Student thesis series INES nr 485

Visualizing the third dimension: Map guidelines for a 3D detailed development plan

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2019
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Stephanie Judge (2019).
Visualizing the third dimension:
Map guidelines for a 3D detailed development plan
Master's degree thesis, 30 credits in *Geomatics*
Department of Physical Geography and Ecosystem Science, Lund University

Level: Master of Science (MSc)

Course duration: *January* 2019 until *June* 2019

Disclaimer

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ACKNOWLEDGEMENTS

I would like to first thank my thesis supervisor, Lars Harrie of the Department of Physical Geography and Ecosystem Science at Lund University. Lars provided support in shaping a thesis closely aligned with my interests through his guidance and well-appointed contacts in the field. I am grateful for his invaluable comments and ideas throughout this process.

I would also like to thank Jonas Andréasson of Lunds Kommun, who supported the project and warmly welcomed me into the GIS department. I am appreciative of the friendly working environment provided to me at Kristallen, as well as the opportunity to meet so many professionals in the field.

This study would not have been possible without the participants, and to that end I am deeply grateful to Jonas Andréasson, John Hellman, Ulrika Thulin, and an additional contributor who wishes to remain anonymous. Each of the participants gave their time and thought to my study and provided insightful and meaningful comments.

A special thanks goes to my fellow comrades at Lund University for all the fika and moral support.

Finally, I would be remiss not to thank Justin Snopek, without whom I would not have had the opportunity to complete a Master's degree in Sweden.

Abstract

The planning process for urban development is key for setting a project up for success and for supporting sustainable growth. Public participation plays a major role during the planning process in Sweden, but current detailed development plans (DDPs) shared with the public in paper-based 2D format are difficult for laypeople to understand. The literature has shown that the introduction of 3D visualizations can improve citizens' understanding of a plan proposal; however, moving from static 2D to digital 3D space requires new cartography tailored to this specific application. The aim of this study is to develop map guidelines for a web-based 3D visualization of DDPs in Sweden, with the intention of supporting a more sustainable building process through an improvement of public understanding of plan proposals. To that end, this study explores the specific questions of whether a 3D DDP improves communication of the plan proposal to the public, whether the establishment of map guidelines supports the use of 3D DDP for future public participation, and what the actual map guidelines for this application are.

Four designs testing various cartographic principles were applied to a 3D DDP for an ongoing proposal in Lund, Sweden. A qualitative analysis of the designs was completed through interviews with four professionals in urban planning or GIS at the municipality level in Sweden. Based on the interviews, a final set of map guidelines for web-based 3D DDPs in Sweden was created. The results of the study highlighted the inherent connection between the visualization of a web-based 3D model and the technology behind it. The map guidelines that emerged from the interviews were broadly grouped as cartography (such as retaining industry-standard colours) or functionality of the digital application (such as including a comparison slider). Further discussion with the participants indicated that a 3D DDP would improve communication of the plan proposal to the public, when care is taken to avoid misleading visualizations. The results of the interviews showed that map guidelines would support the use of 3D DDP and would create a future where the 3D visualization is recognizable and understood more easily by the public.

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1 Introduction

1.1 Background

Preparation plays a key role in any project succeeding, especially when it comes to urban development. Construction delays are said to be universal (Zidane and Andersen 2018), and several studies have noted deficiencies in the planning phase as a key area in the building process that can cause substantial delays (McLaren Loring 2007; Nandalal 2007; Abderisak et al. 2014; Srdić and Šelih 2015). Public participation has been highlighted as an integral part of the planning phase which can affect a project's outcome and success (McLaren Loring 2007; Nandalal 2007).

The link between improving aspects of the planning process, such as public participation, and sustainable development are undeniable. The United Nations states that the realization of sustainable development requires three interconnected and crucial elements: economic growth, environmental protection, and social inclusion (United Nations 2016b). Comprehensive public participation in decision-making was declared "one of the fundamental prerequisites for the achievement of sustainable development" in the Agenda 21 action plan (United Nations 1992a, p. 270). The inclusion of citizens from the beginning of the planning process can contribute to a more robust proposal that takes local knowledge into account and lowers the likelihood of unnecessary delays due to sudden objections of the proposal. The pursuit of more sustainable development is then served by a more efficient planning process that produces a better proposal. Thus, the public must clearly understand the content of plan proposals to effectively comment on it.

Several researchers have conducted empirical studies to investigate the preference for 3D models over 2D plans and concluded that communication of design plans to participants ranging from urban planners to crane operators to students is made more effective through the use of 3D visualization (Kibria et al. 2009; Han et al. 2015; Onyimbi et al. 2018). Indeed, the use of 3D visualizations in effectively communicating with laypeople is already seen in daily life in both paper-based static form, such as in the instructions sent home with Lego and IKEA products, and in web-based digital form, such as in IKEA's online "Kitchen Planner" which allows customers to design their ideal interior space in a dynamic 3D environment (Figure 1). However, Herbert and Chen (2015, p. 31) reinforced "the importance of designing effective visualization methods (and their cartographic elements) to support specific tasks." Different applications employ different cartographic principles and visual hierarchies to focus on the objects of interest. These overarching cartographic principles for a specific application can be defined as map guidelines, and are used to produce well-designed, consistent maps which support the intended message with clarity.

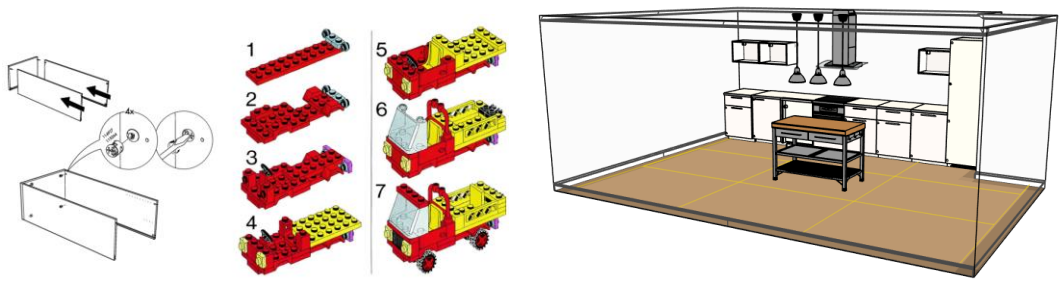

Figure 1. *Examples of 3D visualizations used in daily life, both in static forms from assembly instructions used by IKEA (left) and LEGO (center), and dynamic forms from IKEA's kitchen planner (right)*[1].

In Sweden, a Detailed Development Plan (DDP) is a legally binding document used in the planning process which indicates the details of permitted building construction on a site. Public feedback on the DDP is required several times before it reaches legal status, and a DDP currently consists of a 2D paper-based map with an accompanying written report describing the plan in further detail. Studies conducted as part of a national initiative to increase sustainability in the building industry (Smart Built Environment 2018) have highlighted a 3D digital visualization of a DDP as a way of improving communication with the public (Almqvist et al. 2016; Ljungblom et al. 2017). This application of web-based 3D DDP has begun to be implemented individually by several municipalities in Sweden without a level of standardization for the visualizations. Support for the goal of 3D visualizations of DDPs thus requires the development of map guidelines specific to that task. Although the current DDP used in Sweden is a legal document, the implications of applying that legal aspect to a 3D version are not considered in this study. Therefore, the term "3D DDP" hereafter refers to a 3D visualization of a legal 2D plan.

1.2 Aim

The aim of this study is to develop map guidelines for a web-based 3D visualization of DDPs in Sweden. The intent is to support the broader goal of a more sustainable building process by improving public understanding of plan proposals. Thus, the specific research questions (RQs) to be explored in the study are:

1. Does a 3D DDP improve communication of the plan proposal to the public?
2. Does the establishment of map guidelines support the use of 3D DDP for future public participation?
3. What are the preferred map guidelines for a web-based 3D DDP in Sweden?

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[1] *IKEA images printed with permission (IKEA Customer Support, pers. comm.). LEGO image copyright owned by LEGO Group, material shown in accordance with their Fair Play policy.*

1.3 Study Overview

A literature review is conducted and preliminary map guidelines for 3D DDP are created based on that information. Different cartographic principles are employed to develop four designs of a 3D model for an ongoing development project in Lund, Sweden. The 3D designs are shown to working professionals in the field of urban planning, who are subsequently interviewed to qualitatively analyze the visualizations (RQ3). Additional interview questions are formulated to elicit the experts' opinions on the remaining research questions (RQ1 – RQ2). Finally, the map guidelines for 3D DDP are revised to reflect the results.

1.4 Disposition

Section 2 discusses the theoretical background of the study, detailing previous research in the area and the significance of the topics raised. Section 3 provides an in-depth description of the methodology used and the motivations behind the selected methods. Section 4 presents the results of the study, and Section 5 discusses the results in the context of current literature. Finally, Section 6 provides conclusions for the study as they relate to the research questions.

2 Literature Review

Moving from a static, analogue 2D map to a dynamic, digital 3D model requires research into many different aspects: legality, the exchange of information and the data model underlying it, visualizations, and access to the new model. This thesis focuses on visualizations but also provides discussion on the other factors mentioned above, apart from the legal aspect which is beyond the scope of this study. Thus, the following subsections discuss the topics raised above, as well as the planning process, public participation in urban planning, and give a brief overview of related studies.

2.1 The Planning Process

Significance in Sustainable Development

A process in urban development which has been identified as being key to a project's success is the planning phase. Deficiencies in this phase can therefore have the opposite effect. A notable example of this is a hydropower project in Sri Lanka which, arguably due to a lack of public participation in the early planning stages, experienced a 15-year delay (Nandalal 2007). In Norway, design and administrative processes (i.e. the planning phase) were identified as key areas of project delay (Zidane and Andersen 2018). Conversely, McLaren Loring (2007) found that high levels of public participation was an indicator of project success and public acceptance, based on a review of 18 wind farm projects in England, Wales and Denmark. Proper planning in all aspects of design, communication, and public

participation is therefore critical for sustainable development, not only in mega or industrial projects, but also to smaller developments on the municipal scale.

Public Participation in Urban Planning

Onyimbi et al. (2018, p. 1) define public participation as "the process by which an organization [...] consults with interested or affected individuals [...] with the aim of making widely acceptable and sustainable decisions". The significance of public participation in urban planning has been well established in the literature as allowing citizens to feel more engaged and satisfied with their community development, as well as part of a larger functioning democratic process. On the international stage, the Rio Declaration on Environment and Development in 1992 officially stated the importance of public participation at the relevant levels and the need for information to be accessible (United Nations 1992b). More recently, the United Nations' Sustainable Development Goals included a specific target for enhancing participatory and sustainable urban planning (Goal 11, target 11.3) (United Nations 2016a), and explicitly named social inclusion as one of the core tenets to achieving sustainable development (United Nations 2016b).

However, public participation methods are not all equal. Arnstein (1969) developed the Ladder of Citizen Participation in 1969, in which she classified methods of communication on an 8-rung ladder moving from non-participation, through degrees of tokenism before finally arriving at degrees of citizen power (i.e. true participation), in which citizens are empowered and can effect change. On a national level in Sweden, the need for proper citizen dialogue is also recognized by Boverket. The Swedish agency has developed their own set of "participation stairs" based on Arnstein's work and stress the importance of informing citizens about which level of citizen dialogue is occurring (Boverket 2018a). Boverket also discusses the importance of citizen participation as part of a true democracy, and the added benefit to the project of the public's intimate knowledge of the municipality (Boverket 2018a).

For public participation to succeed, the information to be reviewed needs to be understood by the audience. Public Participation GIS (PPGIS) is an area of GIS that was first established in the 1990s and was borne out of a desire to better integrate the technological achievements of GIS with the human side of urban planning (Obermeyer 2013). It has been argued that, when communicated poorly, GIS can be an isolating technique, and debate has occurred about the use of GIS as a "democratizing or a disenfranchising force" (Obermeyer 2013, p. 66). The potential for unintentional biases led to subsequent PPGIS studies focused on methods to increase public participation in urban planning, or to improve the communication between technical (municipality) and non-technical (citizens) people (Carver et al. 2001).

As early as 2000, Carver et al. (2001) were exploring the usefulness of online GIS systems for communicating with the public. The authors noted the difficulties people had in interpreting highly technical maps and concluded that "standard cartographic techniques may need redefining and new approaches developed" (Carver et al. 2001, p. 919). A new technological approach developed since that time is 3D visualizations. On researching 3D web applications, Alatalo et al. (2017, p. 1) stated that 3D visualizations "have proven useful in enabling the participation of the general public in [urban planning projects] since they facilitate efficient communication of plans to non-professionals". A study that evaluated different visualization tools for empowering citizens found that 3D digital modelling had potential for enabling strong levels of "Integration" and "Independence", two of their identified contributions to design empowerment (Senbel and Church 2011). Onyimbi et al. (2018, p. 10) investigated the use of 3D web-based city models for electronic participation and found that, although the results indicated that the efficiency in which 3D environments could be understood depended on a person's professional background, a "3D web-based tool was more effective [at communicating information] than 2D paper-based representations". Liu et al. (2018) explored the critical success factors for public participation in urban renewal projects in China, and of the top 5 specific factors that were deemed most critical, several concerned data presentations. These included: clarity of information disclosure, diversity in the ways of disclosing information, and results presentation (Liu et al. 2018). A study in an adjacent field found that using 3D visualizations over highly technical 2D plans was more effective at communicating requirements for mobile crane operations (Han et al. 2015). This idea was further supported by Kibria et al. (2009), who found that citizens couldn't easily decipher 2D technical drawings, and had difficulty understanding the implicit 3D nature of the drawings.

At the Swedish level, studies as part of the Smart Built Environment initiative also indicated 3D visualizations could improve citizen dialogue (Almqvist et al. 2016; Ljungblom et al. 2017). Almqvist et al. (2016) conducted a pilot study largely based on interviews with professionals from 15 different organizations, including municipalities, consultants, and academia. Ljungblom et al. (2017) effectively continued this investigation into digital and 3D DDPs with an exploratory work method, studying and analyzing several issues around its implementation. Almqvist et al. (2016, p. 12) specifically stated the importance of "a functioning dialogue and communication process with citizens, where detailed plans are made more easily accessible and understandable"[2], and reiterated several times how communication with the public is assisted through the use of 3D models, which are easier for non-technical people to understand. Lantmäteriet has named the use of 3D visualization in

[2] In Swedish, English translation by author.

communication between municipalities/authorities and citizens as part of the path toward reaching the goal of digital dialogue in Sweden by 2025 (Lantmäteriet 2019).

Detailed Planning Process in Sweden and Lund

Boverket, the Swedish national board of housing, building, and planning, defines a DDP a legally binding document explaining the details of permitted building construction for a specific site (Boverket 2018b). These plans are created to complement the larger comprehensive plans also created by the municipality, which indicate more general intentions for land within the city. DDPs consist of 2D maps (Figure 2) with accompanying written reports describing the plan in further detail. An important goal for a DDP is to specify the limits of what is allowed without prematurely locking in specific designs. As Ljungblom et al. (2017, p 4) stated, "the purpose of a detailed plan is not to allow for one specific building, but for a variety of buildings within the specified boundaries".[3] This purpose can be difficult to communicate to citizens, given its abstract nature.

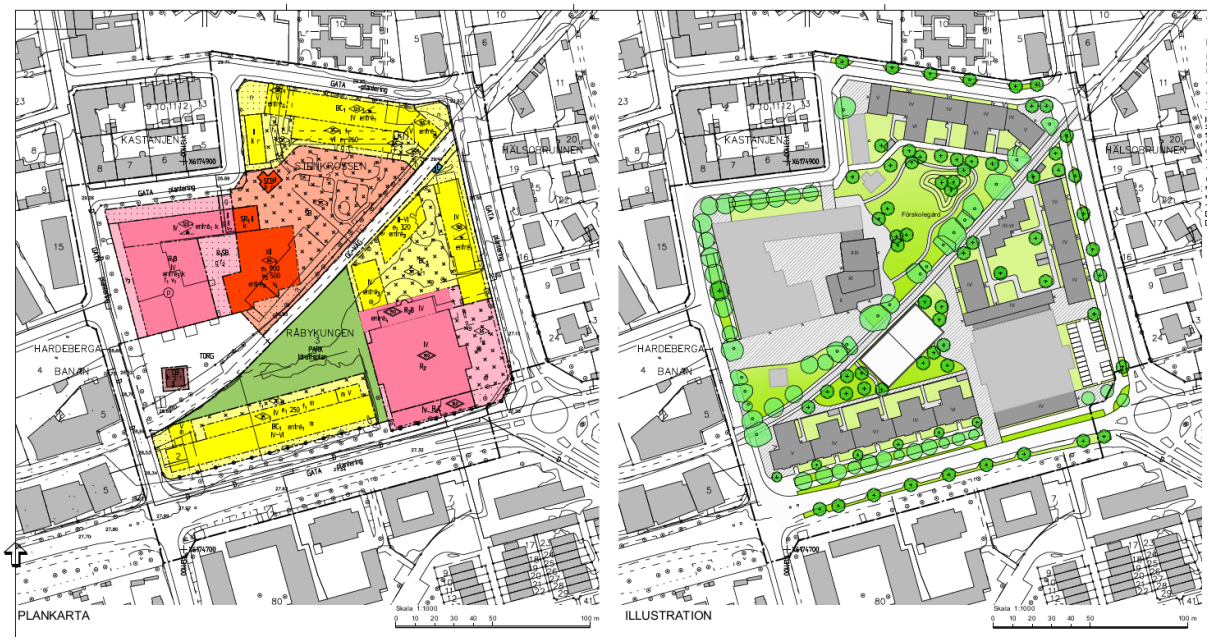

Figure 2. *An example of a Detailed Development Plan (DDP) for the study area (Stenkrossen and Råbykungen) in Lund, Sweden. The legal plan decisions are visualized on the left, and an illustration is provided on the right. The full DDP is included in Appendix A (Figures A1-A4).*

The detailed planning process in Sweden is governed by the municipalities and generally includes public feedback over several iterations of the proposal. Building permit applications are based on the subsequent legal DDP achieved at the end of the process (Boverket 2018b). It is therefore crucial that DDPs are effectively communicated to the public to empower them to understand and comment on the proposal, and to developers who need to design

[3] In Swedish, English translation by author.

appropriate buildings. In Lund, there are three separate points where feedback from the public occurs during the DDP process, although conversations with developers are ongoing throughout this process (Nilsson, pers.comm.). A summarized version of the planning process in Lund is presented in Figure 3. The first step is called plan commission (Swe. *planuppdrag*) and consists of a more general discussion of ideas for the development, such as approximate building heights and existing buildings to preserve but does not include a fully developed plan. The next step is consultation (Swe. *samråd*), followed by review (Swe. *granskning).* The information circulated for public participation at both these steps is a 2D plan map (Figure 3) and a plan description report. The information is circulated in several ways: there is an announcement in the daily newspaper, a post on the municipal website, a map hung in a public place, and paper-based information mailed out to people who live near the proposed development area. The final step of the detailed planning process is called adoption (Swe. *antagande),* once the municipality has confirmed the final DDP proposal. After this point, citizens have 3 weeks in which to officially object to higher courts before the plan achieves legal status and can move forward.

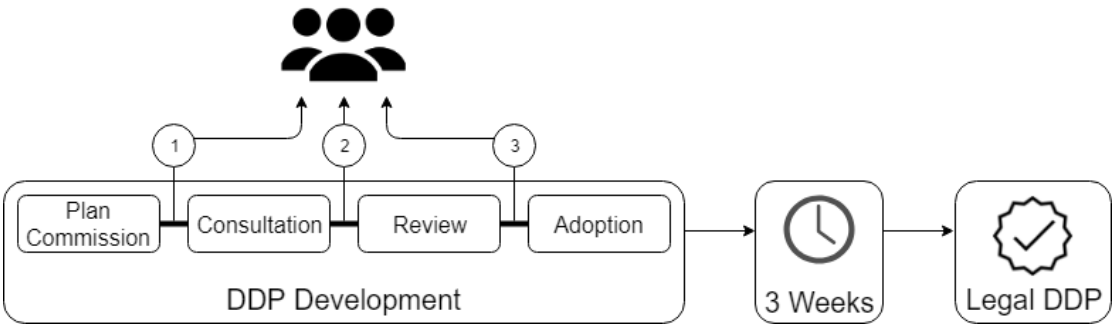

Figure 3. *A summary of the steps taken in achieving a legal Detailed Development Plan (DDP) in Lund, Sweden. If any of the public participation steps (1, 2 or 3) require major changes, the process begins again. If only minor changes are requested, the process moves forward. After the municipality has adopted the plan, there are three weeks allowed for any final objections before the DDP becomes legally binding*

Throughout the comment period, the municipality collects all submissions from the public into one document for response. Common topics of concerns raised by citizens include shade/shadows, views, traffic, and building heights (Nilsson, pers.comm.). The plan map of the DDP includes a large amount of information for a viewer to understand. The technical details and plan decisions are visualized through the colours used for each polygon (which indicate the main use of the proposed building/area), the location and spatial extent of each polygon (which indicate the maximum boundaries of the building/area), the line boundaries (which indicate the extent of the plan, and delineate public from private property), and the textual annotations, which are described briefly in the legend, and more comprehensively in the plan description report. The textual annotations indicate plan decisions such as building

height, building area, number of floors, location of entries, allowance of complementary buildings, etc. The plan description report circulated with the 2D plan map includes pictures of a highly detailed 3D illustration of suggested structures (Figure 4). This is not a 3D DDP but is intended to provide an example of how the rules of the DDP may manifest. However, it may be misconstrued by the public as the finished product of the development and can result in public feedback on non-issues such as the colour of the buildings (Nilsson, pers.comm.). It is important that a 3D DDP communicates the plan decisions to the public while remaining impartial to the final design.

Figure 4. *A highly detailed 3D render of the study area with suggested structures as visualized by Lund municipality in the plan description report.*

2.2 The Information Flow in the Planning Process

The information flow in the planning process refers to the exchange of data that occurs between the different actors involved, such as the public, municipality, architects and developers. There is currently no standard for what type of file format or material is used at each stage of the planning process, with Boverket simply stating, “an application […] must be in writing and contain the information, drawings and other documents necessary for the application […] to be handled“ (Boverket 2018c). This was echoed by a city architect at Lund municipality, who indicated the city receives a large variety of materials from applicants with varying degrees of professionalism (Nilsson, pers.comm.). However, architects often work in a 3D Building Information Model (BIM) environment when designing buildings, while the 2D DDP in Lund is currently made available to developers through PDF or DWG files sent by the municipality. Previous working groups affiliated with Smart Built Environment identified the inefficiency that exists when design documents are transferred between 2D and 3D formats early in the building process, and how information can be lost as different actors switch between the different models (Almqvist et al. 2016; Ljungblom et al. 2017).

Sweden is currently working to digitize and standardize building documents, including DDPs, to increase sustainability in the building industry (Smart Built Environment 2018). Since the DDP process in Sweden is governed at the municipality level, there is a disparity in how each municipality handles the DDP information structure and workflows around it (Ljungblom et al. 2017). Lantmäteriet, the Swedish authority for mapping, has a goal of an "unbroken digital community building process" by 2025, and identifies a main obstacle to this goal as the fragmented and analogous information supply (Lantmäteriet 2019). A national innovation program called Smart Built Environment aims to improve efficiency between involved actors in the building process using standards and technological advancements for changing the way documents are created and shared. The Swedish Standards Institute (SIS) published a standard in 2016 for the digitization of DDP in eXtensible Markup Language (XML) format (Swedish Standards Institute 2016); however, only recently has the legislation been progressing at a national level to make the standard a requirement (Boverket 2019). The Swedish parliament voted in a proposal to amend the Planning and Building Act in 2018, stating in part that all municipalities and authorities should use a common standard for digitizing DDPs (Regeringskansliet 2018). Lantmäteriet has identified the need for standardized information and exchange models in the pursuit of digital urban planning (Lantmäteriet 2019). The standardization and digitization of DDP would provide a strong framework for further technological advancements such as 3D models. It would also allow for the development of a national database of DDP and building permits across Sweden, allowing for a truly transparent building permit process (Almqvist et al. 2016).

It is also recognized that a lack of standards in required file formats coupled with ongoing incompatibilities between Geographic Information Systems (GIS) and BIM hinders the use of novel technological solutions for a more efficient information flow. Almqvist et al. (2016) and Ljungblom et al. (2017) recognized the potential of 3D models in automating parts of the decision-making process. Olsson et al. (2018) investigated the potential for an automated building permit checking system and identified three requirements to support automation: unambiguous DDP rule implementation, a machine-readable DDP, and integration between GIS and BIM formats. (A machine-readable format in this context refers to a format which can be parsed by a computer program, such as an XML format, and does not include PDF.) A Dutch study also explored an automatic building permit check, and discussed the benefits of making the DDP available as a 3D information model for architects to convert to a BIM environment and design permissible buildings (van Berlo et al. 2013).

A full data exchange between developers/architects and the municipality in the planning phase thus require two steps: the existence of the DDP in a 3D, machine-readable format, and compatibility between the GIS and BIM environments. While the focus of this

study is on the 3D visualization of a DDP, it is therefore recognized that the development and use of 3D information models is also an important step toward the goal of lossless data exchange between architects/developers and the municipality. The 3D information model is briefly discussed in the following subsection, but no further studies of this topic are included in this report.

2.2.1 The 3D Information Model

The movement from a paper-based 2D plan to a 3D digital model also implies a movement from a static to a dynamic application. The usefulness of a 3D model comes not only from the visualization aspect, but from the information or content contained within. The information exchange in the planning process is critical, indicating the need for an appropriate information model. The retainment of all the plan decisions from the 2D version would result in a semantic 3D model, wherein the objects have meaning and are linked to relevant information. While the legal implications of the DDP existing in 3D space are still under discussion in Sweden, previous studies have indicated that a 3D DDP should ideally be in a machine-readable format (Olsson et al. 2018), and consist of an open data, or non-proprietary, model in order to bridge the gap between the various software tools used (Ljungblom et al. 2017).

One such open data information model is CityGML, which is based on XML and is used to store and exchange 3D city models (Open Geospatial Consortium 2012, p. 9). CityGML is issued by the Open Geospatial Consortium (OGC) and has been introduced as an "international standard for the representation and exchange of semantic 3D city and landscape models" (Kolbe 2009, p. 16). It is likely that a 3D DDP would be placed within the context of a 3D city model. According to Alatalo et al. (2017), CityGML is frequently used in urban planning and includes visual, spatial and semantic object properties. Indeed, there are numerous examples of CityGML being chosen for various 3D urban models, such as a study on 3D model generation from volunteered geographic information (Goetz 2013), its use in disaster management (Kolbe et al. 2005), and for modelling entire cities including Berlin, Brussels, Helsinki, Lyon and Montréal (3D Geoinformation Group TU Delft 2017).

CityGML currently exists as version 2.0; however, the next major update to CityGML 3.0 is expected for release in 2019 (Kutzner and Kolbe 2018). Kutzner and Kolbe (2018) gave a brief overview of the coming revisions and improvements, one of which is improved interoperability with the data model Industry Foundation Classes (IFC), which is an international standard for BIM. This progression toward GIS/BIM integration further supports the use of CityGML as an appropriate information model for a future 3D DDP, although a full investigation into the information model is outside the scope of this study.

2.3 3D Visualization

The communication of data is as important as its creation and should warrant as much focus. It is beneficial to review how 3D visualizations have been used thus far, and to delve into specific design principles or considerations in effective communication of 3D data.

2.3.1 The Current Use of 3D Visualizations

3D visualizations can generally be split into either visual presentation models or semantic models, with the specific use case dictating the model type. The former can be described as purely a visual representation of the data, while the latter consists of objects connected to underlying information. 3D city models are perhaps the most established use of 3D visualization in GIS. A well-known 3D city model comes from Berlin, but other notable cities with 3D models include Adelaide, Brussels, Cambridge, Helsinki, Lyon, Montréal, Toronto and New York City (3D Geoinformation Group TU Delft 2017). The use of 3D city models is especially widespread in Germany and the Netherlands. An extensive literature review on the applications of 3D city models summarized over 400 references into 29 use cases, split into visualization and non-visualization groups (Biljecki et al. 2015). Examples of visualization applications include such diverse cases as flight simulation, optimizing radio infrastructure, crisis management, and predicting tree growth; while the most similar use cases to this study were urban planning and 3D cadastral plans (Biljecki et al. 2015). A cadaster is a legal document used to represent ownership right and property boundaries and is similar to a DDP in that both are legal documents manifested as 2D technical representations. The 3D visualization of cadastral plans has been a focus area for several recent studies (Ying et al. 2011; Biljecki et al. 2015; Shojaei et al. 2016). Exploration into the use of game engines, virtual reality (VR) and augmented reality (AR) for 3D visualizations in urban planning has also increased in recent years (Schroth et al. 2014; Biljecki et al. 2015; Alatalo et al. 2017).

The use of some form of 3D visualization of DDP is currently implemented by at least 14 municipalities in Sweden, including Gothenburg, Norrköping, Umeå, Stockholm, and Västerås (Trigueiros, pers.comm.). Most of these municipalities are using the Swedish software CityPlanner to develop and view their 3D models. However, as happens without overarching principles, the 3D models and DDPs manifest slightly differently in each municipality (Figure 5). Creating a 3D DDP from the information contained in the plan proposal inevitably results in a box model, a 3D model which shows the outer limits of what can be built. It remains vital that all the information communicated through a plan proposal is retained in a 3D visualization to ensure its functionality. Many of the current Swedish models are mainly for visual presentations instead of being entirely semantic, wherein specific information for each 3D object cannot be selected. Instead, more general information is provided in pop-ups or a sidebar or as a link to a PDF of the DDP. Despite the increased use

of 3D DDP in Sweden, the use of 3D models to communicate plan proposals to the public still requires its own set of map guidelines. As Herbert and Chen (2015, p. 22) succinctly stated, "the cartographic theory that may inform these geovisualizations generally trails the technology", indicating that adoption of 3D models alone does not achieve the goal of improving communication to the public.

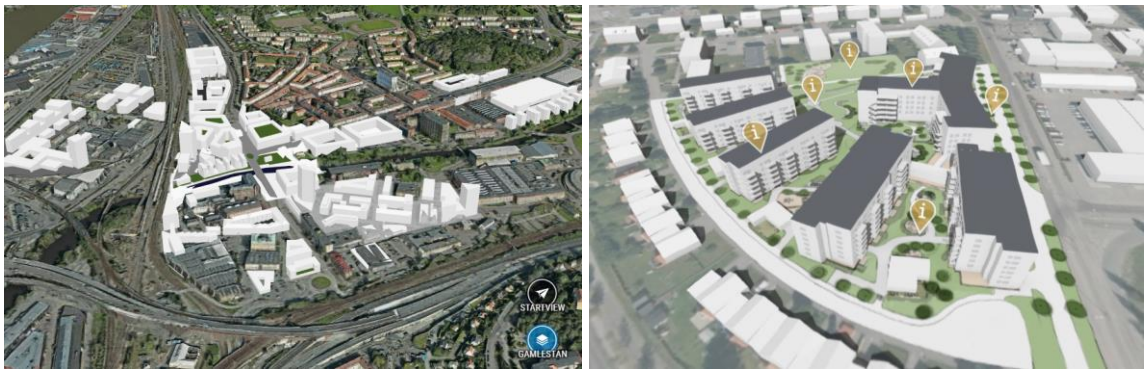

Figure 5. *Various forms of 3D visualizations are being employed by Swedish municipalities, with an example from Gothenburg on the left and Umeå on the right.*[4]

2.3.2 Design Principles for 3D Visualizations

Maps are used to communicate spatial information and are thus "best critiqued on how effectively they achieve their communicative purpose" (Muehlenhaus 2013, p. 412). Different maps use different cartographic principles and visual hierarchies to focus on the objects of interest. For example, the DDP shown in Figure 3 is concerned with communicating information about the proposed development, so the background map and surrounding area is shown in simple grey and white while the study area is suffused with colours representing the DDP rules. These overarching cartographic principles for a specific application can be defined as "map guidelines", used to produce well-designed maps which support the intended message with clarity. The idea of designing visualizations tailored to a specific application is supported by Herbert and Chen (2015).

With the increase in use of 3D city models and visualizations, researchers have started to focus on specific design principles which need to be re-thought when moving from 2D to 3D space. Neuville et al. (2018) explored visualization parameters that conflict with each other in 3D space and developed a program that would highlight these conflicts as a user was styling 3D data. Conflict examples from their study included the use of shadows obscuring other objects, transparency leading to a look of superposition, and the difficulty in choosing the "ideal" camera angle so as not to obscure other data (Neuville et al. 2018). The pursuance

[4] *Gothenburg imagery from https://minstad.goteborg.se/minstad/index.do, retrieved 12 April 2019. Umeå imagery from https://cityplanneronline.com/UmeKommun/360/vasterteg, retrieved 12 April 2019.*

of 3D cartographic principles was conducted in a study by Häberling et al. (2008) who interviewed experts on their preference for various 3D map designs. The authors concluded with 19 design principles concerning degree of abstraction, symbol sizes, camera aspects, lighting aspects, and atmospheric effects; however, an acknowledged study limitation was the focus on static 3D maps (Häberling et al. 2008).

Ljungblom et al. (2017) discussed the benefits of retaining industry-standard colours from 2D plans (Figure 3) to 3D DDP in Sweden to increase the recognition factor and breed familiarity for working professionals. Herbert and Chen (2015) investigated varying shadow visualizations in a 3D model and found preferences for volumetric shadows over ground-draped shadows, a 40% transparency setting or the ability to adjust this, and the colour blue over grey. The study of visual clutter caused by textual annotations in a 3D model highlighted the need for a proper and intuitive method for the user to parse through annotations, indicating that the reduction of visual clutter was necessary to increase the efficiency of finding relevant data (Camba et al. 2014). This was supported by Ljungblom et al. (2017), who concluded that little to no text in a 3D model was preferred, and that the data should ideally be searchable. Herbert and Chen (2015, p. 31) noted that the most significant advantage of a 3D model may be "the ability to adjust viewing angles and position and freely navigate within the digital environment."

Billger et al. (2016) raised several challenges with communicating plan proposals to citizens, such as the difficulty in avoiding misrepresentation of reality or the possibility of alternative (and erroneous) interpretations of the data. The authors found that, "when high photorealism is used, a sketchy proposal can be understood as a fixed solution" (Billger et al. 2016, p. 15). This was supported by a city architect in Lund, who had noted that citizens misunderstood an example 3D illustration as the final project goal (Nilsson, pers.comm.), and was further echoed by a study completed by Kibria et al. (2009) who found the Level of Detail (LoD) in the 3D visualization should match the planning stage (a higher LoD implies more detail has been employed). They explained "[w]hen the building is visualized in LoD2, the viewers focus on local details of the building design and think that the final design may be altered […] when the same design is viewed in LoD3, the viewers perceive that the building will be fairly similar to the realized project" (Kibria et al. 2009, p. 389). Indeed, the disconnect between the fact that high realism can impede the core message and the idea that increasingly realistic data representations are preferable has been called "naïve realism" (Smallman and St. John 2005). Smallman and St. John (2005, p. 12) argue instead that "displays should highlight task-relevant information, and this process of highlighting inevitably entails paring down reality".

2.4 Previous Studies of 3D DDP

Several studies were found which directly dealt with the equivalent of 3D DDPs in countries outside of Sweden. An empirical study of geo-virtual environments in communicating information in urban plans based in the Netherlands partially investigated the "relationship between visual materials and design phase" (Kibria et al. 2009, p. 391). The study found that "the human ability to perceive design increases" when moving from 2D to 3D higher levels of detail, and that the preference or inclination toward 3D visualizations increased as the building process moved from the abstract (i.e. zoning maps) to the actual (i.e. final building designs) (Kibria et al. 2009, p. 390). However, their results also indicated that 2D plans and maps retain their relevance in earlier planning stages (Kibria et al. 2009). Another Dutch study investigated the viability of changing 2D building plans to 3D versions and subsequently integrating the result with BIM for potential automatic building permit checks, but found that technical issues prevented this process from coming to fruition (van Berlo et al. 2013).

A study based on Koh Mudsum, an island in Thailand, explored the improvement in public participation stemming from the use of 3D visualization in the planning process (Wanarat and Nuanwan 2013). The authors visualized different iterations of proposed building densities so that citizens could more clearly understand the visual impact that the proposals would have on the island, and concluded that "3D visualization is deemed appropriate as a communicative tool to facilitate public participation" (Wanarat and Nuanwan 2013, p. 688). A qualitative study based in New Zealand also explored the usefulness of 3D visualizations of buildings based on a detailed plan for the proposal, but with particular focus on shadow visualization (Herbert and Chen 2015). The study found the advantages of 3D visualization included the added contextual information of visualizing the proposal within the urban landscape, shadow effects, and ability to navigate through the environment (Herbert and Chen 2015).

The viability and use of 3D DDP in Sweden were previously explored by Lagerlöf (2014). The author contacted 40 municipalities in Sweden and found that none were using 3D DDP at that time, although two municipalities (Gothenburg and Linköping) were using 3D visualizations to communicate with citizens regarding plan proposals at different phases of the planning process (Lagerlöf 2014). Since then, several Swedish municipalities have begun using 3D DDP as a communication tool with their citizens; however, this has manifested in a more ad-hoc fashion due to the lack of published clear direction on how a 3D DDP should be visualized. There is ongoing work into standardizing the digitization of the DDP, and it follows that further development, like 3D visualization of a DDP, should also be standardized.

3 Method

3.1 Research Design

The aim of this study is to develop map guidelines for a web-based 3D DDP with the intention of improving public participation in the planning process. The goal of gaining insight into preferred visualizations for 3D maps is well suited to qualitative research, which can emphasize a more holistic approach in analysis and allow for more in-depth analysis with fewer participants (Ghauri and Grønhaug 2002). Experts who work in the professions of urban planning and GIS for the municipality were chosen to provide a thorough evaluation of the 3D designs. Wroblewski and Leitner (2009) noted the efficiency gained in using expert interviews to analyze a model, which is beneficial for a study of limited time scope. Interviews are an accepted method for collecting primary data and are preferred over questionnaires for qualitative studies based on the flexibility they allow for the participants' responses (Ghauri and Grønhaug 2002). A semi-structured interview method was chosen in order to strike a balance between allowing for the experts' views and opinions to be expressed while still considering how the research questions would be answered.

The research design is summarized in Figure 6 and described as follows. Based on the literature review completed in Section 2, preliminary map guidelines were created. Four different designs of a 3D model for the study area were created using different cartographic principles. A qualitative analysis of the maps was undertaken using expert interviews and the map guidelines were revised to reflect the results.

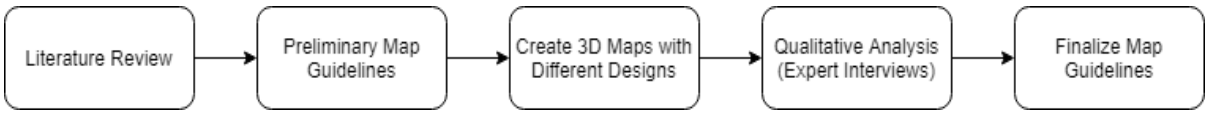

Figure 6. *A summary of the research design for the project.*

3.2 Study Area and Data

The study is based on a DDP created for a proposed development called Stenkrossen and Råbykungen in Lund, Sweden (Figure 7). The planning process for the study area began in 2011, and the city hopes to reach the approval stage by the end of summer 2019 (Nilsson, pers.comm.). Data provided for the study by Lund Municipality is summarized in Table 1. The DDP used as the basis of this study was the version released during the consultation phase of the planning process (Swe. *samrådshandling*) on February 1, 2018 (Appendix A, Figure A4).

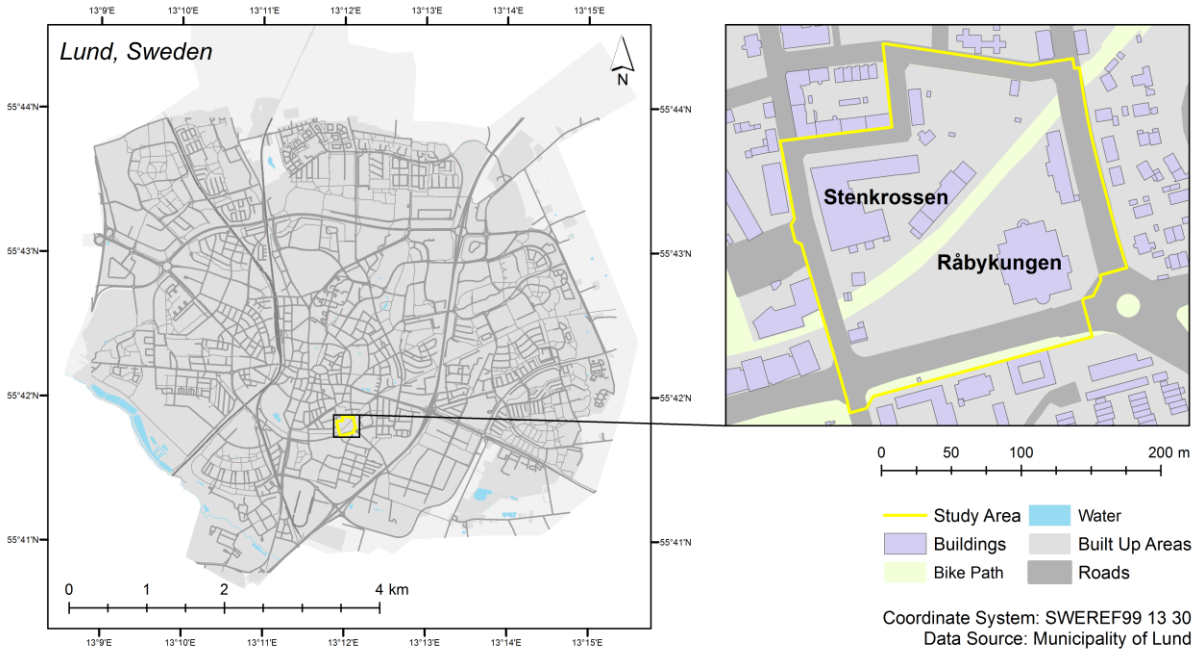

Figure 7. *The location of the study area (Stenkrossen and Råbykungen) within Lund, Sweden.*

Table 1. *Data provided by Lund Municipality for the study.*

2D/3D	File Format	Details
2D	DWG (AutoCAD) and PDF	Detailed Development Plan
2D	Shapefiles (ESRI)	Lund base map data (roads, buildings, land use, vegetation)
2D	GeoTIFF	Digital Elevation Model
3D	Multipatch (ESRI)	Existing buildings (city model)

3.3 Preliminary Map Guidelines

The preliminary map guidelines were based on the reviewed literature which contained guidelines for best map-making practices based on specific studies. Although some of the design principles reviewed in Section 2.4.2 were intended for static maps and were therefore not fully relevant to this application, the preliminary map guidelines that were developed as a starting point for directing the 3D DDP visualizations included the following:

- Avoid known visual conflicts in 3D space – in particular, use transparency, shading, and shadow with caution (Neuville et al. 2019).
- Avoid highly realistic representations (Smallman and St. John 2005; Kibria et al. 2009; Billger et al. 2016).
- Avoid or minimize textual annotations (Camba et al. 2014; Ljungblom et al. 2017).
- Allow for dynamic viewing angles and positions (Herbert and Chen 2015).

Another previously discussed suggestion was to retain industry-standard colours from the current 2D plans (Ljungblom et al. 2017); however, this was excluded from the preliminary map guidelines so as not to hinder the exploration of other colours. Aside from the previous literature, additional guidelines were chosen to support the intended message of communicating the plan proposal to the public:

- Visualize the DDP within a 3D city model for additional contextual information.
- Visualize existing buildings in the study area as a reference point for citizens.
- Visualize an example design to communicate the difference between the DDP and potential buildings.
- Retain all the information found in the 2D DDP.

Four different designs were created which retained these underlying map guidelines. The designs are described in further detail below and can be accessed online at ArcGIS.com. [5]

[5] https://www.arcgis.com/home/group.html?id=cd1fb0dc80174a4795a634def00bc64b#overview

Design 1 (Figure 8) was created to test for industry-standard colours. It mimics the cartography of the current DDP by retaining traditional colours and keeping the focus on the study area. The basemap is visualized with white groundcover and grey streets. The buildings in the city model are visualized as light grey with no further details, and almost blend into the background. The colours used to visualize the study area refer to the primary usage in the proposal.

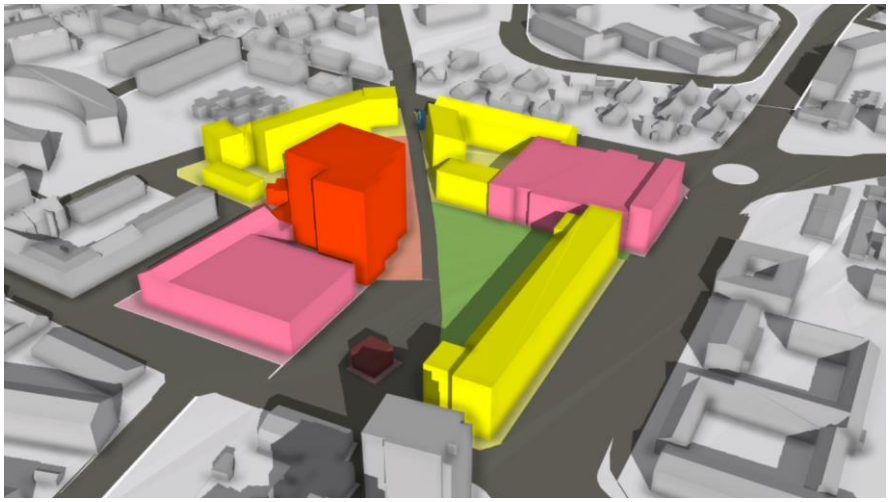

Figure 8. *A screenshot of Design 1 as viewed through the City Engine web application.*

Design 2 (Figure 9) was created to test for a simpler study area with more visual cues in the surrounding area, as a contrast to the style of Design 1. The basemap is visualized with green and tan groundcover and light grey streets. The buildings in the city model are visualized as dark grey with no further details and have a higher contrast with the basemap. The proposed building areas are shown in white, with the groundcover of the study area continuing the style of the basemap.

Figure 9. *A screenshot of Design 2 as viewed through the City Engine web application.*

Design 3 (Figure 10) was created to test a more realistic surrounding with a simple study area. The basemap uses an orthophoto and the buildings in the city model are visualized with fictitious facades created with CityEngine, as there was no previously created 3D model of Lund at that level of detail. The vegetation placement is based on real geo-data, but the tree visualization is generated with the software. The study area is kept in focus by being shown entirely in white, including groundcover.

Figure 10. *A screenshot of Design 3 as viewed through the City Engine web application.*

Design 4 (Figure 11) was created to test a more abstract style of both the study area and surrounding model. It removes some of the detail from Design 3 by using more symbolic styles for the basemap (textures for groundcover, like grass, cobblestone, and dark asphalt) and vegetation. The buildings in the city model are shown in white with no further detail, while the study area is kept in focus with dark grey walls and a dark red roof, intended to pull focus and add detail.

Figure 11. *A screenshot of Design 4 as viewed through the City Engine web application.*

3.4 Practical 3D Map Creation

Currently there is not a go-to application for 3D visualizations in urban planning. Previously reviewed studies used a wide variety of software to generate 3D models including Autodesk Revit, CityEngine, SketchUp, CityPlanner, 3D-Analyst for ArcView, SolidWorks, AutoCAD, FME, and 3DMax, often coupled with in-house development for particular applications. The requirements for this study included the following:

- Availability of the software;
- Ability to import the provided data to create the 3D city model and DDP;
- Ability to share the 3D models with participants; and,
- Additional functionality in the web application for the viewer.

CityEngine fulfilled these requirements and was thus used for the study. Sharing the 3D model through the web application provided the functionality of allowing viewers to navigate through the model and view it from any angle; alter the sun position to view how shadows would change throughout the days and year; search attributes related to the DDP or click on an object to view its attributes in an information pane; and view two scenarios side-by-side in comparison mode (Figure 12).

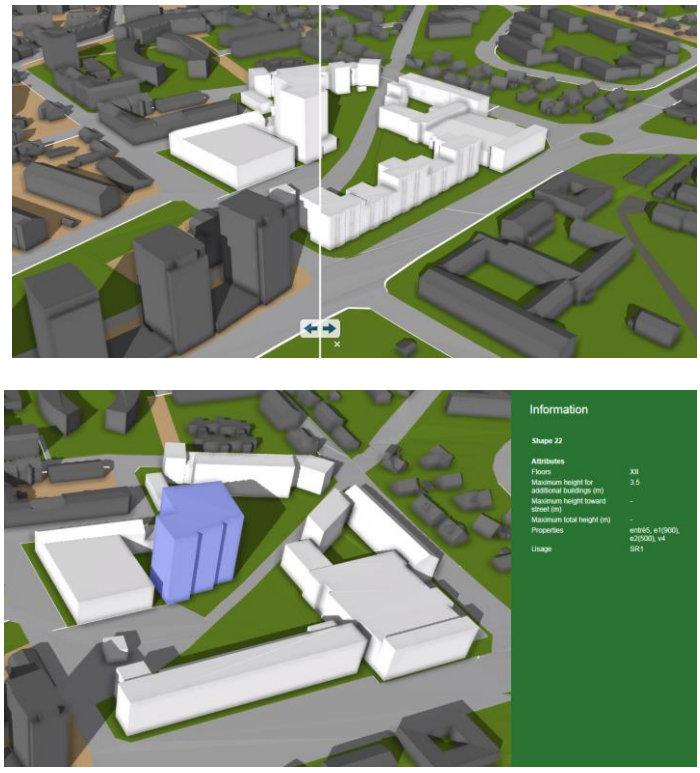

Figure 12. *Using Design 2 as an example, the comparison mode is shown on the top, while the bottom shows the function of clicking on an object in the DDP and being shown its attributes in an information pane.*

The base 3D DDP model was created by first translating the provided DWG file into shapefiles using FME 2018.1 (Safe Software, Vancouver, Canada). The resulting data was processed in ArcMap 10.5.1 (ESRI, Redlands, USA) before being imported into a new scene within CityEngine 2018.1 (ESRI, Redlands, USA). Rule files were created using the CityEngine scripting language Computer Generated Architecture (CGA) shape grammar and were used to generate the 3D content by extruding polygons to their maximum height based on the information found in the DDP, creating a box model. All polygons within the original DDP boundaries became either objects (3D) or shapes (2D) in the 3D model, with attributes expressing the information found in the plan proposal. The 3D model was defined as a type of semantic model, owing to the attribute retention. A 3D city model of Lund does not currently exist, so a surrounding map was created using the provided data in order to place the 3D DDP within the context of its neighborhood. Due to export size restrictions, only a portion of Lund was visualized in the 3D model.

In CityEngine parlance, three different scenarios were created for the study area to provide the user with options to view either the existing buildings, the plan proposal as visualized as a 3D DDP, or an example design of possible buildings. The base 3D model was then styled according to the cartographic principles described in Table 2. For each design, the existing buildings were styled to match the surrounding city model and the example buildings were styled to match the DDP. Once the 3D maps had been completed, they were exported as CityEngine Web Scenes (a proprietary format with a ".3ws" file extension), uploaded to ArcGIS Online, and viewed through CityEngine Web Viewer. Using the comparison slider functionality of the web-based application, two scenarios could be viewed simultaneously with the user retaining the choice for the viewing order (left, right, top or bottom).

3.5 Interviews

Experts were chosen to partake in the study based on their professional area (urban planning, GIS, building permits) and/or employer (Boverket, Swedish municipalities). Ten people were contacted for interviews, of which two declined, four did not respond, and four agreed, for a 40% response rate. The makeup of the participant group was half female and half male, with ages ranging from approximately 30s to 50s. Participants were sent the questions, the original DDP, and a link to the 3D maps found in ArcGIS Online prior to their scheduled interview. During the semi-structured interview process, each participant was asked the same set of open-ended questions (Appendix B). The interviews took place at Kristallen, the municipality office in Lund. To ensure the validity of the primary data collection and analysis for the study, the interviews were recorded using an Olympus Digital Voice Recorder (VIN-741PC) with each participant's permission. A summary of the participants' details is found in Table 2.

Table 2. *A summary of the interview participants and details from the study.*

Profession	Job Location	Experience	Interview Date	Interview Duration
Plan Architect	Urban planning, Helsingborg	8 years	17/04/19	60 min
City Engineer	GIS, cadastral services, Lund	16 years	18/04/19	50 min
Plan Architect	Urban planning, Lund	3 years	24/04/19	105 min
Urban Planning Intern	Urban planning, Lund	6 months		

3.6 Qualitative Analysis of 3D Designs

A process of data reduction was completed for each interview with the aim to "focus, simplify and abstract to create meaning from the mass of words" (Ghauri and Grønhaug 2002, p. 138). The interviews were first transcribed, then the responses were summarized for each question, and finally, key points were highlighted. An important aspect of validity is the ability of the research to demonstrate its statements (Ghauri and Grønhaug 2002); therefore, subsequent interview transcriptions and key points were validated with the participants (i.e. each participant was given an opportunity to confirm their responses post-interview). Further, when key points for each topic are presented in the results, supportive quotes from the interviews are included as a validation of the source. Based on the information summarized from the interviews, the map guidelines were updated, and a final design was created to reflect the results.

4 Results

A summary of the key points from the interviews for each topic is provided below. It should be noted that some of these points contradict each other, owing to the discordant opinions of the participants. The statements are supported by at least one quote from the interviews; and if two quotes are used, they come from different participants. Approximately the same number of quotes was used from each participant.

4.1 Communication Changes

The Role of Public Participation in Sustainable Development

Important for a democratic and well-functioning society
"It is very important because it affects the public; it affects the citizens, the members of society, so they must have a formal ability to say something about [it.]"
"It's very important to have good communication with the citizens regarding what is going to be built in the city [… coming] from a country that has a long history of disregarding the needs of citizens."

Focus on the social sustainability aspect
"It's […] maybe not that much of the economic or environmental sustainability, but from the social sustainability aspect it's extremely important."
Tangible benefit to the plan design
"[Any] time you put more brains together you have […] the ability to get a better result. If you don't do it, it might be wrong."
Public participation might have more impact at an earlier phase
"[In] the comprehensive plan, the dialogue is very important because that's the first step of the planning process. […] If you could collect opinions more widely and more all the time it could be a better [foundation for planners] to work with from the start"

The Design of the Current 2D DDP

Difficult for non-professionals to understand
"Looking at this as someone without any prior knowledge is practically impossible. […] I don't think they are doing a very good job at aiding us in our communication with people who are not of our own profession."
The illustration pulls focus with varying results
"[People] look at what they can actually understand and that is the illustration, […] so, they think this is what it should be, not [the DDP]"
Paper-based document is legal but out-dated
"It's also very small scale and [being] printed it's like a dead document, and you're not able to zoom in […] and I think it's very old fashioned. It's also cut out from the rest of the surrounding and it's important to see the suggestion in relation to the surrounding." *"It does the work for justice, for legalization; […] this is what the legal plan is."*

Change in Communication of the Plan Proposal through 3D Visualizations

Easier for people to understand
"It's always much easier to understand when you have a volume […] When you have the ability to actually get down on the ground level within that model, you get an understanding of heights etc. that you can't get from any perspective."
Dynamism of the 3D model is powerful
"It would be much [easier] to see in relation to your [own situation…] It's a lot of opportunities to see the real impacts."
Touted as the future, with more work required
"[This] is the future. And there's many […] municipalities in Sweden that have 3D platforms […] as a complement to the detailed plans, but they're not so developed that the user can really get this information that one detailed plan contains."

Foreseeable Issues with Using 3D DDP

Risk of false perception of box model and illustrations
"It can be misleading for the public when they see a big block which is showing the max height and max area which can be built here. […] It can also be misleading [to see a] beautiful building or illustration which is not really what will be built there."
Importance of communicating an open planning stage
"It's important to have some kind of communication with 3 models shifting […] this is Variant A, Variant B, Variant C." *"It has to be [a] dynamic model that the user can see that […] it can be any type of architecture there, but with max height and max restrictions."*
Stronger reactions from the public
"People can relate more to it if it's a 3D model and it can be a good thing as well, but […] if you communicate a stronger image of a building plan, then maybe it could be a longer dialogue process."

4.2 Barriers and Support for the Use of 3D DDP

Barriers to the Use of 3D DDP

The change in profession for architects and planners
"[The] major part is just letting go [of the information] and adapting new workflows as well. Because building a 3D model [is] not the same workflow as constructing a 2D plan."
Fear of loss
"The industry talks a lot today about the volume, the mass of the buildings because of the economics, […] but we want to talk more about the life between the buildings and the architecture and the forms […] it's important to not lose those parts of the planning."
Technical details when moving from 2D to 3D space
"In 3D […] coordinates become even more specific in the material. […] There is a culture difference between younger […] and older professionals [in how the accuracy of the data is handled.]"
Usability and inclusion of a new technology
"It should work, and it should work for different people, different ages and different technical skills. […] Interaction design is very important."
Fear of the unknown
"[It's] hard to know how people will react. Because now you know what kind of opinions people have, and […] when we switch to a 3D model it will be […] different opinions that will come in." *"It's actually something in society called "moral panic", and it's usually about technology and innovation. […] There is this fear of change [and] negative effects of the social morale, or any other kinds of negative impacts like maybe losing jobs."*

Support for the Use of 3D DDP

Added value
"Parametric design [is] one thing that could help us understand or show [how] could this plan be used outside our own boundaries."
"You can even simulate events when you use such a model, let's say flooding and natural disasters, which helps for more sustainable planning of the city."
Democratic appeal
"The interactivity of digital media is […] maybe the biggest thing, the participatory culture that media offers to citizens […] to be part of the decision-making process."
Desire to "catch up"
"Society in general goes more with 3D, and I think our industry is kind of behind […] so, to keep up we need to go in that direction."
Interaction design
"The visualization must be proven by the interactive design, and the function of design. You must understand what you do and what you can see and what the aim and the target of this presentation. […] The information model must work."
Standardization
"There needs to be some kind of standardization I believe, to make sure that Lund and Helsingborg don't do entirely different [models] because then we wouldn't have the benefit."

The Role of Map Guidelines in Support for 3D DDP

Standardization supports future development (software and legality)
"I think that's the main reason to have standardization, is to support the development of software. And make sure that it doesn't matter which software, you could work anywhere. […] Then we probably have to have some kind of standardization for visualizing the information within the legal process. […]."
"The programs that are used to create the future 3D plans can be different programs, but they should support the same functions, so architects can create plans according to one common national standard."
Good design should aid the user; consistency breeds recognition
"[As] the design of things, the form of the thing, will tell you how to […] interact. […] It's design of the detailed plan. You need to know what the colours stands for and you will recognize them and […] understand."
"There's a very big difference between a detailed plan and an illustration and it's very important to not make an illustration but to make a detailed plan. […] It's very important to make […] a detailed plan in 3D that is [easy] to recognize."
Data behind the visualization
"The visualization might not be the most important part but how the data is treated behind the visualization. [The visualization] might be adapted towards different [audiences]."

4.3 Design Critique

During the interviews, the participants were shown each design in turn and asked to critique them with prompting questions asked by the interviewer. The results from those discussions are summarized for each design below.

Design 1: The traditional colours aid recognition – especially for planners, but also for citizens who have previously seen detailed plans - and are a strong visual cue for planning, not reality. It was noted that the box model in high contrast colours felt “too strong”. Participants wanted a legend for the plan colours and possibly vegetation. The roads within and outside of the study area should be differentiated.

Design 2: The inclusion of some environmental detail and a slightly more realistic environment was better for orientation. In the planning profession, a white box model represents buildings which can be confusing when applied to the maximum restrictions of a DDP instead. Since the DDP is all white, there is no obvious visual cue that the box model is showing something other than buildings, and although the limits of the detailed plan are now easily discernable, the plan decisions are no longer visible. Hence, it appears more as an illustration since it doesn't convey the regulations. Users felt they were missing transparency, more information, boundaries, and that the detailed plan should be in colours representing their usage.

Design 3: The level of detail distracts viewers and takes too long to load, making it an ineffective work tool. There is a lack of focus on the proposal, as attention is drawn away from the plan to the details around it: the orthophoto, fictitious facades, and vegetation. The use of fictitious facades in the city model would be especially distracting for local citizens; unless there is an exact city model, people will be distracted by inconsistencies between reality and the model. This design doesn't show the plan details visually, but the boundary of the detailed plan is clearly visible. The vegetation inclusion is good in general as it lessens the shock of big buildings, but trees should not be included in the detailed plan unless it is regulated. One participant thought the trees should be more symbolic.

Design 4: The vegetation provoked much discussion. Amongst the participants, it was noted both that the symbolic vegetation was better than Design 3, and that the symbolic trees were annoying, unnatural and distracting. It was suggested that the gaming industry had better examples of vegetation to use. The other main comment was the use of different colours for walls and roofs in the study area, which gave the incorrect impression of actual buildings instead of maximum exploitations. The study area appeared like an illustration, while the city model seemed like the planned area due to the association of white 3D models with planning.

Base 3D Model and CityEngine Web Viewer

The participants also had many comments on the base 3D model and the viewing application which applied to all the designs. These comments and supplied suggestions are summarized in Table 3.

Table 3. *A summary of the general critiques made by the participants about the base 3D model and the functionality of the viewing application.*

Comments	Suggestions
- Need to communicate visualized volumes aren't buildings	- Transparency as a visual cue - Show several different building examples to indicate ongoing planning
- Comparison mode is an especially useful way of helping people understand the difference between DDP and example buildings	- Slider is always visible, possibly with DDP on left and other scenarios on right
- Flexibility of a digital model should be utilized by giving the user options	- User options for changing visualizations; background and city model should be variable
- Visualization should be more interactive and flexible	- Available functionality should be explained better
- Communicate the difference between DDP, existing buildings, illustrations	- Real and proposed buildings should be visually differentiated
- All the information from the 2D plan should be clearly and easily accessible, highlighting especially relevant facts	- Main usage of the building is highlighted - Legend that shows all information, rather than needing to click on individual elements to view the information - Navigation between the 3D model and the attributes can go both ways
- Ease the transition period from 2D to 3D	- Keep the 2D plan on the bottom - Include an option to switch between 2D and 3D environments
- Enhance the box model	- Need to represent different height measurements somehow - Represent other aspects of DDP than height
- Enhance the 2D parts of the study area	- Visualize regulations for 2D areas (where people cannot build) - Visualize public versus private space - Visualize detailed plan boundaries

Based on these results, a list of the final map guidelines was compiled (Table 4), separated into cartography and functionality sections. One final 3D design was created considering as many of these results as possible (Figure 13) and can be viewed online at ArcGIS.com.[6]

[6] https://www.arcgis.com/home/group.html?id=cd1fb0dc80174a4795a634def00bc64b#overview

Table 4. *The final map guidelines based on qualitative analysis of the 3D DDP designs are presented as Cartography or Functionality. Items prefaced with [F] indicate functionality. The column marked "Used" indicates whether the final design (Figure 13) implements these guidelines. An "X" indicates full implementation, a "/" indicates partial implementation, and a "-" indicates no implementation.*

CARTOGRAPHY

Guidelines	Reasoning	Used
Retain colours from 2D DDP	- Recognition for planners and citizens - Visual cue indicating the volumes do not represent buildings (avoids highly realistic representations) - Visual representation of the plan (main usage)	X
Retain ground patterns from 2D DDP (i.e. dots or exes)	- Visual representation of the plan (building limitations)	X
Include the boundaries of the detailed plan	- Keep the focus on the DDP - Provide a clear differentiation between DDP and surrounding area	/
Include the boundaries of public / private space	- Indicates where citizens' comments have clout	/
Use transparency for the 3D volumes	- Visual cue indicating the volumes do not represent buildings - Resulting lighter colours removes the "heavy block" feeling	X
Include the 2D DDP as an optional base map	- Ease the transition from 2D to 3D - Provides diversity in the ways of disclosing information	/
Visualize the DDP within a 3D city model	- Provides contextual information - Allows citizens to view the proposal from their property	X
Visualize the *default* city model in a simple form (light grey, no extra details or facades)	- Keep focus on the study area - [F] Allow the user to change the level of detail of the city model	/
Visualize existing buildings in the study area	- Provides a reference point for citizens - Match the style to the city model	X
Visualize *at least* two example designs for the study area	- Communicates the difference between the DDP and actual buildings - Communicates an ongoing planning process	/
Visually differentiate the example designs from actual buildings and avoid highly realistic visualizations: either plain white, or "gaming-style" iconography	- Communicates the difference between illustrations and reality - White building models have traditional significance in planning - Gaming-style iconography provides attractive illustration while avoiding highly realistic representations - [F] Allow the user to change the visualization	/
Visualize the *default* background map in simple form with some environmental details; avoid orthophotos	- Keeps focus on the study area - Provides environmental context for orientation - [F] Allow the user to change the map	/
Visualize the *default* view without vegetation, but include it as an option	- Reduces the loading time of the application - Provides environmental context for the viewer - Lessens the shock of 3D volumes	X

	- [F] Allow the user to toggle vegetation on/off	
Do not allow vegetation in the 3D DDP unless the regulations include it	- Avoid misleading the public	-
FUNCTIONALITY		
Guidelines	Reasoning	Used
Retain all the information found in the 2D DDP in the form of an easily searchable legend	- Information found in one place - Allow for two-way navigation between the model and the information within it	/
Include a slider to compare the 3D DDP to the other scenarios: example designs or existing buildings	- Communicates the difference between the legal regulations and a potential building	X
Give the user options: collapsible menus with options for vegetation, city model, example designs, and background; separate menus for legal regulations and the others	- Utilize the flexibility and interactivity of a digital model - Give the user control over the visualization	/
Avoid overwhelming the user with options by utilizing interaction design	- Provides options while maintaining a clear interface to appeal to users of all technologic proficiencies - Highlights the relevant tools and functions	-
Include a help section with explanations of functionality	- Ensure the application and visualization are inclusive to users of all technologic proficiencies	-
Include pop-ups with relevant information for each object in the 3D DDP	- Provides easy to navigate and clear information for each object - Highlights the main usage of each area (i.e. sports)	-
Include a timeline of the planning process, and an explanation of the level of public participation	- Communicates the proposal stage and whether the commenting period is still open - Allows for a transparent comment period - Shows the progression of the proposal through time	-

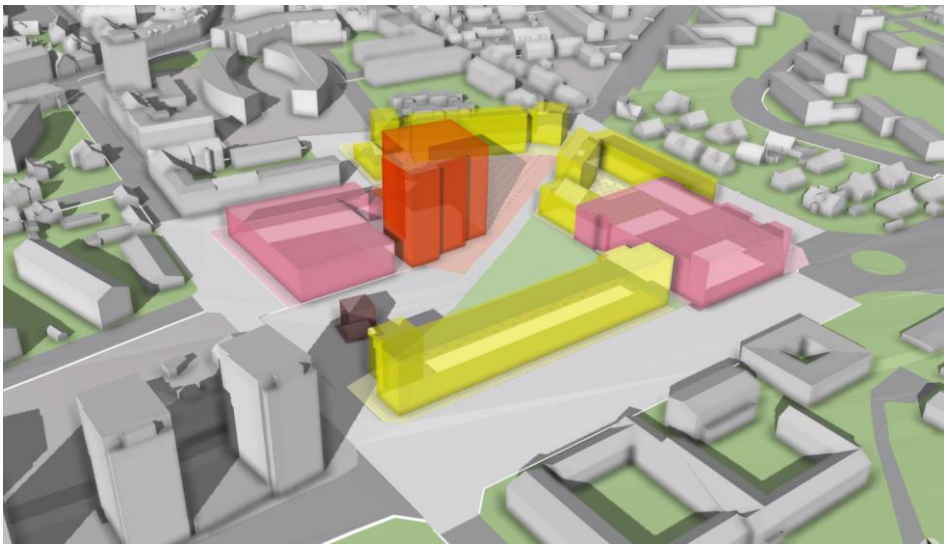

Figure 13. *A final design of the 3D model implementing the map guidelines as per Table 4.*

5 Discussion

5.1 Does 3D DDP Improve Communication?

Several themes were raised by the participants with regards to the role public participation plays in sustainable development. The first was regarding democracy and a well-functioning society, in that urban planning affects the public's everyday lives, so they must understand it and have the ability to comment on it. One participant had the perspective of coming from a country without citizen dialogue and highlighted how it affects the health of society. The importance of social inclusion in sustainable development has been previously established by the United Nations (United Nations 2016b); although two participants highlighted that while public participation is important for social development, it doesn't necessarily directly benefit the economic and ecological aspects of sustainable development.

The second theme was regarding the tangible benefit to the plan design. Participants noted public participation helps planners understand aspects that might otherwise be missed, as generally, more people thinking about a plan leads to a better result. Boverket has also recognized the benefit of including local knowledge in plan proposals (Boverket 2018a).

The third theme was the question of whether public participation can have a true impact at this stage in the planning process. It was stressed that dialogue is important from the first step in planning, and that the public can effect more change during the comprehensive planning situation. The point was also made that collecting public opinions earlier on over the whole municipality would provide a strong foundation for later DDP design. This touches on a larger potential issue of when public participation occurs during the planning process in Sweden, rather than how to improve the current occurrences of it. The need for larger change in the public participation process is supported by Senbel and Church (2011, p. 434), who found, "it is evident that improving dialogue to the point of empowerment requires much more than simple tool development." As noted by Arnstein (1969) and Boverket (2018a), it should be clear to citizens what level of public participation is at play. If there is a limit to what can be changed during the detailed plan development, this should be stated explicitly to the public. However, regardless of where in the process public participation has most impact, the literature still supports a move from 2D paper-based representations to 3D web-based models (Onyimbi et al. 2018), which could be expanded to include the comprehensive plan as well as the DDP.

The general comments about the current design of the 2D DDP included the difficulty in understanding the plan proposal due to the overwhelming amount of information shown on it, coupled with the need for previous knowledge to translate the symbols and markings. The information density of the design hampers viewers in imagining the outcome of the plan, and the inclusion of an illustration may pull focus away from the plan proposal. The paper based

DDP was called old-fashioned and a “dead document” but was noted by one participant to work well from the legal aspect.

In contrast, each participant indicated that 3D visualizations are easier for people to understand, a notion supported by myriad previous studies (Kibria et al. 2009; Han et al. 2015; Almqvist et al. 2016; Ljungblom et al. 2017; Onyimbi et al. 2018). The main benefits expressed by the participants and supported by Herbert and Chen (2015) were owing to the dynamism of the model: users can choose their own viewing angles and perspectives, can go to ground level to understand the impact of building heights, and can view the plan from their own property. In short, the 3D digital model provides better opportunities for the public to visualize the real impacts of the proposal and communicates the aim of the plan proposal better. Far from being old-fashioned, 3D visualizations were touted as the future – although one participant also likened it to physical 3D models made by the municipality in the past. However, one participant indicated that while 3D visualizations of DDP are currently being used by some municipalities as a complement to the 2D plan, they remain lacking from an information model standpoint.

Several potential risks in moving to 3D models were identified during the interviews. Every participant mentioned the risk of false perception in what the box model represents and highlighted the importance of communicating the difference between what a DDP shows and how it might manifest. Highly detailed renders were identified as increasing this false perception, which is supported in the literature (Smallman and St. John 2005; Kibria et al. 2009; Billger et al. 2016). The challenge of trying to capture everything a detailed plan should communicate is difficult for one model or image, which one participant pointed out is ostensibly one of the reasons it doesn’t exist yet. Although it’s difficult to communicate that many variations are possible in the final design, it was noted that a 3D digital model is better suited for the task. It was also noted that the stronger image of a 3D model may elicit stronger reactions (which may require a longer dialogue process), and it can be overwhelming for people to view buildings in 3D if they are not used to it. This supports the idea of diversity in the ways of disclosing information (Liu et al. 2018), as some people may prefer 2D maps.

5.2 What Hinders or Supports the Use of 3D DDP?

A major barrier to the use of 3D DDP was identified as the change to the profession for architects and planners who create DDPs. Participants noted the need for adapting new workflows for planners who do not currently create 3D models, which spurs on fear of losing one’s profession, and highlights the need for time, investment in education, and re-specialization of workers. However, participants noted this transition may become easier if professionals see the added value coming from a 3D model. This can include integration of analyses in the design process, the ability to simulate natural events and design with climate

change in mind, and the use of parametric design to generate different building examples that adhere to the rules of the DDP. The current movement in Sweden toward standardizing and digitizing the DDP would also allow for a simpler workflow required for the creation of the 3D models. For instance, it was time-consuming to recreate the information model of the DDP in CityEngine for this study, as the attributes expressing the plan decisions were manually added for each object.

One participant focused on the perceived loss when moving from an architect's vision for a development to a digital 3D model using analytical results. It was discussed that some architects still draw with pencil and paper, and there is a fear of losing the soul of a project (the discussion on concepts, the details and life between the buildings) in exchange for "architecture by math", and too much focus on data such as building volumes. The fear of losing the art form of design is related to another fear of the change in criticism and how information is received. It was noted that in moving to 3D space, professionals need to give up control of the information and how it is viewed (remove the idea of "selling" a development) and open themselves up to both unknown reactions from the public (compared to generally expected comments received on current DDPs), and being criticized from perspectives/analyses based on data. The authors of a study based on design empowerment touched on this fear of uncertainty, concluding that, "planners have the opportunity to use visualization media to […] share the responsibility of developing appropriate and mutually acceptable neighborhood designs" (Senbel and Church 2011, p. 434). This sentiment reframes the potential criticism as constructive, rather than simply negative.

Support for changing to a 3D environment comes from recognizing the added visualization value in using it and the underlying democratic appeal. Participants said the 3D model is easier to understand for everyone involved in the process, and it's more democratic to use a model that is easier to understand. One participant commented that the interactivity of digital media supports a participatory culture and establishes a strong connection between laypeople and the designers. In that vein, further support for this model would be gained by using interactive design to highlight the aim and target of presentation to have the intended effect. Given the proper visualization, information and layout, the 3D model should communicate more than just building volumes, alleviating architects' concerns of losing the details.

There are also technical differences to consider when moving to the 3D model. One identified barrier was achieving the right level of detail in a model to not mislead the public with what the DDP visualizes, which may require changes in the software's capabilities. One participant raised the difference in level of accuracy between 2D and 3D models, and the difference between professionals in their interpretation of it. For instance, there might be an unspoken allowed leeway of up to 1 m for current plans, but the exactness of a 3D model and

the younger generation's interpretation of it does not allow for that kind of flexibility. Standardization in the data model and how it is interpreted could assuage this concern. There was a comment that urban planning is behind other industries with respect to 3D visualizations, and the desire of the profession in catching up with the current status quo lends support for its further use. It should be noted that other drivers of 3D visualizations, such as the gaming industry, focus purely on aesthetics and immersion, and thus the imagery of those 3D visualizations should not be conflated with the imagery required for a DDP.

Another perceived barrier to the adoption of 3D DDP is the usability or inclusion of a new technology. One participant brought up "moral panic", the idea that the social fabric is threatened by changing concepts - in this case, the adoption of new technology which can also instigate a fear of job loss. It was also noted that the digital gap of citizens may play a role, as people may have unequal access to computers or internet, and the public may experience frustration at needing to learn how to navigate a web-based 3D model. One participant had indicated unfamiliarity with the tools and functions available through CityEngine Web Viewer and expressed a desire for a clear introduction upon entering the web scene, while the need for appropriate interaction design was raised several times by another participant. Literature supports the idea that improving the technology alone is not necessarily enough to improve public participation (Senbel and Church 2011; Heiden 2018). As noted by Heiden (2018, p. 9), "technology is neutral, but if a technology is dropped on top of a social structure that is unequal, all it will do is exacerbate those inequalities." In this case, the move toward 3D digital models could exclude tech-illiterate citizens, and citizens unable to access the models online. A possible solution is for the city to provide a public-use computer in the municipality building for citizens to access and be shown the 3D models.

All participants agreed that standardization is needed for 3D DDP. Cities need to produce similar products which allows for movement of building companies and professionals throughout the country. Visualization standards (i.e. map guidelines) are an important component of that. As one participant noted, the design of any product tells the user how to interact with it, and the same principle should be applied to the detailed plan. It should be recognizable to people, which requires standards. The importance of map guidelines also comes from the need to differentiate between illustrations and detailed plans. Additionally, legally moving to a 3D environment in the future would require visualization standards.

However, one participant noted the main reason for standardization was to support software development; this was echoed by another participant noting that different software programs should support the same functions so architects can create plans according to one national standard regardless of the product used. It was posited that the more important aspect

for standardization is the data behind the model rather than the visualization, as the visualization could be adapted toward different audiences.

5.3 Final Map Guidelines

A clearly emerging idea implicit in the interviews was that moving to a digital web-based model requires the redefinition of "map guidelines". Just as appropriate cartography needs to be redefined for a specific visualization, the definition of map guidelines needs to include functionality and interaction design for 3D digital space. This was immediately apparent when the first design critiques in all the interviews were regarding the box model and web viewer, instead of the specific cartography of the study area and background map. This also highlights limitations of existing software and web applications for achieving all the desired functionality for a 3D DDP. One participant commented that standardization was more important for software development than for visualization – however, it seems the two are inextricably linked when dealing with 3D digital space. For instance, the desire to have object information in a pop-up rather than in an information pane is dictated by how the 3D model is exported from CityEngine and visualized online (using either CityEngine Web Viewer or ArcGIS Scene Viewer). The adoption of map guidelines could thus result in software or applications tailored to the requirements of Sweden's planning process.

Design 1 was preferred by every participant due to the recognition of the colours used and the visual representation of the plan proposal (specifically, the proposed use). It was discussed that the use of planning colours also offers a visual cue that the volumes do not represent actual buildings. An oft-heard comment was the need to clearly communicate what the detailed plan shows, especially when it is visualized as a box model. This can be done explicitly, through a text box that explains to the user what they will see, and implicitly, through visual cues like unconventional building colours and transparency. Either way, the challenge of producing a model that does not misrepresent reality and avoids erroneous interpretations of the data has been identified in the literature (Billger et al. 2016), and serves to underline the need for designing the best visualization for the specific task (Herbert and Chen 2015) of communicating the DDP.

One participant was adamant that map guidelines should purely focus on the DDP and not include the background/surrounding map or example designs. However, these map guidelines are created to support the message of the specific application, and in the case of the 3D DDP, it was noted several times that the inclusion of example designs helps to communicate what a DDP is (or, isn't). Further, participants designated varying designs for the background and surrounding maps as distracting, indicating that the surrounding area does affect the communication of the DDP. While the DDP is the only entity with a legal basis, it is relevant to include the surrounding visualizations in the final map guidelines for

the purposes of the 3D visualization. Further, a main argument was the need for user-led options, which was both explicitly and implicitly stated (such as when participants expressed discordant opinions). Thus, the inclusion of visual guidelines for the background/city model indicate a default version, with the caveat to include options for the user.

The preliminary map guidelines served as starting point for creating the 3D DDP designs. While most of the preliminary guidelines remained relevant throughout the process, two of the points required change:

- Avoid known visual conflicts in 3D space – in particular, use transparency, shading, and shadow with caution (Neuville et al. 2019)
    - Transparency was a key element the participants felt was missing from the 3D maps. It is a clear visual cue signifying a difference between a maximum exploitation volume and a real building. It should be stressed that this applies to the dynamic model, not a static image of a 3D model.
    - In the web application used to visualize the 3D DDP, shadows are optional and dynamic according to the user.
- Avoid or minimize textual annotations (Camba et al. 2014; Ljungblom et al. 2017)
    - It was noted that the 3D models felt too simple at times. More information was desired through pop-ups, or headlines signifying more clearly what the 3D map was showing. Visual clutter should still be avoided, but interaction design should be employed to make the most of textual annotations.

Many of the map guidelines were only partially implemented in the final design due to software, time, or data limitations. For example, while the boundaries of the detailed plan were not explicitly visualized, the extent of the DDP is delineated using different colours for the roads within and outside of the study area. The boundaries of public and private space are also not visualized; however, this information is clearly included in the object attributes. While the default background map and city model adhere to the map guidelines, the user is not given the option to change these visualizations. A simplified version of the 2D DDP is visualized within the study area, but it does not contain all the information from the original plan (i.e. the symbols and text). Only one example design is included for the viewer (Figure 14), and while these buildings are visualized according to the map guidelines, the viewer is not given the option to change this. While the information from the 2D DDP is retained within the attributes, it is not shown in its entirety in an easily searchable form. Finally, while some options are included, the suggested layout and level of functionality is not fully realized.

Figure 14. *The use of the comparison slider in the final design is shown here, with the 3D DDP visualized on the left, and an example illustration on the right.*

5.4 Study Limitations & Biases

The difficulty of analyzing free text such as interviews is acknowledged by Ghauri and Grønhaug (2002, p. 102), who specifically discuss how the interviewer's "background may greatly influence the interpretations, thereby causing problems of objectivity." In this case, the key points that were reduced from each interview were sent to the participants as a validation step to remove this bias. The interviewer's bias may also be present in the formulation of the interview questions. For instance, one of the interview questions was, "Would the establishment of map guidelines for this specific application support the use of 3D DDP?" where the use of "support" may be considered leading language. In an attempt to circumvent the potential influence of the question, participants were first asked the neutral questions, "What are the barriers to the use of 3D DDP for public participation?" and, "What would support the use of 3D DDP?"

Ghauri and Grønhaug (2002) also discuss the bias that relates to over- or underrepresentation of groups within the respondents. This is an admitted bias of this study, which only interviewed participants from the planning point of view, and therefore did not consider the views of third-party architects and laypeople. The preference of all the participants for Design 1, which mimicks the current industry standard, may be an indication of this bias, as people tend to prefer the familiar (Zajonc 1968). Further, there is an inherent selection bias, wherein participants who were interested in the subject matter of 3D DDP were quick to agree to participate, whereas disinterested parties who could have provided alternate opinions did not wish to participate. These biases could be alleviated given a longer

timeframe for the study and the possibility of a larger variety in participants' backgrounds and opinions.

A further limitation of the study comes from the number of interviewees, which included 4 professionals. The low number of participants was accounted for by employing open-ended interviews rather than questionnaires to encourage deeper discussion. It should also be noted that two participants were interviewed together due to schedule accommodations and work relationships, which may have affected how the individuals answered the questions. However, each participant was still given an opportunity to answer each question individually. Employing a limited number of expert interviews in analyzing 3D visualizations was a method identified in several published studies, either as the sole qualitative analysis (Häberling et al. 2008; Herbert and Chen 2015), or as a supplement to questionnaires from non-experts (Nielsen 2005; Schroth et al. 2014; Rautenbach et al. 2016).

5.5 Future research

Future research should include a full usability study of the 3D DDPs with members of the public, as well as professionals from other sides of the planning process like developers and building permit issuers. This should include an interaction design study, so it retains the visual information learned from this study but tests different layouts, functionalities, and how well people can use the different application tools online.

Despite not being included in the scope of this study, the legal role of a 3D DDP was raised several times by the participants. Future research should also focus on the underlying information model for the DDP, rather than just the visualization. This has implications from both the legal and information flow perspective and aligns with the goal of a national database of detailed plans in Sweden. The standardization of the information model coupled with these map guidelines, which indicate visualization and functionality needs, supports software development tailored to 3D DDP in Sweden.

6 Conclusions

The aim of this study was to develop map guidelines for a web-based 3D visualization of DDPs in Sweden, with the intention of supporting a more sustainable building process through an improvement of public understanding of plan proposals. The results of the study are based on interviews conducted with four professionals in the fields of urban planning and GIS. The interview participants indicated that a 3D DDP would improve communication of the plan proposal to the public when care is taken to avoid misleading visualizations (RQ1). It was discussed that the proposal impact is communicated more clearly with a 3D visualization, and that a digital and dynamic model allows more autonomy and flexibility for

the user. However, the visualization of maximum volume must be clearly explained, and differentiated from the visualization of a potential building. Interaction design needs to be considered for the final application, as there needs to be a balance struck between allowing variety for the user and keeping the overall application simple and intuitive.

The question of whether the establishment of map guidelines supports the use of 3D DDP for future public participation is more complex (RQ2). It is clear that standardization in any form is helpful toward future development of 3D visualizations. The results from the interviews indicated that map guidelines would create a future where the 3D DDP is recognizable and understood more easily by the people who need to comment on it. However, the literature indicates that improvement in plan communication should not be conflated with an improvement in public participation. While interview participants recognized the importance of public participation for social sustainability, they also raised the question of when public participation occurs to be most impactful, and it was indicated in the literature that true social inclusion and citizen empowerment requires more than just a new visualization.

Based on the participants responses, it was clear that the visualization of a web-based 3D model is inherently tied to the technology behind it. Themes that emerged from the interviews could be broadly grouped as cartography or functionality of the digital application. It was unanimous to keep the traditional planning colours for the detailed plan, and to use an element of transparency as a visual cue that the box models do not represent actual buildings. It was also unanimous that the comparison slider provided an elegant way to communicate the difference between the detailed plan and example designs. It was thought that the flexibility of a digital model should be fully utilized in allowing users to choose backgrounds and city model environments to their liking – with the caveat that an element of interaction design be implemented so as not to overwhelm users with options. The detailed map guidelines established as a result of the interviews are included in full in Section 5.3 (RQ3).

The importance of the planning phase and the role of public participation therein have been well established in the literature. 3D visualizations have been shown to improve communication with laypeople, which is one part of improving public participation. Sweden is currently focused on improving aspects of its building industry through standardization and new technologies, placing the development of 3D visualizations of DDPs in a particularly relevant spot. The map guidelines established in this study therefore provide a solid foundation for this continued advancement of 3D DDP in Sweden.

References

3D Geoinformation Group TU Delft. 2017. Cities Around the World with Open Datasets. Retrieved 19 February 2019, from. https://www.citygml.org/3dcities/

Abderisak, A., P.-E. Josephson, and G. Lindahl. 2014. Implications of Cost Overruns and Time Delays on Major Public Construction Projects. In *19th International Symposium on the Advancement of Construction Management and Real Estate*, eds. L. Shen, K. Ye, and C. Mao, 13. Chongqing: Springer, Berlin, Heidelberg.

Alatalo, T., M. Pouke, T. Koskela, T. Hurskainen, C. Florea, and T. Ojala. 2017. Two Real-World Case Studies on 3D Web Applications for Participatory Urban Planning. In *Proceedings of the 22nd International Conference on 3D Web Technology*, eds. M. Adcock, and T. Bednarz, 9. Brisbane, Queensland, Australia.

Almqvist, A., T. Lithén, F. Ekelund, and L. Sjölund, 2016. Strategy for 3D Spatial Data - Pre-Study Report. Report, Stockholm. [in Swedish, English summary]

Arnstein, S. R. 1969. A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*, 35**:** 216-224. DOI: 10.1080/01944366908977225

Biljecki, F., J. Stoter, H. Ledoux, S. Zlatanova, and A. Çöltekin. 2015. Applications of 3D City Models: State of the Art Review. *ISPRS International Journal of Geo-Information*, 4**:** 2842-2889. DOI: 10.3390/ijgi4042842

Billger, M., L. Thuvander, and B. S. Wästberg. 2016. In Search of Visualization Challenges: The Development and Implementation of Visualization Tools for Supporting Dialogue in Urban Planning Processes. *Environment and Planning B: Urban Analytics and City Science*, 44**:** 1012-1035. DOI: 10.1177/0265813516657341

Boverket. 2018a. Citizen Dialogue. Retrieved 6 February 2019, from. https://www.boverket.se/sv/samhallsplanering/sa-planeras-sverige/kommunal-planering/medborgardialog1/

Boverket. 2018b. Detailed Planning Process. Retrieved 19 January 2019, from. https://www.boverket.se/en/start/building-in-sweden/swedish-market/laws-and-regulations/planning-process/detailed-planning-process/

Boverket. 2018c. Permits and Notifications. Retrieved 15 March 2019, from. https://www.boverket.se/en/start/building-in-sweden/swedish-market/laws-and-regulations/permits-notifications/

Boverket. 2019. Ongoing Work on Digital Detailed Plans. Retrieved 26 February 2019, from. https://www.boverket.se/sv/samhallsplanering/uppdrag/digitalisering-av-samhallsbyggnadsprocessen/digitala-detaljplaner/

Camba, J., M. Contero, and M. Johnson. 2014. Management of Visual Clutter in Annotated 3D CAD Models: A Comparative Study. In *Design, User Experience, and Usability: User Experience Design for Diverse Interaction Platforms and Environments*, ed. A. Marcus, 405 - 416. Heraklion, Crete, Greece: Springer.

Carver, S., A. Evans, R. Kingston, and I. Turton. 2001. Public Participation, GIS, and Cyberdemocracy: Evaluating on-Line Spatial Decision Support Systems. *Environment and Planning B: Planning and Design*, 28**:** 907-921. DOI: 10.1068/b2751t

Ghauri, P., and K. Grønhaug. 2002. *Research Methods in Business Studies, A Practical Guide*. England: Pearson Education Limited.

Goetz, M. 2013. Towards Generating Highly Getailed 3D CityGML Models from OpenStreetMap. *International Journal of Geographical Information Science*, 27**:** 845-865. DOI: 10.1080/13658816.2012.721552

Häberling, C., H. Bär, and L. Hurni. 2008. Proposed Cartographic Design Principles for 3D Maps: A Contribution to an Extended Cartographic Theory. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 43**:** 175-188. DOI: 10.3138/carto.43.3.175

Han, S. H., S. Hasan, A. Bouferguène, M. Al-Hussein, and J. Kosa. 2015. Utilization of 3D Visualization of Mobile Crane Operations for Modular Construction On-Site Assembly. *Journal of Management in Engineering*, 31. DOI: 10.1061/(asce)me.1943-5479.0000317

Heiden, W. 2018. Coopting Cops with Maps: The Rhetorical Power of Cartography in Modern Policing. *Cartographica,* 53**:** 62-71. DOI: 10.3138/cart.53.1.2017-0026
Herbert, G., and X. Chen. 2015. A comparison of usefulness of 2D and 3D representations of urban planning. *Cartography and Geographic Information Science,* 42**:** 22-32. DOI: 10.1080/15230406.2014.987694
Kibria, M. S., S. Zlatanova, L. C. M. Itard, and M. J. Van Dorst. 2009. GeoVEs as Tools to Communicate in Urban Projects: Requirements for Functionality and Visualization. In *3D Geo-Information Sciences,* eds. J. Lee, and S. Zlatanova, 379 - 395 pp.: Springer.
Kolbe, T. H. 2009. Representing and Exchanging 3D City Models with CityGML. In *3D Geo-Information Sciences,* eds. J. Lee, and S. Zlatanova, 15 - 31 pp.: Springer, Berlin, Heidelberg.
Kolbe, T. H., G. Gröger, and L. Plümer. 2005. CityGML – Interoperable Access to 3D City Models. In *International Symposium on Geo-information for Disaster Management,* eds. P. Van Oosterom, S. Zlatanova, and E. M. Fendel, 16. Delft: Springer-Verlag.
Kutzner, T., and T. Kolbe, H.;. 2018. CityGML 3.0: Sneak Preview. In *Wissenschaftlich-Technische Jahrestagung der DGPF und PFGK18 Tagung*. München, Germany: DGPF.
Lagerlöf, S. 2014. 3D Accounting and Visualization of Detailed Plans: A Municpality Perspective. PhD Thesis. Gävle: Akademin för Teknik och Miljö
Lantmäteriet. 2019. Målbilden för en obruten digital samhällsbyggnadsprocessen 2025. Retrieved May 23 2019, from. https://www.lantmateriet.se/sv/Om-Lantmateriet/Samverkan-med-andra/lantmateriet---utvecklingsmyndighet-for-samhallsbyggnadsprocessen/kompetenssatsning/malbilden-for-en-obruten-digital-samhallsbyggnadsprocessen-2025/?faq=00ac
Liu, B., X. Wang, N. Xia, and W. Ni. 2018. Critical Success Factors for the Management of Public Participation in Urban Renewal Projects: Perspectives from Governments and the Public in China. *Journal of Urban Planning and Development,* 144. DOI: 10.1061/(asce)up.1943-5444.0000467
Ljungblom, M., J. Nellerup, J. Hellman, L. Johansson, S. Danielsson, J. Andreasson, and P. Hagberg, 2017. Digital Detailed Planning Process with 3D Visualization and Analysis: Project Report Group 2 within "Information Supply for Planning, Building and Building Permits". Report 48 pp. [in Swedish, English summary]
McLaren Loring, J. 2007. Wind Energy Planning in England, Wales and Denmark: Factors Influencing Project Success. *Energy Policy,* 35**:** 2648-2660. DOI: 10.1016/j.enpol.2006.10.008
Muehlenhaus, I. 2013. The design and composition of persuasive maps. *Cartography and Geographic Information Science,* 40**:** 401-414. DOI: 10.1080/15230406.2013.783450
Nandalal, H. K. 2007. Importance of Public Participation in Project Implementation: Upper Kotmale Hydropower Project in Sri Lanka. In *International Conference on Small Hydropower - Hydro*. Sri Lanka.
Neuville, R., J. Pouliot, F. Poux, and R. Billen. 2019. 3D Viewpoint Management and Navigation in Urban Planning: Application to the Exploratory Phase. *Remote Sensing,* 11. DOI: 10.3390/rs11030236
Nielsen, A. 2005. Visual Representations, Usability and Urban Planning in Real-time 3D Geovisualization. In *8th AGILE Conference*. Estoril.
Obermeyer, N. J. 2013. The Evolution of Public Participation GIS. *Cartography and Geographic Information Systems,* 25**:** 65-66. DOI: 10.1559/152304098782594599
Olsson, P.-O., J. Axelsson, M. Hooper, and L. Harrie. 2018. Automation of Building Permission by Integration of BIM and Geospatial Data. *ISPRS International Journal of Geo-Information,* 7. DOI: 10.3390/ijgi7080307
Onyimbi, J., M. Koeva, and J. Flacke. 2018. Public Participation Using 3D Web-Based City Models: Opportunities for E-Participation in Kisumu, Kenya. *ISPRS International Journal of Geo-Information,* 7. DOI: 10.3390/ijgi7120454
Open Geospatial Consortium. 2012. OGC City Geography Markup Language (CityGML) Encoding Standard. 344. Open Geospatial Consortium,.

Rautenbach, V., S. Coetzee, and A. Çöltekin. 2016. Investigating the Use of 3d Geovisualizations for Urban Design in Informal Settlement Upgrading in South Africa. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* XLI-B2**:** 425-431. DOI: 10.5194/isprs-archives-XLI-B2-425-2016

Regeringskansliet. 2018. Digitization of Base Maps and Detailed Plans, Prop. 2017/18: 132. Retrieved 10 February 2019, from. https://www.regeringen.se/rattsliga-dokument/proposition/2018/02/prop.-201718132/

Schroth, O., J. Angel, S. Sheppard, and A. Dulic. 2014. Visual Climate Change Communication: From Iconography to Locally Framed 3D Visualization. *Environmental Communication,* 8**:** 413-432. DOI: 10.1080/17524032.2014.906478

Senbel, M., and S. P. Church. 2011. Design Empowerment. *Journal of Planning Education and Research,* 31**:** 423-437. DOI: 10.1177/0739456x11417830

Shojaei, D., H. Olfat, A. Rajabifard, A. Darvill, and M. Briffa. 2016. Assessment of the Australian digital cadastre protocol (ePlan) in terms of supporting 3D building subdivisions. *Land Use Policy,* 56**:** 112-124. DOI: 10.1016/j.landusepol.2016.05.002

Smallman, H. S., and M. St. John. 2005. Naive Realism: Misplaced Faith in Realistic Displays. *Ergonomics in Design: The Quarterly of Human Factors Applications,* 13**:** 6-13. DOI: 10.1177/106480460501300303

Smart Built Environment. 2018. DigSam - Digital Community Building Process. Retrieved 22 January 2019, from. https://www.smartbuilt.se/projekt/standardisering/digsam/

Srdić, A., and J. Šelih. 2015. Delays in Construction Projects: Causes and Mitigation. *Organization, Technology & Management in Construction: An International Journal,* 7**:** 1383-1389. DOI: 10.5592/otmcj.2015.3.5

Swedish Standards Institute. 2016. Geographic Information - Detailed Development Plan - Application Schema for Regulations. 60. Stockholm.

United Nations. 1992a. Agenda 21. In *United Nations Conference on Environment and Development*, 351. Rio de Janerio, Brazil: United Nations Sustainable Development.

United Nations. 1992b. The Rio Declaration on Environment and Development. In *United Nations Conference on Environment and Development,* ed. U. Nations, 19. Rio de Janerio, Brazil.

United Nations. 2016a. Goal 11: Make cities inclusive, safe, resilient and sustainable. Sustainable Development Goals. Retrieved 6 February 2019, from. https://www.un.org/sustainabledevelopment/cities/

United Nations. 2016b. The Sustainable Development Agenda. Retrieved 22 March 2019, from. https://www.un.org/sustainabledevelopment/development-agenda/

van Berlo, L., T. Dijkmans, and J. Stoter. 2013. Experiment for Integrating Dutch 3D Spatial Planning and BIM for Checking Building Permits. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS 8th 3D GeoInfo Conference*, 6. Istanbul, Turkey.

Wanarat, K., and T. Nuanwan. 2013. Using 3D Visualisation to Improve Public Participation in Sustainable Planning Process: Experiences through the Creation of Koh Mudsum Plan, Thailand. *Procedia - Social and Behavioral Sciences,* 91**:** 679-690. DOI: 10.1016/j.sbspro.2013.08.469

Wroblewski, A., and A. Leitner. 2009. Between Scientific Standards and Claims to Efficiency: Expert Interviews in Programme Evaluation. In *Interviewing Experts,* eds. A. Bogner, B. Littig, and W. Menz, 235 - 251 pp.: Palgrave MacMillan.

Ying, S., L. Li, and R. Guo. 2011. Building 3D Cadastral System Based on 2D Survey Plans with SketchUp. *Geo-spatial Information Science,* 14**:** 129-136. DOI: 10.1007/s11806-011-0483-2

Zajonc, R. B. 1968. Attitudinal Effects of Mere Exposure. *Journal of Personality and Social Psychology,* 9**:** 1-27. DOI: http://dx.doi.org/10.1037/h0025848

Zidane, Y. J. T., and B. Andersen. 2018. The Top 10 Universal Delay Factors in Construction Projects. *International Journal of Managing Projects in Business,* 11**:** 650-672. DOI: 10.1108/ijmpb-05-2017-0052

Appendix A: 2D Detailed Development Plan

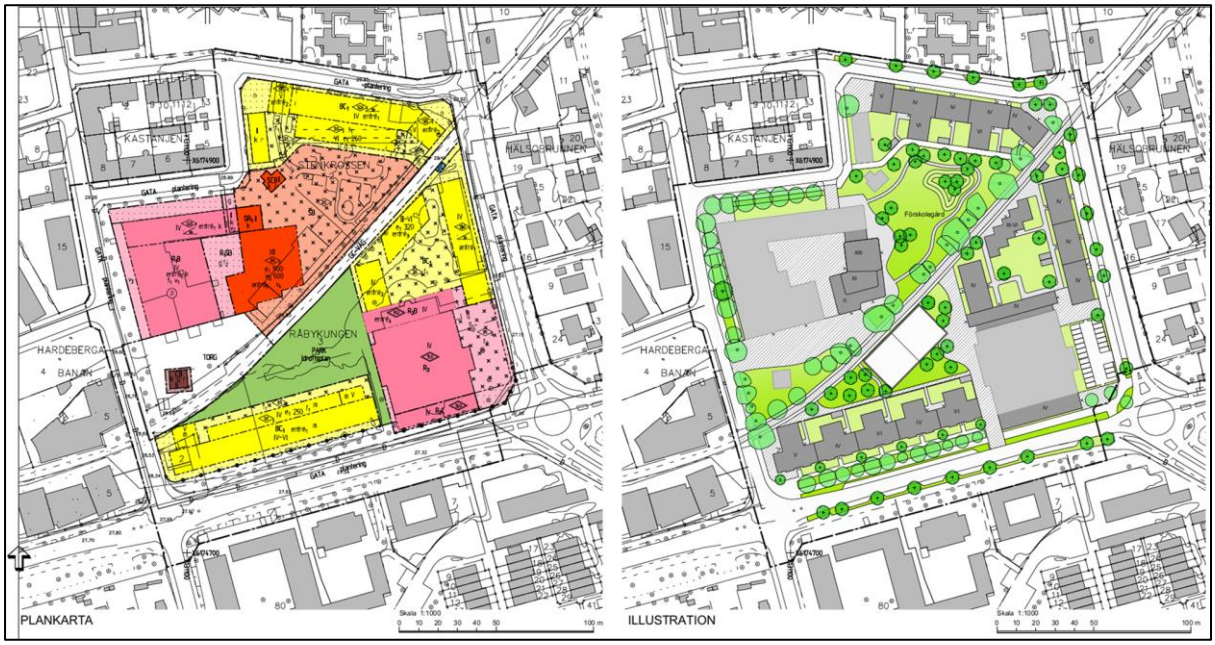

Figure A1. *The 2D plan proposal map (left) and illustration (right) for the DDP used in this study.*

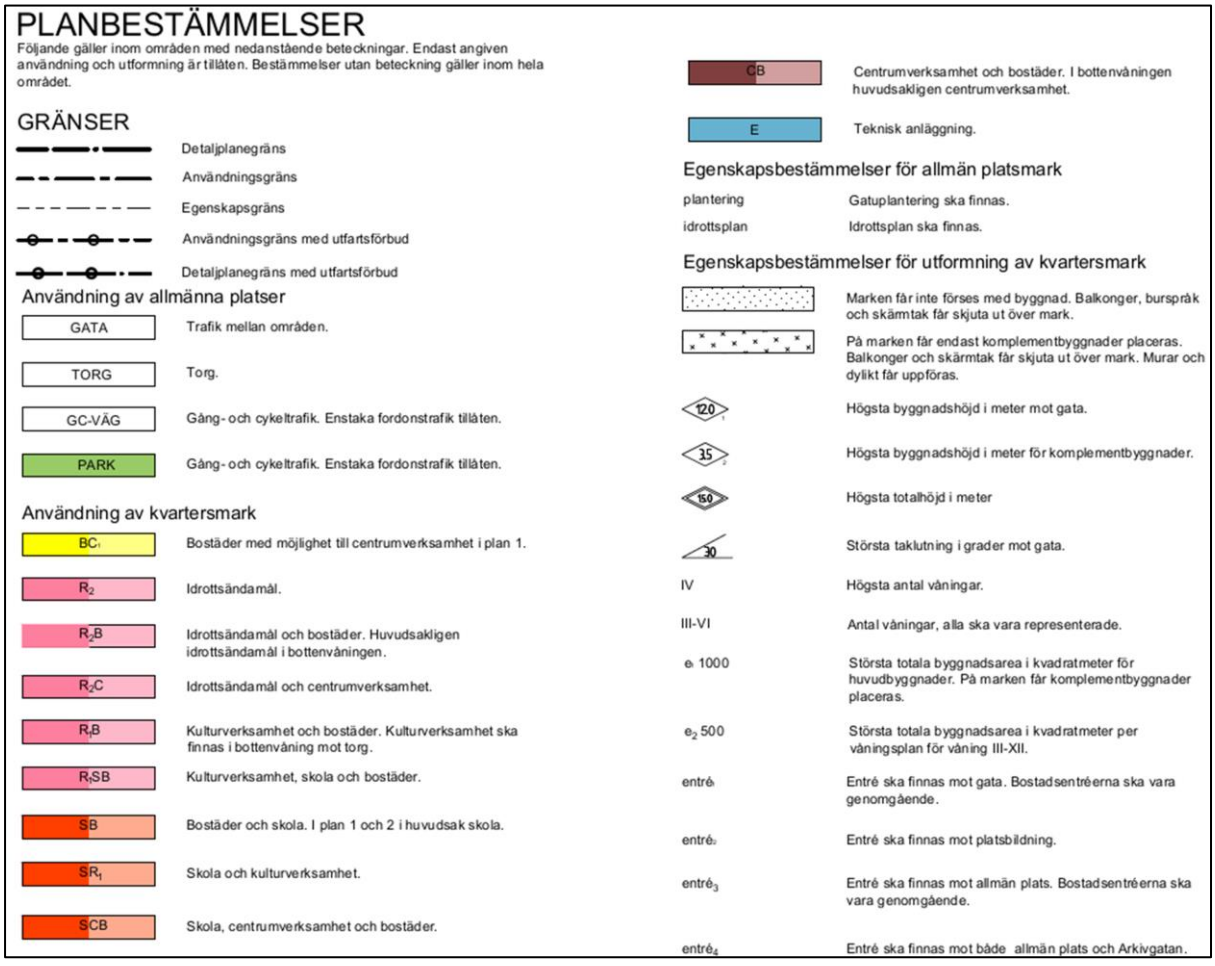

Figure A2. *The legend for the DDP used in this study which indicates the plan decisions (Part 1 of 2).*

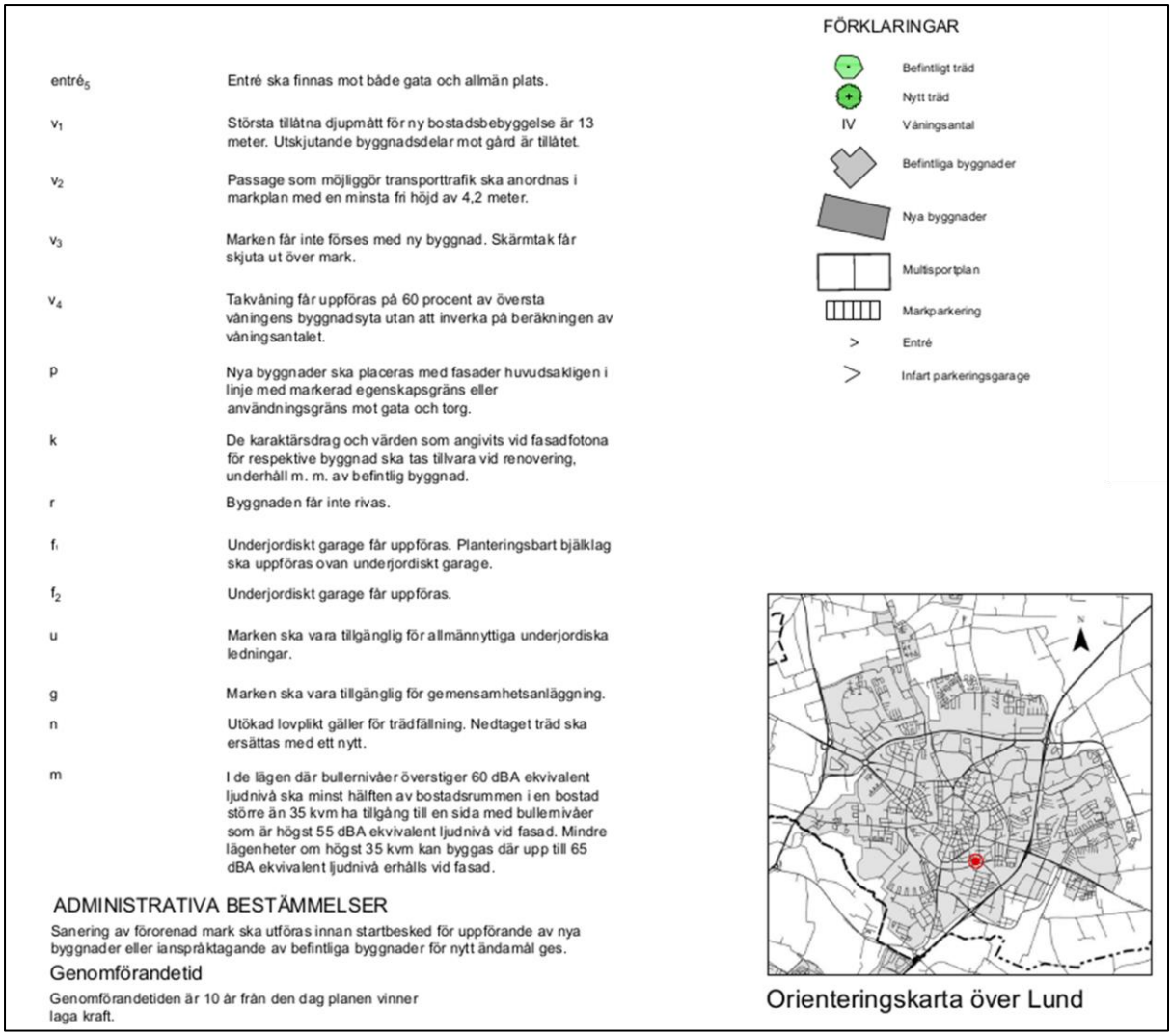

Figure A3. *The legend for the DDP used in this study which indicates the plan decisions (Part 2 of 2).*

Figure A4. *The drawing details for the DDP used in this study which indicates the date, the architects involved from Lund municipality, and the stage in the planning process.*

Appendix B: Interview Questions

The following text outlines the interview questions used during this study. The participants were sent the project overview and questions before their interviews.

Project Overview

The aim of this study is to develop map guidelines for a 3D visualization of Detailed Development Plans (3D DDPs) in Sweden. The intent is to support the broader goal of a more sustainable building process by improving public understanding of plan proposals. The specific research questions (RQs) to be explored in the study are:

1. Does a 3D DDP improve communication of the plan proposal to the public?
2. Does the establishment of map guidelines support the use of 3D DDP for future public participation?
3. What are the preferred map guidelines for a 3D DDP in Sweden?

Map guidelines can be defined as the overarching cartographic principles for a specific application which are used to produce well-designed and consistent maps that support the intended message with clarity. Four different designs of a 3D model were created for an ongoing proposal at Stenkrossen and Råbykungen in Lund, Sweden. Each design uses different cartographic principles which are summarized below.

- Design 1 - Mimics the cartography of the current 2D detailed development plan (colourful study area, white/grey surrounding)
- Design 2 - Opposite cartography to design 1 (white/grey study area, colourful surrounding)
- Design 3 - "Realistic" design (white study area, surroundings use orthophoto, fictitious facades, realistic trees)
- Design 4 - "Symbolic" design (grey and red study area, surroundings use white blocks, realistic textures, symbolic trees)

Interviewee Information

- Name
- Job title/department
- Length of time in this profession
- Role in the planning process
- What is your familiarity with the current DDP (i.e. what they normally look like and information they contain)?

RQ1: Does a 3D visualization of a DDP improve communication of the plan proposal to the public?

- What do you think about the design of the current 2D DDP to communicate the plan proposal to the public? (i.e. the cartography and how public participation is affected)
- How would 3D visualizations change communication of the plan proposal to the public?
- Do you foresee issues with using 3D visualizations as a communication tool with the public?
- What role do you think public participation plays in sustainable development?

RQ2: Does the establishment of map guidelines support the use of 3D visualization of DDPs for future public participation? (Disregarding legal aspects.)

- What are the barriers to the use of 3D DDP for public participation?
- What would support the use of 3D DDP?
- Would the establishment of map guidelines for this specific application support the use of 3D DDP? (i.e. instead of making arbitrary design choices, one can consult established guidelines)

RQ3: What are the preferred map guidelines for 3D visualizations of DDPs in Sweden?

For each 3D design:

- What is your initial impression of the design?
- Do you “understand” it immediately?
- Does it communicate the plan proposal effectively?
- Do you see advantages or disadvantages to it?
- Is there anything you would change? Keep?
- What should the final design look like?

Any remaining thoughts/comments/questions/concerns?