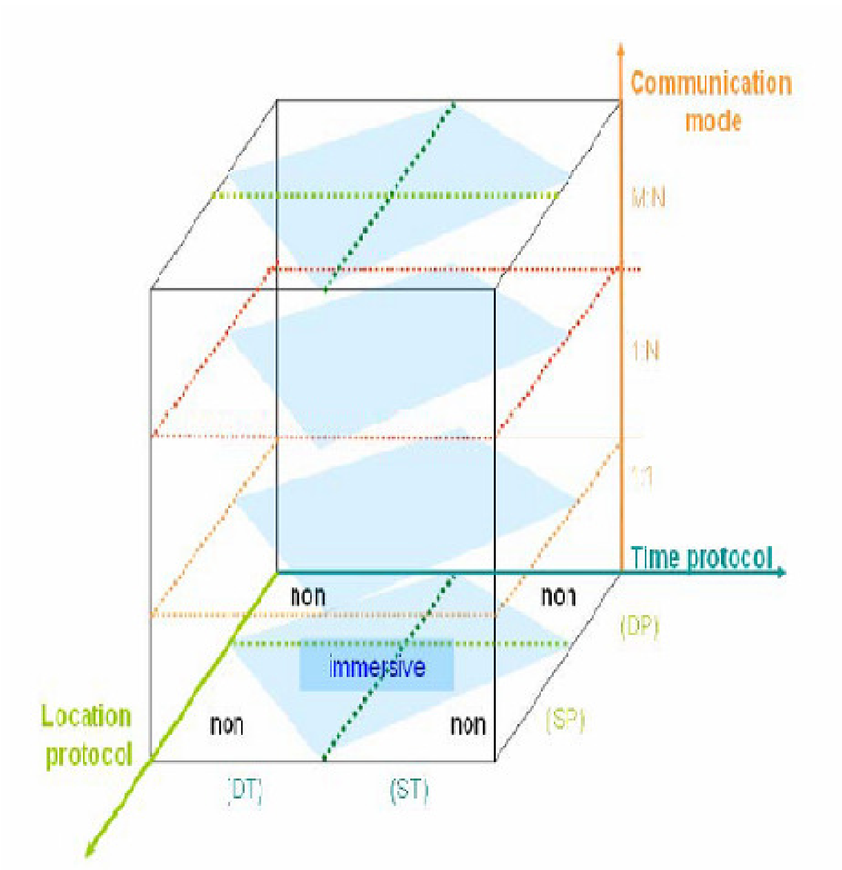


Figure 14. *E-interaction communication protocol cube (van Lammeren et al. 2007)***.**

4.2.4 Relating geovisualization frameworks to zoning plans

In the framework of MacEachren (2004), a zoning plan can be considered as geovisualization tool for the public and presenting much known information to the public. 3D visualization of zoning plans will emphasize especially on the communication with citizens, since in 3D an easier interpretation can be represented, rather than using the zoning plan for analysis. Furthermore, 3D visualization of a zoning plan could also emphasize on interactivity, for example by navigating through an area, activating layers, clicking on objects to get more information. Animations could be used to show the different stages of the zoning plan (preliminary design and final design), but this will not be included in this research.

An attempt can be made to place this research within the ECP cube. A zoning plan offered on the internet is an example of different time and different space slot. Zoning plans can be consulted at any given time and different place with internet. A 3D zoning plan can be characterized as non-immersive, since users are not being in the virtual environment, which is more the case with a CAVE where users have more the feeling being inside a virtual environment. Looking to the communication mode, a zoning plan is especially a 1-N relationship, where the zoning plan is presented on the internet by the municipality as being the sender to the citizens and other actors, being the receiver. Feedback on the zoning plan can be given, however making objections on the zoning plan via the internet can currently not be done.

4.3 Spatial interpretation of geovisualizations

One of the challenges in geovisualization is that visualizations should be able to communicate and be understandable for various users. The accuracy of the visualizations, understanding of the process of visualization and the quality of data are essential (Tyrvainen et al. 2006). The code of ethics Sheppard (2001) presents general principles for optimal visualizations. This will be discussed in this section.

4.3.1 User definition

The use of geovisualization heavily depends on the user and the purpose of the visualization (Nielsen, 1993). This will have implications for the type of modelling and degree of realism. However, Slocum et al. (2001) note, ‘’ a clear specification of tasks (and sometimes of users) is often not possible due to the exploratory and interactive nature of geovisualization.” There have been some efforts to design systems that address the explicit needs of specific user types and researchers have conducted a number of studies regarding the usability of geovisualization (Fuhrman et al., 2005). Andrienko et al. (2006) for example did a research to test the usability of interactive maps in CommonGIS and they found out that users were able to understand and adopt the new ideas of map interactivity and manipulability, however a clear introduction was needed to make the people understand the purposes of the interactive tools. Not only for the visualization it is understandable, also the interface for the geovisualization plays an important role, since the interface transmits the visualization to the user and determines how the visualization is perceived by the user, which interaction and visualization options the interface is offering (Lammeren et al. 2007).

In spatial planning, urban planners often gather around large paper or digital maps to discuss spatial plans. These maps are also used for discussions at meetings with citizens and organizations. In these cases, multiple users can be identified with different backgrounds using the same maps.

4.3.2 General principles for the interpretation of geovisualizations

Geovisualizations needs to be understandable, show credibility and should be bias-free (Sheppard, 2001). Wergles and Muhar (2009) state that planners have to take into account that "although visualizations are not considered reality, they are regarded as a design commitment" (p.182). By this they mean that the reality will be compared to visualizations and a mismatch can lead to a feeling of deceit. However, if visualizations are considered as a means of communication instead of a realistic representation of the real world, then leaving out some of the details are part of the 'code' of non-verbal communication. This of course, has to be clearly communicated to the user (Sheppard, 2001). More importance has to be put into matching visualizations with the communication needs of the targeted viewers (Wergles and Muhar, 2009). Sheppard (2005) suggests a code of ethics which should be taken into account of landscape visualizations for a full understanding by the users:

- Accuracy: Visualisations should simulate the actual or expected appearance of the landscape, without distortion and at an appropriate level of abstraction/realism for the intended purpose.
- Representativeness: Visualisations should represent typical or important views/conditions of the landscape.
- Visual clarity: The details, components, and overall content of the visualisation should be clearly communicated.
- Interest: Visualisations should engage and hold the interest of the audience.
- Legitimacy: Visualisations should be defensible and their level of accuracy demonstrable.
- Access to visual information: Visualisations should be readily accessible to the public via a variety of formats and communication channels.

- Framing and presentation: Important contextual and other relevant information should be presented in a clear, neutral fashion, along with the visualisation imagery.

Accuracy has implications for the realism of the model. The third dimension creates new questions about elements that are insignificant for 2D representations. For example, in 2D the surface represents a building and no attention is paid to windows, doors, roofs etc. In 3D, a building can be visualized as a simple block model, with roofs or with a windows, doors, etc.. Thus, in 3D significantly more detail and realism can be represented of objects in comparison to 2D objects. Wilson and McGaughey (2000) state that the lack of realism is in certain respects an advantage in not providing too precise an image of the world. The ability to interpret computer graphics correctly is also believed to increase through practice, although there appears to be wide variation between individuals in the ability to understand such images (Pietsch, 2000). A high level of realism is required with nonprofessionals, especially with local residents in an urban area (Karjalainen and Tyrvainen, 2002). A high degree of realism, however, is often perceived the same as a high degree of accuracy and authority, which is not always the case (McQuillan, 1998). When the actual consequences of a plan do not match the visualization, people become disappointed. Al-Kodmany (1999) argues that photo-realistic visualizations can be effective tools to inform citizens and he argues that the reason is that these visualizations are a very close representation of reality and participants need little interpretation to understand this information. On the other hand, Appleton and Lovett (2003) pay attention to the fact that high level of detail within geovisualization may cause negative effects, like bias and misunderstanding.

Visual clarity is also an important aspect of the ethics of visualization named by Sheppard (2001) and which can have several issues, such as the content choice, viewpoint chosen and weather and light conditions. Furthermore, Sheppard and Cizek (2009) state that the field of computer visualization is especially technology driven, but issues with deep understanding, truth and safe and more informed decisions may not always solved by the technology to establish a 'good' visualization'. Another issue of concerning visual clarity is that users mention that they feel lost in the environment. This has to do with immersion, already mentioned in section 4.1. In virtual worlds the core problems associated with making users lost are linked to the interface used for navigation, how it is used for orientation, the display space itself and how users related that display space to the geographic space it depicted (Slocum et al. 2001).

Sheppard and Cizek (2009) use further the concepts of validity and reliability in the context of legitimacy. Validity refers to whether an instrument or result is correct, defensible and appropriate. Daniel and Meitner (2001) use the term 'representational validity' where visualizations should be correct, neutral without making value judgements. Reliabilty refers to consistency in repeated applications

4.3.3 Spatial interpretation and visualization of zoning plans

Placing the ethics of visualization in the context of this research, several remarks can be made. Concerning accuracy and realism, zoning plans should be accurate by showing exactly the boundaries of the different zoning functions. Especially in the case of zoning plan this is very important, since zoning plans are juridical bonded plans and therefore the zoning plan should be accurate to prevent legal issues. This is also relates to the aspect of legitimacy.

In addition, a zoning plan should be visualized in such a way it represents the relevant objects and clearly, so that it is easy interpretable for the users, therefore showing no more detail then is required. Especially in 3D more details can be shown how a building should look like, but the danger is to show too much architectural details, which can lead to suggestions how a building should look like.

Visual clarity is very important for zoning plans. Zoning plans are abstract plans, consisting of many (detailed) information and difficult concepts. This makes a zoning plan difficult to interpret, especially for people not familiar using zoning plans. Therefore, a zoning plan should be clear and not showing more details than necessary to make it interpretable for the user.

The aspect of accessibility is also relevant for zoning plans, since it should be easily accessible by citizens, with minimal hard- and software boundaries, else it could lead to lower accessibility and less people are able to consult the zoning plan on the internet.

In the next section the role of 3D geovisualization as a communication tool in the planning process will be discussed and will be related to zoning plans.

4.4 3D geovisualization as communication tool in the planning process

This section will discuss the role of 3D geovisualization in the planning process. Communication is an important aspect in this, since it can help citizens to better understand and make them more involved in the planning process.

4.4.1 3D geovisualization as communication tool

3D geovisualization is a tool which can contribute to a better communication between professionals and citizens. It offers new possibilities for communication of ideas and discussion of design alternatives. Bishop (1994) argues that there is a need for effective ways of communicating spatial planning information to a wider audience, and this becomes very important if a broad community involvement in the planning process is to be achieved. Visualisations are recognized as the common language to which both technical and non-technical participants can relate and visualization can improve aspects of the decision-making process (Orland et al. 2001).

In addition, 3D visualization can offer more insight and understanding of relations (topology) and dimensions (geometry) (Bos et al, 1998) and 3D offers new functionalities, which in 2D are impossible. Many municipalities and urban designers are in process of discovering these new functionalities (Zlatanova et al. 2008, Kibria 2008). 3D geovisualization tools can stimulate spatial reality and allow the viewer to more quickly recognize and understand changes in elevation (Bulmer, 2001:7). For example, in a 3D zoning plan the allowed height levels of buildings can be visualized. If the presentation fits better to the daily visual references (Bishop et al, 2003) then it will improve communication. Visualizations are promising in opening up the planning process to more participation (Pietsch, 2000) especially when communicating with people less familiar with traditional visualization methods such as plan views, etc.

Nielsen (2005) states that 3D geovisualization can be easily interpretable, highly interactive and distributable. Especially due to the increasing complexity of spatial planning issues and the increasing demand of emancipated citizens for taking part in designing and deciding on spatial plans, a quality boost is needed in communication processes between governmental actors and citizens about land use. 3D geovisualization can result in that the citizens or actors become more involved in the planning process, by responding to the plan (through internet) and getting the feeling that they are actually contributing to the process (Al-Kodmany, 2002).

4.4.2 3D geovisualization in the planning process

Much research has been done that discuss the growing importance of computer-aided visualizations in the planning process. Klosterman (1997) states that visualization has emerged as a ‘‘common currency’’ whereby citizens can readily evaluate the work of the planners, and the opportunities for misinterpretations of information are reduced.

Lange (2001) suggests that visualizations should form an integral part of the planning process. Warren-Kretschmar and Haaren (2005) report on the use of visualizations throughout the landscape planning process, whereby interactivity, photo-realism, accuracy and preparation time play a key role in determining the appropriate visualization methods for a planning task.

Hoogerwerf et al. (2006) made a framework for the use of geovisualization for participatory spatial planning processes. Kibria (2008) modified this framework specifically for the use of 3D geovisualization. Six components can be identified consisting of actors (stakeholders), planning phases, participation level, communication protocol, interface and 3D visualization (see figure 15).

According to Hoogerwerf et al (2006), 3D geovisualization in spatial planning consists of multiple actors who interact with each other through visualization in different planning phases. The authors have stated that 3D visualization should interpret the preferences of the various involved actors. In the different spatial planning phases, 3D visualization should support the different activities in the planning process and should visualize and process the information appropriately. In addition, 3D visualization should support the maximum participation of the actors.

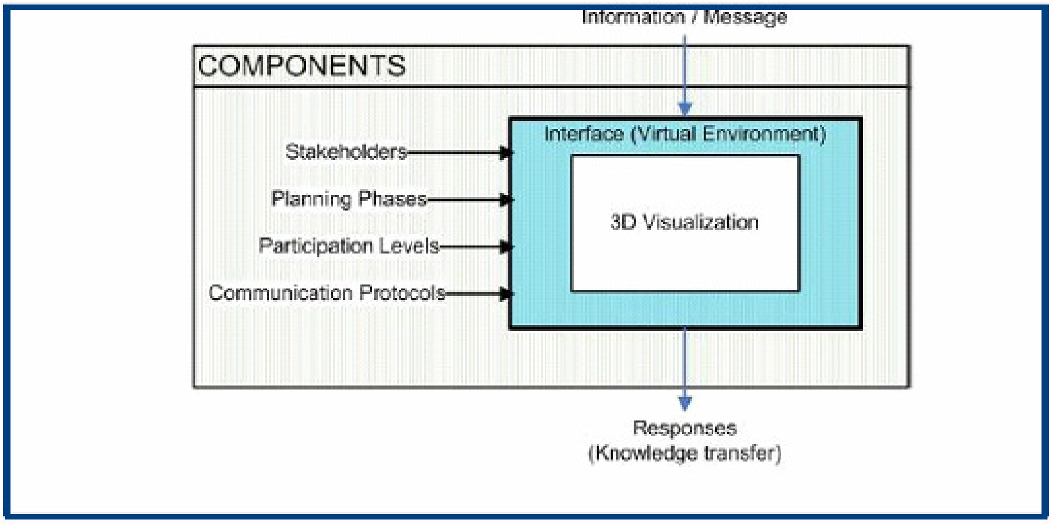


Figure 15. *Conceptual framework for 3D geovisualization, Hoogerwerf et al. (2006), modified by Kibria (2008).*

Through the communication protocol, 3D visualization can be used at the same time and same place (like meetings) or at different time and place (like interactive websites with maps). 3D visualization should be supported by devices, which facilitates various forms of interaction between actors and geovisualizations, called the interface component.

Riedijk et al (2006). developed a model describing the relationship between geovisualization effects (see figure 16). It shows that geovisualization has two main direct effects, which eventually should result in other effects. These main effects are the improved communication between the actors in the process and a better understanding of spatial issues among the actors. The difference between those two main effects is that communication involves the information available to the actors and therefore more input for discussion between the interest groups. The improved understanding includes a better insight in the output of the plans. This is relevant for zoning plans, since geovisualization can help in understanding the zoning plan regulations by presenting it on a map, which can be consulted by the citizens.

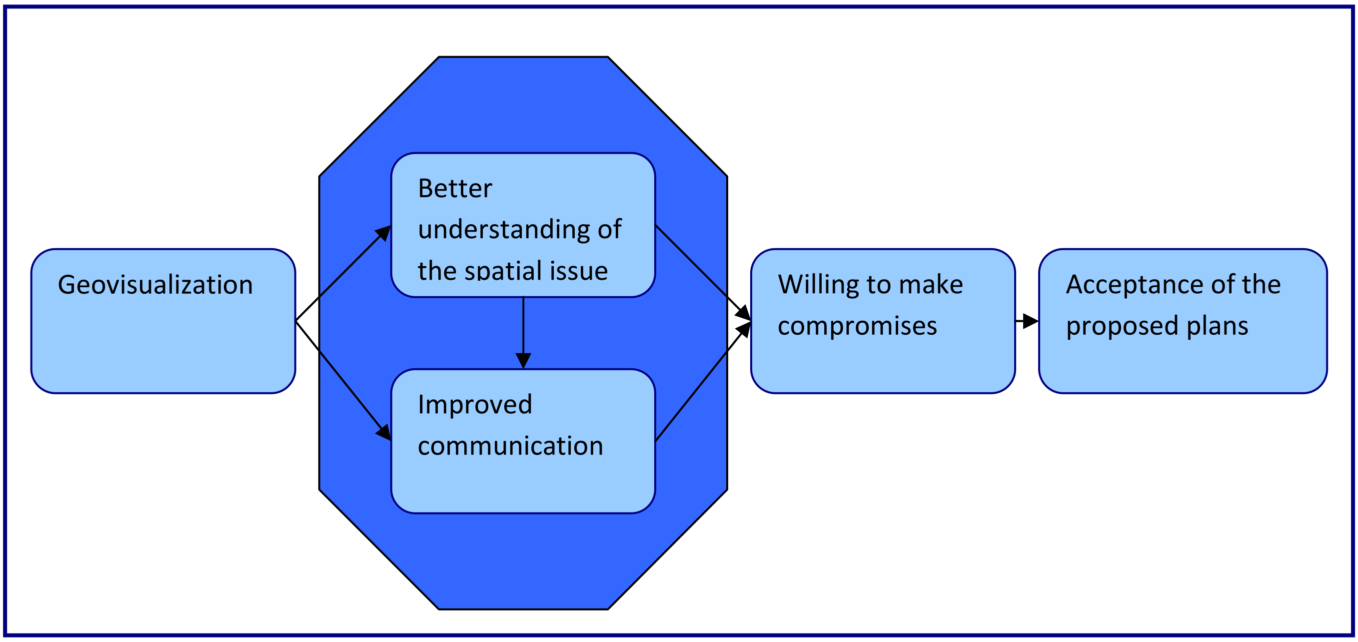


Figure 16. *Relationship between geovisualization effects* (*Rietdijk et al. 2006)*

The potential of 3D visualization can be demonstrated by a number of studies. Schaik (2010) performed a study to the use of interactive 3D visualization for public consultation for outdoor environments. Schaik concluded that interactive 3D visualization of outdoor environments can be useful and can have a strong potential in supporting public-consultation activities..

Lewis and Sheppard (2006) compared 3D visualizations with map representations. They found that 3D visualizations led to a better understanding of proposed management options than simple maps on their own. The visualizations promoted more in-depth and lively group discussion and seemed to facilitate the articulation of participants' preferences for landscape conditions.

Wergles and Muhar (2009) did an experiment to test the adequacy of visualizations for the communication of urban design proposal. They conclude that visualizations can be benefit planners to make ideas and concepts tangible, which can stimulate discussion. However, visualization can be perceived differently as compared to real world landscapes. In some cases, visualizations were unable to convey information on subtle height differences, attributes of objects such as materials, surface texturing and age. Several were even being misinterpreted.

However, 3D does not always have to be a benefit. Dockerty et al. (2006) compared static visualization with 3D real-time landscape models of potential policy and climatic influences on future agricultural landscapes; 3D representation was not preferred over static visualization to evaluate the potential consequences of choices, but the authors noted that a lack of experience with computers may have had influences on the users' responses.

4.4.3 Examples of 3D geovisualization in urban planning

Due the fast growing field of information technology the use of 3D visualization in spatial planning is growing and improving and becoming more interactive (Stoter, Zlatanova, 2003). 3D visualization through the web is also progressing. VRML (Virtual Reality Markup Language) is usually used for 3D urban planning models (Huang et al. 2001). Hetherington et al. (2007) proposed to apply X3D standard to accommodate 3D urban plans for interactive Web visualization of proposals for site developments. Next to VRML and X3D, KML (Keyhole Markup Language) has become a common format for 3D visualization in tools as Google Earth. Visualization tools as Google Earth are growing rapidly in popularity and have found their ways into the Web 2.0 society. These viewers offer navigation, interaction and exchange of data via the Web and the viewers are an open and accessible platform to a wider audience. Google Earth can upload 3D objects modelled in 3D software, for example Google Sketchup and via GIS software through KML. This makes it possible for people to create their own 3D model themselves and scientists and experts can use Google Earth to communicate science to the people (Sheppard, 2009).

In the Netherlands some cities have introduced virtual cities for planning purposes. Cebra B.V., a Dutch Company has that developed the technology behind Virtuocity. VirtuoCity Groningen shows for a large part the municipality of Groningen in 3D as it is now and also future developments are visualized. The model shows the future route of the regional tram, which might be developed in the future. Also plans for another development project can be added to the model, such as the east wall on the Grote Markt. Citizens can freely move around in the streets of the town. In figure 17 the Grote Markt is depicted with the proposed route of the Region tram.

Other cities interactive virtual cities are VirtuoCity Tilburg, Apeldoorn and Helmond. These applications also show the current city and future plans. the plans come alive and bridges the gap between the municipality and its inhabitants, facilitating the growing need for participation and communication between government and the public. According to a civil servant of Apeldoorn, citizens can understand the plans better and the discussion is now more about the contents than about fears and prejudices (VI Matrix, 2010).

Figure 17. VirtuoCity Groningen

The municipality of Helmond is a great success. Many visitors have already been able to take a realistic look at the past, present and future of a part of Helmond current being redeveloped. Visitors can also put their questions and opinions to representatives of the municipal authorities (Riedijk et al. 2006).

4.5 3D geovisualization of zoning plans in the planning process

In the previous section 4.4 the potential of 3D geovisualization in spatial planning was discussed and some examples were shown, demonstrating 3D geovisualization can be useful in the planning process and how it can enhance communication between governmental bodies and citizens and citizens can be better involved in the planning process through interactive 3D geovisualization. This section will discuss how 3D geovisualization can be useful for zoning plans and how it can contribute to better communication and interaction. Furthermore, this section will come up with a conceptual framework for the 3D geovisualization of zoning plans, based on the literature review discussed in this chapter.

4.5.1 3D geovisualization of zoning plans as a communication tool

3D geovisualization can be very helpful for zoning plans and to communicate information to people. First of all, 3D can offer a better impression of an area in comparison to 2D, which is more abstract. By visualizing heights in 3D, people can get a better impression of what the heights described in the zoning plan mean and people can compare the heights to other heights in the 3D environment. Furthermore, since 3D can offer a better impression of heights, it can be easier to interpret than a current 2D zoning plan.

3D geovisualization can also lead to more interaction in the use of zoning plans. Zoning plans can be made interactive, by letting the user to do simple zooming and panning, navigating through the area, view the zoning plan from different perspectives, activating and deactivating layers, clicking on objects. The aspect of time can also be implemented in zoning plans, by showing the old and new situation of a zoning plan and users can observe the differences between the old and new situation.

Internet and information technology can enhance the participation and communication of the public in the planning process of zoning plans. Like a current zoning plan, it should be presented on the website of the municipality, so that people can view the zoning plan every time and on every place . Next to internet, other technology can be used, such as a touch table (see figure 18). This map table could be used for sessions, where the public can discuss a zoning plan with the municipality, which can lead to a more interactive planning process.

Figure 18. *Use of interactive map table in planning process of zoning plans*

A zoning plan consists of several stages. The first part of the planning process deals with the design of the zoning plan and the public has to opportunity to react on the plan. The second part of the planning process is when the zoning plan is made active and no reactions can be given. The first part contains a more active communication when the public has the opportunity to participate in the decision-making process of the design of the zoning plan by reaction on the plan. This could for example be done by clicking on an object in the zoning plan to have the opportunity to type a reaction, which will be send to the municipality. Another option to enhance participation could a discussion forum or a chatbox. The second part of the planning process is characterized by a more passive communication, when the zoning plan is made active and the public only can consult the plan. If a person has questions about a certain zoning plan an option can be to ask questions via the interface and the zoning plan specialists of the municipality receive the question and can answer back.

4.5.2 Conceptual model

Based on the conceptual framework of geovisualization by Hoogerwerf et al. (2006) (see 4.3.2) a conceptual model can be made specified on the 3D visualization of zoning plans.

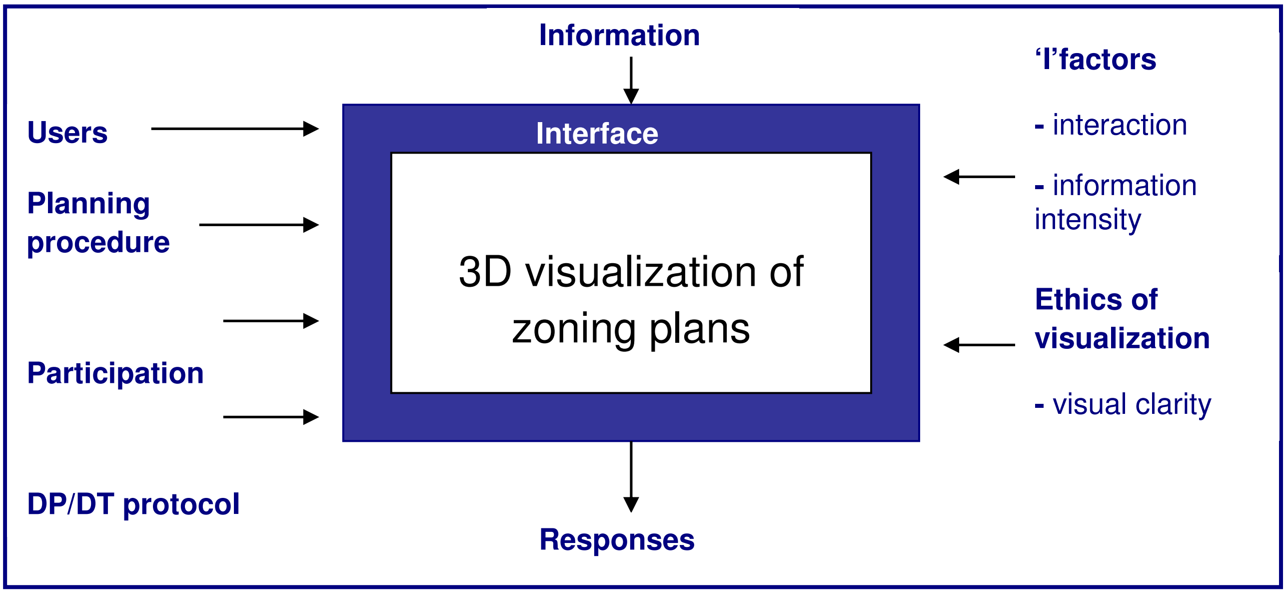


Figure 19. *Conceptual model of 3D visualization of zoning plans*

Users

Citizens are a main group which could consult the zoning plan. Citizens are mostly interested in what is allowed on what place and to which height it is allowed to be build, such as is it allowed to build a shed in the backyard or can someone open a pub below a home. Interest of citizens can be divided into two groups: 1. what is allowed for the citizen itself and what constraints there are on their own property. 2. citizens are interested what the zoning plan means for their neighbourhood (Burger@Overheid, 2003). Citizens can further be divided into different groups, such as age and education. The users of zoning plan are a broad group with different backgrounds and this has implications for the design of the zoning plan, since a zoning plan should be interpretable for every user, whether they are young or old, low-educated or high-educated. Young people are generally more experienced with using the internet and with virtual environments, such as games, where older people generally have more problems getting used to the internet environment (Czaja and Sharit, 1998). Next to citizens, organisations can be interested in zoning plans. This can be for example architects, real estate agencies and building companies. These actors could be interested in new locations for development, where the zoning plan shows regulations of what is allowed and what is not.

Planning procedure

The zoning plan consists of several procedural steps, where citizens have the opportunity to react on the plan. In the first phase the zoning plan is being prepared and a preliminary design is made of the zoning plan, where citizens have the possibility to react. After processed the reactions, the design zoning plan is developed and can be consulted for six weeks. Then the municipal council will decide on the design of the zoning plan and it will be published. From then, the plan can only be appealed by going to court (municipality of Groningen, 2010).

Participation

Arnstein (1969) mentions five levels of participation: informing, consulting, advising, co-producing and co-deciding. A zoning plan is in general about informing the public what is allowed concerning building regulations and land use. However, people can have a voice in the design phase of the zoning plan. Currently, reactions on the zoning plan can be made orally or written. In the future, this could be done more easily when people can react via the interface of 3D visualization of the zoning plan. People could for example click on a certain area or object in the plan and subsequently a menu pops up where the people have the opportunity to type a reaction. In this way, a citizen can easily make a comment. Furthermore, as already said in the previous section, a map table can improve participation of the public in the planning process.

DP/DT protocol

A zoning plan should be offered on the internet, so citizens can easily consult the plan. A zoning plan offered on the internet is an example of different time (DT) and different place (DPS) slot., also mentioned in the ECP cube (van Lammeren et al. 2007). Zoning plans can be consulted at any given time and different place with internet, this makes the plan more accessible.

Interface

The interface for the 3D geovisualization of zoning plans plays an important role, since it transmits the visualization to the user and determines how the visualization is perceived by the user, which interaction and visualization options the interface is offering (van Lammeren et al. 2007). The interface should be easily in use, to make sure citizens can work with the plan, without difficult menus and difficult functions. Furthermore, an interface should have a clear instruction how it works and a clear legend what the objects in the zoning plan represent. This should result in low barriers for users to use the zoning plan on the internet.

'I' factors

In section 4.2.2. 'I' factors of geovisualization were discussed. Especially two factors, interaction and information intensity or relevant for this research. The factor of interaction can be useful for the 3D visualization zoning plans, since interaction can be used from letting people navigate through a zoning plan area, click on objects to get information about the zoning plan regulations. Furthermore, interaction makes it possible for users to view a zoning plan in different perspectives, by zooming in and out and seeing more detail and an option could be to react on the zoning plan through the interface.

Information intensity is also an important factor aspect for zoning plans. Zoning plans are generally not meant to show much detail, but should be represented abstract. It is not an architectural plan, showing a detailed map or a virtual city model, visualizing a city highly detailed and realistically. In the case of zoning plans, LoD1 or Lod2 seems to be more suitable. Showing more detail could give the user the wrong impression the buildings have to look like it is presented in the plan.

The other two factors, intelligence of objects and immersion are not very relevant for zoning plan and therefore will not be included in this research. Intelligence of objects is not very relevant, since a zoning plan does not consists of objects having some kind of behaviour. The factor immersion is not very relevant as well, since a zoning plan is not a reflectance of the real world where a person will have the feeling "being in" the environment, where in for example virtual cities a person would have more this feeling of immersion. A zoning plan is more abstract than a virtual city and the goal of a zoning plan is not to create a realistic model of the world.

Ethics of visualization

In this research the focus will be laid on of the criteria of ethics of visualization (Sheppard, 2001), visual clarity. Visual clarity has very much to do with interpretation. To make a zoning plan interpretable for the user is a challenge, since a zoning plan is abstract and consists of many information. Especially the current zoning plan in 2D is abstract, since it does not give a good impression of the heights. This makes a zoning plan difficult to interpret, especially for people not familiar with using zoning plans. Therefore, a zoning plan should be clear and not showing more details than necessary to make it interpretable for the user. A zoning plan consists of many regulations, however to keep the zoning plan clear choices have to be made what and what should not be included in the plan to keep it clear for the user. Showing too much information in the plan, would result in the user getting lost in the amount of information shown in the plan. Especially in 3D more details can be shown how a building should look like, but the danger is to show too much details, which can lead to people perceiving the zoning plan more as an architectural plan. In 3D this could be visualized better, however, people might not be familiar using 3D visualizations, so that is another challenge which will be interesting to research.

The conceptual model, depicted in figure 19, shows several important components of 3D visualization of zoning plans. This research will not aim to discuss and analyse all of these components. This research will mainly focus on visual clarity and the 'I' factors information intensity and interactivity.

4.6 Conclusions

The literature review in this chapter made clear that geovisualization and especially 3D geovisualization can be considered as powerful tools to give insight in geographic data and which can help in understanding geographical phenomena. Furthermore, geovisualization can stimulate interactivity in spatial planning and involve citizens more in the planning process. Innovative technologies to present geographic data on the internet and visualization tools such as Google Earth and Virtual cities can be useful to share geographic information, make spatial plans better accessible and to explore geographical data by the users. In the perspective of this research, geovisualization could also be considered as very useful for zoning plans to visualize the zoning plan and present it on the internet so the public can consult the zoning plan, give reactions during the planning procedure and the public can make use of interactive techniques in the map. The addition of 3D in the visualization of zoning plans can result in people getting a better impression of heights. These assumptions are mainly based on literature and the case study and survey will make clear how and if geovisualization can be a powerful tool in the visualization of zoning plans in 3D.

The 'I' factors, interaction and information intensity are stated to be relevant for this research. The factor of interaction is useful for the 3D visualization zoning plans, since interaction can be helpful letting people navigate through a zoning plan area and viewing a zoning plan from different perspectives. Information intensity is also an important factor aspect for zoning plans. Zoning plans are generally not meant to show much detail, but should be represented abstract. It is not an architectural plan, showing a detailed map or a virtual city model, in the case of zoning plans, showing more detail could give the user the wrong impression the buildings have to build like it is presented in the plan.

Sheppard (2005) discusses visualization issues which are relevant within this research and which can be considered as conditions for visualizations which can be interpreted by the users. Especially visual clarity is relevant for this research. Visual clarity has very much to do with interpretation. To make a zoning plan interpretable for the user is a challenge, since a zoning plan is abstract and consists of many information. A zoning plan should be clear and not showing more details than necessary to make it interpretable for the user. The user can be a citizen organization which different backgrounds, making it challenging developing a zoning plan geovisualization which is understandable for all. Furthermore, in 3D more details can be shown, but the danger is to visualize too much details, which can lead to people perceiving the zoning plan more as a an urban plan. The results of the survey, which will be discussed in chapter 7, will point out how the developed zoning plan is perceived by the respondents.

In next chapter it will be discussed how the objects of a zoning plan can be visualized in 3D.

Chapter 5. Requirements for 3D visualization of zoning plan objects

This chapter will discuss the planning objects which should be visualized in a 3D zoning plan. Important is how planning objects are described in the IMRO2008 model, which is the guideline for zoning plans. From the way planning objects described in IMRO2008 a translation should be made how planning objects should be visualized in a 3D. Visualization techniques are needed to be able to visualize the planning objects in 3D, therefore requirements will be identified. This chapter will first start to describe the IMRO2008 model, secondly the planning objects which are specific for zoning plans, thirdly the planning objects suitable for 3D visualization and finally the requirements for visualizing the planning objects in 3D.

5.1 IMRO2008

IMRO2008 is the information model for the description and exchange of digital plans for spatial planning and instruments (zoning plans, framework visions). These instruments are defined in the Law on Spatial Planning (Wro, 2008) and are developed for the different administration levels: municipality, province and national.

IMRO2008 refers to and makes use of regulations which are described in a number of norms and standards. Norms are described on the national level at the Dutch Norms (NEN), which is a standard where all Dutch norms are described.

A standard in relation to the IMRO2008 model is NEN 3610:2005 Basis Scheme Geo-information (NEN, 2005) where terms, relations and general rules for the exchange of information concerning the surface related spatial objects are described. IMRO2008 is an application of the Basis Scheme Geo-information, which means that IMRO has to comply with the rules which are described in NEN 3610. IMRO2008 makes use of the object classes described in NEN 3610 and in addition, the objects should as much as possible be described according to the identified attributes from NEN 3610. However, the NEN 3610 is a general model, which is not specific enough in every case for the spatial planning. Therefore, in the IMRO2008 model attributes are distinguished which are not provided in NEN 3610 and more details are added to already existing attributes of NEN 3610.

IMR02008 consists of a number of directives such as the practical directives for zoning plans (Praktijklijn Bestemmingsplannen, 2008) and standards for the representation of the zoning plans (Standaard voor Vergelijkbaarheid Bestemmingsplannen).

5.2 Objects of IMRO2008

In the directive document for zoning plans (Praktijklijn Bestemmingplannen, 2008) the method of digitizing spatial instruments is described. A zoning plan consists of a collection of geo-referenced objects which are stored in a digital spatial information system and which can be consulted via a website. A zoning plan is based on three classes of objects: zoning plan area (bestemmingsplangebied), zoning plane (bestemmingsvlak) and denotation (aanduiding). The zoning plane is the area where regulations are referring to and which should therefore be considered as one object. The zoning plane class expresses zoning functions divided into two types, single zoning and double zoning. Zoning plane classes are based on zoning functions like, housing, recreation, water, nature, culture etc. A special zoning function is the mixed function, for objects which consists of at least two functions. Denotations (aanduidingen) describe the zoning plan area and the zoning plane in more detail. IMRO 2008 names these object types as classes. In figure 20 the schema of zoning plans is depicted. In the appendix the UML diagram of the zoning plan scheme is shown.

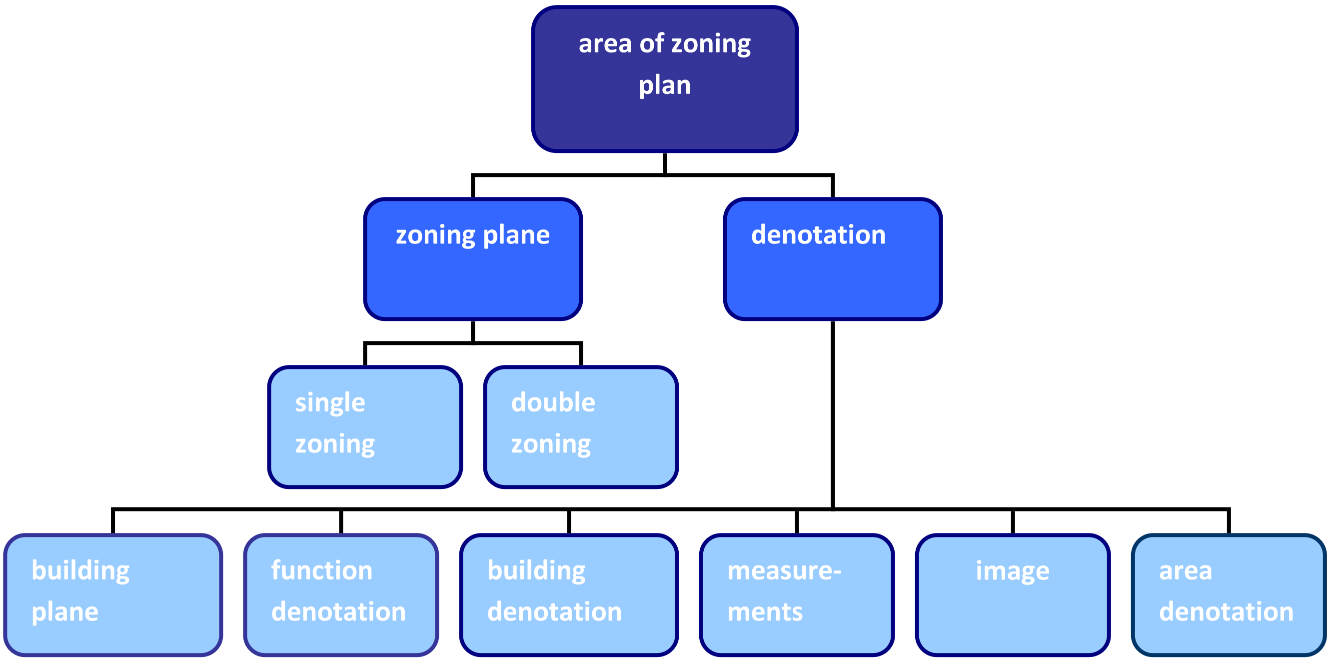


Figure 20. *Zoning plan scheme (source: Praktijklijnen IMRO2008)*

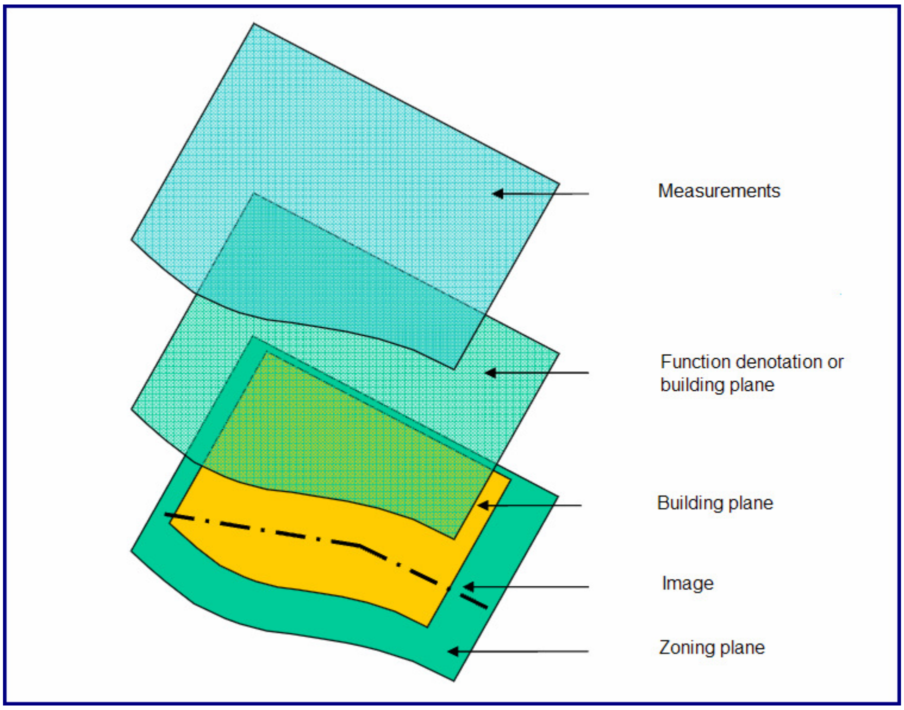


Figure 21: *IMRO2008 objects*

The main principle of the cohesion between objects can be considered as a number of layers of geometrical determined objects on top and related to each other (see figure 21). Mostly a denotation is linked to a building plane (bouwvlak). Also regulations can exist for a certain object, called measurements (maatvoeringen). Another object is image (figuur) which is not a plane, like the other objects, but it has its own geometry (Praktijklijn IMR02008, 2008).

The object ‘building plane’ (bouwvlak) is always inside or equal to the zoning plane. It is possible to have more building planes within a zoning plane. The development plane relates to the zoning plane. Building planes which are stretched out on multiple zoning types (‘bestemmingen’) will be divided for each zoning type, since the regulations of a zoning type only apply to the part of the development

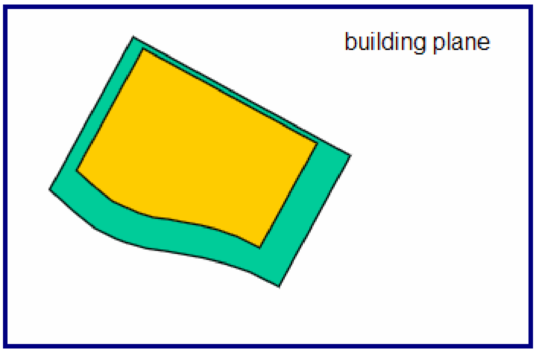


Figure 22 . *Building plane*

which is contained by a zoning type.

The objects 'function denotation' (functie aanduiding) and 'building denotation' (bouw aanduiding) can overlap with the object zoning plane or can consist of one or more parts within this plane (figure 23). These objects can also say something about other denotations. The object function denotation relates to the belonging object zoning plane or another denotation. An example of a building denotation is a type of housing, such as detached housing. An example of a function denotation is a cemetery, cinema, bridge and garage etc.

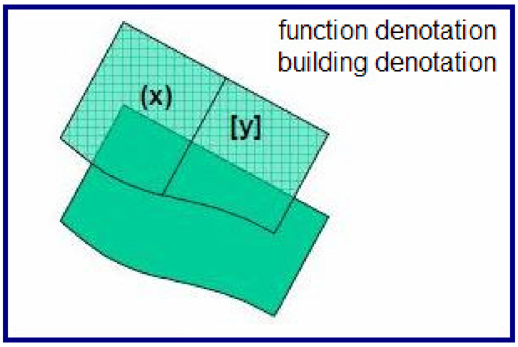


Figure 23. *Denotations*

The object 'measurements' (maatvoering) describes (part of a) development plane or a (part of a) zoning plane, which depends of the regulations (figure 24). The object 'measurements' can also say something about the area denotation. The object relates to the object zoning plan, building plane or area denotation. An example of a measurement is the maximum building height which is allowed.

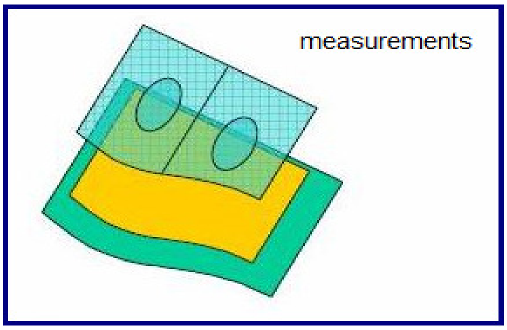


Figure 24. *Measurements*

The object 'image' (figuur) can, depending on the regulations describe one or more zoning types (figure 25). The object relates to the belonging zoning plane, building plane, other denotations and/or zoning area. An example of an image is a gas pipeline.

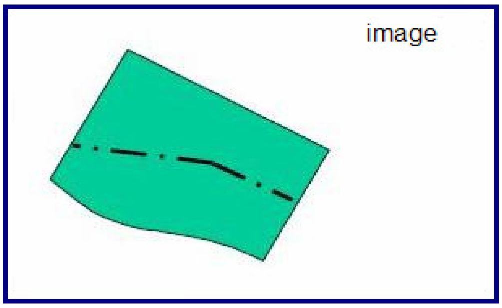


Figure 25. *Image*

The object 'area denotation' (gebiedsaanduiding) characterizes itself because this denotation is independent from zoning planes (figure 26). It can be crossing a zoning plane, overlapping a zoning plane or fall within a zoning plane. An example of an area denotation is a safety zone. The area denotation is depicted as the hatched ellipsoid.

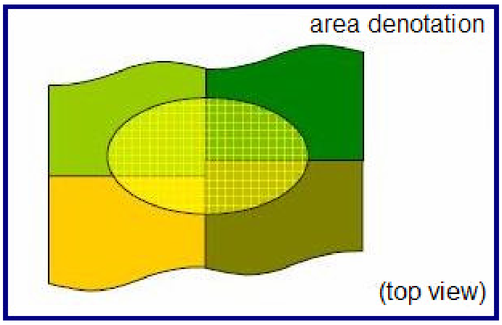


Figure 26. *Area denotations*

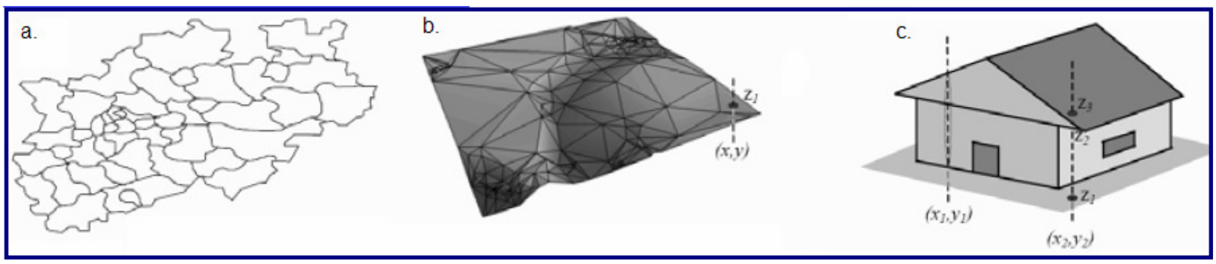
5.3 From 2D zoning plan into 3D geovisualization

The objects of the IMRO2008 model are developed for 2D and in the current model guidelines for 3D are lacking. The third dimension creates new questions how objects should be visualized and how the zoning plan regulations should be taken into account in the 3D visualization. An example that in the IMRO2008 model there are no descriptions to what depth a house is allowed to be build and in what detail buildings should be visualized. Therefore, the IMRO2008 model does not satisfy the requirements of 3D visualization of a zoning plan.

However, the goal of this research is not to develop a new IMRO model for 3D zoning plans, but will focus on the visualization part, rather than the modelling part. Yet, 3D offers new opportunities to visualize objects and which can enhance the interpretation of zoning plans. In 3D it is possible to visualize heights representing maximum heights of buildings, which can helpful in the interpretation of citizens to have a better impression of heights. In 3D objects can also be visualized above and under each other. This gives the opportunity to visualize mixed zoning functions. In 3D also objects below surface level can be better visualized in comparison to 2D, such as transport pipelines.

5.3.1 Dimensions of visualizations

Geovisualization can be represented in 2D and 3D, based on 2D, 2.5D or 3D data (see figure 27). Most geographical data is stored as a 2D data model and is most obviously being visualized in 2D. 2.5D is a simplified 3D surface representation that defines location in 2D space and adding height to the existing datasets such as height data from contours or techniques like GPS or LIDAR data. In a 2.5D map each X,Y location has one Z value. 2.5D is also known as a Digital Elevation Model (DEM).



a. 2D map b. 2.5 map c. 3D model

Figure 27. *Spatial representation in different dimensions*

3D defines location extending through 3D space defined by X, Y and Z axes. These locations position real-world spatial objects which could be regular or irregular in shape. Man-made objects, such as buildings are examples of regular objects, while terrain surfaces, forests and trees are examples of irregular objects (Abdul-Rahman, Pilouk, 2008).

In this research data and descriptions will be used from the current zoning plan and by using height information the zoning plan objects can be visualized in 3D.

5.3.2 Objects of zoning plan with third dimension

The planning objects described in IMRO2008 will be the starting point for 3D visualization. The first step is to define the objects of a zoning plan which contain a third dimension.

Not every planning object has a third dimension and regulations are not in every case suitable to visualize in 3D. Table 1 shows which objects of IMRO2008 have a third dimension. A zoning plane is characterized by a zoning function and does not consist of a 3D component.

Table 1. *3D component*

Planning object IMRO2008	3D component
Zoning plane	no
Building plane	no
Measurement (eg. maximum heights)	yes
Images (eg. transport pipelines)	yes
Building denotation (eg. roof type)	yes
Area denotations (eg. noise zones)	yes
Function denotation (non-spatial)	no

A building plane represents a certain zoning functions and consists of measurements, which are specific building regulations such as the maximum building height, building percentages which are related to a building plane. These maximum heights are suitable to visualize in 3D, since they have a third dimension.

Function denotations are also part of a building plane, which are specific denotations of a zoning function. Function denotations do not have a third dimension, since it only gives a more specific description about a zoning function, such as 'school' for the zoning function 'social services'. However, in some cases function denotations can be visualized in 3D. An example is when a building plane has zoning type 'social services' with the function denotation 'housing'. In the current regulations this is in some cases described as housing is allowed "on upper level floors", however not specifically on which floors. In 3D this can be visualized, however a more specific definition would be needed which describes for every floor a certain function denotation and this is not specifically described in the current zoning plan regulations.

Another denotation is the area denotation, such as noise zones and archaeological values contain a third dimension, which can be considered as virtual volumes. Virtual volumes are more complex to define since they have fuzzy boundaries. Noise differs in heights and therefore has a third dimension. Archaeological values are also suitable to visualize in 3D, since the depth determines the location of the archaeological values.

Building denotations are regulations based on a building plane. It can describe for example what roof types or allowed or the maximum slope a roof of a building is allowed to have. This could therefore be visualized in 3D.

Images can also be visualized in 3D. An example is transport pipeline, which can be located on a certain depth in the underground, making the height component relevant to visualize in 3D.

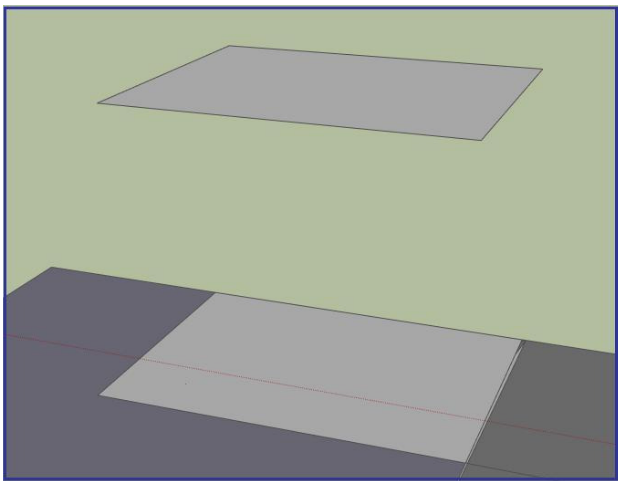
5.3.3 Geometric presentation of objects

In 3D there are several ways to visualize objects of a zoning plan, This will be discussed in this section.

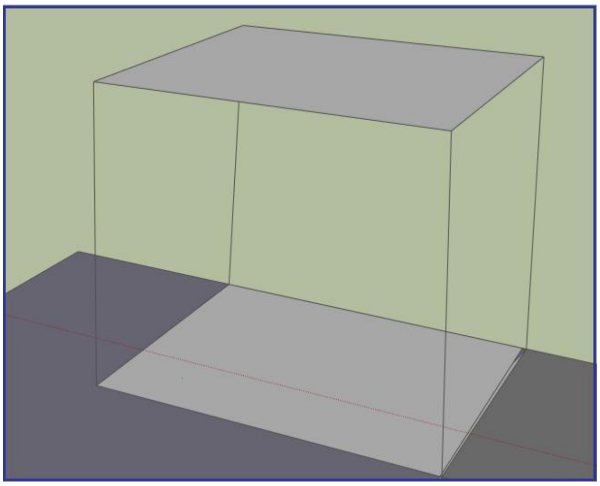
Geometry in 3D is different and more complex than 2D geometry. The third dimension creates new questions about elements that are insignificant for 2D representations. For example, in 2D the surface represents a building and no attention is paid to windows, doors, façade ornaments, etc. As a 3D representation, a building can be associated with a simple box, roofs or with a composite of several boxes indicating windows, doors, etc. A 3D object is constructed by geometric features like vertices, edges and faces, which determine the position, shape and size of the objects (Zlatanova, 2000). The geometry can be simple, such as a simple plane, sphere or a cube object. These basic 3D objects are called 3D primitives.

Maximum heights

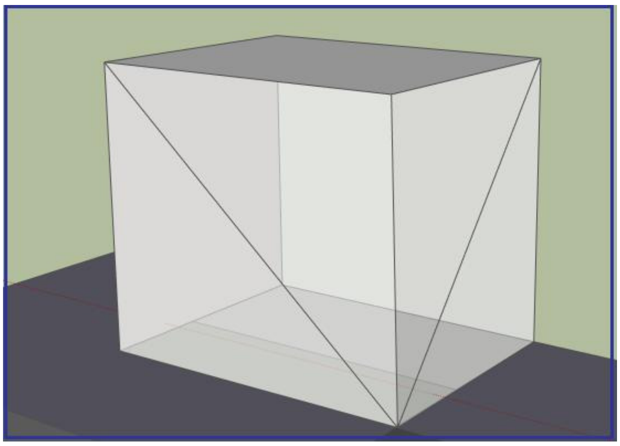
The object measurements, with regulations concerning maximum heights can be visualized in different ways. Heights can be visualized by volumes, such as blocks and spheres or by lines and planes on a certain height. Another option is to visualize a plane on the maximum height (see figure 28a). Another option is to show only lines on the four angles of the building plane (see figure 28b). In this research the maximum heights will be visualized as a block volume (see figure 28c). This volume will be named 'building volume', since it represents that within the volume it is allowed to build. Showing only lines might be harder to interpret and less clear than a volume. Representing heights by a plane on the maximum height, it makes it harder to see what the boundaries are.



a.



b.

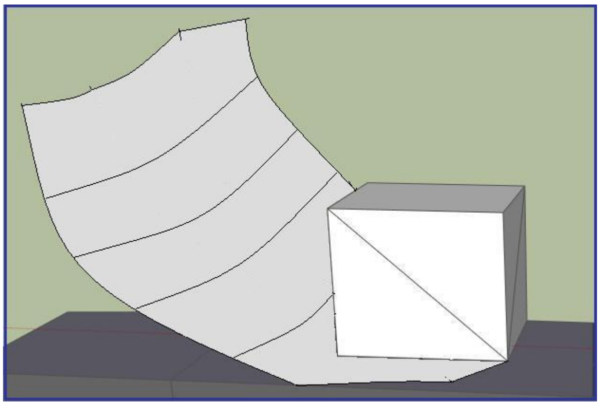


c.

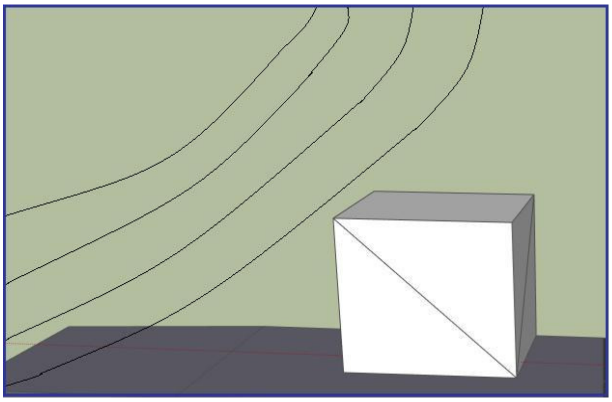
Figure 28. *Geometric options visualizing maximum heights.*

Area denotations

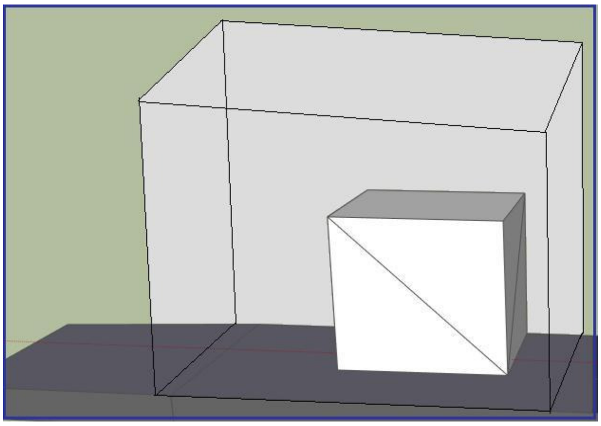
Area denotations are zones which can overlap several zoning planes. An example of a area denotation is a noise zone. In the current 2D zoning plan, only the area is visualized surrounded by boundaries. Noise has a third dimension and a noise zone is therefore suitable to visualize in 3D. It can simply be visualized by extruding the area of the noise zone to a certain height and visualizing it as a block volume (see figure 29c). It can also be done by being more exact and visualize a noise zone based on measurements. This way, a noise zone will be visualized as a certain sphere or isolines (see figure 29a and 29b). Visualizing it as a block volume, it is abstract and when visualizing it as sphere based on measurements, it is more realistic representation of a noise zone. In this research a noise zone will be visualized as a sphere, since then a noise zone can be visualized realistically.



a. sphere



b. isolines



c. block volume

Figure 29. *Geometric options visualizing noise zones*

Building denotations

In a current zoning plan denotations related to the construction of the building are described. Examples of building denotations are ridge direction of a roof, type of housing, such as detached and semi-detached. A building denotation can for example imply that a building may have a roof with a maximum slope of 60 percent (see figure 30).

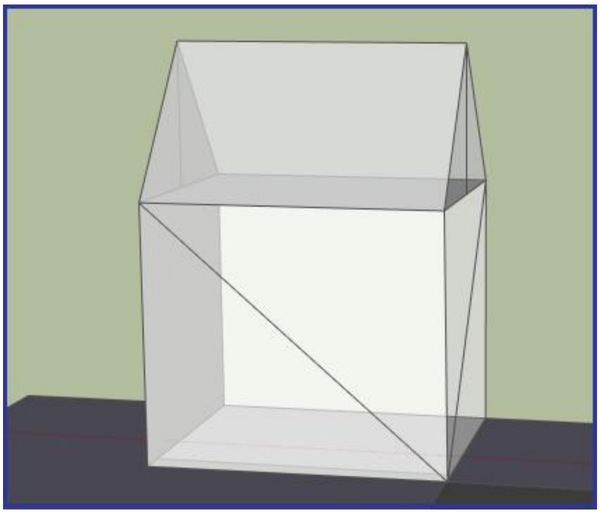


Figure 30. *Building volume with rooftop*

A risk by showing roofs is that this could be misinterpreted by people and people become disappointed (Tyrvainen, 2006). People could interpret it that rooftops should be constructed exactly the way it is visualized. It can be an advantage not showing too much detail in order to suggest providing an image of the reality (Wilson and McGaughey, 2000). Therefore, in this research building denotations will not be taken into account as objects to be visualized in 3D.

5.3.4 Visual variables

Next to geometric features of objects, objects can further be defined by visual variables.

Bertin (1983) proposed an approach to communicate information by visual means. He lists seven basic visual variables: size, value, texture, color/hue, orientation, shape, and position. These visual variables are focused on 2D cartographic representation, but can to a certain degree be relevant for 3D visualization of zoning plans. For example textures can be used by draping raster images on existing buildings. Shape determines the impact of abstraction, generalisation, and the degree of homogeneity within a 3D visualization.

MacEachren (1995) extended the list of visual variables of Bertin (1983) and developed an approach containing twelve variables which can be matched to nominal, ordinal or interval/ratio data with three degrees of appropriateness. MacEachren added color saturation, resolution, crispness, transparency and arrangement to the list of variables of Bertin (1983). Saturation is the colorfulness of a color relative to its own brightness. Arrangements means that patterns can be regular or irregular. Crispness, resolution and transparency are a composite of the visual variable clarity. Transparency is suggested by MacEachren as an effective means of communicating uncertainty values for 3D scenes. It the case of zoning plans transparency could be used when objects are overlapping each other, such as when existing building and building volume overlap each other.

Another visual variable is by using animations to create dynamic visualizations (DiBiase et al. 1992). The dynamic variables are duration, order and rate of change, frequency, display time and synchronization. For 3D visualization of zoning plans this could be useful to include shadows in combination with a timeline to show the shadows on a certain time. The time component could also be used to show the old and the new zoning plan, so people can see the changes in the new situation in comparison to the old situation.

Based on the visualization variables and the geometric options to present objects, which are discussed, a conceptual model can be made (see figure 31).

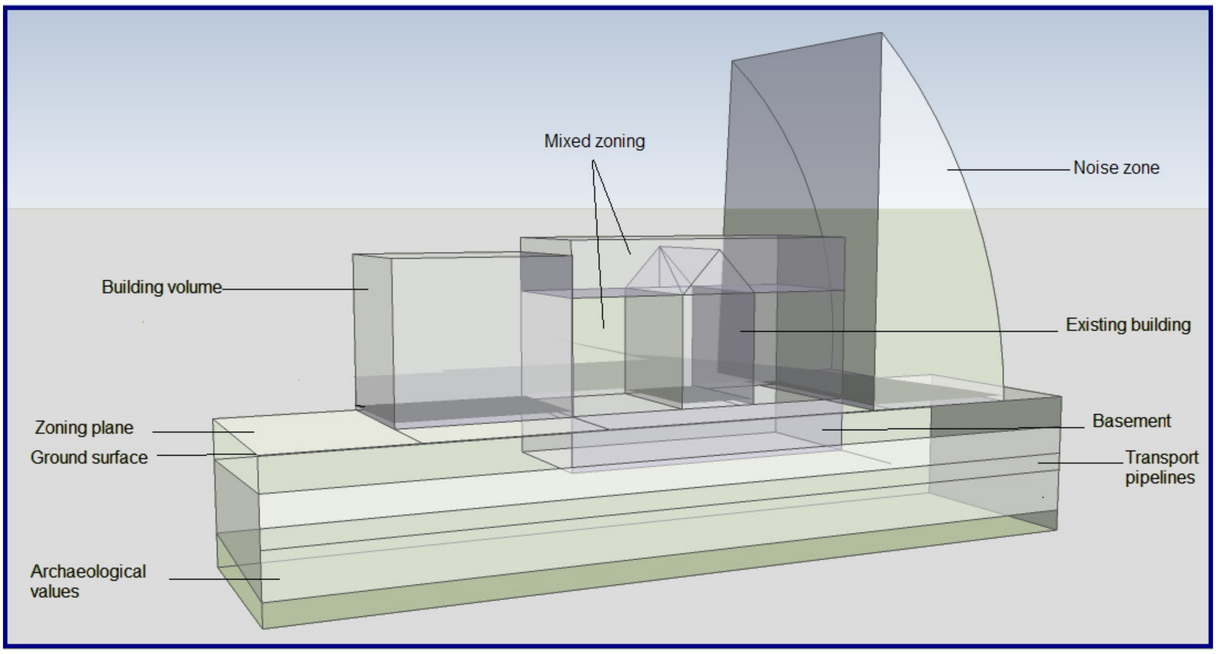


Figure 31. *Conceptual model for 3D visualization of zoning plan*

In this model the objects are visualized for objects above and under the surface, showing how objects can be positioned on top or under each other. Also objects can be positioned inside another object, for example with the existing buildings within a building volume. A building volume is a building plane and extruded based on the height regulations. Objects also can overlap, as can be seen with a noise zone, overlapping a building volume. More information in the underground can be visualized, such as a basement. In the next section for each object, the requirements will be discussed in more detail.

5.4 Requirements 3D visualization objects

This sections described for each object how it should be visualized in 3D. As discussed in chapter 4, visual clarity from the ethics of visualization (Sheppard, 2001), is the main requirement of the objects to be visualized in 3D. Furthermore, the geometric options of objects and the visual variables, discussed in section 5.3 will be taken into account.

5.4.1 Zoning plane

A zoning plane describes a zoning function for a certain area. The zoning plane is not an object with a third dimension it is a two dimensional plane representing a certain zoning function. This will be done by giving the zoning plane a certain color, as already being done in the current zoning plan. The colors have to be clear to distinguish it from the other colors. A zoning plane is divided into single- and mixed zoning. Single zoning functions are functions such as housing, retail, roads and water for one certain area. In the current IMRO2008 model mixed zoning is visualized on the map as a separate zoning function, however more than one zoning functions can be assigned to a zoning plane when it is mixed zoned. On a 2D map it is not visible which zoning functions are allowed on a zoning plane. In 3D it is possible to visualize for each level/floor the zoning function (see figure 32). This would however mean that the regulations should be specified for 3D visualization in such a way that zoning functions are assigned for each building level. In this research a distinction will be made for each level to specify a certain zoning function.

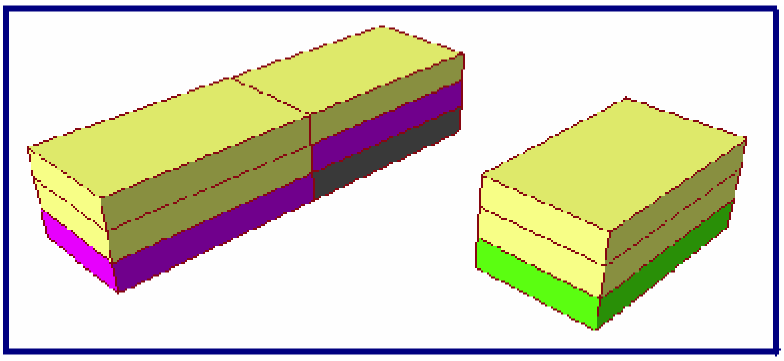


Figure 32. *Zoning functions for each building level*

5.4.2 Building plane

A building plane represents the zoning function and the regulations concerning for example heights. The heights are the most important aspect of a building plane and therefore it can be visualized as a volume. Because of the addition of the third dimension, a better term for building plane would be building volume when visualizing in 3D. A building volume will be created by using the building plane and extruding it to the maximum height level. A building volume can be determined by the measurement attributes, such as the maximum drain- and building height. A building volume should not show too much detail, such as roof details, but should be visualized with a low of detail (LoD1) A zoning plan is not an architectural plan and visualizing details can only lead to suggestions how a building should look like and other negative effects such as misunderstanding (Appleton and Lovett, 2003). The use of shadows can be useful for the visualization of building volumes. By this, citizens can see what the shadow impact is of a building on its surrounding environment. The building volumes should also be visualized with a certain transparency to emphasize the volumes are virtual. The transparency also makes it possible that the existing buildings which overlap with the building volumes are visible (see figure 33).

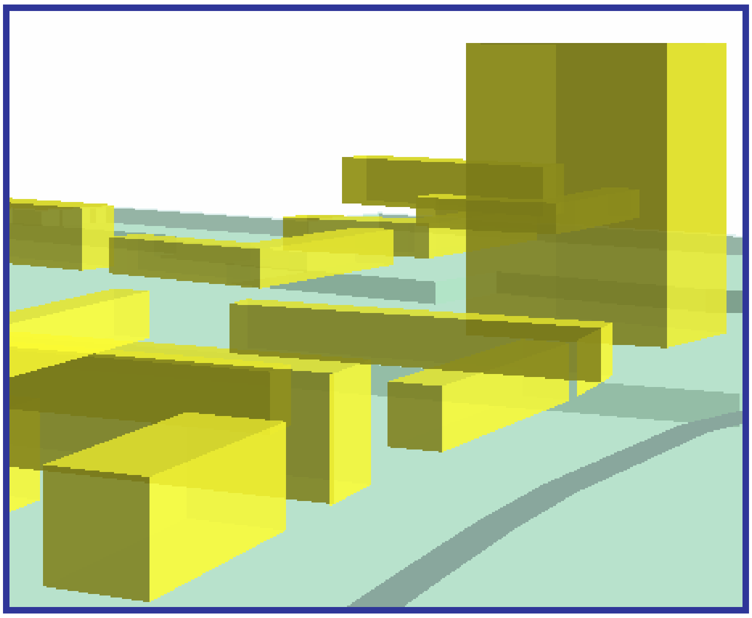


Figure 33. *Visualisation of building volumes*

A building plane can, like the zoning plane, show information in a popup menu. It gives information about the zoning function, measurement data and a link is given to the to the zoning plan regulations.

5.4.3 Development percentage

The object building plane contains of a maximum development percentage, which describes what percentage of the building plane is allowed for development. This is complex to visualize, since the development percentage does not describe where on a building plane the development should take place. By extruding 60% of the zoning plane, it will be misleading, since it is not known in advance which part of the building plane will be developed. Therefore it would be better to visualize the development percentage differently. A visualization technique would be to visualize the development percentages as thematic data (see figure 34). Colours in combination with heights can be used to show the different development percentages. The green colours show a development percentage of 100% and red colours. In addition, information concerning the development percentage can be showed in a popup balloon, which pops up when clicking on a building volume.

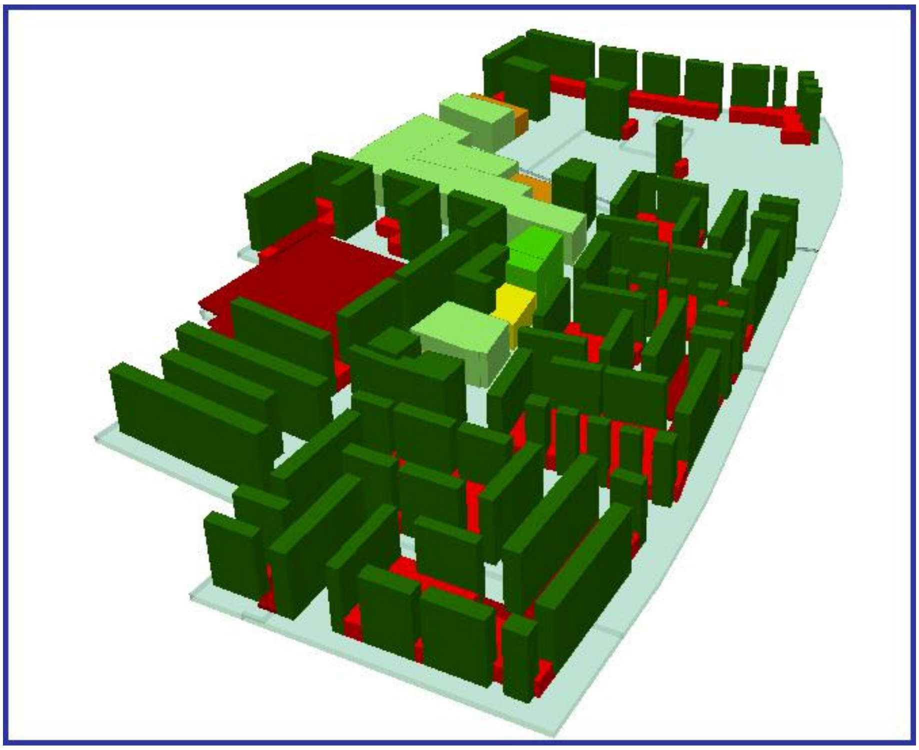


Figure 34. *Example of visualization of development percentage*

5.4.4 Area denotations

Area denotations are described in zoning plan by several different zones, such as noise zones, safety zones, air traffic zones and environmental zones. In the zoning plan regulation normally no third dimension is described. For example in a zoning plan of the municipality of Groningen, a noise zone around a road is only described with a certain maximum decibel and only the x and y boundaries of the zone are described. Therefore, additional data is needed to model a zone as 3D volume.

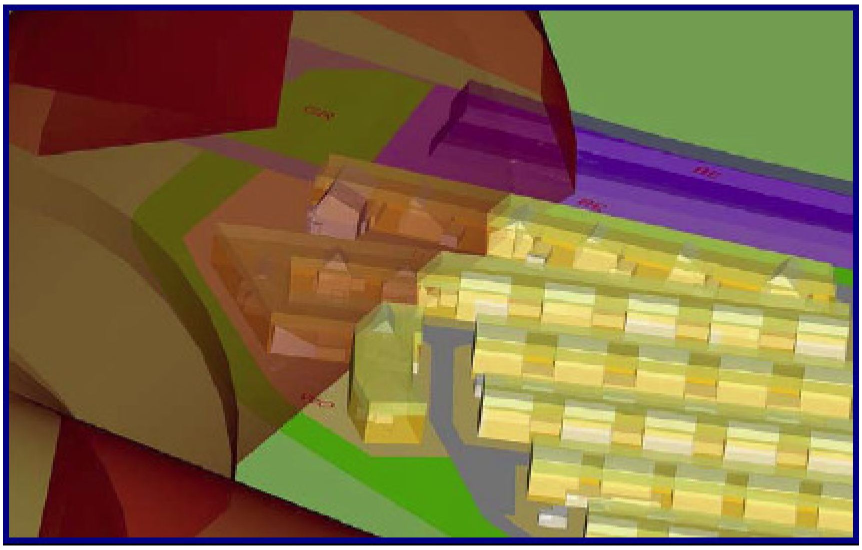


Figure 35. *Visualization of a safety zone of 3D zoning plan of Enschede (source Stohr et al. 2007).*

In the pilot of the 3D zoning plan of the municipality of Enschede a safety zone was modelled in 3D, although no 3D data concerning zones was available (see figure 35). The volume which was visualized was fictional and not modelled based on actual data. In the pilot of Enschede, the zone is modelled as a sphere. If these zones will be used in a 3D zoning plan, transparency is needed for the visualization, since the other objects, such as the building volumes should be visible.

5.4.5 Archaeological values

Archaeological values are zones for the preservation of archaeological values, which are part of the functions denotation objects. In the current zoning plan, archaeological values are represented as planes and not as point locations. In addition, in a current zoning plan map archaeological values are represented with symbols on a zoning plane are categorized as a double zoning function, since it overlaps with more than one other zoning function.

The zoning plan regulations do not give information about the depth of the archaeological value, which is necessary to model it in 3D. In many zoning plans archaeological research has not been done and therefore the precise locations of archaeological values are scarce and mostly unknown. Mostly, archaeological findings are expected and therefore not knowing exactly where they are located. This makes it hard to model it in 3D, since necessary data is lacking. In zoning plans it is regulated that developments larger than 250 m2 an archaeological research is required. Furthermore, when digging in the ground deeper 0.3 meters also an archaeological research is required. Therefore it would be suitable to visualize archaeological values from a depth of 0.3. Normally the maximum depth is not predefined and depends on the planned development. The archaeological values will be made transparent, since other objects, such as transport pipelines will be visible when they overlap each other.

5.4.6 Images

Transport pipelines are the main objects of images. In a current zoning plan transport lined are described as a double zoning type, which can divided into more specific types as can be seen in table 2.

Table 2. Transport pipelines

Transport pipeline
Fuel
Gas
High Voltage (HV)
Oil
Sewer
Water

In a current zoning plan a transport line is being represented in a general way, meaning no distinction is made between for example gas and sewer pipelines. Only in the regulations the specific pipelines are described. The transport pipelines can be visualized differently by using colours (see figure 36). The depth of the transport pipelines are not described in the current zoning plan. However, from other sources it is known that gas pipelines are build on a depth of at least 1.20 in the underground (NAM, 2010). Also images can be located above the surface, such as high voltage lines. In the zoning plan regulations a maximum height is described for high voltage lines.

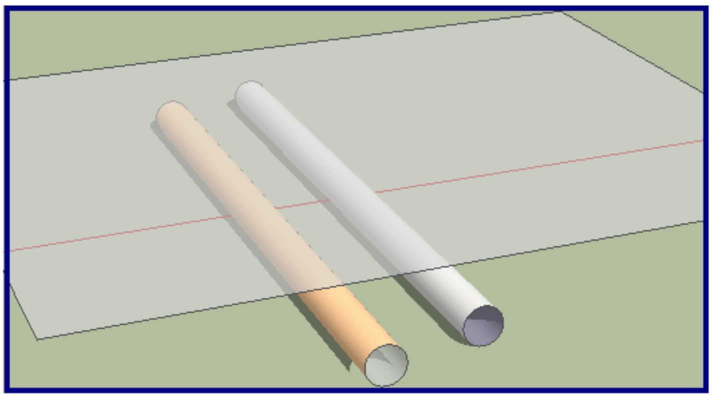


Figure 36. *Visualization of transport pipelines in the underground*

5.4.7 Existing buildings

In a current zoning plan the topography of the existing buildings (based on GBKN) is visualized on the map. However, in the regulations there are no legal descriptions given concerning the buildings, therefore if the zoning plan would be strictly considered, existing buildings should not be represented in 3D in the zoning plan. Though, including the existing buildings would make a zoning plan more recognizable for citizens in comparison when only the building volumes are visualized. A disadvantage is that it is time consuming to construct the existing buildings. In spite of this disadvantage, visualizing the existing buildings in 3D would give an added value, since for citizens this would be useful to recognize buildings. Many researchers (Appleton and Lovett, 2002; Bishop and Rohrmann, 2003) concluded that a higher level of detail support a better mental representation of a landscape and for that similar responses. In addition, by visualizing the existing buildings, one can be able to see if an existing building exceeds the allowed building heights represented by the building volumes. To make the existing buildings visible, the building volume should be made transparent.

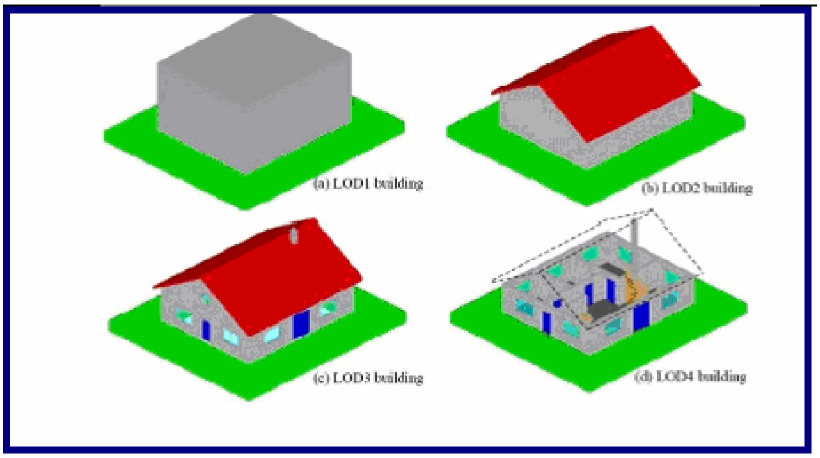


Figure 37. *Level of Detail (CityGML, 2010)*

For the 3D visualization of existing buildings in the zoning plan it is important to use a certain level of detail (see figure 37). Representing a building as block is not sufficient, since not enough detail is represented, making a building not recognizable for citizens. Using LoD2 can considered as a more suitable presentation method, since here a roof is visualized. LoD3 and LoD4 show more architectural details, like windows, doors, textures, interiors, however in zoning plan regulations these levels of detail are not described. Though, from the perspective of citizens it could be relevant to include for example photo images draped on buildings, which should result in a better recognition of buildings.

5.5 Conclusions

This chapter presented the requirements of how the planning objects described in IMRO2008 of a zoning plan in can be visualized in 3D. In comparison to 2D, the visualization in 3D requires more aspects have to be taken into account, due to the addition of the third dimension. Other visualization techniques should be used and more data is needed to be able to visualize objects in 3D.

The IMRO2008 model is suitable for 2D visualization. A number of objects from the model have a third dimension, such as measurements describing the maximum heights of buildings and are suitable to visualize as a 3D object. These objects can be visualized in certain ways, such as with lines, a block or a sphere. The way it should be visualized depends on how it can be done to make it clear to the user and it depends on the zoning plan regulations. In general, the objects should not be visualized very detailed, it should be kept abstract. Important is to keep in mind that a zoning plan is not an architectural plan, therefore not much detail should be visualized.

Next to geometric options to present an object, several visual variables can be used. Transparency can be used be used when objects are overlapping each other, such as when existing building and building volume overlap each other.

Not all objects can easily be visualized to 3D visualization. Objects with a height component are not always described in 2D zoning plans, such as for archaeological values and noise zones. Additional research will be needed to acquire the needed data to be able to visualize it in 3D. There are also objects lacking a third dimension, such as a zoning plane.

Existing buildings are useful to include in for the recognition of an area. This will make a zoning plan easier to interpret and recognizable for citizens, which are important users of a zoning plan. In addition, by including the building in the zoning plan it can be checked whether the buildings satisfy the zoning plan regulations.

In the next chapter a case study will be done to implement the described visual requirements for the 3D visualization of the zoning plan objects.

Chapter 6. Case study Groningen

This chapter will conduct a case study to apply the visual requirements for the 3D visualization of a zoning plan, described in the previous chapter.

6.1 Introduction

An important reason for the visualization of a zoning plan in 3D is to improve the communication between the municipal government and its citizens, in order to involve citizens in the planning process of zoning plans. This was emphasized when a political party in Groningen came with the initiative to present the municipal zoning plans in a 3D environment (PvdA Groningen, 2010). By presenting zoning plans in 3D, they argued, it would be much clearer for the public what the allowed heights of buildings are. This chapter will execute a case study to develop a 3D visualization of zoning plan which should make a zoning plan more understandable for citizens.

6.2 Study area

6.2.1 History

Coendersborg is a neighbourhood in the south of the municipality of Groningen, depicted as a purple surface in figure 38. The name Coendersborg is named after a farm (which is named after a former castle from the family Coenders), now mostly being used for parties. Coendersborg has a rich and long history.

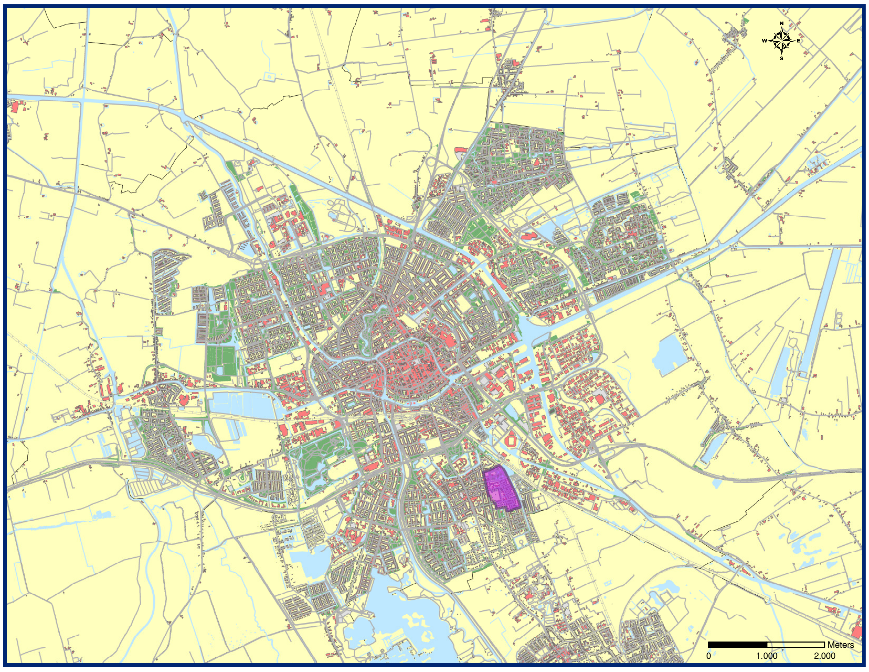


Figure 38. *Location of Coendersborg in Groningen*

The area was early build with castles (borgen in Dutch) and villas of often aristocrat families. A good example is the estate Groenestein from 1685, which is currently in possession by individuals. The neighbourhood is build up spaciously and with lot of green spaces (Municipality of Groningen). The old part of Coendersborg is characterized by mostly social housing from the 1960's and 1970's and the new part exists of mostly high segment housing. The neighbourhood contains a number of services, sport fields and some shops.

6.2.2 Zoning plan Coendersborg

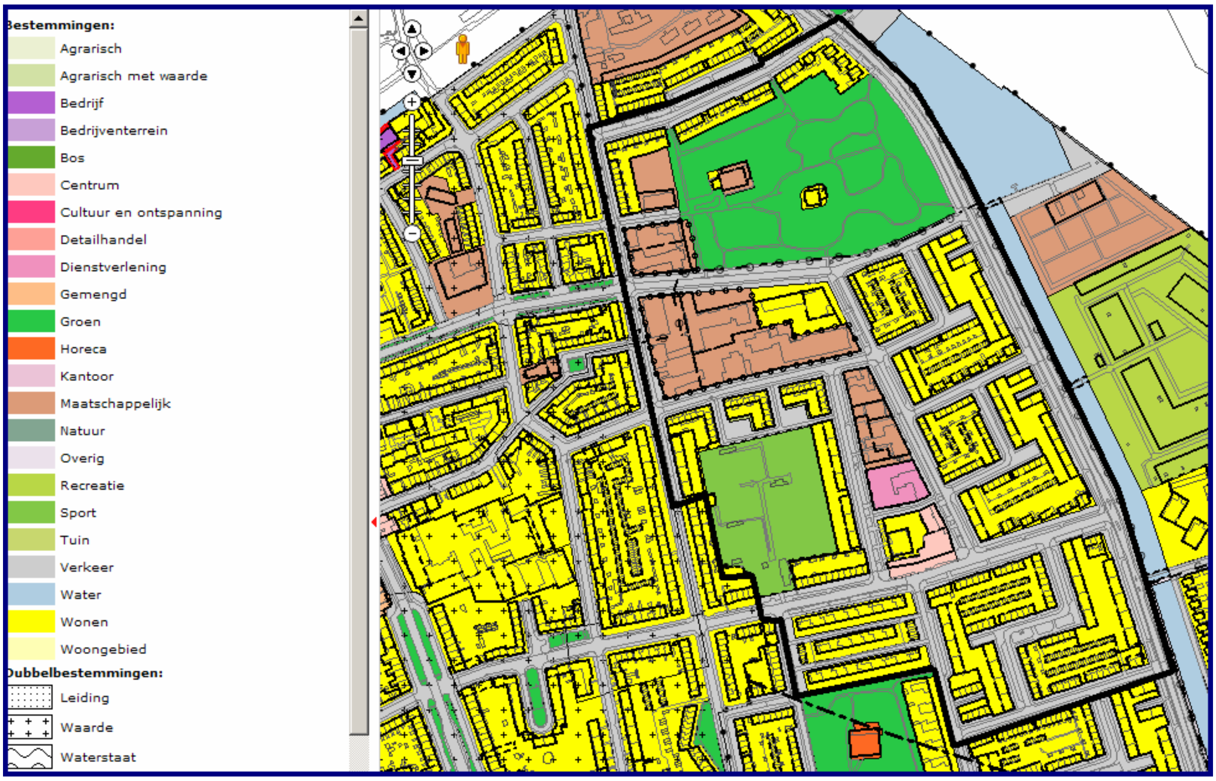


Figure 39. *Zoning plan of Coendersborg(source: municipality of Groningen)*

Coendersborg is chosen for this case study, depicted figure 39 within the black borders, since it consists of a number of interesting features, such as many differences in the heights of buildings, underground zoning functions such as archaeological values and pipelines. Features which are not present in the area, such as mixed zoning will also be included, since it is an important object class suitable for visualizing in 3D. Another object which will be included is a noise zone.

6.3 Software and data sets

6.3.1 Data sets

Table 3 Data sets

Name	Description	Format	Type
bp_coendersborg.dgn	Zoning plan area Coendersborg	vector	Polylines, polygons, points
Hoogte_terrein.dgn	Pit heights	vector	points
Groningen_tenboer_8cm.ecw	Aerial stereo photography	image	raster
GBKG	Existing buildings	vector	polylines
bp_bestemming and bp_maatvoering from Oracle database	Zoning plan attribute data	vector	polygons

6.3.2. Software

- ESRI ArcMap 9.3.1
- ArcScene 9.3.1
- FME Safe Software
- Google Sketchup Pro 7.1
- Bentley Microstation V8 XM Edition
- Google Earth

6.3.3 Hardware:

- Strabox
- PC

6.3.4 Visualization tool

For this case study Google Earth is used as viewer for the 3D visualization of the zoning plan. Google Earth is growing rapidly in popularity and is becoming more and more a platform that is used to explore, visualize and exchange 3D geo-information (Sheppard and Cizek, 2008). Butler(2006) states that virtual globe software such as Google Earth can facilitate the communication of spatial information between stakeholders and the government. Google Earth can be linked to 3D object modeling such as Google SketchUp and GIS software and can be exported to KML exports, which creates an enormous potential (Rodrıguez Lloreta, 2008). With Google Sketchup it is possible to create your own 3D models which can be exported to Google Earth. In addition, Google Earth is freeware, which makes it better accessible for people wanting to view the zoning plan. Furthermore the zoning plan can be implemented in an existing environment, which places it in a better perspective and for citizens it would be easy to recognize where the zoning plan is located. A disadvantage of the viewer is that underground zoning functions cannot be viewed, since only objects on and above the surface can be visualized.

The data format used for the visualization in Google Earth is KML, which can be imported into Google Earth. KML (Keyhole Markup Language) is a XML based ISO standard for geographical data. KML describes a number of features (locations, placemarks, images, 3D models, text, which can be represented in Google Earth and GoogleMaps. The KML specification describes how placemarks, image-overlay, screenoverlay, path and polygons are combined on the Google Earth virtual interface in different LOD and realism (OGC, 2010).

6.4 Modelling process

This section will discuss how the data is processed and it is visualized in Google Earth as can be seen in figure 40.

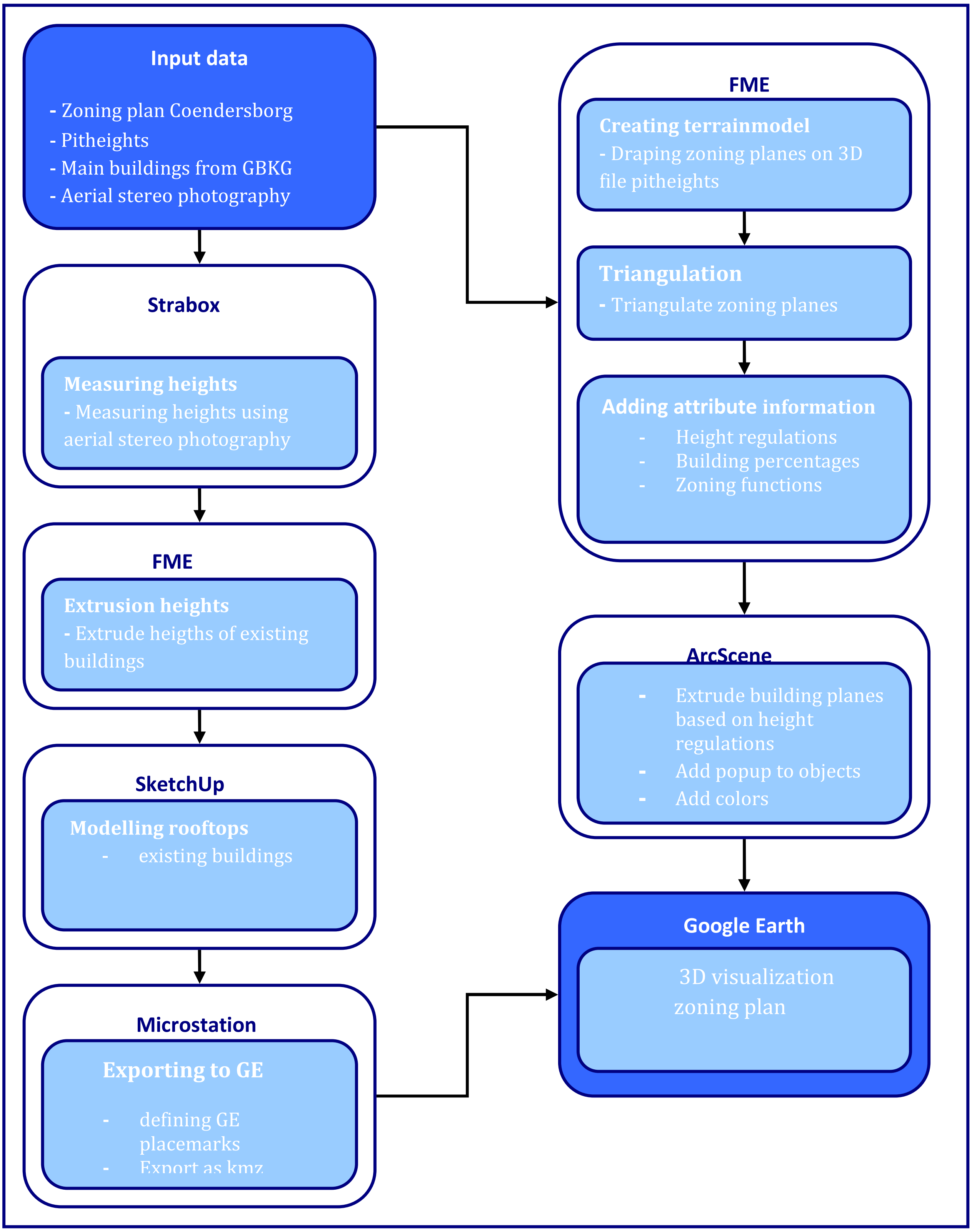


Figure 40. *Modelling process for 3D visualization of zoning plan in Google Earth*

6.4.1 Creation of terrain model

The first step was to create a terrain model with the zoning planes draped on it. The data from the current 2D zoning plan of Coendersborg is used and the zoning planes are imported into FME. However, by importing the zoning planes, the problem occurred that the attribute information was not was imported. Therefore, the zoning planes are imported for the Basic Services Groningen (Basis Voorzieningen Groningen), which is an Oracle database with all sort of geographical information from the municipality. A 3D file containing the pit heights (see figure 41) was also imported into FME in order to create a terrain model. The municipality of Groningen has 11.000 pit heights which are located on the road network. The pit heights are connected to each other based on the road network and the intermediate points are interpolated. The zoning planes from the 2D zoning plan file are draped on the 3D pit height file and as a result the zoning planes are place on the terrain height, according to pit heights of the area. Finally, the draped zoning planes are triangulated in order to make it a terrain model (see figure 42)

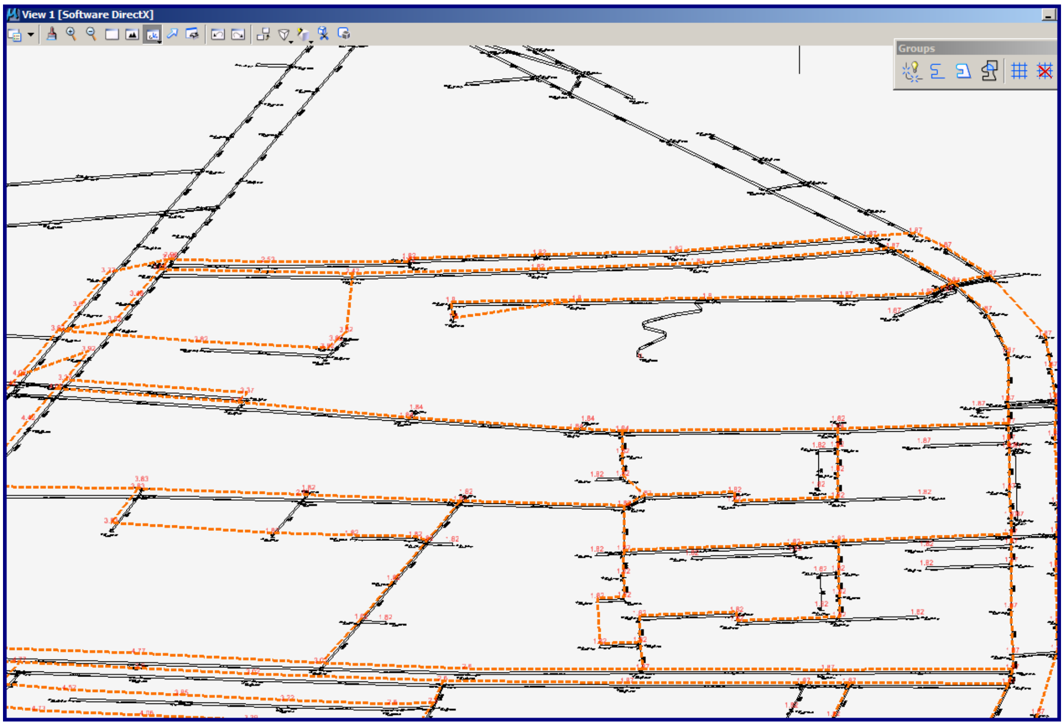


Figure 41. Pit heights

6.4.2 Processing zoning plan data

Next to zoning planes, information is needed concerning the measurements (maatvoeringen) such as the regulated maximum heights of buildings and the development percentage of the building planes. This information is not assigned to the zoning planes, but to the building planes bounded by differentiation boundaries (differentiatiegrenzen), since for these areas the regulations are assigned. Differentiation boundaries are assigned within a zoning plane when different heights are described, such as heights for housing and garages. In FME this information is put into an attribute table and assigned for the different areas. Next to information concerning the measurements also a link to the zoning plan regulations is included. ArcScene has an option to include a HTML popup menu when clicking on an object, so when clicking on a building volume, more information can be made available.

This has been done for the single zoning functions. Next, this information is converted into a shapefile, in order that it can be used in ArcScene to extrude the building planes to the maximum regulated heights.

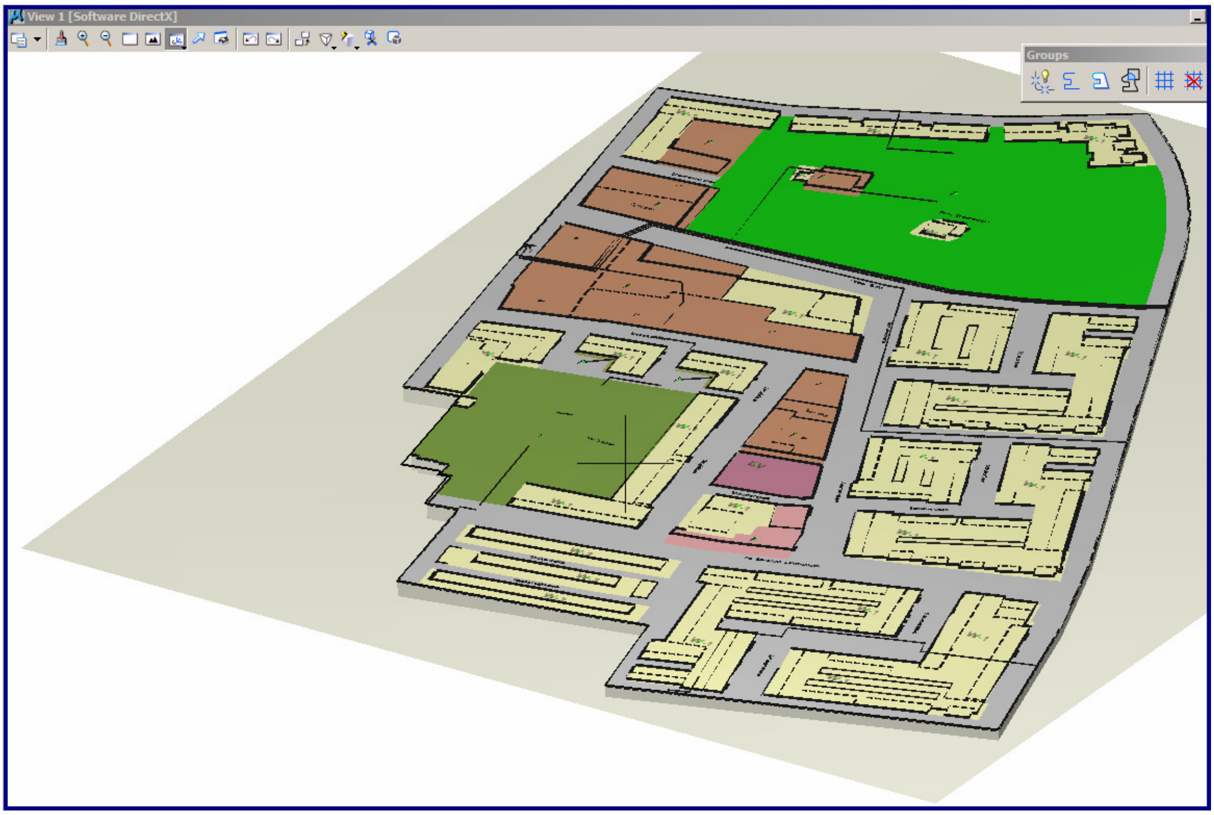


Figure 42. Zoning planes with a terrain model

FME was used to convert the data of the 2D zoning plan (dgn) into a shapefile.

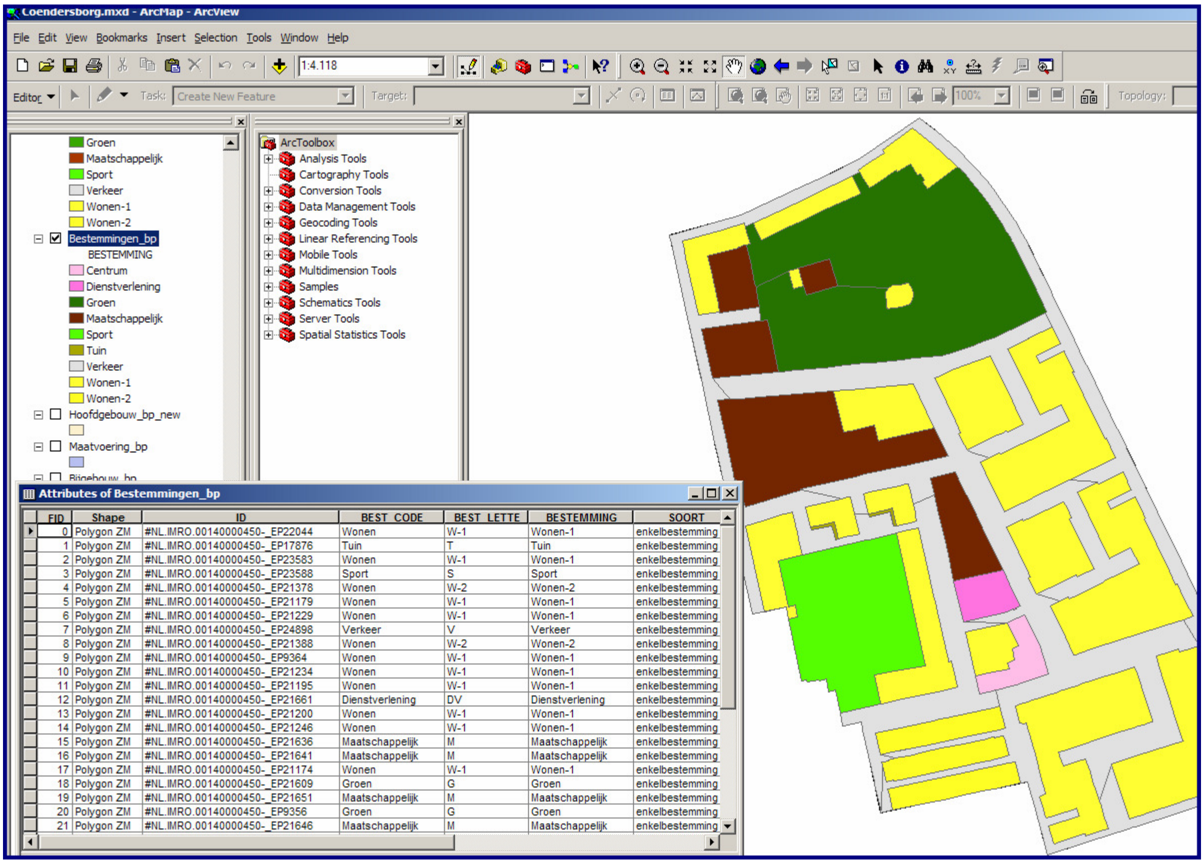


Figure 43. Shapefile with zoning planes

Now a shapefile has been created, including the zoning planes and with measurements based on the building planes (see figure 43).

6.4.3 Extrusion of building volumes

The next step is to extrude the building planes to the regulated heights, present in the attribute table. The building planes will be extruded through ArcScene, which is the 3D software component of ESRI ArcGIS. A difference is made between the heights, since building volumes can have drain heights, building heights or both drain heights in top heights. If for a building volume only drain heights are described, mostly there is information is described concerning the ridge slope. For example a building is allowed to have a maximum of rope of 60 %. This will be modelled in SketchUp. In case when building volumes are described with ridge/top heights the building volumes will only be visualized as a block model. Not all building planes will be extruded, this depends on the development percentage. For example, a sport area in the zoning plane has a development percentage of 5% with maximum allowed building height of 4 meters. Extruding the building plane to 4 meters could be misinterpreted as that the whole building volume can be build, where it is that only 5% can be build. Only building planes having a building percentage of 100% will be extruded. Furthermore, the development percentage will be visualized as a as a separate thematic map.

The double zoning function, in this zoning area of Coendersborg, the transport pipelines and archaeological values will be added separately and extruded downwards. A problem, which already came forward in the previous chapter, is that in the zoning plan regulations it is not described how deep these zoning functions are located. It is only described that for developments larger than 250 m2 an archaeological research is required and also for building in the underground deeper than 0.3 meters. In this case, the archaeological values will be located from 0.3 until 5 meters below the ground surface. The gas pipelines will be located 1.2 meters below ground surface (NAM, 2010).

ArcGIS has a function that can export a shapefile to a KML. The file will be compressed using the zip compression and will have a kmz extension and can be read into Google Earth. Before exporting the shapefile to KML, the projected coordinate system should be correct. The projection of Google Earth is WGS 1984 (see figure 44). Therefore the projected coordinate system will be converted.

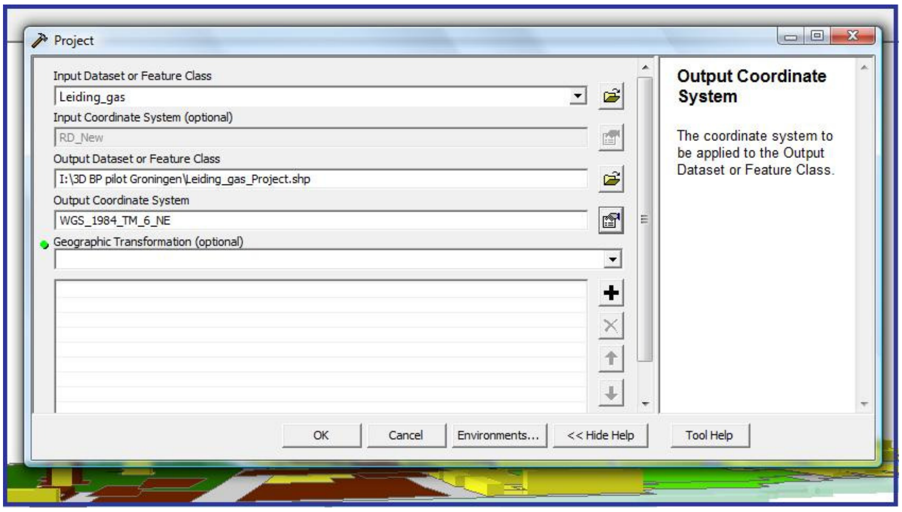


Figure 44. *Convert projection*

Before exporting the shapefile with the extruded building volumes into KML the option to include a HTML popup menu will be added. For zoning plans this would be very useful, since not all information can be visualized and also a link can be given to the zoning plan regulations.

6.4.4 Existing buildings

The next step is to include existing buildings into Google Earth. As already stated in the previous chapter, existing buildings are not part of a zoning plan, but can be very useful to compare the buildings with the building volumes of the zoning plan, showing the maximum heights. In addition, for the recognition of an area it is also useful to include the existing buildings. The heights of the existing buildings will be done by using Strabox. Strabox is a stereo viewing system that make it possible to measure heights through stereo images using passive Polaroid glasses (see figure 45) (Orbitgis, 2010).

Figure 45. *Strabox Stereo Viewing System*

The stereo images which are used for the measurements are from Aerodata and are measured in 2010. The GBKG data will be used as the surface on where the buildings will be modelled. Not only the top heights will be measured, but also the drain heights, since this is essential to model buildings with a sloping roof. When the measurements are done, they will be manually be important into Microstation on the GBKG footprint (see figure 46).

Figure 46. *GBKG with height measurements.*

Next, the GBKG with the height measurements are saved as a Microstation dgn file and imported into FME. In FME the GBKG are extruded to the measured heights. The results are shown in figure 47.

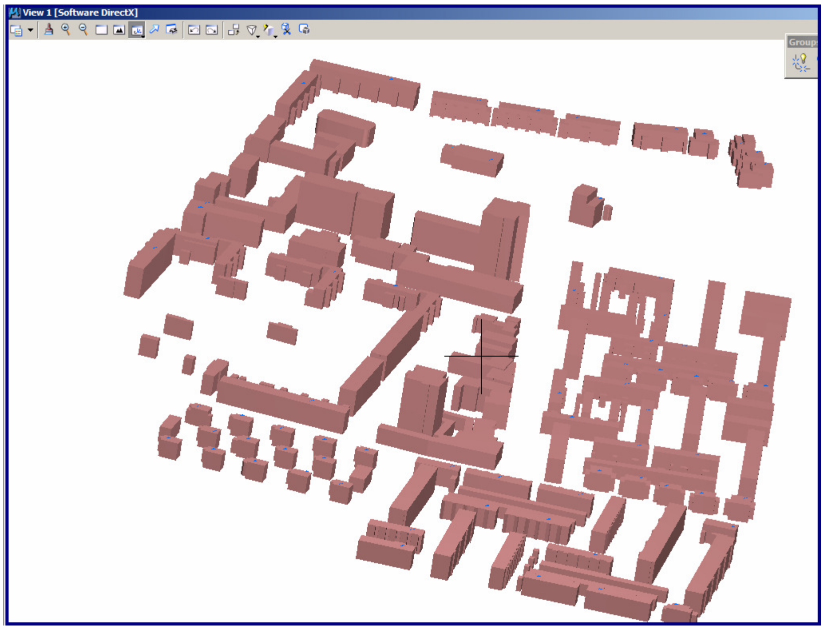


Figure 47. *Extruded buildings*

The file with the extruded buildings is then converted into a Sketchup where for buildings with drain heights, the rooftops will be modelled, depicted in figure 48. The other buildings have flat roofs and therefore nothing needs to be modelled.

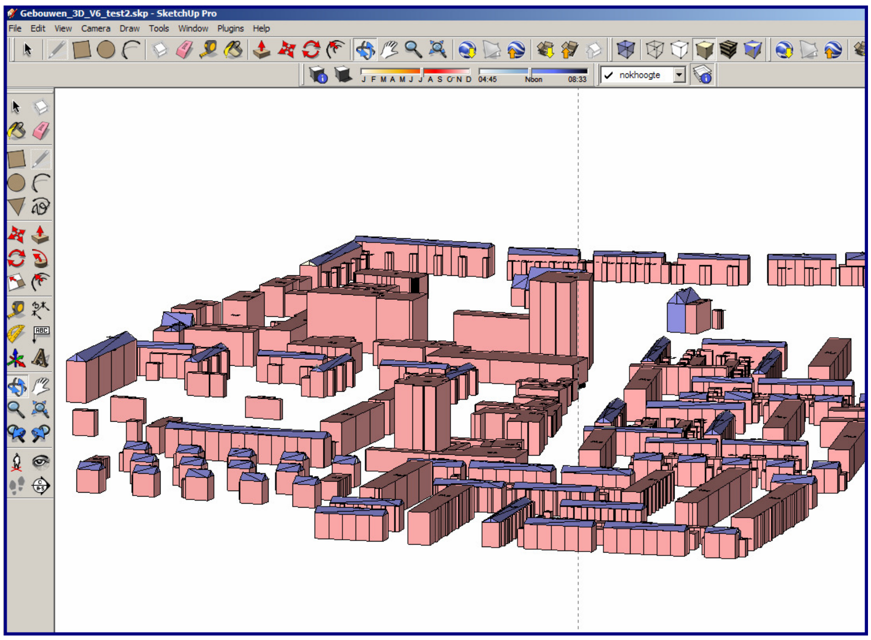


Figure 48. *Existing buildings with rooftops in SketchUp*

The next step is that the existing buildings are exported into Google Earth. In Sketchup it is possible to place a model into Google Earth, however this is more suitable for a small number of objects and not for a large area, which it is in this case of the zoning plan area. When trying to export the zoning plan to Google Earth, it was not placed correctly. Because of this, the choice is made to import the Sketchup file into Microstation. Microstation has a function to define so called "Google Earth Placemark Monuments" which refer to placemarks made in Google Earth. In Google Earth, first a number of placemarks must be assigned, preferably at the edges of the zoning plan area. These placemarks have to be saved in order that they can be related to the placemarks in Microstation. Subsequently, placemarks will be assigned at the same location, but then in Microstation and then they will be related to the placemarks in Google Earth. When this is done, the file can be exported as a kmz file so it can be imported into Google Earth .

6.5 Visualizing zoning plan into Google Earth

6.5.1 Building volumes

The information which will be showed in the attribute table will be the zoning function, the regulated heights and development percentages and a link to the zoning plan regulations. When visualizing the allowed heights of the building volumes it can be hard to get an idea what the maximum height is. Therefore, by clicking on an object this information can be generated. Zoning plan functions are only visualized through colours and in the table of contents in Google Earth the colours and matching zoning functions are given, however it would also be useful to show the information in the HTML popup table. The volumes show the building planes with a development percentage of 100%.

The next step is to export the KML file into Google Earth (see figure 49).

Figure 49. *Zoning plan in Google Earth*

6.5.2 Mixed functions

As stated in chapter 3, mixed zoning is a feature which is more suitable to visualize in 3D than in 2D, since a distinction can be given of the different zoning functions, where in a current zoning plan a building volume can only be assigned as a zoning function 'mixed'. However, in the zoning plan area of Coenderborg no mixed zoning exist, it will be included and visualized. In ArcScene this is done. In ArcScene it is not possible to assign to different colours to one object, therefore it has to be done separately. The building plane is copied and it is saved a new shapefile. Then the building plane is extruded from the height of the building plane it is assigned to minus the building volume you would like to include. So, if a building plane has a maximum height of 40 meters and the building volume with the other zoning function which will be included has a height from 30 to 40 meters, the starting height will be 30 meters and as a result two different zoning functions are visualized on the same building plane (see figure 50). A disadvantage of this method is that the zoning functions are not visualized in one object, but exists out of two objects.

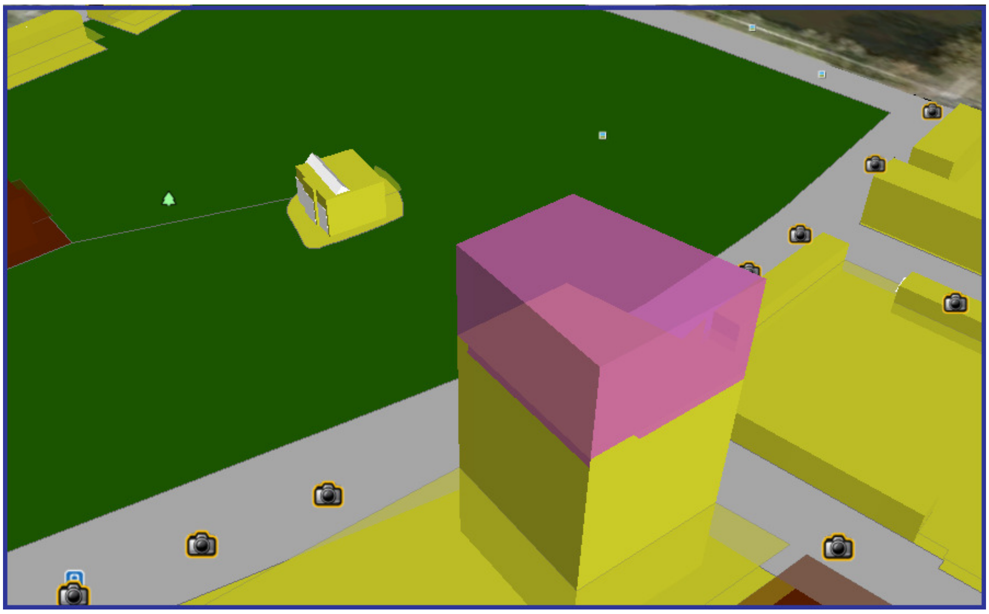


Figure 50. Mixed zoning functions within one building volume.

This method of visualizing two different zoning functions on one location can also be applied for the object function denotation. A function denotation gives more specific information on a zoning function on a specific location. For example a building plane has a zoning function social service with as function denotation housing allowed on upper floors. However, more a detailed description is required from which floor another function is allowed.

6.5.3 Noise zone

Another object which is not present in the zoning plan of Coendersborg is a zone, such as a noise and safety zone. However, a noise zone is suitable to use in this case study, since noise has a 3D component. In current zoning plans no information exist concerning the heights of noise zones and therefore additional field research is needed to acquire the data. However, the municipality of Groningen possess data about noise zones and this can be applied this case study. The data is exists of contours on different heights, which are measurements collected from fieldwork. The contours are assigned to a certain height, subsequently a polygon is made to the next higher situated contour. When this is done for all the contours and polygons are created, they can be triangulated and exported as a KML file. The result are shown in figure 51. It is shown that some buildings are inside the contours and some buildings are partly inside and partly outside the contour.

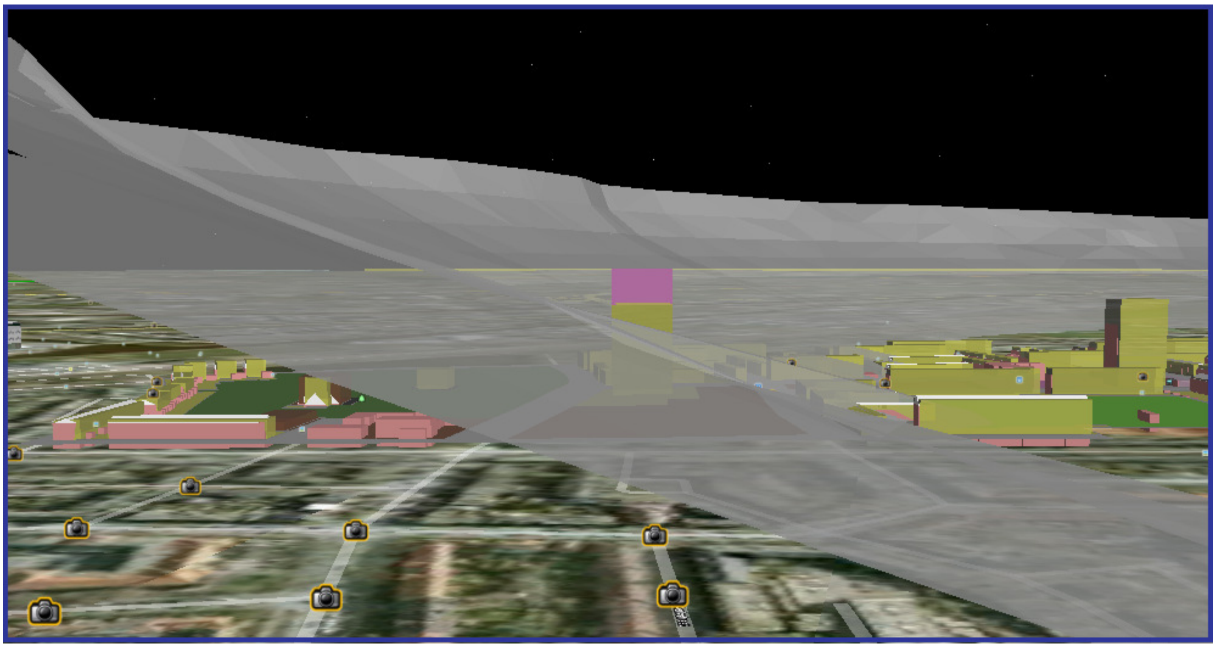


Figure 51. *Noise zone*

6.5.4 Existing buildings

The existing buildings are visualized in Google Earth and it can be seen if buildings arise above the building volumes of the zoning plan (see figure 52). To make the existing buildings better visible the building volumes are made transparent. However due to software problems, the existing buildings do not get visible when the building volumes are made transparent.

Figure 52. *Existing buildings in the zoning plan visualized in Google Earth*

The existing buildings are not showing much detail. Oblique image would be useful to drape on the buildings to make them more recognizable, however no oblique images are available for the municipality. In Google Sketchup it is possible to place street view images from Google Maps, but these images are not accurate enough and not every building a image exists. Though the oblique images are missing, in Google Earth Street view images are implemented, which can help in the recognition of the environment.

6.5.5 Underground zoning

In current zoning plan, zoning in the underground is not being described as extensively as zoning above the ground. In 3D more options are available to visualize objects in the underground and the underground is getting a more import role in spatial planning (see chapter 3). In this study area archaeological values and a gas pipeline are situated. In the future, other objects can be useful to include in a zoning plan, such as basements, thermal energy storage, however in this research how it can be visualized will not be investigated.

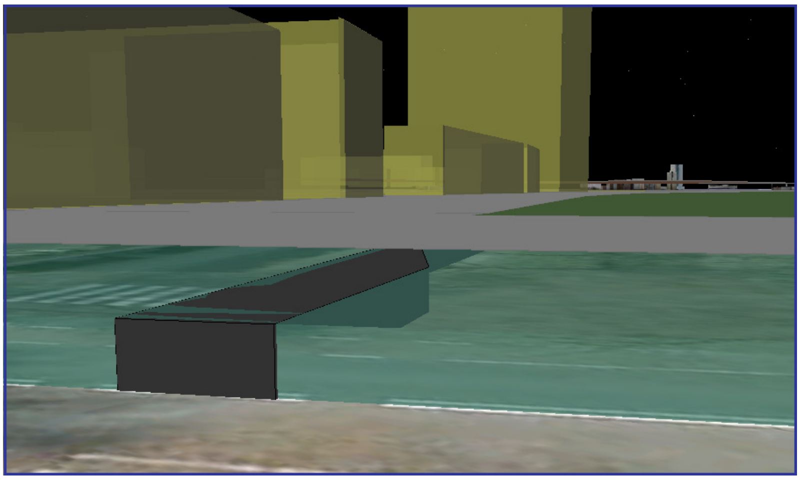


Figure 53. Visualizing basement and archaeological zone

In figure 53 the gas pipeline and archaeological zone are depicted. To be able to show the objects in the underground, the ground surface is raised. The gas pipeline is represented in black. The blue transparent zone represents the archaeological values.

6.5.6 Thematic maps

The development percentage and the maximum heights can also be visualized as thematic maps.

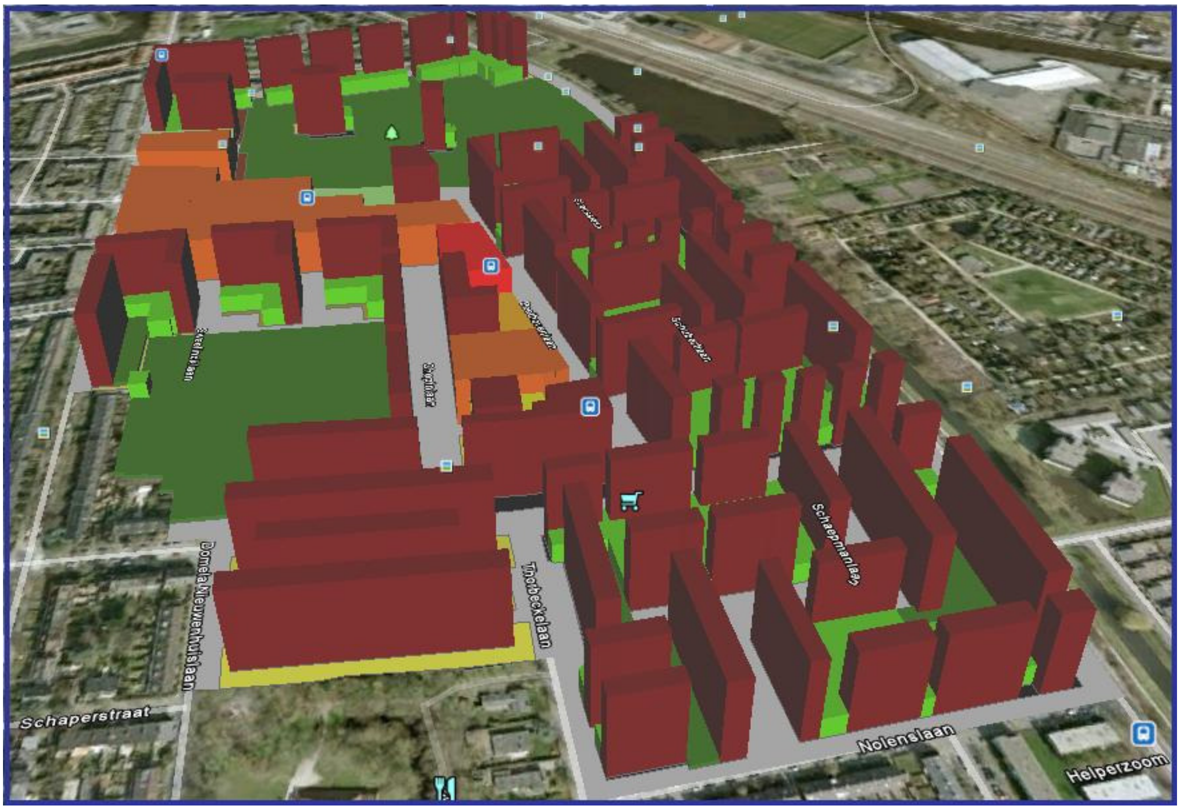


Figure 54. *Development percentages*

Development percentages are visualized with different colours and by heights (see figure 54). The red colour means a development percentage of 100% and the heights are represented as percentages. So, 100% development percentage is visualized by the colour red and the maximum height. Green means only a development percentage of 5%. Important to note here is that heights do not refer to the maximum building heights, but should only see as thematic data.

Another thematic map which can be made is based on the maximum drain- and building heights.

Figure 55. *Visualization of maximum heights*

The heights are depicted in figure 56. The highest heights are coloured in green and given the correct heights. The lowest heights are coloured in red. In the legend of Google Earth, the different heights can separately selected and can be turned on and off.

6.6 Conclusion

The construction of a 3D visualization of a zoning plan in Google Earth is very different from the current 2D zoning plan. Other aspects have to be taken into account and more data is needed to be able to visualize heights. The extrusion of building planes, based on measurements described in the zoning plan regulations is not a difficult task and representing those heights can be considered as an added value in comparison to 2D zoning plans, since citizens can have a better impression of what these heights are. Other height data, to be able to construct a terrain model is not described in a current zoning plan, but the municipality of Groningen possesses pit height data to construct a terrain model, however not every municipality would have this data. An option would be to use height information from AHN (Actueel Hoogte Nederland) to develop a terrain model. To include the existing buildings in the zoning plan was a time-consuming task, since all the buildings had to be measured with Strabox, be extruded to the measured heights, which was done automatically and roofs had be modelled manually. Though it was time-consuming, it surely has advantages to include in the zoning plan, so citizens can recognize buildings and can compare the height of an existing building with the maximum heights represented by a building volume. Using oblique photos could improve the detail of the existing buildings, since it can lead to a better recognition of buildings.

Building percentage is hard to visualize, since it can create misleading visualizations, which can be interpreted the wrong way by users. If building planes with a building percentage lower than 100% would be extruded to the maximum heights and be visualized, it could be interpreted as that the complete building plane can be build. To prevent this possible miscommunication, only the building planes with 100% are extruded. Though by a thematic map, all development percentages are visualized for the complete zoning plan. In addition a height map is included, which represents all the drain- and building heights, so citizens can get a good impression of what heights are allowed.

In Google Earth no objects in the underground can be visualized, however for visualization means, some underground objects are visualized by setting the terrain model on a higher height. Information concerning the depth of objects, such as transport pipelines are lacking in the current zoning plan, therefore additional information is needed to be able to visualize a zoning plan in 3D. The IMRO2008 model should be modified and adjusted to 3D visualization. This also can be said for noise zones, which also have no description of heights in the current zoning plan, however in 3D it can be very useful to visualize.

Also conclusions relating to software can be made. Some disadvantages of KML are that it is not possible show shadows, which can be useful to visualize the impact of the maximum heights of buildings, by showing their shows on the surroundings. Furthermore, clicking on objects to get information is not optimal, since information from the lower is shown or it clicks trough buildings. The disadvantage is that KML cannot be not visualized within the web page in 3D, but should be launched in a separate standalone application, such as Google Earth. Concerning accessibility, this could be a constraint for citizens, since first Google Earth has to be installed, where would not be the case with an application within a web page.

In the next chapter a survey will be done to evaluate the designed zoning plan and to verify if the 3D visualization of a zoning plan is clear and understandable to the user.

7. Results of survey

This chapter evaluates the results of the 3D visualization of a zoning plan through a survey. The main goal is to test if the 3D visualization represented in Google Earth is clear and if the application is user-friendly.

7.1 Survey population

A total number of 51 people were asked to fill out the survey. From this number, 28 people participated in the survey, which is 54,9%. From the 28 respondents, 18 people were experienced with geovisualizations, and 10 people had no experience with geovisualizations. The age of the respondents ranged from 24 to 62 years. From the 28 people, 5 people are from the department of geo information of the municipality of Groningen, the rest are randomly picked.

7.2 Design of setup of the survey

The survey was made available on the internet, via the online application thesistools. Via email, respondents got an invitation to fill out the survey. In the email a short introduction was given about the topic of the survey. A link was given in the email to the website of the survey. To fill out the survey, the respondents were asked to view the zoning plan in Google Earth. The email contained an attachment with the zoning plan in kmz format, which is the data format of Google Earth. To be able to view this file, the respondents had to have Google Earth installed on their computer. In case respondents did not have Google Earth installed on their computer, a link was given in the email to the website where Google Earth could be downloaded.

The survey consisted of 27 questions. Of these questions, 21 of the questions of the survey were multiple choice. In most of the multiple choice questions a scale was used (Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree). This scale is suitable for this research, since the respondent is asked to give his or her opinion on the statements given. A few questions dealt with how clear the zoning plan is. This relates to one of the criteria of the ethics of visualizations (Sheppard, 2005), visual clarity, explained in chapter 4.

The first questions of the survey dealt with the 3D zoning plan in Google Earth, a few questions dealt with the current 2D zoning plan, where the respondents were asked to compare the 3D visualization in Google Earth to the current zoning plan, offered on the municipal website of Groningen. A link was given to this website. Some of the multiple choice dealt with the usefulness of certain components of the zoning plan and the ease of use of Google Earth. This can be related to the theory of technology acceptance model (Davis, 1989). Two important concepts, perceived usefulness and perceived ease of use are part of this theory. The first concept is perceived usefulness, which is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989). The second concept, perceived ease of use, is defined as "the degree to which a person believes that using a particular system would be free of effort (Davis, 1989). This has to do with the application, in this case Google Earth, whether it is a user-friendly visualization tool. This is important, since it can have a substantial influence on how a visualization is perceived by the user.

Next to the multiple choice questions, the survey consisted of some open questions, where the respondents had the opportunity to elaborate more on some specific issues.

In the next section. the results from the multiple choice questions will be shown, subsequently the results of the open questions will be presented. The final section of this chapter will discuss the results of the survey.

7.3 Multiple choice questions

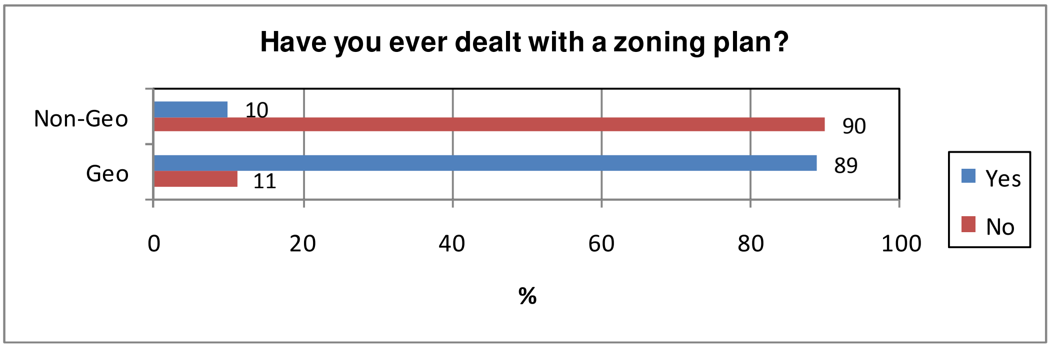


Figure 56. *Experience in zoning plans*

Figure 56 shows the percentage of the respondents which have ever dealt with a zoning plan before. The results are divided in people with and without experience in geovisualisations, in this survey named as geo and non-geo respectively. 16 people (89%) of the geo group have dealt with a zoning plan before, only one person out of 10 of the non-geo group has ever dealt with a zoning plan before.

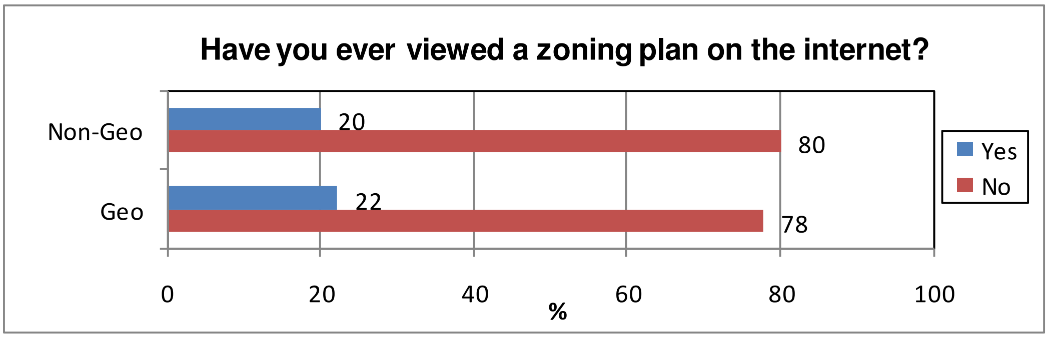


Figure 57.
Zoning plan on the internet

Not many respondents have viewed a zoning plan on the internet before, in the geo group, 22% and in the non-geo group 20%. This low percentage is not very surprising, because municipalities are only from 2010 obligated to present their zoning plans on the internet.

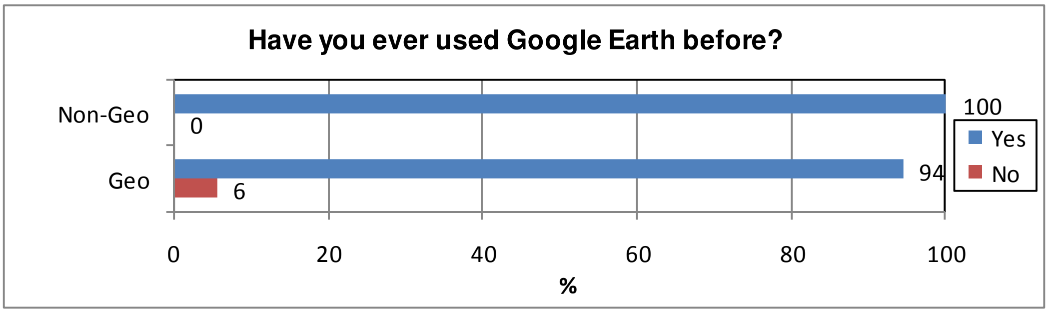


Figure 58.
Use of Google Earth.

As can be seen in figure 58, almost all the respondents are familiar with Google Earth, only one person had not used Google Earth before. Google Earth is a widely used application and this was one of the main reason to use this application for this research, since generally people know how to use Google Earth.

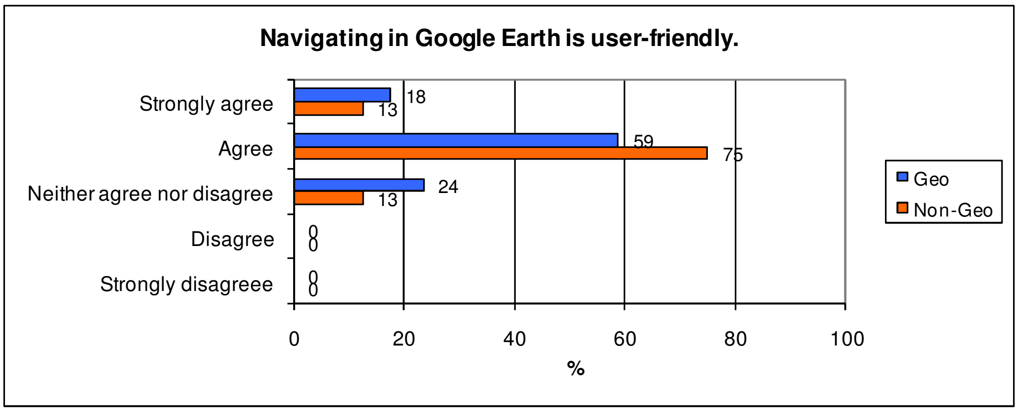


Figure 59.
Navigating in Google Earth.

Most of the respondents from both groups agree on the statement that navigating in Google Earth is user-friendly (59% for geo and 75% for non-geo) and even 18% and 13% for geo and non-geo respectively strongly agree on the statement. None of the respondents disagree on the statement, and 24% and 12% for the geo and non-geo group respectively neither agree or disagree.

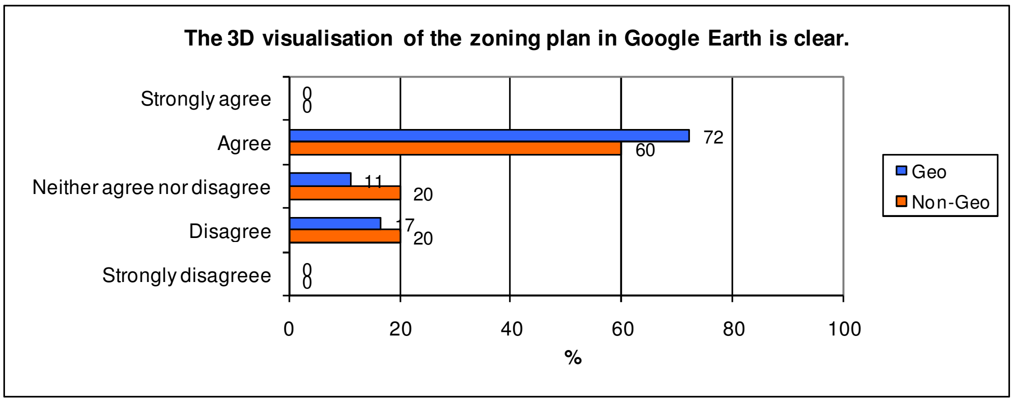


Figure 60. *3D visualization of zoning plan in Google Earth.*

Figure 60 shows that most of the respondents agree on the statement that 3D visualization of the zoning plan, presented in Google Earth is clear, 72% and 60% for the geo and non-geo group respectively. Still a substantial percentage 17% and 20% (geo and non-geo) disagree and substantial group neither agrees or disagrees. Furthermore, a small difference between the two groups can be observed, since the geo group agrees more on the statement than the non-Geo group. An explanation could be that most of the geo group have experience with geovisualizations and therefore can interpret the visualization better than the non-geo group.

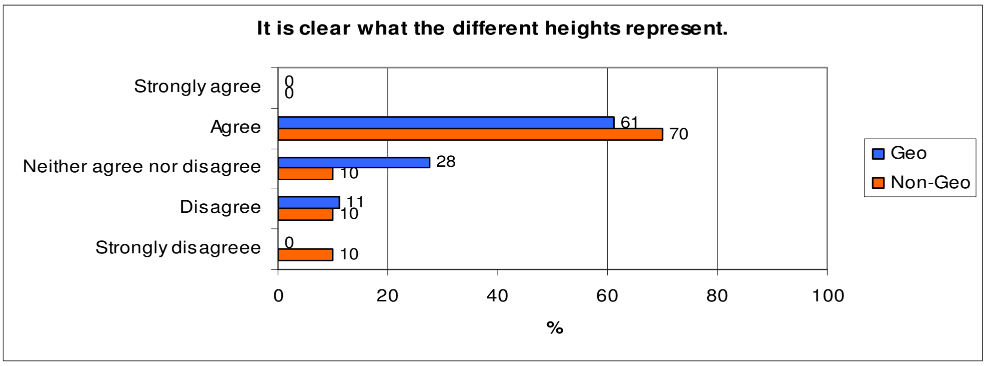


Figure 61. *Heights*

The zoning plan shows heights of the current buildings and of the maximum heights buildings are allowed to have. Most of the respondents agree with the statement that the different heights presented in the zoning plan are clear. However, still, of the geo group 28% does not agree or disagree on the statement, which is a substantial percentage.

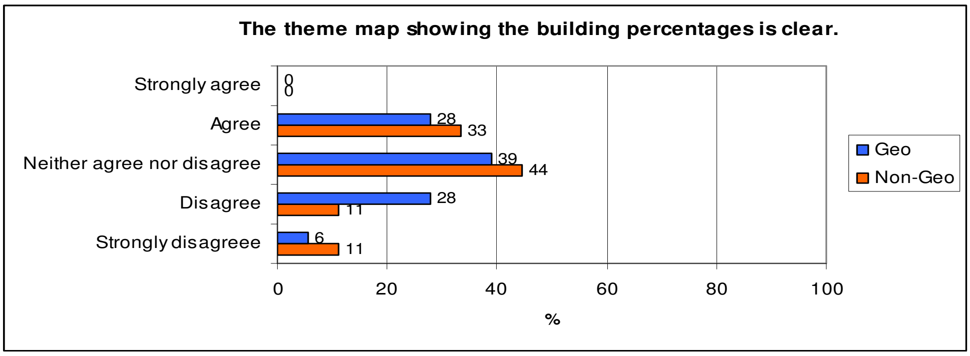


Figure 62. *Building percentages*

The theme map showing the building percentages is not clear according to majority of the respondents of both groups, see figure 62. Only 28% and 33% for the geo and non-geo group respectively agrees on the statement. A possible explanation why the theme map is not clear is because the building percentages are visualized in heights, which are not 'real' heights, but thematic heights, which can be confusing. Furthermore, the concept of building percentages might not be a familiar among the respondents.

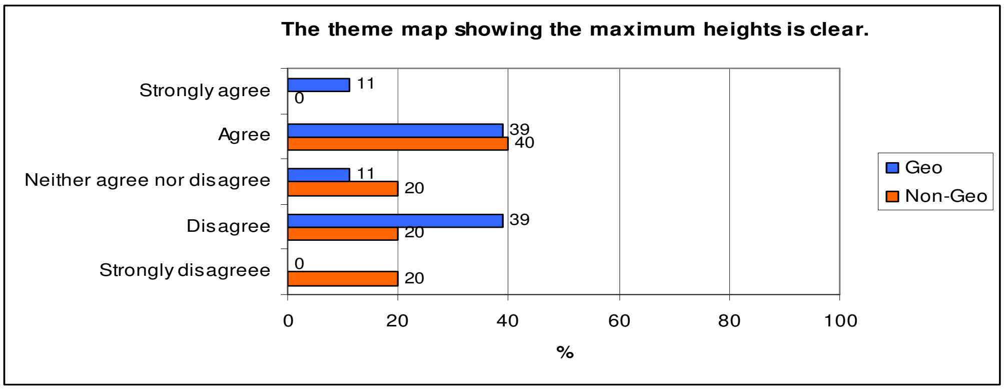


Figure 63. *Maximum heights*

The results of the statement on the theme map showing the maximum heights of buildings with a building percentage of 100% are scattered. 50% of the geo group agrees or strongly agrees on the statement and 39% disagrees and 11% neither agrees nor disagrees on the statement, so the theme map is not clear to everybody. The same can be said for the non-geo group. A possible explanation is that, just as the previous statement, the meaning of building percentages might be unclear to the respondent.

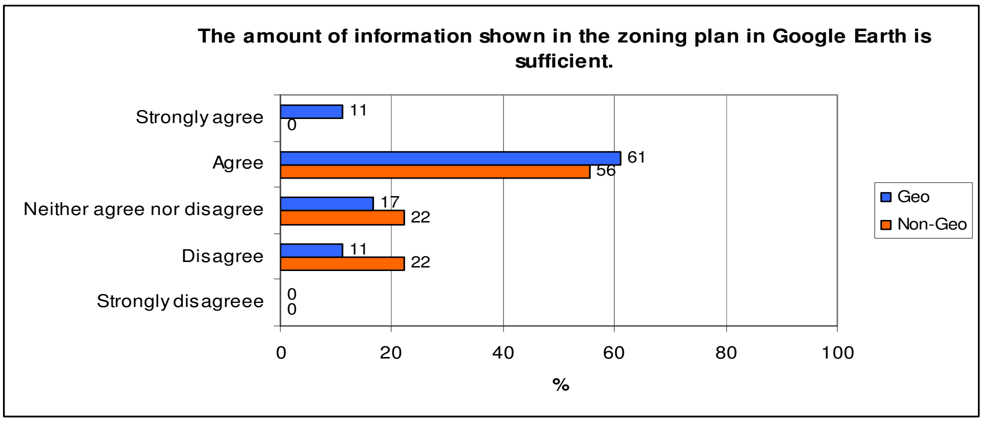


Figure 64. *Amount of information*

The majority of the respondents agree with the statement on the amount of information in the zoning plan. The statement is given to ask respondents if the zoning plan does not show too much information which can make the plan too fuzzy. It could also mean that it contains too little information, making it unclear what is meant. A difference can be observed between the two groups, where the non-geo group has a significantly higher percentage of respondents disagreeing the statement, comparing the geo-group. A possible explanation is that the non-geo group would like to see more information.

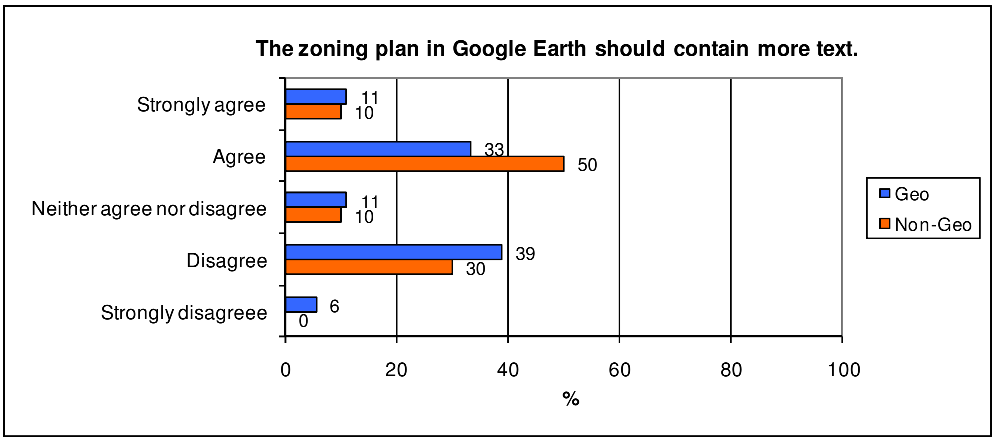


Figure 65. *More text.*

The statement in figure 65 concerns the amount of text in the zoning plan to clarify the different maps. The results are scattered. Of the geo group 44% agree or even strongly agrees and 45% disagrees or strongly disagrees. The results of the non-geo group shows that that the majority agrees or strongly agrees on the statement (60%), while 30% disagrees.

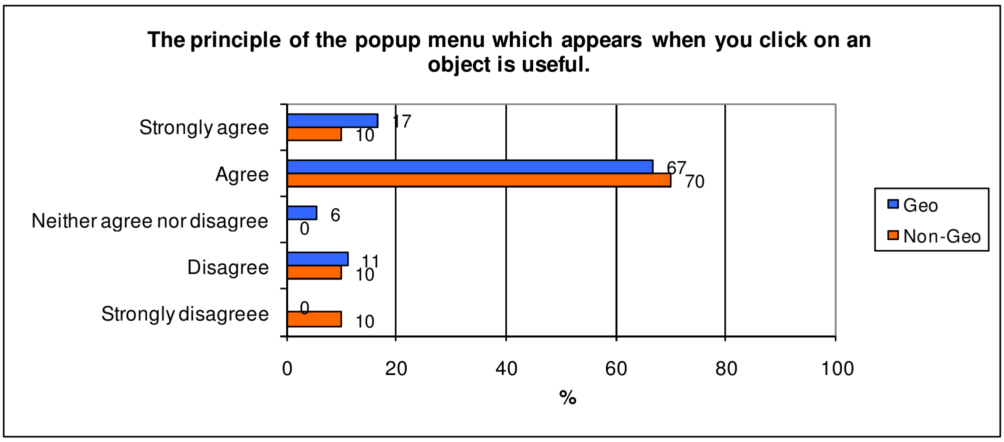


Figure 66.
Popup menu.

The popup menu gives information on the objects on the map and a link is given to the zoning plan regulations. The results of both group are similar, the majority of the respondents of both group agree that the popup menu is useful, 73% of the geo group and 80% of the non-geo group are positive on this statement.

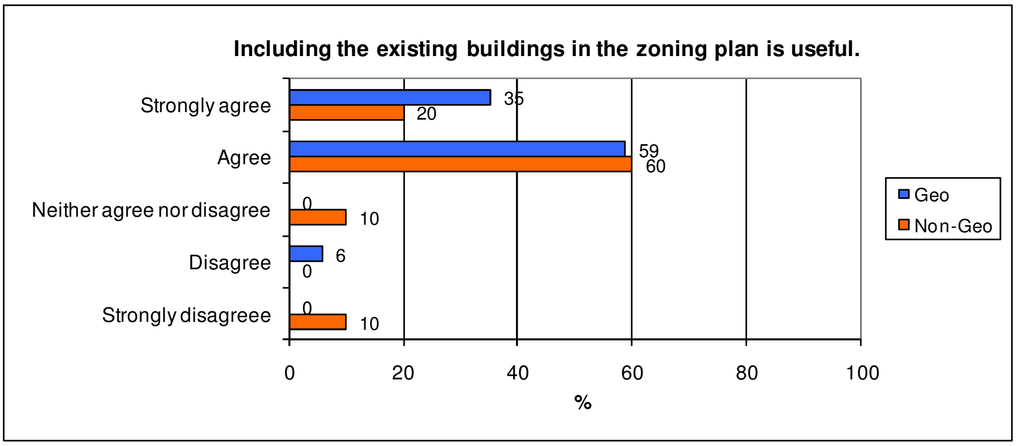


Figure 67.
Existing buildings.

Also this statement was agreed by the majority of both groups, making the choice to include the existing buildings in the zoning plan justifiable.

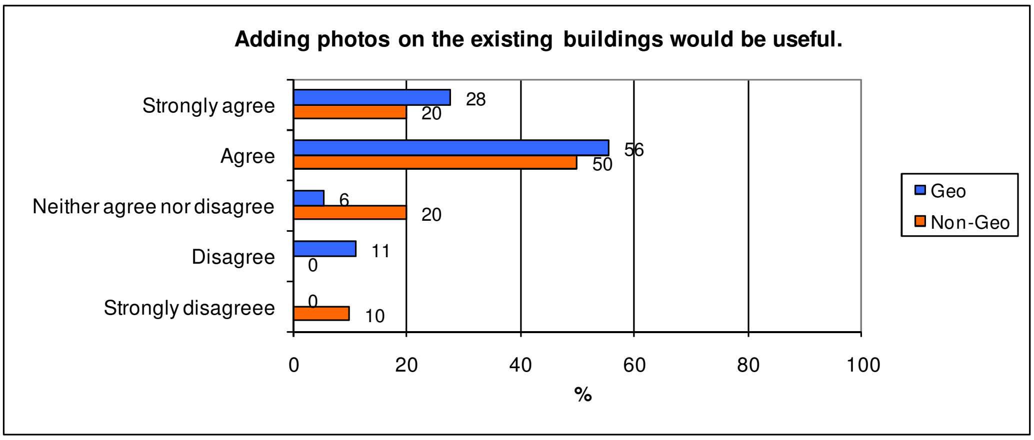


Figure 68.
Adding photos on existing buildings.

In the case study no photos are draped on the existing buildings, since data was not available. However, the great majority of the respondents agree on the statement that adding the photos would be useful. Adding photos can make the existing buildings better recognizable for users.

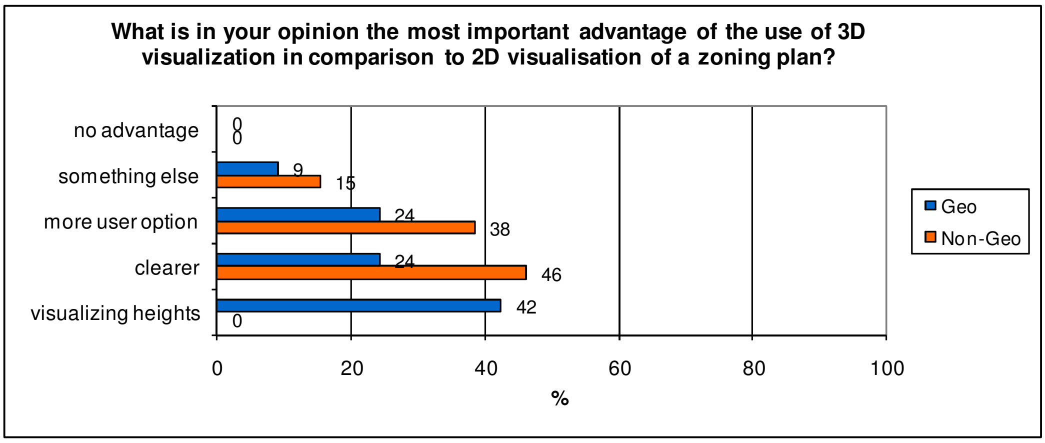


Figure 69. *Advantages 3D in comparison to 2D.*

In this question respondents could choose more than one answer. Most of the geo-group answered that visualizing heights is an advantage, where from the non-group no respondent choose for this option. Most of the non-geo group respond the 3D zoning plan is clearer and has more user options, such as navigating through the environment.

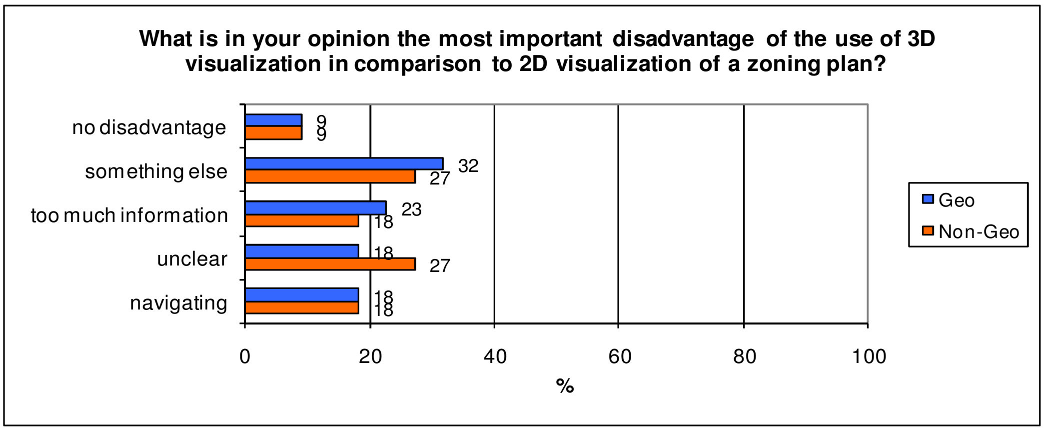


Figure 70. *Disadvantages 3D in comparison to 2D.*

As in the previous question, respondents could choose more than one answer. From the geo group 32% of the respondents choose for the answer 'something else'. In the open question respondents have the opportunity to elaborate more on the disadvantages. From the non-geo group 27% choose also for the answer 'something else' and the same percentage can also be observed for the option that the 3D zoning plan is unclear in comparison to the current zoning plan.

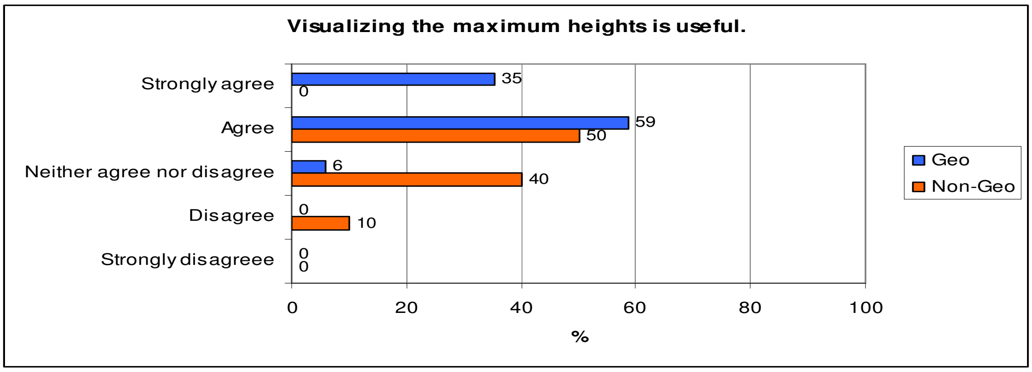


Figure 71. *Visualizing maximum heights*

The goal of the statement shown in figure 71 was to get an impression if the respondents state visualizing the maximum heights is useful. The results of the geo group clearly shows that they agree on the statement. 50% of the non-geo group agrees on the statement, however still a substantial percentage of 40% neither agrees nor disagrees on the statement.

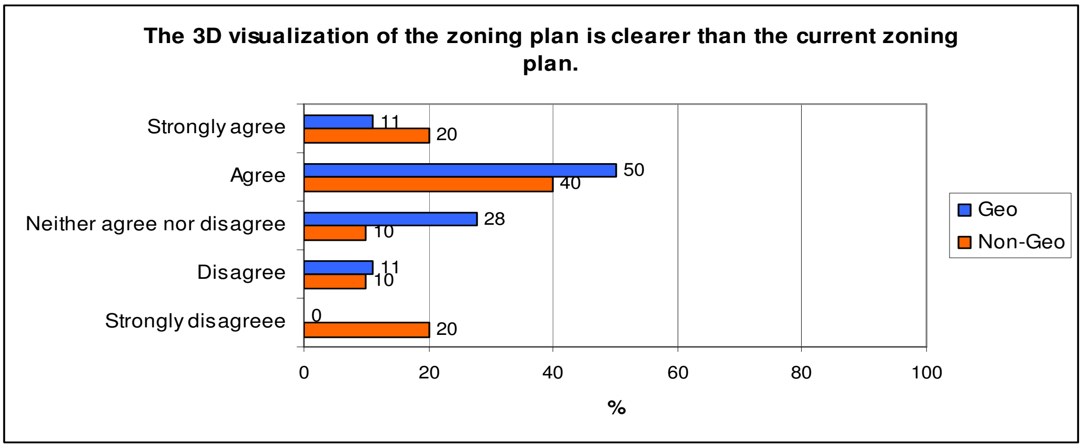


Figure 72. *Comparison 2D to 3D.*

Most of the respondents agree or strongly agree with the statement that 3D visualization of the zoning plan is clearer than the current zoning plan, for the geo group 61% show a positive result, for the non-geo group the percentage is 60%. However, 30% of the non-geo group does not agree on the statement.

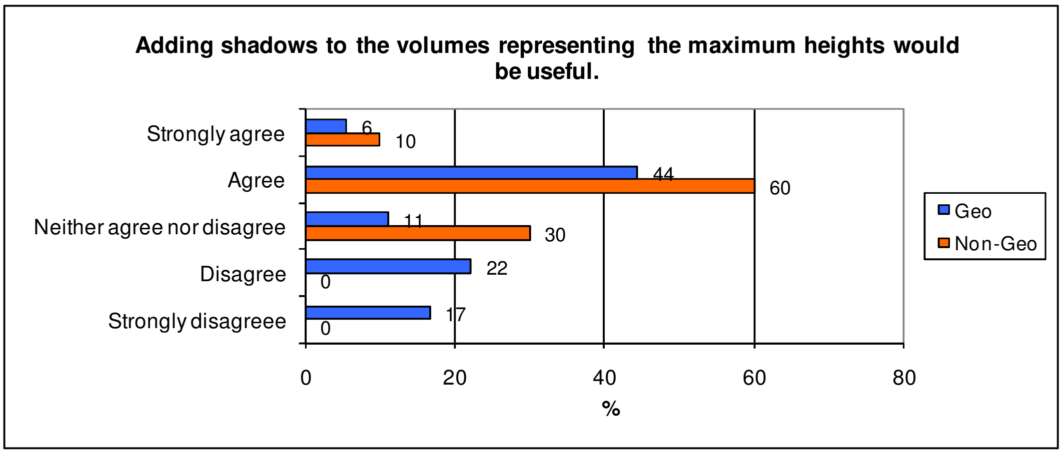


Figure 73. *Adding shadows.*

Google Earth does not have a functionality to show shadows, which can be useful to show the shadow effects of the maximum heights of buildings. The shadow effects can give an impression of the impact of the maximum heights on the surrounding environment. Especially the non-geo group is positive about the statement (70%), for the geo group the percentage is 50%. A substantial percentage of the geo group disagrees with the statement (39%), maybe because they argue shadows should not be part of a zoning plan.

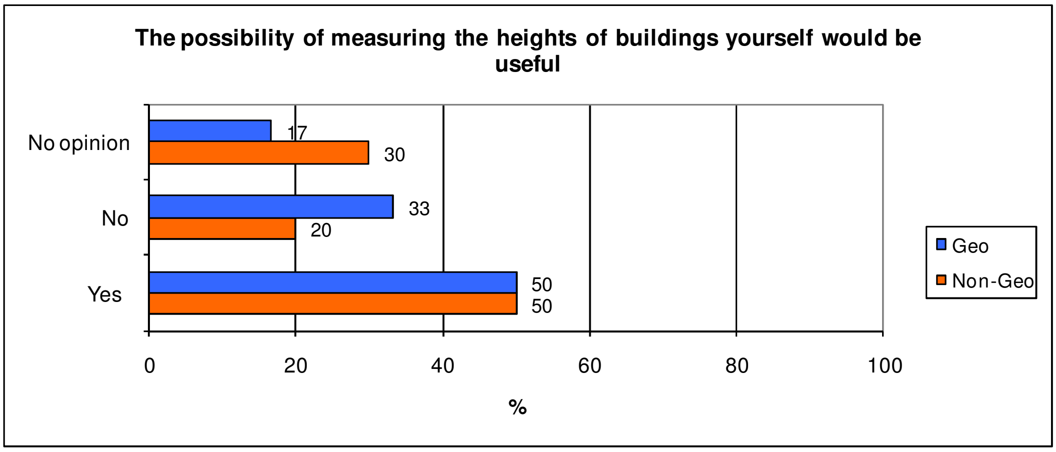


Figure 74. *Measuring heights.*

The statement shown in figure 74 deals with interactivity which enables the user to measure the buildings themselves. In Google Earth it is not possible to measure vertically, only horizontally, but it could be a useful interactive functionality to give the public to measure buildings. This option of to include measuring heights was answered positively by 50% of both groups.

7.4 Open questions

The open questions are made to give respondents the opportunity to answer on some specific issues.

1. What is your overall opinion after viewing both zoning plans: visualizing the zoning plan in 3D or in 2D?

The general opinion is that 3D gives a good impression of heights of buildings, shows more detail and is clearer than a current zoning plan. Furthermore, some respondents state that in 3D an environment is more recognizable than a current zoning plan and that it is more user-friendly than in 2D. Also some drawbacks of visualizing a zoning plan in 3D are stated. One respondent states that a citizen might interpret the zoning plan as an urban plan, by seeing the volumes as future buildings. Some respondents mention that 3D visualisation of a zoning plan should be considered next to a current zoning plan and not as a replacement of the current zoning plan. In addition, the legal aspect of visualizing a zoning plan is questioned, since the current zoning plan is fitted to 2D and descriptions for 3D are lacking.

2. What are deficiencies of the 3D visualisation in Google Earth?

Most of the respondents state that the legend in Google Earth is unclear, making the zoning plan more difficult to interpret, since the respondents might not know what all the objects visualized in Google Earth represent. Navigating is also an aspect which is experienced by some respondents as hard. This might be because people are not used to navigate in a 3D environment. Some respondents mentions clicking on objects is not working well, because sometimes the wrong information popup. Also a comment is made that the plan shows too much information mixed through each other. This probably deals with the different layers, representing different maps, which might be confusing. However, in Google Earth it is possible to activate and deactivate layers, to see one layer at a time.

3. What functions or data did you not like in this application?

Many respondents state the layer of building percentages is not clear. A possible explanation is that most of the respondents do not know what building percentages mean. The respondents can also interpret the building percentages as real heights, however the building percentages are representing percentages as thematic heights. Another drawback which was stated by many respondents was the lack of a clear legend. In addition, the lack of an explanation of all the layers of the zoning plan was named by a number of respondents as a negative aspect. This made the interpretation of a zoning plan harder to interpret, especially for people not familiar with zoning plans.

4. What functions or data would you have liked to use in this application?

A respondent came with the idea to include heights of green objects, such as trees or other large objects in the plan. This could result in a better recognition of the area. Adding historical material in the plan was also mentioned as an improvement of the plan. Further, adding photos on existing buildings and including a clear explanation of the zoning plan for people not familiar with zoning plans were mentioned as aspects missing.

5. What suggestions do you have which could improve the zoning plan?

As stated before many respondents suggest a clear legend, which is lacking in Google Earth. Another suggestion, which was mentioned before, was to include a clear explanation of all the layers in the zoning plan and explanations of the user options in the interface. Other suggestions are made, such as the possibility to show the old situation of the zoning plan, so it can be compared to the new zoning plan. Also it was suggested to include a link to the monumental status of buildings. Another interesting suggestion was made to create maps for different users, such as for citizens, architects and utility companies. Each of these groups have different interest in zoning plan, therefore specific maps for each group might be useful.

7.5 Discussion of results

The survey has given a good insight on how the zoning plan is perceived. Several conclusions can be made relating to the criterion visual clarity from Sheppard (2005) and the concepts perceived usefulness and ease of use from Davis (1993).

7.5.1 Visual clarity

In general the respondents answered that the zoning plan presented in Google Earth is clear and gives a good impression of the maximum heights buildings are allowed to have. In the open questions it also came forward that in 3D the environment is more recognizable and can give a better overview of the plan. The most important advantages of 3D visualization of a the zoning plan in comparison to the current zoning plan were that 3D is clearer and gives a good impression of the heights than 2D. The most disadvantages were the unclear legend of Google Earth and some people had trouble navigating through the plan. In addition, the thematic map with the development percentages was not clear for most of the respondents. An aspect which made the zoning plan unclear was the lack of an explanation of the zoning plan. Many respondents mentioned this in the open questions, therefore this should have been included. The public does not have the knowledge of what everything means what is visualized in a zoning plan and though 3D can make the interpretation easier by for example visualizing heights an explanation and user guide is required to make the plan understandable.

7.5.2 Perceived usefulness and ease of use

The multiple questions on usefulness were generally answered positively, for example on the inclusion of existing buildings. The proposals to improve the zoning plan, by adding shadows were also answered positively. Google Earth was stated by the respondents as a user-friendly in

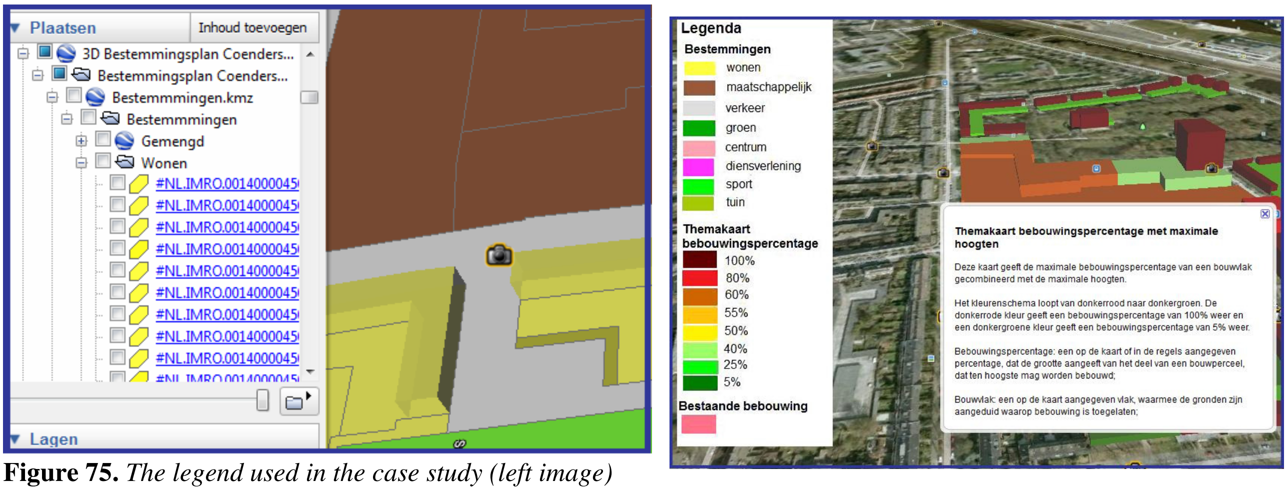


Figure 75. *The legend used in the case study (left image) and an example of an improved legend with a explanation of one of the maps (right image).*

navigating through the plan, though a few respondents had some trouble with navigating, for example one respondent did not have a good overview of the plan. Looking to the concept of ease of use respondents answered more critically. The legend of Google Earth was said not be easy in use, because it not clear what all the objects and colors of zoning plan meant (see figure 75).

The unclear legend also relates to the criterion of visual clarity, because it deals with how understandable the zoning plan is. Clicking of objects to get additional information was named by some respondents as not working well.

7.5.3 General conclusions

Concerning the population of the survey a few comments can be made. The results of most of the answers on the multiple choice questions of both groups do not differ greatly from each other. The geo group is more experienced in geovisualizations, but this does not clearly come forward in the multiple choice questions. For example the question on the thematic map of buildings percentages, more of the non-geo group answered it was clear than the geo group, where one would expect it would be the other way around. A small difference can be observed whether the respondents think the 3D visualization of a zoning plan is clearer than the current zoning plan. For the non-geo group, 30% disagrees or strongly disagrees on this statement, where for the geo group this is 11%. This can be explained by the lack of experience of the non-geo group to interpret the zoning plan. Furthermore, the application lacks of an explanation of the zoning plan. This have influence on how the zoning plan is perceived. A zoning plan is a difficult plan and for a person without experience in zoning plans it can be hard to interpret the plan.

A comment on the population is that a population with a more equal rate between the number of experienced and non-experienced respondents in geovisualizations would have been better to make a better comparison between the two groups. However, the survey was useful for this research and gave interesting insights, especially the open questions, where the respondents could specify their comments.

8. Conclusions and discussion

In this chapter the main research question will be stated again and will be answered subsequently. Furthermore, the results of this research will be discussed and this chapter ends with some directions for future research.

8.1 Answering the research question

In the introduction the following main research question was formulated:

How can a zoning plan be visualized in 3D and how can it be visualized such that it is understandable?

The last couple of years, the zoning plan went through a number of developments. In 2000 the project DURP, which stands for the digital exchange in spatial processes, was introduced by the Ministry of Housing, Spatial Planning and the Environment (VROM) to make the spatial planning process more effective and efficient through the digitalizing and standardization of the development, use and exchange of spatial plans. . In the light of these developments 3D could be the next step in the development of zoning plans. In addition, a current zoning plan has several limitations. One the main limitations of the visualization a current zoning plan in 2D deals with the interpretation of zoning plans, in particular the interpretation of heights. 2D maps are abstract and can be hard to understand. From literature, it is stated that by visualizing in 3D, users can get a better understanding and impression of a plan. This research has explored how a zoning plan can be visualized in 3D and how it can be done it is understandable for the public.

In chapter 4 the role of 3D geovisualization in zoning plans was analyzed and specific aspects of 3D geovisualization were discussed which are of importance regarding zoning plans. The case study and the survey in chapter 6 and 7 were done to explore how a zoning plan can be visualized in 3D and to verify if it is understandable for the public. Important factors of geovisualization which are relevant for this research, discussed in chapter 4, will be reflected below against the results of the case study and survey .

It was assumed in chapter 4 that geovisualization can be considered as a very useful tool for zoning plans, since a zoning plan can be made more understandable through the addition of 3D.

An important technique is by showing heights in 3D. By visualizing the maximum heights according to the zoning plan regulations, the public should get a better impression of what these heights imply. In the case study maximum heights were visualized in 3D and the survey showed that visualizing heights in 3D gives a good impression of heights in a zoning plan and was considered as an important advantage in comparison to 2D. Furthermore, respondents stated that in 3D an environment is more recognizable than current zoning plan. Another visualization method used was the implementation of existing buildings into the zoning plan. By including existing buildings, the public can recognize buildings easier and can compare the height of an existing building with the maximum heights. The survey made clear the majority of the respondents argued including existing buildings is useful, though it could have been done in more detail.

Another important factor of geovisualization is interactivity. It was assumed in chapter 4 that geovisualization can stimulate interactivity when for example the public can give reactions on the zoning plan during the planning process. This could be done by giving the public the opportunity to react via the interface of 3D visualization of the zoning plan. Users could for example click on a certain area or object in the plan and subsequently a menu pops up where the people have the opportunity to type a reaction or to request an explanation on a part of a zoning plan. In the case study a popup menu was used, however users could only use this to get more information when clicking on an object. The survey made clear that using a popup menu is useful, however in Google Earth this technique did not optimally work. In the case study other interactive techniques, such as navigating were also being positively judged. The survey could not make clear that interactivity leads to a better understanding of a zoning plan.

Next to interactivity, information intensity is an important factor in geovisualizations which is relevant for this research. Information intensity is about the level of detail with which objects are represented in geovisualizations. Zoning plans are generally not meant to show a high level of detail, but it should be represented abstract, since it is not an architectural plan, showing a detailed map or a detailed view of an area. In 3D, objects can be visualized in many different geometric shapes and the choice was made to visualize the objects in a low level of detail and as simple blocks. Therefore, in the case study the zoning plan objects are visualized abstract. The survey could not implicitly point out that the zoning plan shows too much or too less detail, but it could point out that the majority of the respondents answered that the zoning plan does not show too much information. However, some respondents mentioned existing buildings could be visualized in more detail by draping photos on the buildings.

Interpretation of geovisualizations was also stated to be important and this turned out to be true in this research. Interpretation of geovisualizations is related to visual clarity, one of the criteria of the ethics of visualization. Interpretation of zoning plans is very important, since it determines how the user experience the visualization and if the public is able to understand what is visualized by the zoning plan. One of the criteria ethics of visualizations (Sheppard, 2005) is visual clarity and deals with how the details and overall content of the visualization can clearly be communicated to the user. The survey made clear that the zoning plan applied in the case study is clear and gives a good impression of the maximum heights buildings are allowed to have. The most important advantages of 3D visualization of a the zoning plan in comparison to the current zoning plan were that 3D is clearer and gives a good impression of the heights than 2D. However, some aspects were unclear. One of the main components of the zoning plan which was unclear was thematic map showing building percentages. In the case study, a map was made showing the development percentages as thematic heights. The survey pointed out that most of the respondents answered the map was not clear. A possible reason could be that the building percentages are visualized as heights, representing the building percentages, which are not 'real' heights, which can be confusing. Furthermore, this could partly be explained that most of the respondents are not familiar with the zoning plan object of development percentages.

The interface used for the case study, Google Earth, had a substantial influence on the interpretation of the zoning plan. The survey made clear that most of the respondents stated that navigating in Google Earth was user friendly, but the legend of Google Earth was unclear, making it harder to understand what is visualized in Google Earth. Furthermore, an explanation of the zoning plan was lacking, which is required to make the zoning plan more understandable.

The general conclusion from this research is that 3D can stimulate the interpretation of zoning plans, because users can get a better impression of the plan by visualizing heights and is less abstract than a current 2D zoning plan. However, the interpretation of a zoning plan, also in 3D, is complex. A zoning plan is a complex and an abstract plan and this research has attempted to find methods to develop a 3D visualization of a zoning plan which is understandable for users. For a substantial part this research succeeded in this goal. The case study delivered a zoning plan which through a survey was in general judged positively by the respondents, however some aspects could have been better or were missing, leading to misinterpretations.

8.2 Discussion

This section will reflect on the research done and some directions for future research will be given.

8.2.1 Choice of Google Earth

The use of Google Earth for this case study seemed to be legitimate, since it is a widely used application and easy is use. This also became clear in the survey. However, Google Earth has some disadvantages. One of the main disadvantages was that in Google only objects above the surface can be visualized. Especially in the case of zoning plans, the underground is interesting to visualize in 3D, objects such as archaeological values and transport pipelines. For the future, other objects could also be visualized in 3D which are currently not described in zoning plans, such as basements and locations for thermal energy storage.

Another disadvantage is related to the legend of Google Earth. A main problem of Google Earth is the legend which is complex and can be hard to understand. A user cannot easily see the colours on the map and how they are explained in the legend, the user has to open the layer in the legend until the colour is shown.

Clicking on objects to get a popup menu showing more information about an object was another disadvantage, mainly with 3D objects. Often when clicking on an object, the wrong information pops up, because lowest layer will popup. In figure 76, this problem is depicted. The popup menu should show information about the building volume, depicted in yellow, but it shows the zoning function ‘verkeer’.

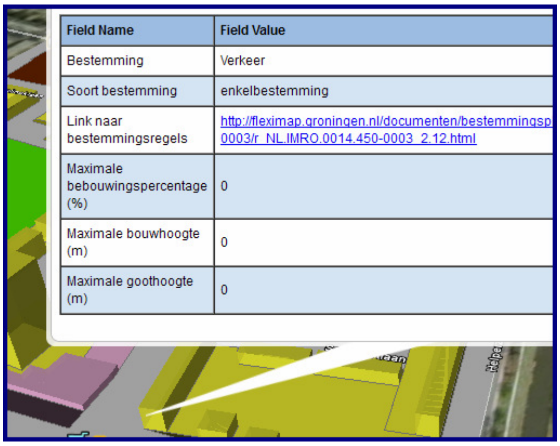


Figure 76. *Clicking on objects*

The use of transparency did also not optimally work. Transparency was meant for the building volumes, indicating these volumes are not real. Furthermore, it had an important function to be able to see the existing buildings through the transparent building volumes, but this did not work.

8.2.2. Results of the case study

The case study showed that the development of a zoning plan in Google Earth in 3D is complex. In comparison to a current 2D zoning plan, other aspects have to be taken into account and more data is needed to be able to visualize heights. The extrusion of building planes, based on measurements described in the zoning plan regulations was not a difficult task. The inclusion of existing buildings in the zoning plan was a time-consuming task, since all the buildings had to be measured, be extruded to the measured heights and roofs had be modelled manually. Though this was time-consuming, the survey made clear that including the existing buildings in the zoning plan was useful.

As already pointed out in the previous section, the objects in the underground cannot be visualized in Google Earth. However, some visual requirements have been described and discussed in the case study (see chapter 5 and 6), but how the objects in the underground are perceived by the users was not tested in the survey. That was a limitation of this research.

8.2.3 Survey

The survey gave a good insight in the interpretation and use of the 3D visualization of the zoning plan. Especially the open questions returned useful answers from the respondents. For example the answers of the open questions showed that the legend was unclear and an explanation of the zoning plan was required. A disadvantage of using multiple choice questions is that it only gives answers if respondents agree or disagree, but not the reasoning by their answers. Therefore it might have been better to include more open questions in the survey.

A comment on the population of the survey is that a population with a more equal rate between the number of experienced and non-experienced respondents in geovisualizations would have been better to make a better comparison between the two groups.

The survey could have been more focussed on the difference between 2D and 3D. In the survey a few questions were related to the difference between 2D and 3D, but this could have been done in more detail. A comparison could have been made between the current zoning plan and to the zoning plan of the case study, where the respondents had to score the both zoning plans based on factors as visual clarity, information intensity, interactivity and the use of the application. By making this comparison a better verification could have been given how the respondent interprets and perceives the zoning plan developed in the case study.

8.3 Future research

This research has shown that 3D visualization of a zoning plan has many advantages, but it cannot yet be considered as the replacement of a current zoning plan. However, this research can be considered as a step towards a 3D zoning plan and the research made clear that 3D can give a good insight in the heights and can help in the interpretation of the plan, but the interpretation of a zoning plan in 3D is complex. To offer a 3D zoning plan to the public more aspects have to be researched. One aspect deals with two criteria of the ethics of visualization (Sheppard, 2005), accuracy and legitimacy. A zoning plan is a binding instrument and it has to be accurate and juridical correct, which is not yet the case in 3D, since the regulations of a zoning plan do not fit to the requirements of 3D. The IMRO2008 model is made suitable for 2D and not 3D, therefore an IMRO model for 3D needs to be developed. Another aspect deals with the availability of data. 3D data is not easily available or has to be captured in order to visualize objects in 3D, for example for noise zones and underground zoning. Another important notion is that in order to develop a 3D zoning plan, the approach should be to consider 3D as the starting point in the process of developing a zoning plan and not by considering 2D as a starting point, which was the case in this research.

This research did not focus on possibilities to visualize objects in 3D which are not described in the current IMRO model. Examples of these objects are basements, locations for thermal energy storage etcetera. Therefore, it would be interesting to research how those new objects can be implemented in a 3D zoning plan.

The user plays an important part in the interpretation of visualizations. In this research, a case study was being done and requirements were made based on literature and not based on a user need analysis. Only a survey was done after the zoning plan was created to test how the plan was being interpreted. Conducting a user need analysis could given a good insight in the preferences and requirement of what users expect of a zoning plan. However, in general users mostly do not know what to expect, since they do not have the knowledge what is (technologically) possible.

This research could have been improved the validation of the case study by executing an expert test next to the survey. This could be done by organizing a workshop where zoning plan experts are invited to discuss the zoning plan applied in the case study. This could result in more input and perhaps more specific comments on the zoning plan.

In this research, Google Earth was used, however, not all the functionalities are suitable for 3D visualization of zoning plans, so a tailor-made application for 3D visualization of zoning plans can be a solution. A useful feature to include in this application could be the addition of shadows, showing the shadow effects of the building volumes on the surrounding environment. Also the ability to perform queries could be useful, such as a query showing all the building volumes from the zoning function 'housing' with a maximum height of 15 meters. Also the possibility to search on a specific address could be useful. Another option could be to give the user the opportunity, during the planning stages of a zoning plan, to react via the interface. By clicking on a certain area in the zoning plan a screen pops up where the user can give a reaction. Subsequently, this reaction will send to the municipality. Another interactive option deals with building percentages. The user could be given the opportunity to draw a polygon in a building plane within the maximum building percentage of the building plane, so the user can draw a part of the building plane he/she wants to use for a certain development.

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Appendix A Survey

Survey questions

Multiple choice questions

1. **Ben u een man of een vrouw?**

Man
Vrouw

2. **Wat is uw leeftijd?**

3. **Heeft u ervaring met Geografische Informatie Systemen?**

Ja
Nee

4. **Heeft u weleens met een bestemmingsplan te maken gehad?**

Ja
Nee

5. **Heeft u weleens een digitaal bestemmingsplan op het internet bekeken?**

Ja
Nee

6. **Heeft u Google Earth weleens vaker gebruikt?**

Ja
Nee

7. **Het navigeren in Google Earth is gebruiksvriendelijk.**

helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

8. **De 3D visualisatie van het bestemmingsplan in Google Earth is overzichtelijk.**

helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

9. **Het is duidelijk wat de verschillende hoogten aangeven.**

helemaal mee oneens
oneens

niet mee eens/oneens
eens
helemaal mee eens

10. De themakaart die de bebouwingspercentages laat zien is duidelijk.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

11. De themakaart die de maximale bouwhoogten laat zien is duidelijk.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

12. De hoeveelheid informatie op de kaart in Google Earth is voldoende.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

13. Het bestemmingsplan in Google Earth moet meer tekst bevatten.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

14. Het principe van het popup menu dat verschijnt wanneer u op een object in het bestemmingsplan is handig.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

15. De bestaande bebouwing heeft een toegevoegde waarde op de kaart.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

16. Het toevoegen van foto's op de bestaande bebouwing zou nuttig kunnen zijn
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

17. Hier is een link naar een huidig 2D bestemmingsplan:
http://fleximap.groningen.nl/gnmaps/bestemmingsplannen/
Wat vindt u het grootste voordeel van gebruik van 3D visualisatie tov 2D visualisatie van bestemmingsplannen? (meer antwoorden mogelijk)

tonen hoogte
duidelijker
meer gebruiksmogelijkheden
iets anders
Er zijn geen voordelen

18. Wat vindt u het grootste nadeel van gebruik van 3D visualisatie tov 2D visualisatie van bestemmingsplannen? (meerdere antwoorden mogelijk)
navigeren
onduidelijk
teveel informatie
iets anders

19. Het visualiseren van maximale hoogten die gebouwen mogen hebben in 3D is een meerwaarde.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

20. De 3D visualisatie van het bestemmingsplan is duidelijker dan het huidige bestemmingsplan.
helemaal mee oneens
oneens
niet mee eens/oneens
eens
helemaal mee eens

21. Het toevoegen van schaduw van de volumes met maximale bouwhoogten zou nuttig kunnen zijn.
helemaal mee oneens
oneens
niet mee eens/oneens
eens

helemaal mee eens

22. Het zelf kunnen meten van de hoogte van gebouwen zou nuttig kunnen zijn.

Ja

Nee

Weet niet

Open questions:

23. Wat is uw algemeen oordeel na het bekijken van beide bestemmingsplannen in 3D en in 2D?

- Ik vind 3D een enorme vooruitgang tov 2D. We zien alles dagelijks in 4D (dus 3D + tijd). 3D is voor mensen dus heel natuurlijk. Alles wat je ziet in 3D visualisatie is dan ook direct herkenbaar en duidelijk.\r\nOok basiskaarten zouden in 3D gemaakt moeten worden.
- Een bestemmingsplan gevisualiseerd in 3D heeft naar mijn opvatting een toegevoegde waarde, maar kan een 2D bestemmingsplankaart niet vervangen. Daarvoor mis je teveel informatie.\r\nDaarnaast is het van groot belang om te bepalen voor wie je een bestemmingsplankaart maaakt, m.a.w. wie kijkt ernaar en kan het begrijpen. Het wekt voor een leek op grafisch gebied gauw de indruk van een stedebouwkundige invulling van het gebied.
- 3D\r\n3D kan meer en overzichtelijk informatie bevatten.
- Het geeft een duidelijk beeld.
- Geeft een mooi totaalbeeld van het plan t.o.v zijn omgeving. Aan en afvoerwegen zijn goed herkenbaar en eventueel capaciteits analyses kunnen worden uitgevoerd. Programma is gebruiksvriendelijk en praktisch gezien er meerdere opties kunnen worden aangevinkt.
- niet in plaats van maar additioneel
- Deze pilot geeft aan dat er wel mogelijkheden zijn om een bestemmingsplan in 3D te visualiseren, maar ook dat een juridisch sluitende afbakening in 3D lastig is. Deels komt dit door de magere visualisatie mogelijkheden van Google Earth, waardoor je niet gemakkelijk meerdere lagen (bv. Dubbelbestemmingen) over elkaar heen kunt leggen. \r\nBestaande elementen zoals bebouwing of overige topografie is lastig te visualiseren en neemt al snel een te prominente plaats in. Toch heeft met name het opnemen van bestaande bebouwing wel nut voor de herkenbaarheid. Hier zal nog verder onderzoek naar moeten plaats vinden.\r\nHet is een goede vonst om het 3D bestemmingsplan op te delen in meerdere lagen, waardoor je de mogelijkheid hebt om te schakelen tussen themalagen. Hoewel de themalagen door het ontbreken van een legenda wel weer lastig leesbaar zijn.
- Het bestemmingsplan in 3D is een stuk duidelijker dan het bestemmingsplan in 2D. Het bestemmingsplan in 3D geeft veel meer informatie.
- Het is een mooie aanvulling ter verduidelijking, maar uiteindelijk is een kaart nog altijd het meest praktisch, denk ik.
- 3d kan duidelijker zijn maar denk dat het altijd nuttig is om op de lokatie te kijken.
- Goed. Goede toevoeging, met name doordat gebouwen nu met elkaar te vergelijken zijn.
- Dat het 3d plan toegevoegde waarde heeft voor mensen die er dagelijks mee werken. Voor leken zal het onduidelijker worden ivm visualisering van hoogtes die eigenlijk een waarde hebben en geen hoogte zijn.
- Ik zou liever met een bestemmingsplan in 2D werken, omdat ik dat overzichtelijker vind.
- Het idee is op zich wel duidelijk, dat het extra visuele informatie moet geven. Maar het wordt er niet altijd overzichtelijker van (te veel informatie). Een klik op een gebouw en je hebt dezelfde informatie in een overzichtelijke tabel bij elkaar. Voor wie is de 3D kaart bedoeld? Als burger kijk je meestal naar de eigen beperkingen van je perceel en dan lijkt mij een tabel voldoende. Dat de geluidscontour er zo mooi overheen schuift is wel heel handig.
- Ik ben altijd voor 3D. Ik ben visueel ingesteld, dus een idee van hoogte maakt je orientatie veel beter. En met 3D is 2D ook mogelijk door er gewoon loodrecht boven te gaan hangen.
- Wow, respect voor de applicatie. Dit is de toekomst van het visualiseren van bestemmingsplannen. Daar ben ik nu van overtuigd.
- Geeft goede indruk van hoogte en schaal van gebouwen
- Realistischer dan 2D

- Inzichtelijker
- 2D bestemmingsplannen zijn veel te globaal, dan moet achteraf nog uitgezocht worden welke straat in welk gebied ligt.
- Gebruiksvriendelijker
- Meer detail tov 2D.
- Herkenbaarheid
- Het kunnen zien van bouwhoogten is echt een voordeel, maar wanneer er zoveel kaartlagen door elkaar komen, is het niet meer duidelijk. mss kleurtegenstellingen duidelijker maken, of watermerk.
- Prima, het is makkelijker voor te stellen.
- helder, duidelijk , realistisch.
- Zeer aangenaam: een plezier om in rond te vliegen. Gedetailleerd weergegeven bebouwing.

24. Wat zijn de tekortkomingen van de 3D visualisatie in Google Earth?

- Legenda/lagen en menu
- Teveel info en door elkaar
- 3D is uitermate geschikt als model van de (toekomstige) werkelijkheid. Dat is een bestemmingsplan niet.
- Een probleem is dat niet iedereen goed overweg kan met digitale 3D-bestanden.
- Hangt van gebruiker af. Misschien wat meer tekst en uitleg.
- Omgeving! Ik weet niet hoe de hoogte van de gebouwen zijn tov de omgeving
- Het is lastig meerdere lagen over elkaar te plaatsen. Aanklikken van de objecten leverde niet altijd het juiste object op, maar bv een die er achter ligt. De legenda is niet goed ontsloten.
- Het navigeren; geen direct overzicht op alles.
- Dat het maar een beeld is op de computer niet echt.
- Een duidelijke legenda ontbreekt. Je moet goed in de gaten houden welke lagen je aan en uit hebt staan.
- Geen duidelijke uitleg wat je moet doen en wat je dan ziet.
- Het kost veel tijd om uit te vinden hoe het precies werkt en hoe je er naar moet kijken. Voor een leek is dit best lastig. Ik zou me voor kunnen stellen dat het voor een professional wel handig zou kunnen zijn.
- geen duidelijke legenda per thema.
- Third part usage (verplicht gebruik van google Earth ipv standaard benadering (via een plugin) via de webbrowser).
- De legendafunctie.
- Ik kan de legenda met kleuren niet vinden, maar dat kan aan mij liggen. Mocht die ontbreken dan zo dat wel een handige toevoeging zijn.
- te veel info en voor een leek staat er veel te veel door elkaar.
- Navigatie
- 1. Als (zoals bij aanvang) meerdere layers/lagen aanstaan geeft dit een wat verwarrend beeld met verschillende kleuren/legenda\'s/overlap door elkaar heen. 2. De link tussen kleur en betekenis v/d kleur kan nog duidelijker. Nu blijkt dit alleen via het aanzetten/uitzetten van een layer en niet uit een legenda.

25. Welke gebruikers functies of data vond u minder geslaagd in deze applicatie?

- De volumes van de bebouwingspercentages zijn wat verwarrend, het lijkt om een fysieke hoogte te gaan ipv percentages.
- Legenda is wat onduidelijk, je moet teveel bladeren in het menu links
- bebouwings100%?
- Het inzoomen en het ontbreken van een duidelijke legenda. Maar de 2d bestemmingsplannen vond ik super onhandig dus dit is al een hele verbetering. Nu is ook duidelijk waar de bestemmingen op rusten, op welke straten e.d.
- bebouwingspercentages, geluidscontour. voordeel is wel weer dat je die gewoon uit kan zetten...
- De bebouwingspercentages
- 1. Bij het aanklikken ook meteen een weergave van dubbelbestemmingen. 2. Een gebouw in kunnen / 3. Ondergronds kunnen
- Themakaart bebouwingspercentages kan onduidelijk zijn als je niet weet wat de hoogte in de kaart inhoud.

- Wat volgens mij belangrijk is dat ik een indruk krijg van het plan en gevolgen voor bestaande gebouwen en omgeving etc. Met aan- en uitvinken van bijvoorbeeld hoogtes, bewoning etc heb ik die indruk niet gekregen.
- De themalaag bebouwingspercentages geeft niet weer wat je zou denken, omdat het percentage is omgezet in een hoogte, Het was misschien een mogelijkheid geweest de themalaag maximale bouwhoogte in te kleuren met een kleurtint die het bebouwingspercentage weer geeft. De themalaag bestaande bebouwing leidt af van de bestemmingsplandata. Wellicht is dat anders als deze laag beplakt is met gevelfoto\'s, waardoor de representatie een duidelijk andere \'look\' zou krijgen dan de bestemmingsplandata.
- Ik begrijp niet wat er met bebouwingspercentage bedoeld wordt, maar weten diegenen die ermee moeten werken ongetwijfeld wel...
- misschien de extra menu\'s met de regels maar denk dat komt door dat ik het nooit gebruik. (vaker gebruiken)
- Dat popup. Daar moet veel meer info in. Nu heeft het geen waarde.
- Het blijft voor leken onduidelijk dat waarden een hoogte krijgen in een 3D visualisatie.
- De oriëntatiepunten waren niet altijd duidelijk, er was wel erg veel informatie.
- Ontbreken van een duidelijke legenda.

26. Welke functies of data had u graag willen gebruiken voor deze kaart?

- (Hoogte van) stedelijk groen en andere grote objecten
- historisch materiaal
- kenmerken van een gebouw verschijnen zodra je over dit gebouw heen gaat met de muis
- foto's op bestaande bebouwing
- de toolfunctie geschiedenis hoe het vroeger was voorbeeld 30 jaar geleden
- Fotos met mogelijke uitzichten
- Extra data uitzetten en dat de kenmerken van een gebouw verschijnen zodra je over dit gebouw heen gaat met de muis.
- overzichtelijke legenda.
- 1. Bij het aanklikken ook meteen een weergave van dubbelbestemmingen. 2. Een gebouw in kunnen / 3. Ondergronds kunnen
- Hoogtemeting
- Schatting van het aantal woningen/appartementen en kantoorruimte.
- Het gaat hier om een bestemmingsplan en niet om een buurt 3D te maken waar andere data van belang kan zijn. Volgens mij zit alles wat een bestemmingsplan betreft er wel in.
- meer zij aanzicht
- Legenda

27. Welke suggesties heeft u om de kaart te verbeteren?

- Legenda
- Extra informatie bestemmingsplan
- Mogelijkheid voor 2D weergave
- Laag met oude situatie tov nieuwe situatie
- Ondergrondse gegevens
- Link naar monumentenstatus, cultuurhistorische waarde
- Verduidelijking betekenis geluidscontour
- Duidelijke uitleg bestemmingsplan en werking applicatie
- Kaarten voor verschillende gebruikers maken (leken, architecten, (nuts)bedrijven).
- Misschien wat meer van vroeger hoe het vroeger was.
- Fotos met mogelijke uitzichten
- fotos op bestaande bebouwing
- wellicht biedt toepassing in Vituel City nog meer mogelijkheden
- Een hele goede uitleg op niveau "leek" om het goed te kunnen gebruiken.
- Hogere resolutie en/of meer detail van bestemming
- Uitleg plan en manual voor gebruik (met uitleg wat bedoeld wordt)
- Duidelijker aangeven waar precies in de stad het bestemmingsplan betrekking op heeft.
- duidelijke legenda\'s toevoegen per themakaart, nu is het veel doorklikken
- Optie om schaduwen aan te vinken. Foto links.

- Indien het object in 3D is toegevoegd zie je duidelijk of het strijdig is met het bestemmingsplan of niet. Ik kan me voorstellen dat mensen op basis daarvan bij de gemeente aan de bel trekken om opheldering te vragen. wellicht handig om via een hyperlink naar de betreffende (scan van) ontheffing te kunnen gaan.
- 1. Volledigheid, dus voor elk stukje Groningen (zowel bovengronds als ondergrond en zowel voor infrastructuur, bebouwing, groen etc) de mogelijkheid het aan te klikken (ook als er geen 3D-elementen een rol spelen) 2.Ook een weergave/verwijzing naar niet in het bestemmingsplan genoemde, maar wel van belang zijnde zaken (zoals een monumentenstatus, een cultuurhistorische waarde, andere niet in het bestemmingsplan juridisch geregeld, maar wel van belang zijnde en/of wettelijk geregelde aspecten).

28. Heeft u vragen of opmerkingen die niet in deze enquête vermeld zijn?

- Belangrijk is de snelheid waarmee zo\'n 3D-bestemmingsplan aan het publiek \'geleverd\' kan worden. Het huidige 2D-bestemmingsplan laadt zich op internet namelijk vaak zeer traag. 2. Hoe zit het met de schaal? Is 3D ook te gebruiken voor fietsenhokken, de weergave van bomen en andere kleine stadslandschapselementen? Hoe betrouwbaar zijn de vlakken? Welke rechtsgeldigheid kent het 3D-bestemmingsplan? Als ik inzoom op mijn huis, wordt de (bijv) afwijkende bouwhoogte van mijn huis ten opzichte van de buren dan ook precies correct weergegeven? (m.a.w. betrouwbaarheid) En functioneert 3D ook in een lastigere te digitaliseren omgeving met zeer uiteenlopende gebouwvormen- en hoogtes, zoals in de binnenstad?
- Door het gemaakt te hebben kunnen we een goede discussie voeren over de waarde van een 3D bestemmingsplan.

Appendix B Interviews

Interviews with Municipality of Rotterdam and Enschede

Ed van 't Erve – Municipality of Enschede
Dick Bosch - Municipality of Enschede
Ignace van Campenhout – Municipality of Rotterdam

1. Wat willen jullie met een 3D bestemmingsplan/ondergrondse gegevens?
2. Wat is het draagvlak van de ruimtelijke planners?
3. Wat waren jullie verwachtingen met een 3D bestemmingsplan?
4. Welke mogelijkheden zien jullie?
5. Wat zijn volgens jullie de beperkingen 2D (bestemmingsplan)?
6. Wat doen jullie met hoogte van gebouwen en maaiveld?
7. Wat voor 3D model hebben jullie gebruikt?
8. Wat voor datasets hebben jullie gebruikt?
9. Wat voor detail hebben jullie gekozen voor het modelleren?
10. Hebben jullie er een database achter zitten? Zo ja welke, hoe hebben jullie dat gedaan, hoe z component opgeslagen?
11. Wat doen jullie met meervoudige bestemmingen?
12. Welke beperkingen kwamen jullie tegen bij het 3D visualiseren?
13. Welke objecten van een bestemmingsplan zijn volgens jullie vooral geschikt voor 3D?
14. Welke software pakketten hebben jullie gebruikt? GIS en/of CAD/Microstation?
15. Hoe worden zones (veiligheid, geluidszones) gerepresenteerd?
16. Wat moet er nog verbeterd worden aan het 3D model?
17. Is 3D visualisatie een meerwaarde, of is het nog te complex en past het niet binnen de ruimtelijke planprocessen?
18. Wat willen jullie er in de toekomst mee gaan doen?
19. Welke rol zien jullie voor bewoners, om ze te betrekken bij het bestemmingsplan?