Exploring the added value of a 3-dimensional city model for stakeholder participation within collaborative spatial planning

MSc. Thesis

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Summary

Planning support systems (PSS) can be used to aid a spatial planner in resolving complex planning issues. However, current adaptation of PSS systems is lacking, with a multitude of bottlenecks often preventing the successful adaptation of a PSS. Currently, 3D city models (3DCMs) are being developed. The usage of 3D is said to offer multiple improvements in comparison to a 2D model. Hence, this study has investigated the added value a 3DCM can offer for citizen's collaboration within the framework of collaborative spatial planning. It has done so by comparing the expected versus the experienced added value of a 3-dimensional city model with the help of the following research questions

What is the expected versus the experienced added value of a 3-dimensional versus a 2-dimensional city model for stakeholder participation in the framework of collaborative spatial planning?

In order to be able to test the expected and experienced added value, this research has made use of a framework to objectively test and compare the experienced and expected added value. With help of a literature study, five criteria have been selected: communication, learning, efficiency, analysis and collaboration. Subsequently, a qualitative research has been carried out to test added value with the help of these selected criteria. A total of 12 stakeholders in the field of collaborative spatial planning with experience in using 3DCMs have been interviewed during the spring of 2019.

Results show stakeholders having mostly negative to mixed (a combination of positive and negative) experiences when making use of a 2D model. The communicative and analytical criteria are rated as negative. Interviewees have mixed experiences for the criteria learning and efficiency. Only for the criterium collaboration interviewees cite positive experiences.

In contrast, for both the expected and experienced added value of a 3DCM results generally find mixed to positive expectations and experiences. However, results do show a discrepancy between the expected and experienced added value. Results had expected a 3DCM to be positive for the communicative criteria. In contrast, actual experiences show mixed results. For collaboration, expectations for the added value of a 3DCM were mixed. However, this research shows the actual experienced added value to be positive. Lastly, results show a match for the criteria learning and analysis (with interviewees citing positive expectations and experiences) and efficiency (finding mixed expectations and experiences).

To conclude, this research finds that making use of a 3DCM for stakeholder collaboration is experienced as a major step forward. However, this research also finds that many 3DCMs are still in development, limiting the currently available for testing the experienced added value. Therefore, this study recommends to further investigate the added value a 3DCM can offer ones more 3DCMs become available. Doing so will hopefully contribute in taking full advantage of the added value a 3DCM can offer.

Preface

This research has been written as part of the graduation requirement of the master's programme Geographical Information Management & Applications and was conducted in the period September 2018 – June 2019.

First of all, I would like to express my special gratitude to all interviewee candidates for their willingness to participate in this research. They have provided me with valuable information and insights. Without their cooperation, this research would not have been possible. Secondly, I want to thank my supervisors Stan Geertman and Derek Karssenberg for the valuable feedback, guidance and assistance they have provided me over the course of this research. Lastly, I would like to thank my family, friends and fellow students for their support, advice and feedback.

I hope you will enjoy reading

Oscar Stoop
Utrecht, August 8th 2019

List of abbreviations

PSS = Planning support system
LOD = Level of detail
GIS = Geographical information system
3DCM = 3D digital city model

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1. Introduction

Spatial planning is often a complex process (Te Brömmelstroet, 2013). Planners are increasingly being confronted by an ever-growing number of challenges. For example, across the globe the stress on the built environment is growing because of an increasing urban population (United Nations, 2018). Furthermore, spatial planning is faced by multiple complex challenges, such as climate change and the subsequent need for sustainable development (Trubka, Glackin, Lade & Pettit, 2016). Many of such issues are not new to the Netherlands, which has a high urbanization grade and is prone to environmental disasters (e.g. flooding) (CBS, 2014; CBS, 2016).

Besides the challenges discussed above, spatial planning faces more challenges. The demand for stakeholder participation is growing, both from stakeholders and politics (Wu, He & Gong, 2010). Including the public and other stakeholders is often seen as a way to increase the effectiveness and efficiency of a plan and result in a better plan and provide for major benefits for planning. Secondly, holding stakeholders partly accountable for the quality of their own spatial environment makes them more likely to contribute in a positive manner to their own spatial environment, helping to create a better environment. Thirdly, stakeholder participation is said to result in efficiency gains. By including the voice of citizens and other stakeholders, it is hoped that any proposed plan can be implemented faster. Lastly, citizen participation enhances the democratic level of government and political responsibility of citizens (Boonstra & Boelens, 2011; McCall & Dunn, 2012). However, increasing the participation of stakeholders (e.g., citizens) also results in more interests and opinions which need to be included in the planning process. Thus, increasing the overall complexity of the process.

A planning support system (PSS) is said to be able to aid a planner in navigating these many different and often conflicting interests (Pelzer, 2017). Thus, such a tool would be well-positioned to deal with the increasing levels of participation and different views (Pelzer, Geertman & Van der Heijden, 2015). A PSS is a tool which uses GI-instruments in order to support the planning process, while also including planning related theory (Geertman & Stillwell, 2009; Pelzer et al., 2015). However, many of these tools tend to be underutilized, with PSS being only sparsely used (Pelzer et al., 2015). If the usage of PSS would increase, this might help in realising a more efficient planning process with a more high-quality outcome.

Currently, multiple Dutch municipalities are in the process of, or have recently acquired, a 3D city model (3DCM) (Geonovum, n.d.; Municipality of Amsterdam, 2018; Municipality of Rotterdam, 2018). This study aims to investigate the added value a PSS can generate in the field of collaborative spatial planning. Special focus will be paid towards the possible added value generated with the help of a 3DCM in order to find out what the added value of a 3DCM is.

1.2 Reading guide

The build-up of this thesis is as follows. Firstly, a literature review will be presented in chapter 2, focussing on PSS and the possible added value a 3DCM might offer. Chapter 2 will culminate into the main research question and sub questions at the end of the chapter. Chapter 3 will critically discuss the chosen methodology for this research and chapter 4 will discuss the results. Subsequently, chapter 5 will provide the conclusion, which will provide an answer to the formulated research questions. To conclude, chapter 6 and 7 will provide the discussion and recommendations of this research. Lastly, appendix 1 will provide the used interview topic list.

2. Literature review

This section will provide a general introduction towards Planning Support systems (PSS), and will focus on exploring PSS literature. Furthermore, it will introduce the concept of 3D with regard to PSS. Attention will be paid towards the possible contribution of 3D city modelling for PSS. Firstly, there will be discussed what is actually meant by a PSS, and a link will be made to current literature regarding the topic. Secondly, the focus will shift towards the potential added value of PSS and 3D city modelling To conclude this chapter will end by formulating the research questions. Consequently, a bridge is made to chapter 3, which will discuss the methodology for the to be carried out research.

2.1 An introduction to Planning Support Systems

In recent years, the importance of including citizens in planning processes has been stressed by multiple authors. Collaboration in planning is a trend that is coming from multiple groups. Both the government but also citizens are increasingly interested in collaborative spatial planning. Inviting the general public and other stakeholders to take part in the planning process is seen as a way to make sure that the needs and demands of these groups are integrated in the proposed development and to make for a more democratic and effective planning process (Healey, 2003; Irvin & Stansbury, 2004; McCall & Dunn, 2012). Here, 'other' stakeholders can be defined as anyone with a legitimate interest in the planning process at hand (Healey, 1998) Hence, collaborative spatial planning can be defined as a collaborative learning process among stakeholders which have different and sometimes conflicting interests. Thus, it is not just the technical process of making a spatial plan (Elbakidze, Dawson, Andersson, Axelsson, Angelstam, Stjernquist, Teitelbaum, Schlyter & Thellbro, 2015; Raghothama & Meijer, 2015; Te Brömmelstroet, 2013; Trubka et al., 2016; Zlatanova, Itard, Kibria & Van Dorst, 2010). Furthermore, a planner inevitably has to deal with the future which is per definition riddled with uncertainties. As a consequence, the planning practice has to find a way to deal with this uncertain future in an adequate manner (Pensa, Masala & Lami, 2013; Spit & Zoete 2013). In order to resolve such planning issues, it is important for stakeholders to be able to relate, discuss, reflect and verify information (Elbakidze et. al., 2015).

However, the collaborative approach is not without its criticisms. The goals of collaboration can be in contrast to other often formulated goals for the planning process; decisiveness and the speed of the planning process. Since collaboration is often a time-consuming process, it often involves additional cost. However, it could be argued that the cost of not including stakeholders and subsequently facing the risk of an even lengthier implementation process as a result of legal objections made by stakeholders could be even costlier. Thus, raising the question how to meet one goal without compromising the others. Besides, western society is becoming ever more individualistic, raising the question if inclusive collaboration in such a situation is even possible at all, and that it is almost impossible for the citizens that do participate to represent all different interests of e.g., a community (Brand & Gaffikin, 2007; Irvin & Stansbury, 2004). Elaborating upon this argument, it can be argued that citizens will only take part in a collaborative process if they can spare the time to do so. Research shows that this is often only the case for richer and higher educated citizens, who subsequently are over represented in a collaborative process (Irvin & Stansbury, 2004).

Pelzer (2017) states that it is possible to support planning with the help of computer programs, such as planning support system (PSS). A PSS can be an important aid for a spatial planner when dealing with the complexities of (spatial) planning. Consequently, it is stated that a PSS can help to come towards a better planning solution (Pettit, Bakelmun, Lieske, Glackin, Hargroves, Thomson, Shearer, Dia & Newman, 2018). Hence, many PSS have been developed with the goal of improving spatial planning practice. To be more precise, a PSS can be described as the use of a wide range of (geo)instruments to support planning (Geertman & Stillwell, 2009; Pelzer, Geertman, Van der Heijden & Rouwette (2014); Pelzer, Geertman, & van der Heijden, 2016). Couclelis (2005) further elaborates on the driving forces behind PSS development, stating that PSS are developed by the wish of having a scientifically sound and easy to use tool which can test the outcome of different planning alternatives.

When investigating a PSS in further detail, it is found that it compasses a wide range of tools and an equally wide range of possible definitions (Te Brömmelstroet, 2013). The author comes to a similar definition of PSS as in the previous paragraph. Irrespective of one's exact definition of PSS, most definitions share a similar characteristic: a PSS is being used with the goal of improving planning (Te Brömmelstroet, 2013). Since PSS is aimed at helping the planner, one might expect that PSS is specifically aimed at this group of users. However, this is not the case. A PSS is also developed with the goal of fostering collaboration and participation of the general public and other stakeholders in spatial planning, linking the usage of PSS to the collaborative turn in planning (Pelzer, 2017; Raghothama & Meijer, 2015). This point can be further illustrated with the help of the following quote: *"PSS attempt to merge bottom-up and top-down planning processes by facilitating discussions around scenario-planning that involve the interests of various key stakeholders including city planners, policy makers, experts and communities"* (Pettit et al., 2018, p. 15). Hence, a PSS should be seen as a framework that includes multiple elements. The role of the PSS is to help diagnose the planning problem and subsequently provide a method to resolve this planning problem often with the help of data models (Pettit et al., 2018). The above described participation of multiple stakeholders is important. Their inclusion into the planning process allows for a more democratic planning process and to make sure that the needs of as many as possible stakeholders are met. Lastly, stakeholders are also said to be able to provide planning proposals themselves (Raghothama & Meijer, 2015). It is this framework which makes a PSS differ from planning support. Planning support can take the form of any activity aimed at supporting spatial planning (and can also use tools to support this process not specifically developed for spatial planning), whereas PSS is a way of fulfilling planning support for a specified planning problem with a tool specifically developed for the field of spatial planning (Pelzer et al., 2015).

2.1.2 Planning Support Systems & geo information

From the previous section, one might conclude that PSS is just another form of GIS, using geo-information to provide answers to certain questions. This however, is not the case. The concept of PSS is further discussed in the work of Klosterman (2009), who states that a PSS is not like any other geo tool (e.g. a GIS). Although a PSS does contain many geocomponents, a PSS has got a set of unique capabilities and characteristics which set it aside from the standard GIS application. Hence, a PSS can be described as a set of "*dedicated digital instruments to support planning and policy processes*" (Pelzer, 2017, p. 84). Still, *"The heart of any PSS will undoubtedly be a GIS"* (Klosterman, 2001, p. 15). Subsequently, the goal of a task to be performed in PSS differs from a task executed in a standard GIS application. "*It is this particular goal of supporting informed forward-looking action that differentiates PSS from geographic information systems (GIS) that organize information to support routine management tasks and decision support systems (DSS) that facilitate executive decision making within an organization" (Klosterman 2009, p. v).*

Studies of Geertman & Stillwell (2004) and Pelzer et al., (2015) elaborate upon this difference by discussing it in further detail. They conclude that a PSS is a framework into which multiple elements come together: *"The specification of the planning tasks and problems at hand, including the assembly of data; the system models and methods that inform the planning process through analysis, prediction and prescription; and the transformation of basic data into information which in turn provides the driving force for modelling and design"* (Geertman & Stillwell, 2004, p. 293). Hence, it can be concluded that a GIS is part of a PSS, and the analytical capabilities of a GIS are included. However, a GIS is a more general-purpose system which can be used to solve a wide range of problems which do not have to be specifically related to planning. In contrast, a PSS is intended and designed to support a planning task. Offering analytical functions of GIS, and two more PSS-specific functions: assembling the data and converting data to information (Geertman & Stillwell, 2004; Pelzer et al., 2015).

2.2 Identification of PSS Users

Paragraph 2.1 has provided an introduction into PSS. This paragraph will further elaborate on this topic by identifying different types of PSS users.

"*PSS began as a collection of tools to support 'planning for people' but increasingly they are becoming toolboxes to be used in 'planning with people'*" (Batty, p. vi, 2003).

The quote above provides a first indication with regard to potential PSS users. Although PSS is mainly focussed on aiding spatial planners, this seems to be no longer the sole focus of PSS. The emphasis of many PSS systems is not only to provide solutions for a planning problem, it is often recognized that providing such a solution is difficult and beyond the reach of many PSS systems. However, a PSS is able to communicate planning problems and solutions. Thus, offering support for resolving planning questions (Batty, 2003). This does raise the question who the potential users of PSS are, and who needs to be involved in using PSS, and thus solving the planning problem at hand.

According to Batty (2003) a PSS is a tool which can help anyone with an interest or stake in a potential planning problem, ranging from the professional planner to an everyday citizen with little to no knowledge in the planning field. Taking into account the actual user of PSS is important for measuring any potentially generated added value. Pelzer et al. (2014) further state that, in order to answer the question whether or not added value is generated, it is important to focus on the (possible) users. Pettit et al., (2018) provide a general description of different type of PSS users, stating that they are the key stakeholders in a planning process. A more detailed overview is presented in table 2.1 (below).

Table 2.1: Different types of PSS users based on Vonk, Geertman & Schot (2007), expanded by author.

User Type	
Professional planners	It is argued that a PSS is developed with the goal of supporting a planner. Hence, a main group of users indicated here are spatial planners and they are an important group to include in PSS assessment (Pelzer, Archiniegas, Geertman & Lenferink 2015; Russo, Costabile, Lanzilotti & Pettit, 2015; Russo, Lanzilotti, Costabile & Pettit, 2018; Vonk et al., 2007)
Executives	This group can be identified as politicians and decision makers. It is claimed they make little to no use of PSS (Vonk et al., 2007).
Geo-information experts	This category refers to the GI-specialists who perform tasks with the goal of supporting spatial planning (Vonk et al., 2007).
Citizens and other stakeholders	It is often argued that one of the goals of PSS is to include the general public and other relevant stakeholders in the planning process. For example, Te Brömmelstroet (2013) concludes that a PSS is there to facilitate and realise the inclusion of stakeholders and/or citizens in the planning process. Involvement of the general public is an important trend in the field of spatial planning, especially with regard to the collaborative turn in planning. At the very least, those who are subject to the proposed planning intervention should be included in the planning process. These stakeholders are often able to provide local knowledge of an area and the object of planning. It is believed that this helps to increase the quality of the planning process (Boroushaki & Malczewski, 2010). Professional stakeholders refer to organisations which have an interested in a planning process (Vonk et al., 2007). Examples of such stakeholders are real estate developers (Thomas, 2002).

2.3 Current usage of Planning Support Systems

Previous paragraphs have provided an introduction to PSS and its possible users. This paragraph will elaborate upon the previous paragraphs by discussing the current usage of a PSS. Literature suggests states that many PSS tools are often not used in planning practice. Many planners are said to be careful about using new tools which might aid them in their planning practice. This despite the prospect of this tools being of help in resolving complex planning issues (Geertman, 2006; Russo et al., 2018). Literature provides multiple reasons for this being odd:

- Many PSS are of-the-shelf, meaning that they have surpassed the prototype and experimentation phase (Geertman, 2006).
- Planning tasks are becoming ever more complex, meaning a PSS can be a useful aid (Geertman, 2006).

Te Brömmelstroet (2013) further attempts to report on the added value of PSS, linking back the potential usage and support of a PSS towards the complex process of spatial planning. PSS is expected to be a vital aid for spatial planners. Despite this, most research suggests this is not the case. "*Time and time again PSS scholars find a persistent gap between developed applications and their use in planning practice"* (Te Brömmelstroet, 2013, p. 299). Pelzer et al., (2015) makes a similar claim, stating that many planning agencies and organisations do not (or only in a limited fashion) use a PSS. These claims are not new. Already in 2007, Vonk et al., (2007) found that a PSS is not used in every day planning practice.

Literature identifies multiple bottlenecks which are said to hamper the implementation of a PSS in practice. First of all, potential PSS users and their respective organisations often do not have the right knowledge to adequately apply PSS in their working practice. This due to a lack of skill within their organisation (Pelzer et al., 2015; Pettit et al., 2018; Russo et al., 2018; Vonk et al., 2007). Elaborating upon this claim, Te Brömmelstroet (2013) argues that a PSS is often too complex. Thus, providing a possible explanation for the lack of skills. Thirdly, PSS systems are believed to not meet the required needs of planners and the field of spatial planning. Often, a PSS is too much focussed on technology, rather than aimed at solving a planning question. Thus, this mismatch can be seen as a reason for a lack of usage (Pelzer et al., 2015; Russo et al., 2018; Te Brömmelstroet, 2013). Fourthly, potential users are not sufficiently aware of the existence of PSS, and subsequently do not use PSS in their working routine (Vonk et al., 2007; Pettit et al., 2018). Lastly, it is argued that potential users are not willing to use PSS (Vonk et al., 2008; Pettit et al., 2018). Pettit et al., (2018) elaborates upon these bottlenecks, stating that a PSS also needs to address potential future bottlenecks such as more complex analysis and more visualization techniques helping communication in order to overcome the current lack of adoption.

Most research focussing on the usage of PSS has had the tendency to only focus on PSS (and its related technology) itself, not on the possible added value that it can provide. Hence, the added value possibly generated by a PSS is being seen as self-evident (using PSS automatically leads to a better planning profession) and not often researched (Pelzer et al., 2015; Russo et al., 2018). This has not seemed to change over time. Already in 2006, Geertman (2006) made a similar claim. Thus, in the roughly 10 years between the research of Geertman and Pelzer, there seems to be suggested that little seems to have changed. The following section will further discuss the possible added value of a PSS.

2.4 Added value of Planning Support Systems

Klosterman (2009) states that, although over time many PSS systems have been developed, most of these systems have only seen limited use. Many not surpassing the stage of prototype or being used as a one-time only application. Paragraph 2.3 has already identified the bottlenecks hampering the adaptation of PSS. This section will further investigate the role of added value.

To understand the (non-)usage of PSS it is important to look into the added value PSS can generate. A broad and general description is provided by Pelzer et al. (2016), who state that usage of PSS contributes to a better overall planning process. Pelzer et al. (2014) discuss multiple levels on which added value can occur: the individual level, group level and outcome level. At the individual level, learning is the most important. PSS can help to learn about the object of planning and the effect of the proposed planning interventions. It can help an individual to better understand the view of other stakeholders. In this situation, this is not solely a citizen learning about the opinion of another citizen, but also a planner who might learn about the views of other stakeholders. This is further elaborated upon by Vonk et al., (2007), who state that a PSS is useful and an excellent tool for dealing with complex planning issues. As a consequence, using a PSS should result in added value through better planning outcomes and efficiency gains. Secondly, a PSS provides multiple types of added value on a group level: collaboration and communication (e.g., the exchange of information with and discussion among those involved in the process), consensus and efficiency (PSS usage speeds up the process of planning) (Pelzer et al., 2014). Lastly, PSS can add value at the outcome level. Here, added value occurs at four main aspects which measure the results of a plan: effect, net benefit, external validity and internal validity (does the plan work as it is supposed to?). With the help of PSS, a proposed plan and its expected impact can be tested (Pelzer et al., 2014).

Besides the three beforementioned levels of added value above, added value can also be generalized into the following three different categories identified below (Vonk, 2006; Pelzer et al., 2016; Te Brömmelstroet, 2013):

- Informing. PSS has the goal to provide the user access to information and knowledge that forms part of a planning-related process.
- Communicating. The communicating role of PSS differs from the informing role. Communicating is focussed at promoting communication between the different stakeholders in a planning process, which can be subdivided into internal (within the own organisation) and external (which refers to communicating to stakeholders outside the own organisation).
  The goal of communicating information with the aim of supporting the planning process is further confirmed in research conducted by Geertman & Stillwell (2004), stating that a PSS can be used for this goal, and for fostering participation of citizens and other stakeholders. Communication between stakeholders can be considered one of the most important elements of PSS (Pelzer et al., 2014).
- Analysis and design. Helps to better make use of (spatial) data to support the planning process and thus provide the user with an answer towards a certain question. An example is provided by Pelzer (2015) in the form of analysing the effect of a possible planning intervention or simulating different scenarios (in other words: different proposed planning interventions) over time in order to analyse the impact of each scenario.

Pelzer (2015) goes on to argues that the types of added value generated by PSS usage can be classified into two groups. Firstly, there is added value which results from efficiency and better knowledge that has been generated by PSS. Examples include analytical and communicative tools which might result in knowledge and efficiency gains. Secondly, added value comes in the form of perception. A PSS might raise the perception that one is better equipped to perform the planning task at hand. (Pelzer, 2015).

When comparing the types of added value identified in previous PSS researches, a general overview is presented by Pelzer et al., (2016), which discusses multiple articles that actually try to measure the added value of a PSS in practice. The authors do so with the help of a framework presented in table 2.2 (copied from the work of Pelzer et al. (2016)). As can be seen from table 2.2 multiple benefits can occur from the usage of PSS, ranging from learning about the object of spatial planning, to efficiency gains.

Table 2.2: Possible types of added value generated by the usage of PSS. Table copied from Pelzer et al. (2016)

Added value	**Definition**
Learning about the object	Gaining insight into the nature of the planning object.
Learning about other stakeholders	Gaining insight into the perspective of other stakeholders in planning.
Collaboration	Interaction and cooperation among the stakeholders involved.
Communication	Sharing information and knowledge among the stakeholders involved.
Consensus	Agreement on problems, solutions, knowledge claims and indicators.
Efficiency	The same or more tasks can be conducted with lower investments.
Better informed outcome	A decision or outcome is based on better information and/or a better consideration of the information.

Source: Pelzer et al., (2016)

The different types of added value described in table 2.2 can be found in multiple PSS studies (e.g., Pelzer et al., 2014; Pelzer et al., 2016). Te Brömmelstroet (2013) has paid further attention to assessing the added value of PSS. By using the classification of PSS previously presented in this paragraph (informing PSS, communicating PSS and analysing PSS). Performance of the three different types of PSS is assessed with the help of multiple criteria. When compared to the different types of added value from Pelzer et al., 2016 (as presented above in table 2.2) it can be concluded that, though different terms might be used, assessment is conducted by using generally the same criteria.

To gain a better understanding into possible added value provided by PSS, it is important to look into the usage of a PSS in its intended planning context. This context can help explain why certain types of added value are (ir)relevant in a certain situation (Pelzer et al., 2015). When doing so, two criteria stand out. Firstly, the importance of being able to predict a planning outcome (impact analysis) is stated to be one of the primary driving forces behind added value of PSS (Pelzer et al., 2015), referring back to the header *better informed outcome* of table 2.2. PSS can generate added value by investigating the outcome of possible planning interventions, helping to better understand the impact of a proposed planning intervention (Pelzer et al., 2015).

Secondly, the communicative turn in planning is said to be of importance, which refers to the importance of participation and involvement of others in the planning process. PSS is able to fulfil an important role in these goals. Looking back to the framework presented in table 2.2 it can be argued that the added value generated under the header communication, is thus of great importance. With the help of GI tools included in a PSS the proposed interventions can be visualized, aiding a PSS users' ability to communicate with other stakeholders and better explain a proposed outcome. Couclelis (2005) comes to a similar conclusion, claiming that it are the GIS tools included in a PSS which allow for improved communication and the effects of proposed planning actions.

2.4.1 The importance of communication

Section 2.4 already stated the importance of the communication as a type of added value and function of PSS. The importance of communication is further elaborated upon in the work of Vonk et al., (2007). Though PSS are only in limited use for the exploration of proposed changes, it is believed that it has a large potential in this field. The same goes for informing (through communicating) and consulting stakeholders in the planning process (Wu et al., 2010). Lastly, a PSS can also be used to communicate by simply publishing a plan, allowing the communication and informing of stakeholders of the plan.

Jiang, Huang & Vasek (2003) go on to discuss the role of geovisualisation, stating that it can be used for exploration and collaboration. Hence, it is stated that any good PSS should have a part of the system dedicated to visualization (Brail, 2006). Geo visualisation techniques can be used to communicate planning proposals and ideas. It can be referred to as using cartographic visualisation techniques, while also using principles from GIS and cartography (Jiang et al., 2003). Visualisation is an important tool in fostering communication between stakeholders. Through visualization of GI data, complex issues can be made more easily understandable. With the help of adequate visualization techniques, it is possible to communicate with different types of groups, which all have a different level of knowledge regarding the subject matter. Lastly, it is said that a visual form of communication tends to be perceived as more reliable when compared to e.g., a written document (Langendorf, 2001).

Furthermore, visualization holds the power to change our view regarding a subject (Langendorf, 2001). The GI Component of PSS forms an important part of communication and visualisation. Through the use of GI data planners are offered the possibility to explore, analyse and visualise scenarios, both in 2D and 3D (Langendorf, 2001). Visualisation offers the advantage of being easy to understand for people with different levels of expertise, ranging from everyday citizens to professionals (Wu et al., 2010).

In order to adequately implement participation, communication and exchange of information and ideas with citizens is necessary (Lieske, Mullen & Hamerlinck, 2009). Maps can be used to foster collaboration, but also exploration of a planning scenario. Exploration of a planning topic can be done with the help of multimedia, such as a (3D) geospatial virtual environment. The benefit of creating such an environment is that it allows for the virtual exploration of a proposed spatial planning design. Thus, allowing stakeholders to see how the proposed change will look like in a real-life situation (Jiang, et al., 2003). The evaluation of planning scenarios is seen as a major pro, allowing municipalities and those involved to quickly assess and discuss different options with stakeholders such as planners, experts and policy makers (Pettit et al., 2018).

Multiple roles for geovisualisation can be de distinguished. The first roles are mainly related to the scientific world, whereas the latter are mostly suited for the general public. Firstly, geovisualisation can be used by professionals. Professionals mainly use geovisualisation for visual thinking (exploring possible planning scenarios and their consequent impact). With regard to the general public, geovisualisation is used to present the results of a proposed planning interventions to others. Furthermore, it can be used in the role of citizen participation. Besides citizens, the results can also be presented to other professionals in order to foster further communication and collaboration (Jiang et al., 2003).

2.5 The added value of 3D

The perception of peoples' space and environment can differ among people. Every person has his or her own mental view of reality. This is called an environmental image. Such an image is shaped by the way how people interact with their surroundings but also by their own personal values. As a consequence, it is unlikely for people to have a similar environmental image. This can hamper spatial decision making. Firstly, because people might not know the environmental image of others. In other words, how do other people see their surroundings? Secondly, it might be difficult for them to shed their own environmental image, which is deemed a prerequisite to be able to understand the image of someone else. In order to overcome this problem, it is helpful to create a collective environmental image among stakeholders. Such a collective image would subsequently allow for a fact-based discussion among stakeholders (Devisch, Poplin & Sofronie, 2016).

Currently, collaboration with stakeholders takes the form of presenting 2D maps to those involved (Wu et al., 2010). Visualisation through the usage of 2D maps present drawbacks to a user. "*The map reading process can be* thought *of as reactive, i.e. maps are passive, and readers have to make an effort to understand the map symbols and what they represent"* (Jiang et al., 2003, p. 179). Because of these drawbacks, it has been argued to make use of a 3DCM. Benefits of using a 3D technique are that it allows for more realistic representations of the urban environment, and the possible impact a development might have on the urban environment. As a result, outcomes of e.g., a PSS are said to be more comprehendible when 3D geovisualisation techniques are included. Furthermore, a 3DCM will allow for e.g., the exploration of a proposed spatial planning design. Thus, allowing stakeholders to easily see how the proposed change will look like in a real-life situation, since many stakeholders perceive the built environment as a 3D environment just like real life. It is these types of benefits which are believed to make stakeholders prefer 3D communication (Jiang et al., 2003; Wu et al., 2010).

Multiple techniques can be used to build a 3DCM. Examples of such techniques are the usage of LIDAR data or making use of CAD software (Biljecki, Ledoux & Stoter, 2016; Qing et al., 2009). The actual visualisation of the 3D data is an important part of 3D city modelling for spatial planning. This in contrast to situations in which acquiring the 3D data without visualising it. Hence, only storing a z-coordinate will not suffice (Biljecki, Stoter, Ledoux, Zlatanova & Cöltekin, 2015). Here, it is important to note that multiple views to what actually is 3D exist. Some maps and models do not offer a 'true' 3D representation but offer 2.5D. To be more precise, a 2.5D representation is a 2D map with the inclusion of z-coordinates of the boundary of the represented object. However, any variation in the z-coordinate within the object is not shown. Subsequently, a 2.5D only shows the outline of an object and is only able to visualize simple forms and objects. Hence, it is argued that a full 3D model of an object is needed (De Cambray, 1993; Qing et al., 2009). Furthermore, 3D models can be made for non-human (e.g., trees) and human-made objects (such as houses, roads, etc). Presenting a 3DCM can more precisely be defined as "*a representation of an urban environment with a three-dimensional geometry of common urban objects and structures, with buildings as the most prominent feature*" (Biljecki et al., 2015, p. 2843). Thus, a 3DCM focusses mainly on the human made objects (De Cambray, 1993; Qing et al., 2009; Stoter, Vosselman, Goos, Zlatanova, Verbree, Klooster & Reuvers, 2011).

When studying the development of 3DCM in further detail, it is found that many 3DCM are being developed according to the CityGML standard. This standard offers a method for describing objects in a 3DCM (Arroyo Ohori, Biljecki, Kumar, Ledoux & Stoter, 2018). When building such a 3D environment, multiple levels of detail (LOD) for the 3D model can be defined. One can choose to make a very detailed representation of a city, and thus include a high level of details in a 3DCM. Likewise, it is also possible to make a low-level model. Subsequently, the higher the level of detail, the higher the potential usage of a 3DCM e.g., allowing for more accurate analysis results (Arroyo Ohori et al., 2018; Biljecki et al., 2016). The chosen LOD level is often related to the goal of the to be developed application. A more detailed model is most often costlier to develop and might also not always be needed to meet the stated goal of the 3DCM (Biljecki et al., 2016). Generally speaking, 3DCMs of cities have become more detailed over time. This is partly so because of a growth on the demand side (e.g., the rise of smart cities has resulted in an increasing demand and potential usages of a 3DCM (Arroyo Ohori et al., 2018)). However, as mentioned above, there is no one-size fit all LOD level. The different LOD-levels can be seen in figure 2.1 (next page).

Figure 2.1: Different LOD levels as described by Biljecki et al., (2016)

Source: Biljecki et al., (2016)

Literature further discusses the potential added value of 3D, claiming that its usage has multiple benefits with regard to collaboration. Firstly, the usage of 3D, in comparison to 'normal' 2D maps, is believed to allow stakeholders to better understand any proposed changes and its subsequent (spatial) impact. This due to the fact that a 3D visualized environment, due to its higher level of interactivity, allows for better exploration of any proposed change (e.g., by visualizing the proposed planning intervention). Consequently, helping stakeholders to to learn about the topic (Biljecki et al., 2015; Hu, Lv, Wu, Janowicx, Zhao & Yu, 2015; Jiang et al., 2003; Santosaa, Ikaruga & Kobayashi, 2016; Trubka et al., 2016; Yin, 2010). Secondly, a 3DCM provides the possibility of analyzing a proposed planning intervention and the effects of the proposed intervention in relation to the urban environment (Biljecki et al., 2015; Nouvel, Zirak, Dastageeri, Coors & Eicker, 2014). Thirdly, 3DCM can help in informing stakeholders. The sole use of 3D visualisation can help in consulting stakeholders and informing about proposed changes. This without performing a spatial analysis, but by simply displaying and communicating a proposed planning intervention (Biljecki et al., 2015).

A fourth benefit is found for communication. Santosaa et al., (2016) emphasize the importance of communication in the planning process, which they believe will result in better planning outcomes. As discussed in paragraph 2.4.1, communication is an important aspect of PSS (Pelzer et al., 2014). Hence, it is important to have access to the necessary tools that allow for effective and easy to understand communication between planning agencies and stakeholders involved. Subsequently, proper use of (3D) geovisualisation techniques can be an important tool for good communication between different stakeholders. Especially the possibilities offered by 3D are said to enhance communication and participation (Jiang et al., 2003; Santosaa et al., 2016). In a discussion of the CommunityViz PSS, which includes the option of 3D scenario visualization (specifically with regard to the built environment), it is found that being able to use 3D visualization has allowed it to better communicate with stakeholders. This communication tended to be more objective and consequently helped to shape better and more balanced opinions. Mainly so because 3D allowed to separate fact from fiction. Information such as building heights can be presented in a more objective manner. In contrast, a 2D map representing building heights might leave room for multiple interpretations leaving room for different environmental images among stakeholders (Pettit et al., 2018). Hence, it can be concluded that the inclusion 3D might provide an improvement of the communicative aspect of PSS.

Over time, 3D is said to have advanced, and as a result, more types of applications and added value of a 3DCM can occur besides communication (Biljecki et al., 2015). Billen (2013) goes on to argue that the inclusion of 3D does not only generate added value for the communicative aspect, inclusion of the third dimension allows for increased possibilities for spatial analysis regarding the built environment. Furthermore, the impact of proposed spatial developments can be visualized through e.g., augmented reality. Not only does the inclusion of 3D data allows for new types of analysis, it can also help to improve analysis which can also be done in 2D. For example, noise propagation in an urban environment can be more accurately analyzed with the help of 3D data (Biljecki et al., 2015). Some studies have already been conducted with the aim of testing the effects of a 3DCM. Research conducted towards the possible application of 3D visualization in the City of Dublin (Ireland) has revealed multiple types of added value which would result from the creation of such a model. Furthermore, the authors have conducted a cost-benefit analysis of the proposed 3DCM. It is stated that such a model would have a significant positive effect (with a benefit to cost ratio of 2.1:1) and would also generate the following benefits (European Spatial Data Research, 2017):

- The application of a 3DCM would allow to make more individual planning regulations and adapt these regulations more easily to the local context (European Spatial Data Research, 2017).
- The development of a 3DCM allows for increased citizen participation. The authors state that a 3DCM is easier to understand. Results are clearer, subsequently resulting in less debate about the outcome of a proposed planning intervention (European Spatial Data Research, 2017).
- Making use of a 3DCM would allow municipalities and other users to conduct more advanced analysis, helping to resolve difficult planning questions. As a consequence, the cost and time involved in answering these difficult questions will be reduced (European Spatial Data Research, 2017).

Despite being argued that 3D offers numerous advantages, it is found that 3D has not yet gained a firm foothold in the field of spatial planning. The use of 3D GI information is limited. Numerous reasons are cited. Firstly, the lack of proper GIS software capable of dealing with 3D (Yin, 2010). Secondly, it is believed that many users will access a 3D model through the web. Because of this there needs to be made sure that the model is supported by the devices of potential users and will need to have fast enough loading times for the model to be useful for potential users (Alatalo, Koskela, Pouke, Alavesa & Ojala, 2016). Besides, there are the high costs involved and the required skills necessary to use and construct 3D models (Qing et al., 2009; Yin, 2010). Though in recent years major steps have been made in automatically constructing a 3DCM, this is still a time consuming and labour intensive process (Nouvel et al., 2014; Qing et al., 2009). Thus, providing a possible stumbling block for the creation of a 3DCM.

2.6 Towards a research question

The previous paragraphs have given an overview of the already existent literature regarding the topic. Combined with the relevance discussed in the introduction, this section will formulate the research questions for the remainder of the research.

The foregoing literature review has shown that PSS is currently not as widely used as one might expect and a number of reasons have been introduced why this is the case. However, the literature review has also shown that 3D might provide additional added value with regard to stakeholder participation in the framework of collaborative spatial planning. Hence, the main research question is as follows:

What is the expected versus the experienced added value of a 3-dimensional versus a 2-dimensional city model for stakeholder participation in the framework of collaborative spatial planning?

The scope of the research question is twofold. Firstly, attention will be paid towards the promised added value by the academic world and providers and/or users of PSS of a 3-dimensional city model, this to identify the expected added value of PSS in general and the potential usage of 3D. The foregoing literature review already made a first start for this. For the further research, added value will be defined as follows: '*a positive improvement of planning practice, in comparison to a situation in which a 2D PSS is applied*' (Pelzer et al. 2014, p. 16). It is important to stress that, in the context of this research, a 3DCM is seen as a form of PSS. Thus, in this situation, the added value of PSS is further narrowed down by focussing on added value specifically generated when using 3D). Besides, the scope of this research is as such that there will be focussed on the added value as experienced by stakeholders in the planning process. To determine whether or not this positive improvement does occur, a framework to test this will be developed in the methodology section in chapter 3, helping to measure the added value on the basis of a number of criteria. Thus, this will allow for the testing of the actually experienced added value, which will be done with the help of interviews. This will be discussed in more detail in the methodology section in chapter 3.

In order to answer the main research question, multiple subquestions have been formulated. These subquestions can be considered the stepping stones which eventually will allow for answering the main research question. The subquestions have been formulated as follows:

-Subquestion 1: What is the importance of stakeholder collaboration in collaborative spatial planning?

-Subquestion 2: What is the experienced added value of a 2-dimensional city model

-Subquestion 3: What is the to be expected added value of creating a 3-dimensional city model?

-Subquestion 4: What is the experienced added value of creating a 3-dimensional city model?

2.6.1 Societal and scientific relevance

The literature review has addressed multiple reasons why current adaptation is less than optimal This research aims to investigate if these shortcomings can be overcome by helping to identify the experienced benefits (added value) of using a 3DCM. With the help of this research, future PSS can potentially better address these shortcomings. Thus, helping to increase the added value generated by PSS.

Many current PSS research currently provide case studies. Where many articles do stress the importance of added value in PSS, research in this field tends to be lacking and mostly conducted in a non-systematic manner. Despite this shortfall, it should be noted that more and more authors recognize the need to do so (Pelzer, 2017). Hence, this research hopes to fill this gap. Secondly, many studies focussing on the added value of a PSS conducts experiments with students. Results gathered among students might not be representative for the real world (Pelzer et al., 2016). To address this shortcoming this study will only contact real world users.

Lastly, current research into 3DCM usage is limited. Looking at the research which has been conducted up until now, Biljecki et al. (2015) point out that only little attention has been paid towards the usage of 3D or a 3DCM. Hence, the output of this research can hopefully be used to make recommendations for improving the added value of a PSS by looking to a 3DCM model as a possible way of improvement. Hopefully increasing the usage of PSS to make for a more efficient and better planning process.

2.6.3 Research Limitations

This research is being conducted as the master thesis for the GIMA program and has a limited time scope, imposing limits on the scope of the thesis. Secondly, this research focusses on PSS (and its subsequent usage of 3DCM) usage by planning and GI professionals. Hence, no attention will be paid to the possible usage by citizens. Not including citizens is a deliberate choice. At the moment of writing this thesis, many 3DCM models have only recently been completed, or are still in the development or testing phase. Subsequently, many of these models have not been used by citizens as of yet, making it difficult to include these groups in the research. Lastly, since many 3DCM are still being developed or have not been fully implemented as of yet, it is expected that their content and capabilities might change over time. Hence, the same research carried out again ten years from now might yield different results. Therefore, care needs to be taken in generalizing and the results of this thesis, since they may not be fully replicable.

3. Methodology

This chapter provides an overview of the selected methods used to carry out the research. The type of research to be carried and a framework for analysis are being discussed. The proposed framework is based on literature and provides a first indication of the to be expected results according to literature review. Furthermore, it will allow for a structured and objective analysis of results. The following section will firstly discuss the chosen research methods.

3.1 Chosen research methods

3.1.1 Qualitative Research

Pelzer et al. (2016) provide a general overview of best practice research methods for PSS. Often used methods include the use of questionnaires and interviews (Pelzer et al., 2016; Russo et al., 2015). This thesis will use similar methods; hence a qualitative research has been chosen. Boeije, 't Hart & Hox (2009) provide a definition of qualitative research, stating that the goal is to understand behaviour and experiences of the target group. These goals match the stated goal of this research.

For this research the target group is the GI and planning profession, and the behavioural aspect which is aimed to understand is the (possibly) experienced added value of using a 3DCM model for stakeholder participation in collaborative spatial planning. Citizens have not been included in this research. Many 3DCMs are still in development or have only recently been completed. As a consequence, many organisations that make use of such models have not used these together with citizens at the time this research is conducted. Thus, making it impossible to include the expectations and experiences of citizens.

3.1.2 Interviews

This thesis will focus on the usage of interviews. Experts and stakeholders on the subject of PSS and 3DCM will be interviewed. In order to obtain the needed information, a semi-structured interview technique will be used. A semi-structured interview technique allows for flexibility during the interview regarding the content and order of the questions, the order in which the questions are asked and hence the possible answers an interviewee can provide. Subsequently, subjects and questions which might not have been perceived before starting the interview can be addressed, while the interviewer maintains in overall control of the interview (Boeije et al., 2009). Interviewing is a suitable technique for exploring the topic of added value, which is often a subjective perception of those involved. Hence, other techniques with a more spatial and/or statistical approach might prove to be unsuitable for evaluating such a subjective topic (Dunn, 2010). With the help of interviewing candidates who are familiar with 3DCM, PSS and an interest in collaborative spatial planning, there is aimed to answer the research questions.

Since a semi-structured interview technique will be used, an interview guide will be used to make sure that every subject is covered during the course of an interview. This guide can be described as a list with a general description of the to be covered topics. This list will help to make sure that all topics are discussed. However, this list is not a list of predefined questions, but an aide-mémoire for the interviewer, allowing for flexibility during the interview. (Dunn, 2010). The interview guide used during this research, can be found in appendix 1.

All interviews have been conducted during the spring of 2019. Lastly, a Dutch province also provided a live demonstration of their 3DCM during an interview, helping the author of this research to gain a better understanding of how such a tool works in practice.

3.1.3 Selection of interviewee candidates

Identifying possible candidates has been a recurrent process (e.g., a possible interview candidate might suggest another candidate for interviewing). In order to make sure that relevant potential interviewee candidates with adequate knowledge about the topic were contacted, a number of criteria have been formulated of which each respondent and his/her employer should meet as many as possible:

- The contact or his/her employer is familiar with PSS
- The interviewee contact not only has relevant experience in the field of planning but is also familiar with 3DCM.
- The contact meets one of the four different user types identified in table 2.1. However, one exception does exist with regard to the above candidate criteria. As previously stated, many 3DCMS are not yet being used for citizen participation. Hence, it is not yet possible to include citizens and their views into this research.

The above criteria are of importance. Any results obtained with contacts and organisations which do not them might provide an inaccurate picture. Hence, all contacts included in this research either work with some form of PSS or 3DCM or have done so recently.

There has been established contact with Dutch municipalities and other levels of government to investigate the usage of 3DCM in practice. Within these organisations, as many different user types as possible have been interviewed in order to get a good and comparable picture of the added value a certain tool or 3DCM provides for different user categories. However, it sometimes proved to be impossible to interview multiple persons within the same organisation because a 3DCM in some organisations was still in its infancy or because of the reluctance for some candidates to participate in the research.

Table 3.1 (next page) provides an overview of the persons who have agreed to participate in this research. Indicated are their organisation/employer and also their role within the organisation. In total, 12 persons among 5 different organisations have been interviewed. To safeguard the privacy of the interviewees, the name of each interviewee has been replaced by a number (these numbers will be used as a reference in the result chapter), and their job title has been generalized. The full name and job title of each interviewee are known to the author.

Table 3.1: Interviewed contacts

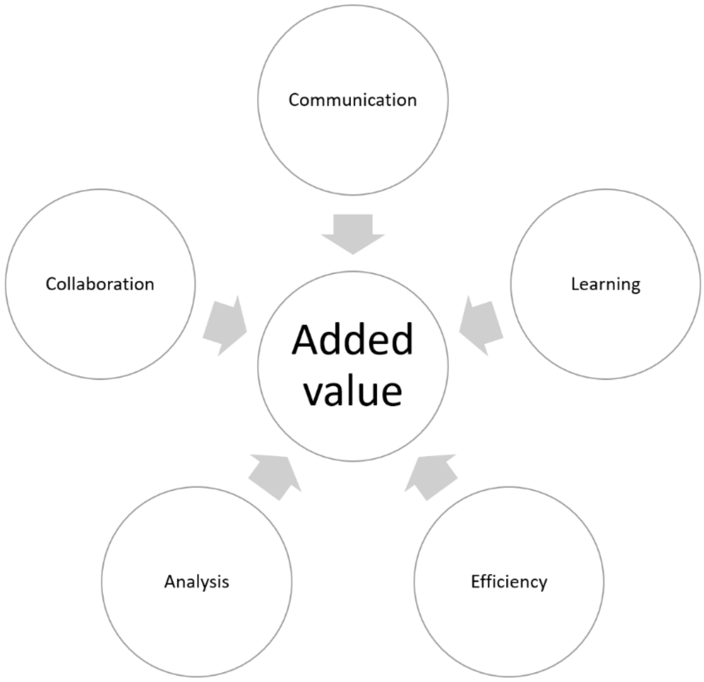
Interviewee candidate	Role	Presence of PSS and/or 3D within the organization/company
Municipality of Rotterdam		
Interviewee 1	Urban planner	The Municipality of Rotterdam has developed a 3D digital twin of the entire city (Municipality of Rotterdam, 2018).
Interviewee 2	Project member smart city	
Municipality of The Hague		
Interviewee 3	Project member 3D	The Municipality of The Hague is currently in the process of developing a 3DCM the entire city (Geonovum, n.d.).
Interviewee 4	Urban designer & policy advisor	
Municipality of Almere		
Interviewee 5	GI expert	The Municipality of Almere is currently conducting a 3D pilot by making a 3DCM of two neighbourhoods. Furthermore, Almere currently makes use of a 2D PSS maptable.
Municipality of Nijmegen		
Interviewee 6	GI expert	The Municipality of Nijmegen has previously conducted a pilot by developing a small 3DCM. Furthermore, Nijmegen currently makes use of a 2D PSS maptable.
Province of Utrecht		
Interviewee 7	GI advisor	The Province of Utrecht currently makes use of Tygron Engine, a 3D planning support tool. Furthermore, it has also made use of 2D maptable software specifically aimed at planning support
Interviewee 8	Tygron Engine	
Interviewee 9	Senior advisor physical living environment	
Interviewee 10	Policy officer	
Interviewee 11	Policy officer	
Imagem		
Interviewee 12	GI advisor	Imagem provides software which enables the creation of 3D digital twin city models

3.2 Analysis Framework

In order to analyse the interview results and prepare interview topic lists, an assessment framework has been developed to judge the added value of a 3DCM within the framework of collaborative spatial planning. The framework will help to formulate criteria on which different perceptions regarding the usage of a 3DCM can be described and measured in a unilateral way, thus helping to establish criteria on which results can be compared. These criteria are formulated based on the conducted literature review and are thus expectations of possible influences on, and experiences of, added value. The framework will be used as a guideline during the further research.

As discussed in the literature review, the role of communication seems to play an important part in the experience of added value. However, the framework does not only focus on the communicative aspect. This because literature also revealed other possible aspects of added value. As a consequence, these will be taken into account as well. For example, 3D is also said to provide opportunities in the field of analysis (Billen, 2013). Hence, attention will also be paid to this field of added value. An overview of the types of added value selected from the literature review is presented in figure 3.1.

Figure 3.1: selected types of added value



In table 3.2 (next page) the detailed framework is presented, which is based on the selected criteria. Each criterion is explained in further detail. This framework is based on the types of added value indicated by Pelzer et al., (2016) which has previously been discussed in the literature review. However, it has been adjusted where necessary to better fit the needs of this research. In order to make sure that formulated criteria are measurable and can be included in the results, the criteria are also included in the formulated topic list, which can be found in appendix 1.

Table 3.2: Framework assessment criteria (framework is based on Pelzer et al., 2016 and is adjusted by the author)

Criterium	**Justification**
Communication	PSS can be used to communicate (Vonk et al., 2007), both between stakeholders and planners (referred to as external communication) and between planners (referred to as internal communication) (Geertman & Stillwell, 2004; Pelzer at al., 2014). A more precise define of communication is: *“sharing information and knowledge among stakeholders involved”* (Pelzer et all., 2016, p. 26). 3D information helps to share information in a manner close to reality and therefore possibly help to communicate this information a similar environmental image to all those involved (Jiang et al., 2003; Wu et al., 2010). Hence, this criterium will look if the usage of 3DCM can help in communication within the process of collaborative spatial planning, for both external and internal communication.
Learning	Learning is perceived to be a type of added value. A PSS is able to facilitate two types of learning (Pelzer et al., 2016): • Learning about the object of planning (Pelzer et al., 2016). 3D objects are said to be more easily comprehendible (Jiang et al., 2003; Wu et al., 2010) and thus can facilitate in the learning process of the object of spatial planning • Learning about the views of other stakeholders involved in the planning process (Pelzer et al., 2014; Pelzer et al., 2016).
Efficiency	Efficiency will be defined as: *“The same or more tasks can be conducted with lower investments”* (Pelzer et al., 2016, p. 26). Thus, this criterium will study if a planning process conducted with the help of a 3DCM results in a shorter amount of time being necessary to conduct the process, and less money spend on the process of planning (Pelzer et al., 2014).
Analysis	Analytical capabilities form part of a PSS (Geertman & Stillwell, 2004). Usage of 3DCM is said to allow for new and enhanced spatial analysis capabilities. An example of such a new analytical capability is the study of noise propagation (Billen, 2013; Biljecki et al., 2015; Santosaa et al, 2016). Furthermore, usage of a 3DCM is said to allow for analysing a proposed planning intervention by taking into account the urban environment (Biljecki et al., 2015; Nouvel et al., 2014).
Collaboration	Collaboration will be defined as: “*Interaction and cooperation among the stakeholders involved*” (Pelzer et al., 2016, p. 26). Proper use of (3D) geovisualisation techniques can be an important tool for good collaboration between different stakeholders. Especially the possibilities offered by 3D are said to enhance collaboration. The 3D virtual environment is partly responsible for doing so, because a 3D environment is said to allow for a high level of interactivity (Jiang et al., 2003). This can help collaboration by providing new forms of interaction among stakeholders.

Most criteria have been selected from the work of Pelzer et al., (2016), who has developed a framework for measuring added value provided by a PSS. However, this framework has been customized to better suit the needs of this research. Subsequently, it has been chosen to also include analysis as a criterion. Though not included in the original framework, the literature review has shown that analysis capabilities are an important part of PSS (Pelzer, 2015) and that usage of a 3DCM will most likely result in new and improved analysis capabilities (Nouvel et al., 2014).

3.2.2 Interview Analysis

The to be conducted interviews will provide the necessary data for completing this research. The interviews will be analysed according to the developed framework as can be found in table 3.2. With the help of this framework, added value of PSS and its subsequent 3DCMs can be assessed. The framework further helps to analyse all interviews in a similar manner.

In order to successfully Interviews will be analysed with the help of Nvivo software, which is accessible through Utrecht University. Nvivo helps in the search for patterns and relations in interview data by coding the interview data (Dunn, 2010). The coding scheme uses the same criteria as listed in table 3.2.

3.3 Ethics

Interview contacts have been asked about their personal and professional opinion regarding the interview topics. Hence, some answers might represent a person's own opinion instead of the opinion of the relevant organization. In order to prevent any unintended blowback to the interviewees, or interviewees providing so-called desirable answers because out of fear for such blowbacks, multiple precautions have been taken. Therefore, importance has to be placed on ethical issues that might arise from this research (Russo et al., 2015).

Before starting the interview, all the interviewee candidates have been asked for permission to record the interview and have been informed for which goal the interviews were recorded. Secondly, the name of each respondents has been anonymized (as discussed in section 3.1.3), providing a level of privacy protection (all interview contacts are known to the author). Lastly, all the respondents have been offered to acquire a copy of the transcript and the full results of this research.

4. Results

This section will discuss the results in a step by step manner with their order based on the different assessment criteria of added value listed in table 3.2: communication, learning, efficiency, analysis and collaboration. During the course of the interview, it has been made sure that all of these criteria have been addressed during the interviews. Results will be discussed according to these criteria in order to answer the research questions in a structured manner. With regard to all criteria, there will first be discussed the experienced added value of 2D, subsequently the expected and experienced added value of 3D are discussed. References to interviewees are made by indicating the interviewee number (as provided in table 3.1) between brackets. To conclude, this chapter presents a summarized overview of the results which can be found in table 4.1 (page 38-39).

4.1 Communication

4.1.1 Communication: the experienced added value of 2D

Results for the experienced added value of a 2D system yielded multiple views. Municipalities which have experience in using the 2D communication tool, by using a 2D map table to inform their stakeholders, value the communicative aspect the tool offers. Not only does it help in informing stakeholders about e.g., a planning proposal, but also in sharing information with external stakeholders when discussing the proposed plan [5]. An interviewee who has experience in working both with 2D and 3D tools clearly illustrates these benefits, with the interviewee, stating that the PSS allows them to easily communicate why a certain decision has been made and on which facts and legal regulations this decision has been made [10].

Though the previous section might suggest a positive image of using 2D for the communicative aspect, results do show notable drawbacks. Firstly, 2D maps and visualisation are experienced as complex for non-professionals to understand since important details might be either missing or misunderstood by stakeholders. Hence, it sometimes proves difficult to share information in an understandable format with external stakeholders to adequately understand what is going on [2, 3, 6, 7, 9]. An example of such a situation is that a proposed building development in 2D might lack important details of which stakeholders are not informed. In 2D a proposed development shows no detail of e.g., the final aesthetic quality or building height (instead, it is represented as a simple 2D square on the map). Thus, stakeholders are not presented with all information. Consequently, this makes it very difficult to objectively discuss a proposed development since different stakeholders might have a different or incomplete environmental image because they have not been provided with all necessary information [3].

Furthermore, results suggest that even for expert professional stakeholders such as urban and spatial planners, a development proposed in 2D might be difficult to understand due to the simplifications of a 2D model. One interviewee states he experiences that 2D models which are easy to understand for an expert in urban design are often difficult to understand for an urban planner due to a different level of expertise between the two types of stakeholders [1]. Furthermore, rules and regulations which are presented might be unclear (with not all information presented on a map and a difficult to understand appendix being necessary for interpreting all rules and regulations), open to multiple interpretations or completely missing. Many important details are often included in an appendix, which interviewees experiences to contain difficult to understand technical terms [1,2]. Subsequently, stakeholders often do not fully understand the information provided, with different types stakeholders perceiving the provided information differently [2]. One interviewee has experienced that some stakeholders take advantage of such unclarity: a proposed building development might not show its full impact on a 2D tool due to a lack detail, conceiving stakeholders in giving their permission [2].

Despite the different advantages and disadvantages listed above, results also state that a 3DCM will become a necessity for communication with stakeholders in the planning process and that 2D will no longer suffice. Some interviewees state that many stakeholders are influenced by developments outside the realm of GI and spatial planning, and e.g., use tools like Google Maps and Google Streetview in their everyday life. Subsequently, it is expected from the government that they will use a similar instrument [2, 6], with one interviewee stating the following:

> "What I consider to be a relevant example is a recently organised townhall meeting for a development plan which was to be realized in our municipality. In the area in which the plan was to be carried out happened to live a few architects. In their own time, they created a 3DCM of the area (…). So, we had this meeting. On one side of the room stood the municipality with [2D] zoning plans and regulations. On the other side of the room stood the architects with their 3DCM. You can guess on which side of the room people were standing" [2].

4.1.2 Communication: the expected added value of 3D

This section will focus on the expected added value of 3D with regard to the communicative aspect. Firstly, 3D is expected to allow to communicate in a common language which is understood by all stakeholders [2, 3, 4]. Thus, it is here where a 3DCM is expected to provide a major advantage. 3D can be described as a common tongue that is expected to be understood by stakeholders with different levels of expertise in the field of GI and spatial planning and different cultural backgrounds. For example, reading a 2D map might be difficult for non-Dutch speakers due to the legend being in Dutch. Especially in communication with citizens and non-expert stakeholders this can be a large advantage, making it easier to inform them about a proposed development [2, 6].

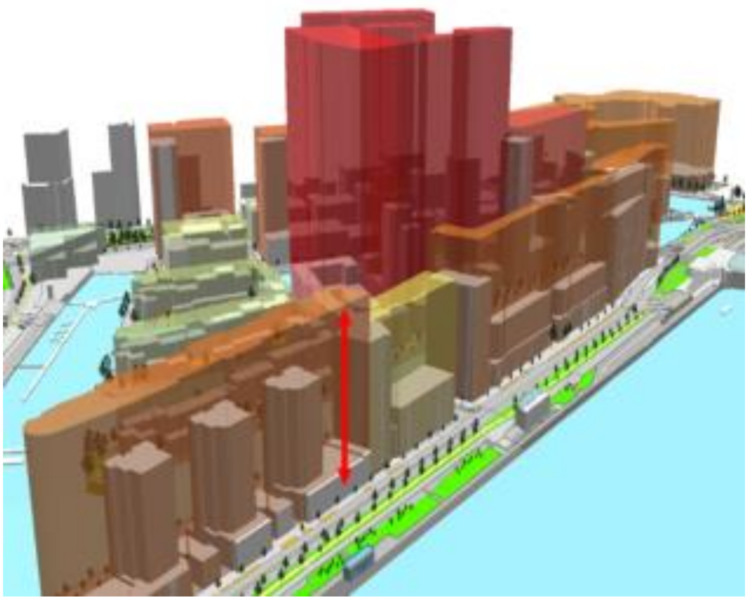
Secondly, in a 3DCM objects are expected to be recognized easier. People are able to recognize stores, buildings etc. because stakeholders are able to visually orientate themselves by using real world landmarks. It is believed this will help stakeholders to better locate the object in a 3DCM, subsequently helping them to better understand and share information and knowledge about the object [5, 10]. Other interviewees elaborate upon this claim, expecting the output of a 3DCM to be comparable to an easy-to-understand SimCity like model [3, 4]. Secondly, interviewees provide an example of building height, expecting the height of a building to be clearly understandable for all stakeholders when presented in a 3DCM, creating a similar environmental image among stakeholders [3, 5].

4.1.3 Communication: the experienced added value of 3D

First experiences in the usage of a 3DCM show mixed results. Firstly, usage of a 3DCM results in improved communication with stakeholders. Whereas some stakeholders consider a map reading process to be difficult, it is experienced that the recognizability of e.g., landmarks and the physical environment in a 3DCM helps to overcome these problems [3, 12]. A possible proposed development can be shown in its real-world physical surroundings with the help of a 3DCM, providing stakeholders with a better understanding and a more complete picture of a possible new development [1, 3, 12]. However, for this to be successful it is important for a 3DCM to have sufficient level of detail and completion. A sole 3D representation of one or only a few buildings will often not be enough, with many stakeholders still experiencing difficulty to grasp the output of the model [1].

Many interviewee candidates further elaborate upon the above by providing examples for these claims in the form of building height. When discussing the building height of a proposed development 2D might pose a problem. Various stakeholders might conceive the proposed height differently, each forming a different mental image of the communicated information. In 3D, the actual height of a proposed development can be easily represented, proving stakeholders with better information and understanding of the impact of the proposed development [1, 3, 7, 11]. An example in real world practice is a city council which was first presented a 2D map of a proposed high-rise development, with the council giving their approval for further development. After subsequently seeing the approved development as a 3DCM, many council members were said to be shocked about the actual height of the approved construction, having misunderstood the information when presented in 2D and only realizing the actual height while seeing the development as part of a 3DCM [2], stating that: "*The city council was completely flabbergasted when first looking upon this image. They had the feeling: no, did we make this possible? Yes, city council, you made this possible. However, there actually is a relatively easy explanation, since the city council consists mostly of non-experts*" [2]. Figure 4.1 provides an illustration how the inclusion of the building height of a proposed new development in a 3DMC looks like.

Figure 4.1: Building height of a proposed new development (illustrated by the red and orange squares) in comparison to the building height of the current built environment.



Source: Municipality of Rotterdam, (n.d.)

Furthermore, interviewees experience the usage of presenting different 3D scenarios to stakeholders as positive [3, 4, 7]. By constructing scenarios, stakeholders can quickly glance over multiple scenarios in detail. Here the improved visualisation of 3D allows for easier understanding and spotting of potential differences. For example, a 6-story development with a nice façade might have a completely different impact than a 6-story development without a nice façade. Such details can immediately be shown in the 3DCM, without the need for additional tools, allowing for easier communication among stakeholders because everyone sees the same picture and does not have to translate a 2D image to a 3D image themselves. [1, 3, 4, 12] Thus, by using scenarios it is possible to communicate a large amount of information (in an understandable format) of possible courses of development to stakeholders in a short amount of time [3, 4, 7].

The chosen LOD-level is experienced as important for the effectiveness of a 3DCM. However, results show contradicting opinions. Some interviewees state that a low LOD-level is to basic and will provide little added value for the communicative aspect [6, 12]. First experiences showing that even expert stakeholders within a municipal organisation finding it difficult to orientate themselves in a low detail model [3]. In contrast, other interviewees disagree. Believing that too much detail in itself can also be dangerous and that the actual challenge is to develop a model with a sufficient LOD-level to inform stakeholders, without including a higher LOD-level than necessary [1, 7]. With the required LOD-level often depending on the group of stakeholders with which is tried to communicate (e.g., non-expert stakeholders are likely to require a higher LOD-level in comparison to expert stakeholders) [1, 6, 9]. If the wrong level is chosen, one runs the risk of having a discussion with stakeholders about the model (what do we actually see?) instead of the to be discussed topic [7, 9].

However, interviewees do not only see added value in using 3D. Some drawbacks were also raised. Firstly, when including a potential development in a 3DCM, the increased detail and inclusion of the plan in the 3DCM might arouse the impression among stakeholders that a decision has already been made. Thus, where the goal is to share information with stakeholders, stakeholders might still interpret this information wrong [1].

Secondly, interviewees experience it sometimes to be difficult to share information in a 3D format. In certain instances, current rules and regulations still require a 2D format for final decision making, limiting the usability of 3D. This can be illustrated by the establishing of a zoning plan within a municipality. Currently, such a plan still needs to be stablished in 2D, making it impossible to share information in a 3D format [2, 11].

4.2 Learning

This section will discuss the results with regard to learning as an added value. Firstly, the results will be discussed for the experiences with 2D. Secondly, expectations and experiences will be discussed for a 3DCM. For all categories, learning has been split-up into two types of learning: learning about the object of planning and learning about other stakeholders.

4.2.1 Learning: the experienced added value of 2D

Numerous experiences have come forward with regard to the usage of 2D tools. Firstly, results show 2D is used to make for an easy and better-informed dialogue [11]. With the help of GI data, interviewees state they are better able to guide a dialogue by making a 2D representation of the current situation. The 2D representation of objects makes it easier for stakeholders to understand the objects that are being discussed, since stakeholders are able to place the location of a proposed development on the map. Consequently, a 2D can also be used to present stakeholders a proposed future situation, by integrating proposed changes and objects in the model. Doing so is considered a major upgrade, with stakeholders stating they better understand a proposal. Previously, interviewees state they used to work with sketches that were difficult to understand. Inclusion of the proposed change in a 2D model presented in e.g., a maptable is experienced as a step forward since stakeholders better understand the proposed change [5].

Besides learning about the object of planning, interviewees also state that a 2D tool helps stakeholders to learn from one another [5, 6]. Here, one interviewee provides the example of the redevelopment of a playground in a municipality, stating they have altered the proposed development after stakeholders learned the details of the proposed development. Stakeholder proposed changes were subsequently included in the plan by the urban planners. During this meeting stakeholders were optimistic of the usage of a 2D tool [5].

However, results also show interviewees experiencing limitations when using a 2D model. 2D models are often complex and objects lack detail, making it difficult for expert and non-expert stakeholders to correctly understand the object of planning [2, 7, 9]. This lack of detail has resulted in different stakeholders formulating different environmental images of an object [2]. For example, interviewees state that building height of an object is perceived differently in stakeholders' minds. Consequently, all stakeholders form a different environmental image of the building height. These images may differ from reality [2, 3, 4]. Secondly, many non GI experts often have trouble in reading a map and understanding its information [3] and consequently having trouble orientating themselves on a 2D map [5]

4.2.2 Learning: the expected added value of 3D

This section will focus on the expected added value of 3D. Firstly, interviewees expect improved learning of the object of planning, since they believe a 3D representation makes it easier to recognize objects. Here, it is expected that a higher LOD-level is of help with one interviewee stating:

"*the more you schematize [objects] the lower the recognizability of the objects*" [6]. Without this higher LOD-level, it is expected that objects are still difficult to understand for stakeholders (this despite the object being in 3D) [5]. A high LOD-level is expected help stakeholders to easily recognize and understand objects [5].

Secondly, learning about others has only been mentioned in a limited fashion by interviewees. It is expected 3D brings better understanding of other stakeholders' opinions. However, it should be mentioned that the interviewee partly considers this a consequence of the object being presented in 3D. A 3D object is expected to be easier to talk about. The interviewee believes this will result in stakeholders being better able to share opinion and learn about the opinions of other stakeholders [6].

4.2.3 Learning: the experienced added value of 3D

Learning as an experienced added value of 3D has only been mentioned in a limited fashion by interviewees. Firstly, results show positive experiences regarding learning about the object of planning. Looking back among the example provided by interviewees, one stands out. With a city council being surprised by the actual approved building height when visualized in 3D, not realizing this height when first proposed in a 2D format [2]. Here, 3D clearly helps to learn about the object. Other interviewees have also provided the example of building height to explain that 3D has helped stakeholders to better learn about the object. Consequently, a shadow cast by a potential new building Is immediately understandable by stakeholders [7, 12]. With one interviewee describing 3D as a *lingua franca* through which an object or 3DCM can be understood by all [2].

Furthermore, interviewees state a 3DCM is of help to better understand the consequences and impact of one's opinion and how this might impact other stakeholders. With the help of a 3DCM different opinions of stakeholders can be visualized and their impact shown to the stakeholders. Doing so is believed to help stakeholders better understand and learn from one another's views. In 3D stakeholders have a better idea of the actual object they are discussing and a similar environmental image, since 3D is experienced as less open to multiple interpretations [7, 11]. Besides a better understanding of the object of planning, one interviewee stated that he has experienced that a better understanding of the object of planning has resulted in increased support for a planning proposal. This because stakeholders could see that the proposal put forward by the municipality was the best proposal, which tried to balance as many conflicting interests as possible [11].

Lastly, results find that the chosen LOD-level is of importance. First experiences with 3D show that a (very) low LOD is not of help, such a model is to much a generalization of reality. Here, 3D usage is not experienced as an advantage over 2D usage since stakeholders still have a difficult time to learn about the object [3, 4, 12]. "*Currently we have a 3DCM which consists of white objects. Even my colleagues within the municipality do not fully understand this model, not understanding where something is located. It looks really nice, but I don't completely understand what I am looking at"* [3]. However, interviewees also argue that a high LOD is not necessarily better and that it is important to find the right LOD for the right application and stakeholder. Result show that citizen is likely to require a more detailed model compared to GI-experts. Thus, the LOD is dependent on the usage of the tool [1, 12].

4.3 Efficiency

4.3.1 Efficiency: the experienced added value of 2D

Different views come forward when focussing on the experienced added value of 2D. Firstly, interviewees cite the low initial cost of using a 2D model. For a 2D model it is often not necessary to collect additional (GI) data, since municipalities are legally required to collect and update data such as the BAG and BGT [6]. Due to the availability of this data, organisations can easily use this data. One interviewee stating the following with regard to the possession of up-to-date and complete 2D data: *"The advantage is that we can immediately show our topography as it is in real life. And how will the area look like in the future? We can with relative ease show it on the map. Instead of using difficult to understand sketches etc. Furthermore, we can do analysis and other things with the data in 2D"* [5].

Thus, conducting tasks which previously required additional data and work for the realization of sketches etc. have now been replaced by a 2D dataset [5].

Despite this, a 2D model does pose limitations from an efficiency point of view. Interviewees state that many projects or development proposals proposed by non-governmental stakeholders (e.g., project developers) often submit their plans in a 3D BIM format. Civil servants state that the process for evaluating proposals is a 2D process, forcing them to perform additional tasks to translate the 3D BIM to a 2D format in order to test and evaluate a proposed planning intervention [1, 3, 4].

4.3.2 Efficiency: the expected added value of 3D

Interviewees have cited multiple mostly positive expectations for a 3DCM. Currently, many project proposals are being submitted in a 3D BIM format (as discussed in section 4.3.1). Interviewees among municipal organisations express the desire to be able to load such a 3D plan into a 3D PSS like tool, expecting this will enable them to quickly make a first evaluation of a plan. Thus, participants state that having the possession of a 3DCM will likely provide them the advantage of quickly testing and evaluating such a proposal. Requiring less time, effort and steps needed to conduct such a process [3, 4]. Interviewees elaborate upon this, stating that the ideal future situation would be to be able to automatically include proposed developments and plans in a 3DCM in order to automatically test these to relevant regulations and decide whether e.g., a permit or permission to build is granted. This is hoped to bring large efficiency gains since currently testing whether a proposed plan meets regulations can be a time-consuming process [3, 4, 12]. However, others object to the idea that such efficiency gains can be made possible by automatically testing proposals a 3DCM, stating that regulations are often very complex and depend on expert judgement to reach a proper conclusion. However, this is not to say that the inclusion of a 3DCM cannot be of help in said situation. It can help e.g., policy makers and civil servants to reach a proper decision faster because in a 3DCM it is believed to able to better and quicker evaluate the effects of a plan, resulting in efficiency gains. It just cannot be done automatically [7]. Furthermore, many BIM models are often not georeferenced and thus unsuitable for inclusion into a 3DCM [12].

A second expected gain is the ability of a 3DCM is to visualise multiple proposed developments for the same area and see how these different proposals or ideas influence one another and the existing world and regulations. Currently, such development proposals would result in a different testing process for each proposed development (in other words, does the proposed development meet rules and regulations). A 3DCM is expected to merge these different processes into one. Not only limiting the time and effort needed to test these proposals (since only one testing process is required) but also having the benefit of showing the impact of one proposed development on another proposed development [1].

Thirdly, efficiency gains are mostly expected by identifying bottlenecks in a potential development early on. Examples of such bottlenecks include unforeseen consequences of the proposed development or planning document which could not have been foreseen during the (2D) planning phase: "*If you make your design in 3D you will encounter problems not encountered during the initial design stage, which is great since you are not already building the proposed development. If you are already building it will cost much more time and money to correct problems (…), with such costs sometimes totalling 6% of the entire costs of the project*" [6].

However, one interviewee who is currently considering the development of a 3DCM does not only expect efficiency gains, stating that currently the cost of developing a city wide 3DCM to be so high it will likely nullify any savings a 3DCM might offer later on [6].

4.3.3 Efficiency: the experienced added value of 3D

Results show a 3DCM can be of help when formulating policy. Scenarios can be quickly glanced over, and differences can be better highlighted because of the detail provided by 3D. This instead of studying and discussing more difficult to understand drawings and maps [3, 6, 7]. However, usage of 3D in scenarios also contributes in efficiency gains for the field of planning. A Dutch province currently makes use of a 3DCM which allows for the study of different scenarios. In their experience, the impact of each scenario can be easily tested by parameters included in the tool (e.g., noise, traffic etc.), allowing policy makers to make a first quick and dirty analysis of which scenarios are feasible to start a follow-up on and which are not. Previously, scenarios would be discussed and only after selecting a scenario, experts would go to work on calculating the effects of such a scenario. By being able to make a first quick and dirty analysis on the spot, spending time and resources on working on unrealistic or unfeasible scenarios can be prevented [7, 10]. One interviewee has shown an example of this during a hands-on demonstration of a 3DCM. In order to improve the sustainability of an area a windmill was placed to provide renewable energy. In doing so the 3DCMC was immediately able to show the placement of the windmill would result in unacceptable noise- and visual pollution. Thus, quickly eliminating the placement of a windmill as a feasible scenario subsequently preventing time and money being spent on further study of the windmill scenario [8].

However, the efficiency gains discussed above are often not fully realised in practice, mostly due to the fact that a 3DCM is used too late or because of reluctance in using a 3DCM [7]. Using the tool when a decision is already been made on a certain scenario mitigates the efficiency gains. Reluctance is often caused by planners and policy makers who are used to a certain way of working, and are reluctant to change this (we already have this method and it works, why change to another method?) [7].

Results show further developments which mitigate or nullify efficiency gains. One of the most heard arguments among interviewees is the complexity, time and cost involved in creating a 3DCM, this posing a major obstacle in the development [4, 5, 6]. These claims however are countered by others. For example, a Dutch province makes use of a 3DCM tool that creates a 3D environment 'on demand' and largely automatically by using open data. Hence, cost and time involved in creating the 3DCM are limited, since it is only necessary to make a 3DCM of the project area when it is actually required to do so [7]. Furthermore, another interviewee with expert knowledge on the technical development of a 3DCM states that, with current techniques, it is already possible to develop approximately 80% of a 3DCM automatically and that the cost and time involved in developing such a model are becoming ever lower [12].

Lastly, using a 3DCM to communicate with stakeholders and share information does poses technical challenges. A 3DCM often requires a fast computer in combination with a fast internet connection. Such factors are not always present when meeting with stakeholders. One interviewee providing the following experience: "*The moment I bring my computer to a community center I am already glad that I have a place* [where we can discuss the plan]. *I don't have any other facilities. Certainly not a fast internet connection. It turns out that in such a situation usage of a 3DCM is complicated. Maybe I could have used it, but I couldn't rely on the tool working properly"* [1]. The interviewee goes on to argue that, instead of sharing information about the inteded topic, one runs the risk that the discussion will be about the tool not functioning correctly. As a consequence, he mentioned he prefers to bring a paper map when meeting with stakeholders [1].

4.4 Analysis

4.4.1 Analysis: the experienced added value of 2D

Results show mostly negative experiences with regard to the added value of 2D. Interviewees state that usage of 2D limits analysis possibilities, proving multiple examples in the form of noise propagation and air pollution. Analysis results are said to be less detailed. When analysing noise propagation or air pollution, results are restricted to XY-coordinates which not include details of noise propagation or air quality at a certain height. Thus, the analysis not showing if there is a difference in the experienced noise propagation at ground level and the fifth floor of a building [2, 6, 8, 9]. Interviewees believing that this limits the usability and understandability of analysis results [2, 7]. With one interviewee stating: "*Many effects are in 3D, such as noise. Thus, it makes sense to simulate these effects in 3D"* [7].

Secondly, interviewees state they experience limitations when performing an analysis in 2D, one interviewee citing the example of using a city model for change detection. Here, a 2D image of year X is compared with a 2D image of year Y in order to see if e.g., any new buildings have been constructed without planning permission. It is stated that a 2D model has its limitations in detecting such changes. One interviewee citing the example that a 2D not allows for detecting (illegal) changes in the height of the build environment [6].

4.4.2 Analysis: the expected added value of 3D

This section will focus on the expected added value of a 3DCM. Firstly, interviewees state they expect new forms of analysis will be possible with a 3DCM. An example mentioned by numerous interviewees is the ability to conduct a shadow analysis that also shows how a shadow is cast by e.g., a building in different moments of time [1, 2, 6]. Secondly, one interviewee further elaborates upon the expected analysis capabilities by stating that a 3DCM can be used for a broad range of analytical purposes, stating the following: "*We* [the municipality] *also have a department focusing on safety. They want to know the places in the city in which people feel unsafe. A 3DCM could be of big help in showing such locations. You could switch on the street lights and perfectly see which places remain dark* […]*, showing the places in a street which require additional attention"* [5].

A third example cited by interviewees is the investigation of noise propagation. Interviewees expect a 3DCM will allow for a more accurate analysis for noise propagation [6, 12]. Here, it is stressed that an accurate 3DCM will likely result in more accurate analysis results. A simple LOD1 level (a general representation of a building, without taking into account the shape of the roof) is expected to provide less accurate analysis results in comparison to a model that contains an accurate representation of the roof, since the form of the roof might impact the way a shadow is cast or noise propagation is experienced [6, 12]. This can be further illustrated by elaborating on the example of noise propagation, with an interviewee citing that increased traffic noise might have a more severe impact on apartments located the ground level of a building then those on the 6th floor. Here the inclusion of an analysis conducted within the 3DCM (and taking into account the 3D element within the analysis itself) is likely to result in more accurate results which also includes height [6]. However, results do also show that the required LOD-level is partly dependent on the type of analysis to be carried out. Stating that a higher LOD-level is not always a necessity [5, 12]

Fourthly, results show that a more advanced expected application would be to include sensor data in the 3DCM, subsequently creating a dynamic 3DCM. If realized, such a model would be able to detect and analyse problems in real-time and show these problems within the 3DCM. As a consequence, problems which might occur only during certain times of the day might be more easily detected [5]. Though such a model might sound farfetched, examples of such models already exist. For the city of San Francisco (California, USA) such a 3DCM has been created by including real-time sensor data into the model. These sensors have, among others, been mounted on buses and analyse a variety of criteria (air quality, traffic noise etc.). Doing so allows for real-time analysis of locations in urban places and allows a model to show and analyse these variables on different moments of time (e.g., do the values differ during rush hour and noon?), possibly helping in the formulation of policy. However, the interviewee has no personal experience with the usage of a San Francisco like model [12].

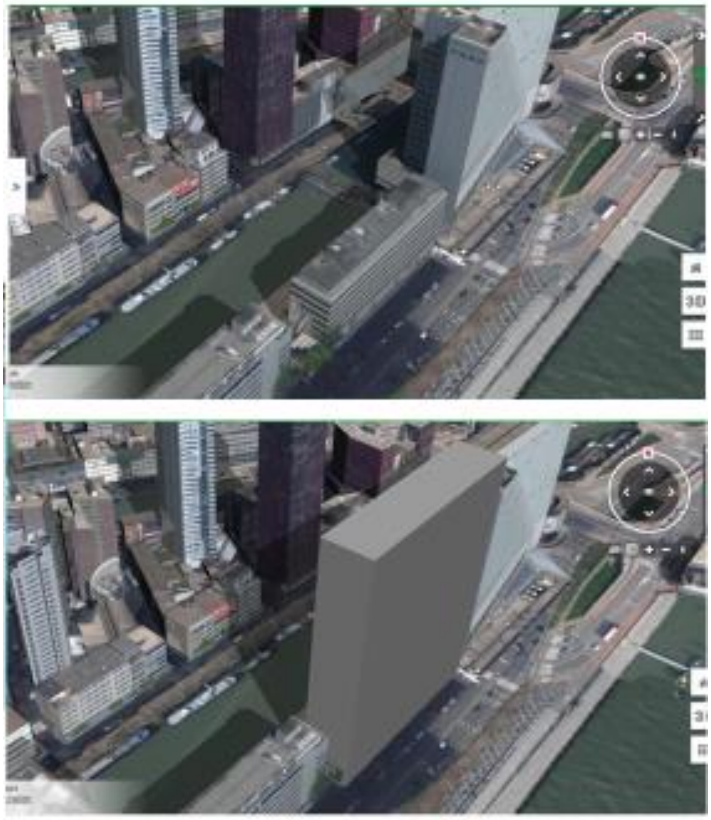
A further expected added value resulting from analysis is the automatic testing of proposed developments (e.g., a new building) by integrating these developments into the 3DCM which represents the current state of a city. Although interviewees all state that this is currently not in use as of yet, some of them do state that they hope this will be possible in future. If done, stakeholders such as project developers would be able to upload e.g., a proposed development in a BIM model format into the 3D city model. Consequently, within the 3DCM an automatic analysis would be carried out by the tool in order to test if the proposed development would meet legal requirements and what the impact of the development would be on air quality, noise propagation etc. Thus helping an urban planner to easier test the BIM to regulations, and providing a project developer with a faster result [3, 4]. Furthermore, a spatial planner would have the opportunity to easily communicate the results of the analysis to his/her colleagues of other departments who need to give permission for the proposed development to go ahead, with all different departments having the same easy to understand overview and output [3]. Although the above development might sound promising, other interviewees stress the above as wishful thinking, stating that many (building) regulations are often contradictory or too complicated for a computer program to form a judgement. Hence, many proposed developments are believed to quickly become too complex to be automatically tested and that human expertise is necessary to form a judgement [1, 7].

Lastly, it is expected that a 3DCM will also result in benefits not directly related or immediately applicable to the field of PSS. Such an example is provided by a municipality, who currently uses a 2D tool to detect unlawful changes made in the built environment (this by comparing an overview of the current built environment with that of a couple of years ago in order to detect any changes made). However, certain drawbacks are listed. For example, in the current situation it is difficult to detect any unlawful changes made related to the height of the built environment. Conducting such an analysis in a 3DCM is expected to resolve such a drawback, since a 3DCM allows for better testing of changes in the height of objects. Though not immediately applicable to stakeholder collaboration, such side effects of a 3DCM are deemed important in formulating a proper business case for the creation of a 3DCM [6].

4.4.3 Analysis: the experienced added value of 3D

Interviewees have shared multiple positive experiences with regard to the experienced added value of 3D. Firstly, 3DCM experiences show new forms of analysis become possible. Numerous examples are provided by interviewees, with the most occurring example of a new analysis type being the ability to better calculate the shadow a new development might cast on its surroundings. By taking into account the surrounding environment of e.g., a new development, such an analysis yields more accurate results when conducted in 3D. Furthermore, it also immediately shows the interaction among the proposed development and existing world (in other words, what is the effect of the already present city on a proposed development?) [1, 4]. An example of such an analysis is shown in figure 4.2 (next page).

Figure 4.2: Example of analysis results visualized in 3D. The image shows the shadow cast by the built environment in the current situation (upper image) and the shadows cast by a proposed new development (lower image).



Source: Municipality of Rotterdam, (n.d.)

Interviewees stress that certain effects, such as shadow and noise propagation, show themselves in 3D in the real world. As a consequence, it is also desirable to conduct these types of analysis in a 3DCM [4, 7, 9]. An example is provided by a Dutch province, who stated that a 3D model shows how noise propagation affects different floors of a flat, with different floors experiencing different levels of noise propagation. Thus, providing more accurate results when compared to a 2D situation. These more accurate results can help in formulating more accurate policy goals. The interviewee provides the example of measures needed to make the flat meet noise propagations laws. Because of the more accurate results, policy can now be formulated for e.g., only making the first three floors sound proof, the remaining (higher-up) floors needing no additional measures [9].

Secondly, an analysis conducted in a 3DCM is considered more transparent (and subsequently easier to communicate) by interviewees. Interviewees cite as most important reason that the results can immediately visualised in an understandable manner. An example is provided during a demonstration of the 3D PSS tool Tygron, which includes a 3DCM of the project area. The tool allows for easy calculation of among others, shadows. When a windmill would be placed in the project area (which can easily be placed in the project environment during a stakeholder session due to the interactivity provided by the tool), the shadow casted by this windmill would immediately appear in the 3D environment of the tool. This shows stakeholders the impact of the proposed development and provides an easy to understand output of the analysis in comparison to a 2D tool. Here the shadow of the proposed windmill would be illustrated by lines on a 2D map [7, 8, 9, 10]. Though such a possibility generates added value on the analysis aspect, one could also argue this is the case for the categories efficiency and learning about the object of planning. The analysis results in less work for the user of the tool, with the tool automatically calculating and visualizing the impact and stakeholders better understanding the output of the analysis because of the enhanced visualisation qualities.

A third benefit not specifically related to a 3DCM, but an important aspect of the above tool, is the usage of indicative scores for e.g., noise propagation, air quality etc. In other words: how does the proposed project or current situation scores on a number of chosen criteria on a scale 1-10, helping the tool to easier communicate analysis results. By building such scores into the 3DCM and automatically calculating how a proposed change might affect these scores, stakeholders are provided with an easy to understand indicator of the analysis result. Here, the combination of using such scores in combination with a 3DCM tool results in an even stronger overall tool, providing the ability to quickly analyse, visualise and understand the impact of a proposed change (see figure 4.3 for an example). Interviewees state that these scores were, at first, not included in the tool and were considered a major miss [3, 8, 9]. Hence, it can be concluded that the combination of these two aspects can be of major help.

Figure 4.3: Example of a 3DCM making use of indicative scores. The scores are displayed on a 1-10 scale for multiple criteria (displayed by the green, orange and red bars)

Source: Provincie Utrecht, (2018)

4.5 Collaboration

4.5.1 Collaboration: the experienced added value of 2D

Interviewees have shared numerous experiences with regard to the experienced added value of a 2D PSS. Firstly, interviewees have positive experiences with the use of 2D in the format of a maptable. The maptable allows stakeholders to express their views and support their arguments by pinpointing these on an exact location on the map and rating a proposed development. Since views of stakeholders in such a situation are immediately georeferenced, potential bottlenecks in a development stand out on the map allowing for a follow-up discussion on such bottlenecks during the same meeting, when all stakeholders are still present. This subsequently allows for easier cooperation with stakeholders in discussing potential alternative scenarios which might better suit their needs [5, 6].

When comparing the scenario described above to a situation in which no 2D map table is used, interviewees experience stakeholders only noting their views on paper forms which need to be analysed by a civil servant later on. Only after these papers have been analysed by the municipality, an (often) internal follow-up discussion might take place in which no longer all stakeholders are included. Hence, interviewees point out the improvement a 2D provides with regard to the collaborative aspect in comparison to the usage of no such tool at all [5, 6, 9].

4.5.2 Collaboration: the expected added value of 3D

Interviewees have shared only limited expectations with regard to the expected added value of 3D. Firstly, a 3DCM is expected to provide stakeholders a method to easily show each other's wishes and opinions by for example adding or removing a building, with the 3DCM automatically calculating the effects of such a change. It is expected this will help stakeholders to work together and come to a compromise during the course of the process [7].

Elaborating upon the previous paragraph, one interviewee expects a 3DCM to bring improvements. With the usage of a 3DCM stakeholders can better bring forward (and make visible to other stakeholders) their interest. Doing so is expected to result in a situation in where no longer the project manager makes tries to balance the different interests but stakeholders themselves by cooperating with other stakeholders [9].

However, not all are convinced by the added value a 3DCM can provide. With one interviewee stating that he already experienced similar results with the usage of a 2D tool [5]. A second interviewee elaborates upon this experience by stating that a 3DCM does not provide added value for collaboration, believing that collaboration in his expectation is not dependent on whether a 2D or 3DCM is used but on the willingness of those involved to collaborate [6]. Another interviewee shares a similar experience by stating he has experienced municipalities trying make collaboration more difficult by organising a stakeholder session during the summer months (when many stakeholders are absent due to vacation), subsequently hoping they can move proposed plans forward faster by minimizing collaboration with others. Thus, in some situations a tendency towards minimizing collaboration does seem to exist. If this is the case, it is expected a 3DCM alone will not be enough to achieve collaboration and a fundamental shift in policy is needed [2].

4.5.3 Collaboration: the experienced added value of 3D

This section will focus on the experienced shared by interviewees regarding the added value of a 3DCM for collaboration. Currently, many 3DCM are still in development or in a testing phase [1, 3, 5, 9]. Hence, actual experiences with a 3DCM for the field of collaboration are still limited. First results however show positive experiences when using a 3DCM. Currently, one municipality is (internally) testing the usage of a 3DCM for collaboration, citing positive experiences. With the help of the 3DCM the views of different stakeholders come forward more clearly (for some stakeholders economic development is more important, for others urban green space etc.). The 3DCM used has the capability to automatically show the impact of a choice made during a stakeholder session (e.g., more stores for economic development, more urban green space etc.) in a game like environment. Doing so has helped to make stakeholders aware of the consequences of their own point of view and the interests of other stakeholders. Interviewees experience increased awareness among stakeholders for the need to collaborate and balance their interests in order to come towards a realistic planning proposal. Furthermore, they experience a 3DCM as a great help in doing so [3, 4]. One interviewee elaborates upon the experience above, stating that his organization also uses a 3DCM for similar goals. However, besides showing stakeholders the consequences of each other views, he experiences a 3DCM also helping to show how stakeholders views meet rules and regulations, helping to cooperate with the legislator to make sure a planning proposal meets legal requirements [7].

4.6 Summary of results

Table 4.1 (next page) provides a summary of the results. For each category, results have been classified as negative, mixed or positive.

Table 4.1: Overview of results

	Experienced 2D	Expected 3D	Experienced 3D
Communication	**Negative experiences.** Interviewees experience many limitations in the transfer of information in 2D. Information is either missing because of a lack of detail or experienced as difficult to understand for stakeholders.	**Positive expectations.** Interviewees expect a 3DCM will make information more understandable since 3D is experiences as a *lingua franca* by stakeholders. Furthermore, the recognizability of landmarks and objects is expected to provide necessary context.	**Mixed experiences.** Results show improved communication with stakeholders through the help of a 3DCM. Sharing information among stakeholders is easier due to the recognizability of 3D. Secondly, the usage of 3D scenarios is experienced as a good way to share information. However, results show multiple drawbacks in using a 3DCM. Increased detail with which information can be shared with stakeholders might arouse the impression a decision has already been made. Furthermore, current rules and regulations do not always allow for the usage of a 3DCM tool.
Learning	**Mixed experiences**. Using 2D is considered an upgrade in comparison to a situation in which no tool is used. Here, 2D helps to better understand the object of planning and to better understand the opinion of other stakeholders. However, interviewees do experience limitations imposed by 2D, stating that objects in 2D are often difficult to understand for stakeholders, resulting in different stakeholders formulating different environmental images .	**Positive expectations**. Interviewees expect a 3DCM provides a better understanding about the object of planning. Secondly, a 3DCM is expected to help better understand the opinion of other stakeholders, since a 3DCM allows for the visualization of a stakeholder's opinion.	**Positive experiences.** Results have shown stakeholders are able to better understand the object of planning when a 3DCM is used, creating a similar environmental image among stakeholders. Furthermore, interviewees have indicated that a 3DCM is of great help in learning from the views of other stakeholders.
Efficiency	**Mixed experiences**. The keeping of 2D data (bag, bgt etc.) is legally required, resulting in low additional costs. However, interviewees experience limitations when solely working with 2D, with 2D requiring extra steps to perform certain tasks.	**Mixed expectations.** Interviewees expect high efficiency gains, believing a 3DCM will save considerable time and effort. However, the cost for developing a 3DCM are high, with interviewees expecting the cost might nullify efficiency gains achieved by developing a 3DCM.	**Mixed experiences.** A 3DCM is experienced as saving time and effort since it prevents working on unrealistic and unfeasible scenarios. Using a 3DCM is not part of the everyday working routine of stakeholders. Consequently, efficiency gains are often not fully realized. Costs of developing a 3DCM are sometimes considered to nullify efficiency gains. However, interviewees do not seem to agree if development cost limits efficiency gains, with interviewees having differing experiences.

			Lastly, a 3DCM poses technical challenges which need to be overcome. These technical challenges are experienced to hinder efficient usage of a 3DCM.
Analysis	**Negative experiences.** Interviewees experience limitations and loss of detail when using 2D to carry out an analysis.	**Positive expectations.** Interviewees expect a 3DCM will allow for improved and new analysis capabilities and have high expectations for advanced applications (e.g., displaying live sensor data in a 3DCM). However, the chosen LOD-level is expected to be of influence on these capabilities.	**Positive experiences.** Results have shown a 3DCM results in new and improved analysis capabilities. Examples cited by interviewees of such types of analysis are a shadow analysis and the measurement of noise propagation.
Collaboration	**Positive experiences.** A 2D PSS provides improved interaction and cooperation among stakeholders in comparison to a situation in which no tool is used at all.	**Mixed expectations.** Interviewees expect a 3DCM to help stakeholders collaborate and balance interests in order to come to a compromise. However, others already experience similar positive results with the usage of a 3D tool. Furthermore, results also suggests that successful collaboration is dependent on the willingness to facilitate the process of collaboration, and not on the tool alone.	**Positive experiences.** Results show a 3DCM helps stakeholders to collaborate and balance their interests among each other. Furthermore, it can help to show how the views of stakeholders meet rules and regulations However, many 3DCM are not or have only recently been used for collaboration limiting experiences.

5. Conclusion

The main goal of this research was to identify the expected versus the experienced added value of a 3-dimensional versus a 2-dimensional city model for stakeholder participation in the framework of collaborative spatial planning. Four subquestions were formulated to achieve this goal: (1) investigate the importance of collaboration between stakeholders in spatial planning, (2) identify the experienced added value of a 2-dimensional city model, (3) identify the expected added value for the creation of a 3DCM, (4) identify the experienced added value of creating a 3DCM.

This chapter will first answer the subquestions (paragraphs 5.1.1 – 5.1.4). Each subquestion will be answered by discussing the five criteria through which added value has been identified. These criteria were communication, learning, efficiency, analysis and collaboration. With the help of the subquestions, the main research questions of this research will subsequently be answered in paragraph 5.2.

5.1 Subquestions

5.1.1 The importance of stakeholder collaboration in collaborative spatial planning

The first subquestion was formulated as follows: What is the importance of stakeholder collaboration in collaborative spatial planning? Subquestion 1 has partly been answered with the help of the literature review conducted in chapter 2.

The importance of stakeholder collaboration has been discussed in the literature review, resulting in mixed results. First of all, authors claiming collaboration to be of importance for including the views of stakeholders (Healey, 2003; Irvin & Stansbury, 2004; McCall & Dunn, 2012). Others however notice potential problems arising from stakeholder collaboration. Stating that collaboration is often a time consuming and costly process, resulting in a slower planning process (Brand & Gaffikin, 2007; Irvin & Stansbury, 2004). However, this research has revealed that all interviewees have agreed upon the importance of stakeholder collaboration in the planning process, providing similar justifications as found in the literature review: identifying and meeting the demands of stakeholders and providing transparency of the planning process. Despite this, results do show that collaboration can sometimes be hampered by factors:

- Collaboration is not always priority number one among responsible government organisations, results showing that a tendency to minimize stakeholder collaboration does seem to exist from time to time, hoping this will result in a faster planning process [2]. This is in line with previous research, which concluded collaboration can be a time consuming and costly process. However, literature also counters the claims made above by stating that not including stakeholders in a planning process is likely to result in even lengthier and more costly legal objections made by stakeholders (Brand & Gaffikin, 2007; Irvin & Stansbury, 2004).
- Stakeholder collaboration is dependent on the willingness among stakeholders to participate in the process, even if best efforts are made to provide the opportunity for stakeholders to participate, some might choose not to do so [6]. An earlier study of Irvin & Stansbury (2004) came to a similar result. The authors concluded that only those who can spare the time and resources to do so are likely to participate.

To conclude, the first subquestion can be answered by stating that there are mixed results regarding the importance of stakeholder collaboration in collaborative spatial planning. Both interviewees and previous literature studies have agreed upon the importance of stakeholder collaboration. However, results also show collaboration can be a time consuming and costly process.

5.1.2 The experienced added value of a 2D city model

The second subquestion was formulated as follows: *What is the experienced added value of a 2-dimensional city model?* With the help of the second subquestion the experienced added value of a 2D model has been investigated. Added value has been measured by focussing on the five dimensions identified in chapter 3 (communication, learning, efficiency, analysis and collaboration). In order to answer the subquestion, the results for these five dimensions will be discussed in a step by step manner.

The first criterium has focussed on the communicative aspect of added value. Results have shown **negative** experiences among interviewees. Firstly, in 2D information is often experienced as missing. Exact information regarding e.g., building height and aesthetic quality cannot be provided in 2D. Stakeholders have to create their own image of building height, resulting in differing environmental images among stakeholders [2, 3, 6, 7, 9]. Secondly, information in 2D is considered difficult to understand. Often, an appendix or legend is necessary to communicate all relevant information [1, 2]. These results are in line with results from earlier studies which have been discussed in the literature review. Firstly, Jiang et al., (2003) concluded that with a 2D the readers of the map are the ones who have to make an effort translate the map and its relevant symbols themselves. Secondly, results from a study conducted by Devisch et al., (2016) have shown how a different environmental image among stakeholders can hamper a (spatial) planning process.

The second criterium, learning, has revealed **mixed** experiences among interviewees. Having the possession of a 2D helps stakeholders to learn about the object of planning [5]. Furthermore, 2D experiences show learning occurring among stakeholders, with a 2D tool facilitating the learning process [5, 6]. However, interviewees also experience limitations. 2D objects are considered to lack detail (e.g., regarding final building height, aesthetic qualities etc.), making it difficult to properly learn about the object [2, 7, 9]. In a previous study, Pelzer et al., (2016) identified learning as the most important experienced added value by PSS users. Thus, the mixed results for this category are partly at odd with previous research.

Results have shown **mixed** results for the third criterium, efficiency. Costs for the construction of a 2D city model are often low. The required data is already present since current rules and regulations require municipalities to collect this data [5, 6]. However, efficiency gains in the planning process which can be achieved with the help of a 2D are limited, results showing non-governmental planning proposals more and more often have a 3D-format. This requires extra time and effort from civil servants who first need to convert these to a 2D data format before being able to continue working [1, 3, 4]. This result is partly in contrast with an earlier study expecting PSS usage to provide efficiency gains (Vonk et al., 2007).

Negative experiences have come forward with regard to the fourth criterium, analysis. Analysis are restricted to the XY-coordinates when conducted in a 2D environment, eliminating height from the results. This results in less detailed analysis (e.g., the effects noise propagation can only be studied at ground level) [2, 6, 8, 9]. Furthermore, results show some types of analysis are not possible in 2D. Results providing the example that a 2D city model has difficulty in detecting changes in building height [6]. An earlier study already identified limitations in analysis as a potential bottleneck, with Pettit et al., (2018) suggesting a PSS needs to address such shortcomings by providing the ability for more complex forms of analysis.

Results have shown **positive** experiences for the fifth criterium: collaboration. Interviewees experienced better cooperation and interaction among stakeholders when making use of 2D [5, 6, 9]. This result is in line with previous studies, which found that one of the major motivations to develop a PSS is to foster collaboration (Pelzer et al., 2017).

With the help of the discussed criteria an answer can now be formulated for subquestion 2: the experienced added value of a 2-dimensional city model is mostly mixed to negative. Only for the collaborative aspect interviewees cite positive experiences.

5.1.3 The expected added value of a 3-dimensional city model?

The third subquestion was formulated as follows: *What is the to be expected added value of creating a 3-dimensional city model?* With the help of the third subquestion the expected added value of creating a 3DCM has been investigated. Similar to subquestion 2, added value has been measured by focussing on the five dimensions which have been formulated in chapter 3 (communication, learning, efficiency, analysis and collaboration, see table 3.2). In order to answer the subquestion, the results for these five dimensions will be discussed in a step by step manner.

For the communicative aspect results have shown **positive** expectations. Results show a 3DCM is expected to act as a lingua franca understood by a wide variety of stakeholders [2, 6]. Furthermore, the increased recognizability of objects in a 3DCM is expected to help stakeholders locate themselves on a map, helping to better understand information the object of planning [5, 10], results showing interviewees expect a 3DCM to be like an easy-to-understand model comparable to SimCity [3. 4]. These expectations are in line with previous research of Jiang et al., (2003) and Wu et al., (2010), who considered a 3DCM representation to better resemble the real world and information presented in a 3DCM to be better understandable.

Results have shown **positive** outcomes for the second criterium learning. Firstly, with regard to learning about the object, results show high expectations with objects being easier recognizable when making use of a 3DCM [6]. However, it should be noted that the chosen LOD-level will be of influence. Results expecting a very low level 3DCM does not provide better recognizability [5]. Multiple studies have come to a similar conclusion, stressing the better recognizability of 3D objects helps stakeholders to learn about the topic (Biljecki et al., 2015; Hu et al., 2010; Jiang et al., 2003; Yin, 2010).

Results have shown **mixed** outcomes for the efficiency criterium. First of all, results show many expected positive applications which will likely provide efficiency gains. These expectations range from small time savings through the usage of a 3DCM, to a 3DCM which can automatically judge a proposed development (and give a go or no go for such a development) without human interference [3, 4]. Despite these positive expectations results also show some criticism, with the cost of developing a 3DCM to be expected to be so high it might nullify any savings it can provide [6]. Such criticism is not new, earlier studies citing the cost and time involved in the construction of a 3DCM as a potential obstacle. However, literature does note, in contrast to the results, that major improvements are being made in automatically constructing a 3DCM which are likely to bring down the development cost and time (Nouvel et al., 2014; Qing et al., 2009; Yin, 2010).

Positive expectations have come forward for the fourth criterium, analysis. Firstly, results suggesting stakeholders expect new and more accurate forms of analysis to become possible (e.g., a 3DCM can show the shadow a new development might cast on its surrounding area) [1, 2, 6]. Secondly, the inclusion of sensor data into a 3DCM is expected to bring new gains. Thirdly, more advanced expectations have been found such as the creation of a dynamic 3DCM which includes sensor data. Such a 3DCM is expected to detect and analyse problems in real time [5, 12]. Previous research has already stated the expectation a 3DCM would bring more advanced analysis capabilities (Billen, 2013; European Spatial Data Research, 2017). However, it should be noted that more advanced applications such as the creation of a dynamic 3DCM with the inclusion of live sensor data is, to the best of the authors knowledge, not discussed by literature.

For the fifth criterium, collaboration, **mixed** expectations have been found. First of all, results show positive expectations. Interviewees expecting a 3DCM to be a tool which helps to help stakeholders compromise on the spot [7, 9]. Such expectations are in line with previous research, which concluded that the possibilities offered by a 3DCM will improve collaboration (Jiang et al., 2003; Santosaa et al., 2016). However, results have also shown more critical expectations. Results suggesting not all expect a 3DCM to be of extra help for collaboration. Stating that experiences in 2D are already positive or that successful collaboration is depend on those involved in the process and not dependent on the type of tool being used [2, 5, 6]. A previous study conducted by Irvin & Stansbury (2004) came to a similar conclusion. Concluding that only those who can spare the time and resources to do so will take part in a collaborative planning process.

With the help of the discussed criteria subquestion 3 can be answered. Stakeholders state mixed to mostly positive expectations resulting from the usage of a 3DCM. Results showing specifically positive expectations for the communicative, analytical and learning aspect.

5.1.4 The experienced added value of a 3-dimensional city model?

The fourth subquestion was formulated as follows: What is the experienced added value of creating a 3-dimensional city model? As with the previous subquestions added value has been identified with the help of the five criteria identified in table 3.2.

For the first criterium, communication, **mixed** results have come forward. Results show multiple positive experiences. Information communicated through a 3DCM is said to be better understandable, since the 3DCM provides a recognisable real-world environment in which information can be shared [1, 3]. Here, results provide the example of building height. The height (and impact on the surrounding area) of a proposed new building clearly comes forward when integrated in a 3DCM [1, 3, 7, 11]. This finding is in line with previous studies, which stressed the benefit of having a 3DCM, since a 3DCM has the ability of showing a proposed development in the context of the further urban environment (Biljecki et al, 2015; European Spatial Data Research, 2017; Jiang et al., 2003; Pettit et al., 2018; Wu et al., 2010). Secondly, the usage of scenarios constructed in a 3DCM is experienced as positive. With the help of scenarios, a lot of information can be communicated with relative ease [1, 3, 4, 7]. However, results also show experienced drawbacks. The detail provided by a 3DCM giving the unjust assumption a topic is already been decided upon since the inclusion in a 3DCM makes it look final [1]. The finding of this drawback is new, to the best of the author's knowledge previous studies do not conclude this might be a risk of a 3DCM. Lastly, rules and regulations do sometimes not allow usage of a 3DCM. Results showing e.g., a zoning plan still needs to be established in 2D [2, 11]. Contrary, previous research found a 3DCM helps in formulating regulations (European Spatial Data Research (2017), whereas this study finds current rules and regulations to be an obstacle for using a 3DCM as a method to capture rules and regulations. A possible explanation of this discrepancy is the fact that 3DCMs are still new. It often takes a couple of years for rules and regulations to catch up with such new developments.

Results show **positive** experiences for the second criterium, both for learning about the object and learning about others. With regard to learning about the object results show interviewees again citing the example of building height, stating that the height of an object in a 3DCM is immediately clear [2, 7]. These results are in line with previous studies, also concluding the clarity of objects in a 3DCM to be a major pro (Biljecki et al., 2015; Hu et al., 2010; Jiang et al., 2003; Yin, 2010). Secondly, results show positive experience for learning about other stakeholders. [7, 11].

Mixed experiences have come forward for the efficiency aspect. Firstly, results show positive experiences. The usage of a 3DCM saving time when testing a planning proposal. With a 3DCM it can quickly be decided which proposals are worth working on and which not. Thus, preventing time and money being spent on working on unrealistic planning proposals [7, 10]. Results show the high cost and time involved in developing a 3DCM to be a major obstacle [4, 5, 6]. However, results also show experiences in which cost and time needed are being limited by automatically constructing a 3DCM on demand of only a small area [7]. Thus, results showing contradictory experiences regarding the time and cost required for the construction of a 3DCM. This contradiction is also found in previous research. For example, some studies already stated the high cost to be an obstacle, despite ever increasing automation (Qing et al., 2010; Yin, 2010). In contrast, a different study stated the benefit to cost ratio of constructing a 3DCM to be 2.1;1 (European Spatial Data Research, 2017). Furthermore, results show a 3DCM not always being used due to technical difficulties of using such a tool. The potential lack of a good internet connection and the requirement of a fast computer posing an obstacle [1]. These experienced obstacles are in line with a previous study of Alatalo et al., (2016) which found it is not uncommon for users to experience said troubles in the running of a 3DCM and that a good quality internet connection and device is necessary to make good use of a 3DCM.

Positive experiences have come forward for the analysis aspect. Results showing new forms of analysis to become possible. For example, the effects of noise propagation can now be studied in 3D [9]. Secondly, results show a 3DCM provides a better understandability of analysis results in comparison to a 2D. Results providing the example of the shadow cast by a potential development. When calculating and subsequently displaying the analysis results in a 3DCM, it is experienced that the analysis are immediately understandable by stakeholders involved [7, 8, 9, 10]. These results are in line with previous studies who also stated new and more advanced analysis capabilities to become possible (Biljecki et al., 2015; European Spatial Data Research, 2017; Nouvel et al., 2014).

Lastly, results show **positive** experiences for the fifth criterium: collaboration. Experiences with a 3DCM showing the tool provides a game-like environment in which different stakeholders can see the effects of their opinions and interact with others to balance their interests [5, 6]. This result is in line with findings of previous research which concluded 3D to be a good tool to show the impact of ideas of stakeholders and proposed developments (Jiang et al., 2003; Wu et al., 2010). However, it should be stressed that actual experiences with a 3DCM for collaboration are still limited due to many 3DCM still being in development or testing [1, 3, 5, 9]

To conclude, subquestion 4 can be answered by stating that interviewees have had mixed to mostly positive experiences when using a 3DCM. Results show specifically positive experiences for learning, analysis and collaboration, whereas experiences for communication and collaboration are mixed.

5.2 Answering the main research question

The previous paragraphs have answered the subquestions. With the help of these subquestions the main research question of this research will be answered, which was formulated as follows:

What is the expected versus the experienced added value of a 3-dimensional versus a 2-dimensional city model for stakeholder participation in the framework of collaborative spatial planning?

When comparing the experiences of stakeholders between 2-dimensional and 3-dimensional city model results show mixed to negative experiences for a 2D model. In contrast, the experienced added value of a 3DCM is mixed to largely positive. Only for the categories efficiency and collaboration stakeholder experiences remain the same (with mixed experiences for the efficiency criterium and positive experiences for the collaborative criterium).

Comparing the expected versus the experienced added value of a 3DCM, results show mixed to largely positive results for both the expected and experienced added value. However, results do show that the fields in which these positive or mixed expectations and experiences occur differ. For learning, efficiency and analysis expectations generally match experiences. However, for communication and collaboration this is not the case. Results expected a 3DCM to be positive for the communicative criteria whereas actual experiences show mixed results. For collaboration, expectations for the added value of a 3DCM where mixed. In contrast, this research shows the actual experienced added value to be largely positive.

To conclude, this research has found that the usage of a 3DCM for stakeholder collaboration within the framework of collaborative spatial planning is experienced as a major step forward in comparison to the usage of a 2D tool. Furthermore, research has shown that stakeholders have mixed to positive expectations and experiences regarding the added value a 3DCM can provide for stakeholder participation within the framework of collaborative spatial planning, despite some differences existing between the listed expectations and experiences.

It should be noted that the main research question can only be answered by stressing that many 3DCM are still in development or have only just been recently finished, limiting the available results. Thus, it is the believe of the author that expectations and expectations will positively develop over time, once new and more mature 3DCMs become available.

6. Limitations

This research is among the first to investigate the expectations and experiences of a 3DCM, providing a first useful insight for science and the practice of spatial planning towards the added value of such models. This research can act as a starting point for further research and can help the field of spatial planning to better manage their expectations for 3DCM usage.

However, this research does have limitations which are important to address. Firstly, for this research it was not possible to include citizens as a stakeholder into the research. Currently, many 3DCMs are still in development, or development of the model has just been finished. As a consequence, organisations who make use of such models have not yet used these models together with citizens and planned meetings in which they intend to do so are rare to non-existent. As part of this research a stakeholder meeting which included citizens was agreed upon with a Dutch municipality. For reasons beyond control of the author, this meeting was cancelled at the very last moment. Due to the set time limit of this thesis and the current scarcity of stakeholder sessions in which citizens are included, it was impossible to make arrangements for another such a meeting. Making it impossible to include the expectations and experiences of citizens in this research. This has proven to be an important limitation of this research, since the originally intended focus of this research was to focus on the experiences and expectations of citizens. Subsequently limiting the generalisability of the results, with current expectations and experiences not representing those of citizen stakeholders. However, a demonstration session of a 3DCM has been provided by a Dutch province, providing valuable insights in the actual workings of a 3DCM during a stakeholder session. In order to make most use of this demonstration, different types of stakeholders within this organization have subsequently been interviewed, allowing for the inclusion of the expectations and experiences of a wide variety of stakeholders. However, the 3DCM in use by the Dutch province has not yet been used for citizen participation as of yet, since it has only recently been adopted. Thus, no expectations and experiences of citizens could be included.

The currently limited availability of 3DCMs in active usage has also been of influence on the chosen methodology for this research. If more 3DCMs had been in more active use, it would have been interesting to include a survey in the methodology in order to provide a more quantitative approach towards answering the research question, possibly comparing different types of 3DCMs. Due to the limited availability of 3DCMs currently available (and stakeholders which have experience in working with a 3DCM) this has proven not to be possible.

Furthermore, this research has made use of five criteria (communication, learning, efficiency, analysis and collaboration) in order to measure the added value of 3DCMs. A study using different criteria might yield different results. However, it should be noted that the chosen criteria have been selected after a thorough literature study and are believed to be proper criteria for measuring experienced and expected added value of a PSS tool.

Lastly, results for this research have been gathered in the first half of 2019. Currently, as previously stated, many 3DCMs are still in development or have only been recently released. It is expected that, once more 3DCMs become available, new functionalities will also become available. Therefore, current results are likely not to be fully applicable for future 3DCMs.

7. Recommendations

The results for this research have been gathered in the first half of 2019, in which 3DCMs were only available in a limited fashion or still in development. Hence, it is recommended to conduct a further large-scale follow-up research towards the added value of a 3DCM for stakeholder participation within the context of collaborative spatial planning once more 3DCMs have become available. Doing so will hopefully allow to also include the views of citizens with regard to these 3DCMS, comparing their expectations and experiences with those of other stakeholders. It is recommended to make use of questionnaires if possible, in order to compare the experiences of large groups of stakeholders. Hopefully, such a study contributes in making optimal usage of any future 3DCM.

Secondly, it is recommended to further investigate the different LOD-levels required by different users. This research has already identified that the chosen LOD-level needs to match the stated goals for the usage of a 3DCM. How the LOD-level differs for different tasks and different stakeholders remains a question which still needs answering. With ever more 3DCMs becoming available in the coming years, it is recommended to further study the effects of the chosen LOD-level. This can hopefully help in making sure that a to be developed 3DCM will match the stated goals of a developed tool as closely as possible.

Thirdly, it is recommended to conduct a study comparing the added value provided by different types of 3DCM tools once more 3DCMs become available. This study has only focussed on investigating the added value provided by 3DCMS in general, whereas experiences might differ among different types of 3DCM. Here, it would be interesting to make use of a fixed planning scenario/challenge in order to test and compare different 3DCMs in a similar and objective manner.

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Appendix 1: interview topic list

In order to conduct interviews, a topic-list has been developed. This topic list functions as an aide-memoire for the interviewer, helping to make sure all the topics are covered during the interviews. Furthermore, it has also been used to provide interviewee contacts with a form of preparation for the interview. Since the interviewee candidates were Dutch, the topic list was formulated in Dutch. An English translation of the topic list is included below.

Introduction

Currently I am performing research to complete my master thesis for the study Geographical Information Management and Applications (GIMA) at Utrecht University. My research is focused at the usage of geo-information and planning support systems within the field of (participatory) spatial planning. This with an emphasis on the possible (non-) usage of 3D geovisualisation techniques.

The topic list presented below represents a general overview of topics aimed to discuss during an interview session. The entire interview is confidential (any answers provided will not be shared with others).

Usage of Geo-information

-In hoeverre wordt binnen uw organisatie gebruik gemaakt van geo-informatie en daaraan gerelateerde geo-systemen?

-To what extend does your organization make use of gi-systems and geo related information?

-Speelt het gebruik van geo-informatie een rol in het ruimtelijk planproces?

-Does the usage of GI-information play a role in the spatial planning process?

-Indien ja, op wat voor manieren wordt geo-informatie gebruikt binnen het ruimtelijke planningsproces?

-If yes, in what ways does the usage of GI-information play a role within the field of spatial planning?

Awareness and usage of Planning Support Systems

-In hoeverre bent u bekend met het bestaan van speciale GIS-systemen ter ondersteuning van de planologie (Planning Support Systems)?

-Are you aware of the existence of dedicated GI-systems for the field of spatial planning?

-Zo ja, bent u van mening dat dergelijke tools een nuttige toevoeging zijn op het normale gebruik van GIS?

-If yes, do you believe that these types of tools can be a useful addition to the standard GIS tools?

-Zo nee → het gebruik van Gis data en planning theory uitleggen.

If no → explain the usage of GI data combined with planning theory

-Gelooft u dat GI-tools specifiek ontwikkeld voor spatial planning een nuttige toevoeging kunnen zijn?

-Do you believe that dedicated GI-tools for the field of spatial planning can be a usefull addition

-Learning / leren

-Level of detail

-Communication / communiceren

-Efficiency / efficiëntie

-Analysing / analyseren

-Zo nee, bent u van mening dat een dergelijke tool van toegevoegde waarde kan zijn ten opzichte van een standaard GIS-toepassing → ja/nee

Voorbeelden: Learning, collaboration, communication, efficientie, analyseren

-If no, do you believe that a dedicated GI tool for spatial planning can be of added value for the field of spatial planning?

Examples: learning, collaboration, communication, efficiency, analysis

-Bent u van mening dat een PSS-tool handig kan zijn voor het betrekken van burgers in de besluitvormingsprocessen?

-Do you believe that a PSS tool can be of added value for a citizen participation process?

Current (non)-usage of 3D

-Bent u bekend met 3D-city modelling

-Are you aware of the existence/usage of 3D-city modelling?

-Denkt u dat 3D stadsmodellen van toegevoegde waarde kunnen zijn in de planologie?

-Do you believe that a 3D city model could be of added value for the field of spatial planning?

→ Zo ja, op welke gebieden bent u van mening dat 3D van toegevoegde waarde kunnen zijn

→ If yes, in which areas do you believe that 3D could be of added value?

- -Learning (about the object of planning and about other stakeholders)
- -Level of detail (different LOD levels)
- -Communication (sharing of information, visualisation of proposed changes)
- -Efficiency (lowering of costs, faster processes)
- -Analysing (e.g. noise propagation, traffic modelling etc.)

→ Zo nee, enkele voorbeelden aanhalen van in de literatuur genoemde 3D voorbeelden aanhalen (denk aan visualisatie, analyse etc.). Waarom vindt u 3D niet interessant?

→ If not, mention examples of added value found in literature. Why do you believe 3D not to be interesting?

-Eerder heeft u aangegeven wel/geen gebruik te maken van Planning support Systems. Bent u van mening dat een 3D element een interessante toevoeging kan zijn om deze tools verder te verbeteren danwel het gebruik van een dergelijke PSS-tool in de toekomst interessant kan maken? Waarom?

-Bent u van mening dat 3D voor de toekomst interessant kan zijn/hoe zou dit interessanter kunnen worden gemaakt?

-Do you feel that 3D could be more interesting within the near future/do you have any recommendations yourself how this could be made more interesting.