Master Thesis

Details matter: The influence of the Level of Detail on the effectiveness of 3D models for planning processes

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Master research in partial fulfilment of the requirements of the degrees:

DDM Water and Coastal Management
University of Oldenburg
MSc Environmental and Infrastructure Planning
University of Groningen

Title: *Details matter: The influence of the Level of Detail on the effectiveness of 3D models for planning processes*

Topic: *Effectiveness of 3D models for planning processes*

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"Of all of our inventions for mass communication, pictures still speak the most universally understood language."

Walt Disney (source unknown)

Abstract

Understanding conventional 2D plans requires knowledge and interpretation skills. It has been shown that these abstract and encoded drawings often fail to deliver information effectively, leaving a gap between experts and laypersons. Acknowledging the boundedness of 2D plans, this research introduces 3D visualisations as a more effective communication medium. Yet, different levels of detail (LODs) are influencing the tool's effectiveness. This research reveals that the entire span of LODs is needed. The 3D model and its details depend highly on the context it is used in and purpose it is used for. Thus, the derivation of a standard for the use of certain LODs is not useful, yet the definition of characteristics of LODs stays important as a framework. This research introduces a co-creation process as a method to achieve a fruitful collaboration and learning process between academia, practice and civil society and a co-design process to reach a tailor made 3D visualisation for the purpose and context of the 3D model and planning process.

Keywords: *visualisation, 3D modelling, Level of Detail, communication, participation, effectiveness, co-creation, co-design*

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Abbreviations

2D	**T**wo **D**imensional
3D	**T**hree **D**imensional
AIA	**A**merican **I**nstitute of **A**rchitects
AIT	**A**ustrian **I**nstitute of **T**echnology
BIM	**B**uilding **I**nformation **M**odelling
CityGML	**C**ity **G**eography **M**arkup **L**anguage
ICT	**I**nformation and **C**ommunication **T**echnology
LOA	**L**evel **o**f **A**bstraction
LOD	**L**evel **o**f **D**etail
LoD	**L**evel **o**f **D**evelopment
OGC	**O**pen **G**eospatial **C**onsortium
POI	**P**oint **o**f **I**nterest

1 Introduction and relevance

Planning as a profession, is nowadays highly connected to interaction and communication with stakeholders. Consequently, planners are required to produce plans of the future that are graspable, simple and comprehensible. Along the line of innovative improvements of communication modes during the last decades, the intrinsic value of communication changed as well: It became more diverse, technologies became more multifunctional and information richness became more complex. As a result, images of the future have to be multidimensional: simple enough to be understood by a layperson, but comprehensive enough to be a sound basis for political decision-making and transparent enough to ensure a fair discourse. The remaining question is now how communication can be used as a tool to effectively achieve all this.

Approaches concerning the depth, platform and setup of communication and participation differ, but overall consensus should be the final result. Therefore, the governance approach, i.e. the setting communication and participation processes are embedded in, is crucial for even discussing how these processes should be shaped and if used tools are effective. Additionally, the quality of communication and participation and the effectiveness of applied tools depends highly on the communication approach itself. Planners are asked to come up with new attractive collaborative approaches to generate human resources, follow upcoming trends of social interactions, make the planning process more transparent and finally, react on our changing society. The planner seems to be on the road of becoming the new communication manager in an information and communication technology (ICT) driven world.

Along with the communicative turn as a new emerged paradigm in planning theory and practice in the late twentieth century (Huxley and Yiftachel, 2000) the toolbox of planners traversed a fresh update too. De Roo and Porter (2007, p. 99) describe this paradigm change as a "[...] shift from an object-oriented form of planning towards an inter-subjective approach, where the roles, perceptions, behaviour and motivations of the actors involved are becoming increasingly important." Instead of a clear, top-down and technocratic approach towards planning, communication and collaboration with actors and shared responsibilities become important (de Roo and Porter, 2007).

This Resulting from this change in mindset, it became clear that communication and participation are vital elements of planning. Planning is impossible without communication. The following changes of society over time led to more diverse interests, which demanded more communication, resulting in a need for improved communication competences.

While fasting forward to today's world increasing medialization, digitalisation and the disconnection of communication with a face-to-face experience creates a new sphere of interaction which questions conventional methods and approaches. These new technologies and trends make the communicative turn an iterative process rather than a one-time revolution. As a response to this "[...] 3D [...] visualizations have shown great potential as valuable [new] communication tools." (Wissen Hayek, 2011, p. 921)

Specifically 3D modelling has the potential to improve the planning process in regard to the transfer and perception of information by clarifying for instance future scenarios, decisions and developments (Yamu, 2015). The transformation of possibly complex scenarios and analyses into a more easily graspable medium can additionally enhance the decision making process (Yamu, 2015), motivate stakeholders to participate and provide a new platform to gather information (Wissen Hayek, 2011). As such 3D models can help "to overcome the hurdles caused by various backgrounds, perspectives, and visions of […] participants that often hamper the systematic flow of the […] process, and thus […] [foster] their wider involvement in the decision-making process." (Al-Douri, 2010, p. 92) In other words 3D models can be considered an effective communication tool for planning processes.

Nevertheless, there is the need to critically evaluate general information innovations emerging from computer based technologies (Kim, 2005) whereas a further need for general research specifically about the characteristics and quality of such tools is emphasised in literature (Biljecki, 2013; Biljecki *et al.*, 2014; Biljecki *et al.*, 2016b; Biljecki *et al.*, 2016a; Wissen Hayek, 2011; Pietsch, 2000). Especially the characteristics and quality of 3D visualisations can vary substantially, considering the lack of an internationally acknowledged standard. Different levels of detail (LOD) seem to be used randomly, instead of following a specific logic when used for communication purposes. Hence a clear scientific position is missing.

This study empirically assesses the effective use of 3D visualisations in different LODs for communication and visualisation purposes and investigates related, current standardisation attempts. In the following the term 3D models refers to digital 3D models.

Following chapters pursue the topic and discussion by elaborating on 3D visualisation embedded in the context of planning theory and history. Subsequent chapters introduce different definitions of the LOD concept and the multiple standardisation approaches as well as they clarify the scientific relevance of this research.

1.1 Expert vs. layperson

"Communication between experts and laypeople has become an almost ubiquitous phenomenon." (Bromme *et al.*, 1999, p. 17) This phenomenon constitutes an important underlying issue of this research and every participation process. The gap between experts and laypersons is already evident in the terminology: Experts resort to years of experience, even academic education, whereas laypersons commonly miss the required, specific knowledge to understand the matter regarded (Bromme *et al.*, 2004).

To overcome this knowledge deviation, the intersection of their cognitive frames of reference, in short their *common ground*, has to be extended, in order to provide enough shared understanding of the matter to reach an informed decision (Bromme *et al.*, 2004). The medium and technical execution of communication determines its success (Bromme *et al.*, 2004).

Accordingly, 3D modelling may be seen as an attempt to bridge this gap and extend the *common ground* i.e. the shared foundation of communication between experts and laypersons. Wissen (2009) refers to this as a language problem and emphasises the importance of translating technical language. 3D visualisations are commonly used as translation of a complex situation, viz. an expert's idea to a more comprehensible format, in order to approximate *common grounds*.

The success of a 3D visualisation, however, depends on its attractiveness and quality, that is to say its usefulness and ability to objectively deliver necessary information. The attempt to close the gap between experts and laypersons is a commendable endeavour, yet scientific knowledge is missing regarding what these visualisations should look like. The lack of scientific research in this matter leaves us in the understanding that, experts are currently designing visualisations according to what seems to be appropriate for planning processes. Again, this procedure resembles more of a trial and error approach than a way along a structured path to greater understanding of 3D visualisations and how to use them effectively.

1.2 Problem definition and relevance

The introduction above already gives an insight into the driving forces and the complex of problems constituting the fundament of this research. It is clear that communication and participation in the planning process are a result of the emerging call for more rights of co-determination. This strive is illustrated and supported by upcoming multilevel governance or decentralisation approaches, resulting in a paradigm shift with more attention on individuals, participation and communication (-tools) and social interactions, i.e. the communicative turn (Zuidema, 2016b).

Consequently, urban planning or rather urban planners, are obliged to communicate plans regarding the future to all sorts of concerned stakeholders and provide, within the planning process, a platform for the creation of mutual understanding. 2D plans require specific knowledge and interpretation skills to be readable and, thus easily can be misunderstood (Pietsch, 2000): Urban planning "[...] is full of assumptions and conventions that result from communicating the spatial structure in a 2D medium" (Al-Douri, 2010, p. 75)

It is also clear that the possible lack of knowledge to understand a 2D plan and the connected misinformation represent not only a communication distortion, but also an unequal distribution of power among the participants (Forester, 1982), hence, can hamper the efficiency of any planning process. In other words, the partly encoded information of plans remains inaccessible for non-planning professionals (Pietsch, 2000). This barrier between non-professionals and professionals can be overcome by increasing the quality of visualisations, and by introducing 3D modelling into planning processes (Pietsch, 2000; Wu *et al.*, 2010). Simultaneously, moving "[...] towards visualisation models reflects the acknowledgement that conventional drawings fail to communicate effectively or clearly [...]." (Pietsch, 2000, p. 521)

"There is a wide agreement about the potentials of visualisations but opinions about their format and application are equally wide apart from each other. Until now there is only little knowledge about the actual effectiveness of 3D visualisations as communication tools in the planning process. A scientific documentation about the role of visualisations in planning and the influence of their imprecision or their impact on decision making is missing." (Wissen, 2009, p. 68)

In other words, 3D visualisations have different specificities and numerous appearances. The complexity of the urban environment is reduced by 3D visualisations, but the gradient of simplification can vary. This distinction between "different degrees of resolution" (Kolbe *et al.*, 2005a, p. 886) is most commonly referred to as Level of Detail or short LOD (Biljecki *et al.*, 2014).

The LOD concept, elaborated more explicitly at a later stage, communicates the cityscape and buildings on different levels, ranging from a simplistic level to a complex detailed one. The basic rationality behind it can be seen in Figure 1.

Despite the conventional use of the concept, Biljecki *et al.* (2015) point to the loose use and distinction of LODs, missing a focus on the performance of the different levels and underline the importance of minimum standards for certain uses. Consequently, diverging effectiveness in the planning process between a simplistic representation of the urban environment or a more complex detailed one remains unknown and is the core question of this research.

Thus it is clear that 3D visualisations are a superior communication medium compared to 2D plans. To which extend, however can we simplify a complex situation, such as our environment, in order to provide, planners as well as laypersons, with sufficient information to objectively analyse and judge the situation. In short: Which 3D model should be used?

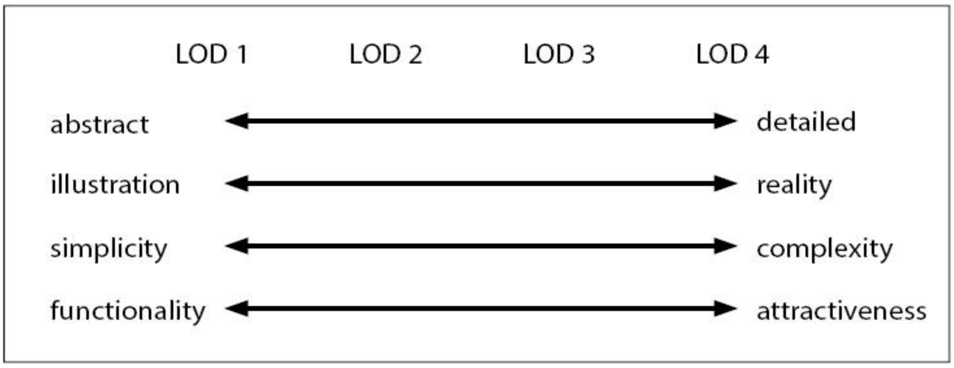


Figure 1: Basic rationality of the LOD concept (own source)

This leaves the upcoming chapters with three main questions: Firstly, does the 3D visualisation's effectiveness change with different LODs? Secondly, what contributes to a more effective and eventually efficient use of 3D visualisations? And finally, what role does standardisation play in the current and future use of 3D visualisations? Overall, the question is whether a LOD, due to its superior effectiveness, can be set as a standard for a given situation.

It should be mentioned that Glander and Döllner (2009) argue that the term LOD rather refers to the simplification of visualisations based on computer-dependent processing power than to visual and cognitive simplification, whereas the term Level of Abstraction (LOA) would be more appropriate, also in regard to this research. Also Biljecki *et al.* (2014) mention the manifold terms, but stick to the labelling LOD to simplify matters and to be consistent with related research. Along with the latter reasoning, the term LOD is used in the course of this research.

1.3 Research Objectives

The primary objective of this document is to reveal the effectiveness of varying LODs in 3D models in planning processes. The effectiveness of a tool, as an instrument used to reach a desired goal, as a matter of course influences the efficiency of the planning process it is used in (Niekerk, 2015b):

Here, the term efficiency refers to process efficiency, consequently also to 3D modelling and its effects on the planning process. Efficiency focuses thereby on the process, its performance as well as its effectiveness on the means, tasks and the attainment of goals (Niekerk, 2015b). Thus, efficiency is process, time, effort and goal oriented, whereas effectiveness can only be seen as goal oriented. The focus of this research is predominately on the latter issue, while process efficiency, is inevitably a part of the discussion.

The investigation of different LODs in 3D scenarios (displayed in Figure. 3) by means of literature research and questionnaire is aimed at pointing out the strengths, specific potentials and effects of each LOD. Yet, 3D visualisations at large and standardisation efforts in detail are critically investigated and challenged. Even though standardisation approaches of 3D visualisations are not per se investigated, the immersion into different LODs inevitably includes and requires the discussion about standardisation.

Conclusions referring to influences on the efficiency of the planning process can be derived, from these results and from literature research and expert interviews. The latter are meant to uncover gaps, critiques and problems concerning the time, effort and lacking standardisation of 3D modelling and the LOD concept as well as uncover needs and opinions of academia and practice.

In other words, this research aims at the assessment of the general perception, tangibility and usefulness of the investigated LODs. Consequently varying perceptions of displayed information, revealing significantly influential factors of the various LODs, influencing ones contextual perception consequently the effectiveness, are investigated. Table 1 depicts the main research questions.

Table 1: Main research question and sub questions (own source)

main questions		
How does the effectiveness of 3D models for planning processes vary according to their Level of Detail (LOD)?	What contributes to the more effective and eventually efficient use of 3D visualisations?	What role does standardisation play in the current and future use of 3D visualisations?

subquestions			
Which LOD provides the most understandable way of displaing information?	Are there factors or characteristics significantly improving or deteriorating the effectiveness of 3D modela?	How are 3D visualisations currently used in practice and are there obsticels for the effective use of 3D models?	What are future possibilities to improve the effectiveness/ efficiency of 3D models?

1.4 From simple to complex LOD - an Introduction

The concept of LODs is of great importance for 3D modelling and originates from computer science. Its meaning often varies and an internationally accepted, standardised approach does not exist (Biljecki *et al.*, 2014; Biljecki *et al.*, 2013). While Glander and Döllner (2009) see it as a grade of generalisation, Goetz (2013) regards it as multiple uses on multiple scales. Forberg (2007, p. 104) defines it as „[...] a common way to enhance the performance of interactive visualization of polyhedral data“ and Lemmens (2011) equals it to the term of resolution and states that it is related to how much detail is present in the data and may refer to space, time and semantics.” (Lemmens (2011) in Biljecki *et al.*, 2014, p. 1)

Biljecki *et al.* (2014) phrases the concept of LODs more generally and states: "It is used to define a series of different representations of real world objects, and to suggest how thoroughly they have been acquired and modelled." (Biljecki *et al.*, 2014, p. 1)

Generally, 3D visualisations in city modelling are usually independent from the position of the observer, whereas in computer sciences factors such as the distance to the observer influences the LOD of the model (Biljecki *et al.*, 2013). Attempts to standardise the LOD concept yielded in, amongst others, the five LODs of CityGML, presented in Figure 3 or the similar BlomLOD elaborated in a later stage *(Biljecki et al., 2013).*

In this work, the concept of LODs generally shall be used as the gradient of simplification of complex urban situations, aiming at communicating and visualizing planning scenarios to a variety of actors. The basic logic behind different LODs of objects in a cityscape is clarified in Figure 2.

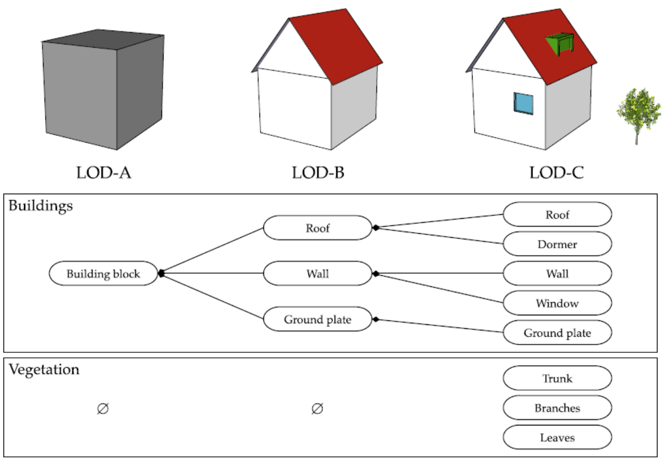


Figure 2: Basic logic of the LOD concept in the context of a cityscape (Biljecki et al., 2014, p. 4)

Figure 3: Varying Levels of Details in 3D urban planning models according to CityGML (TU Delft, 2016)

The CityGML standard (see Figure 3), as the most prominent standardisation approach, consists of five LODs. The first, LOD0, represents a 2D model with height as an attribute to it. In other words, it is a terrain model merely including building outlines.

LOD1 displays plain blocks of buildings and up to LOD 4 every new LOD increases the complexity of the representation and adds geometrical as well as semantical details. In LOD2 the shape of the roof is added to the plain building block model and, as a further step, LOD3 adds additional openings, external features and different surfaces. (Open Geospatial Consortium, 2012; Biljecki, 2013; Biljecki *et al.*, 2014)

In practice, however, LOD3 is often reduced to mere openings in buildings (Biljecki *et al.*, 2013). LOD4 represents the LOD3 geometry and simply adds interior equipment. Nevertheless, there are no specific LODs for urban features such as traffic lights, street furniture and vegetation. In LOD0 and LOD1 vegetation might be indicated by the underlying map or topography, whereas cityscapes in LOD2 may also contain vegetation (Kolbe *et al.*, 2005b). Additional vegetation, street signs, urban furniture et cetera are then added in LOD3 representations (Kolbe *et al.*, 2005b).

For this study, it is assumed that LOD0 and LOD4 are rarely applied in conventional planning processes LOD1, LOD2 and LOD3, however, are more commonly used. Consequently, the focus of this study lies on the suppositionally diverging tangibility between the latter three.

2 Theoretical background

The following chapter outlines the theoretical entity building the foundation of this research. Selected topics of planning theory are discussed in the context of 3D modelling in planning processes. Their connection to the topic is highlighted and their importance for this work outlined. Considering the chronological order of planning theory, the discussion starts with the rise of communicative rationality and participation proceeding further via the acknowledgement of power relations in planning, eventually finding its way to developments in 3D visualisations. This chapter represents the crucial planning-theoretical background to this research and traces communication and 3D visualisation as a tool back to its roots in planning theory and practice.

2.1 Participation on the rise, the origin of 3D visualisations

"One cannot not communicate" (Watzlawick *et al.*, 2011, p. 32) – communication is always there but was not always as present in our minds as today. Nowadays communication and social interaction are given more attention and what seems today as an implicitness has a long history of finding its way in different fields such as planning:

The *communicative turn* in planning theory as dominant communicative paradigm evolved partly as response to past theories *inter alia equity*, *advocacy* and *comprehensive planning* (Huxley and Yiftachel, 2000). It represents the starting point or rather the margin of the process from a rigid, traditional top-down planning process towards a "[...] pluralistic governance system, which adapts in accordance with the balance of the various interests, and the relations between stakeholders." (de Roo and Porter, 2007, p. 98)

Healey contributes amongst others most influentially to this shift with her in 1997 published book "Collaborative Planning: Shaping Places in Fragmented States". She reappraises the key steering issue of planning under the view of diversity and experience, underwent by individuals in every day live, leading to plurality and differentiation (Hamedinger *et al.*, 2008): "Collaborative Planning is a plea for the importance of understanding complexity and diversity, in a way that does not collapse into atomistic analyses of specific episodes and individual achievements, or avoid recognizing the way power consolidates into driving forces that shape situational specificities." (Healey, 2003, p. 117) On the foundation of communicative rationality, *collaborative planning* draws a model focused strongly on the involvement of all stakeholders, relational and power dynamics as well as local knowledge and reaching consensus in a process with emphasis on the process itself (Healey, 2003). Healey's example can be seen as a deeper clarification and insight into the driving forces and changes in participation and communication processes in planning theory of that time. At the same time these changes are the origins of todays need for communication and visualisation tools, such as 3D modelling.

De de Roo and Porter (2007) outline that it is the recognition of uncertainty, consequently the mounting complexity that moves planning away from its oblong praised technical rational and develops it towards a communicational rational with a process oriented, participative interacting planner functioning as the "manager of change".

"Making people concerned to participants"[1] is a postulation of the Austrian Journalist and futurologist Robert Jungk (1913-1994) and also expression and clarification of his participative model of designing the future, the "Zukunftswerkstatt"[2] (Spielmann, 2015). The beginnings of the future factory can be found in the 1960s when knowledge about the future became according to Jungk more valuable and no signs of participation were visible in the 'planning the future' process. This example of Jungk represents like Healy's (2003) approach, not only one of the early initiations of the call for more co-determination, inclusiveness and communication, but also the starting point of a time series which clearly shows transformations or rather improvements in participation forms (Selle, 1996). Improvements which continuously led to a new "force" in decision making processes resulting in more reflective, just and democratic results. The way of gaining these results was and still is modified in the course of time and includes various approaches. 3D visualisations are merely one of these approaches and thereby todays answer to past developments.

2.2 Collaboration, discourse and more effective communication

The Austrian journalist and future researcher Robert Jungk , for instance, wants people affected by planning to become involved (Spielmann, 2015). Healey (2003) on the other hand stresses the involvement of all stakeholders accordingly frames a bigger base and right for being included in planning processes. While fasting forward to today's world, which is becoming more fragmented, heterogenic and diverse (Zuidema, 2016a), scepticism arises in how far this involvement of all stakeholders ends in a fruitful, significant consensus a lá *collaborative planning*. Finding the highest common factor among diversity seems a profound if not unfeasible endeavour, presuming the setting even allows it. The setting of certain political or social systems can dilute or even supress participation and dispatch the objective of consensus in unforeseeable future. Assumed the regarded system provides an ideal setting for participation the consensus generated from diversity runs the risk of being unclear, superficial and ineffective. Brand and Gaffikin (2007) exemplify this by means of a collaborative case study in a more challenging setting like Northern Ireland, where results appeared promising, but where deceiving, as participants just paused their conflicts and agreed to outcomes also in times of non-conformance.

[1] Orig.: „Betroffene zu Beteiligten machen"

[2] „future factory"

What seems like a throwback for consensus building, can be explored in a different context, when leaving the approach of *collaborative planning*. Looking through the lens of a more structured approach, consensus can be reached with help of mediation, moderation as well as the limitation and selection of individuals taking part and furthermore with a set of predesigned procedures and steps (Innes, 1996). Referring to this, more discussion culture in a more organised environment can lead to more suitable, effective outcomes. This poses not only a critic on the wider range of interests and the frank open agenda of collaborative planning, but also strengthens the importance of opposing interests in participation processes. While the example of collaborative planning in Ireland depicts a "craft of cosmetic conflict suspension" (Brand and Gaffikin, 2007, p. 304) a more dialectic approach can lead to a new synthesis. Also Brand and Gaffikin (2007)encourage the need of a more agonistic influence in *collaborative planning*.

The developments of social interaction and communication of the past decade however stand in contrast to this plea for more discourse. Increasing medialization and the disconnection of communication with a face-to-face experience shifting towards a social media generation, where smartphones, computer et cetera become the new mouthpiece of society, creates a new sphere of communication which questions conventional methods and approaches also in regard to (discursive) communication in planning. Poplin (2012) picks up this trend, reflects and discusses a more innovative approach called „serious games" where participation for deciding the future of the campus of the University of Hamburg takes place via an online-game and consensus is reached as a compromise of monetary flow and stakeholder satisfaction. Innovative approaches like these are demanded to, on the one hand reach the public and build up a satisfying capacity of actors and on the other hand to make participation not only more attractive but more understandable, clear and transparent.

Behind collaborative planning, discursive communication and every other approach stands the condition of understanding each other, possibly also of habamasarian values of undistorted communication and most certainly the notion of speaking a common language. The question remains, if an expert and a layperson speak the "same" language, consequently if they are understanding each other. This leads to the possible assumption that experts, as a matter of their specific knowledge, argue from a whole different perspective than laypersons, which puts the latter in a more powerless position hence an unfortunate foundation of a participation process, whereas undistorted communication recedes into the distance (Bromme *et al.*, 2004).

With introducing 3D modelling as a communication tool, the barrier of knowledge inhomogeneity can be overcome and a possible easier common language can be used as a basis of further discussion. With 3D modelling a possibly more effective platform for discourse and eventually reaching consensus can be introduced into planning processes.

2.2.1 3D a powerful tool – enabling tangibility

Nevertheless, as already broached, there is also a power component to communication, which plays an important role in the participation and also decision making process, consequently in 3D modelling, which is elaborated shortly in the following.

"Power is everywhere; not because it embraces everything, but because it comes from everywhere." (Foucault, 1978, p. 93) This quote of Foucault certainly adds a new perspective of the term power to the commonly negative afflicted terminology and disconnects it from the semblance of an institution, a structure or a force towards a more situational depended theoretical construct (Foucault, 1978).

The sources of power, its emergence and effects can be manifold. Allmendinger (2002) underlines thereby three situations in which power can be exercised by planners: “offering information, structuring the agenda and strategy development. In these three situations, images and language are used by the planner (and other professionals involved, such as architects and surveyors) that should not exclude people or ‘close off’ avenues for investigation […]” (Allmendinger, 2002, p. 219)

Forester (1982) adds to this and reveals the planners’ power to control information as the most influential source of power. He pinpoints the basis of power and furthermore the allocation of information disruption to numerous different areas: “technical problems, organizational needs, political inequality, system legitimation, or citizen action and the correction of misinformation.” (Forester, 1982, p. 69) In contrast to the purpose of the communicative turn, which is to give people a saying in planning matters, this shows that planners are still left with a variety of possibilities to exclude valuable participants. The necessity of a common language and basis of discussion becomes explicit.

One may say that 3D visualisations are mainly concerned with information provision, the use of images and the same language as well as citizens’ action but 3D modelling as a powerful tool can provide information about alternatives, foster interactive discussions and break down complexity to a more graspable level (Yamu, 2015). Consequently, it depicts a tool to steer information provision, citizens action and the correction of misinformation.

It is imperative at this point to state, that 3D modelling can also be a source of misinformation and manipulation, but for the following, 3D visualisation will be investigated assuming it is used as a tool free from <u>intentional</u> manipulation and misinformation.

Concluding from the mentioned peculiarities not only different aspects of power can be investigated but also different initial points of the noticeable steering forces can be highlighted. These origins can be broadly categorized as van Assche *et al.* (2014) do in power *on*, *of* and *in* planning.

In short, the power on planning can be defined as the influences coming from outside and putting pressure on the planning system by for instance the greater society. The power *of* planning becomes more evident when looking at the outcomes of planning projects and the general influence power has on the wider society (van Assche *et al.*, 2014). Regarding power in planning van Assche *et al.* (2014) argue in general for more complexity, hence more diverse angles in planning, in order to reduce distortion and create a “model of the outside world that is subtle enough to operate upon” (van Assche *et al.*, 2014, p. 2319).

The connection to the topic of 3D visualisation is mostly located in the latter power dimension which constitutes the relations between actors involved. The power relation of actors changes when focus is set on barrier free communication and visualisation resulting in communication and participation in a more universally spoken language such as 3D models.

Nevertheless these three spheres of power cannot be individually discussed without mentioning their interdependency (van Assche *et al.*, 2014).

Figure 4 positions 3D visualisation as a specific tool within in the named broader stages or spheres in which power can be exercised.

Clearly, power is imminent in the planning process, in which 3D modelling is deeply embedded. Especially in regard to comprehensive representation, information richness, comprehension and communication, 3D representations can be effective and powerful.

Figure 4: 3D visualisations embedded in the spheres of power in planning (according to van Assche, Duineveld & Beunen 2014, Forester 1982 & Allmendinger 2002

2.3 Decision-making in the light of a new dimension

The images from cities we have in our minds are largely a construct fed by real world experience and other information we get (Hanzl, 2007). If the real urban environment is going to change, the translation of visions, the uniform perception and therefore the new picture in people's minds are essential (Hanzl, 2007).

Adding another dimension to the commonly used 2D drawings comes with a more comprehensive understanding of our complex environment and a superior perception and understanding of ideas, scenarios or the context (Al-Douri, 2010; Biljecki *et al.*, 2015). As briefly mentioned before, 3D modelling can be seen as a tool to bridge comprehension difficulties between different actors and translate the seemingly coded language of plans into a more comprehensible format.

Not only decision making, comprehension, information provision and participation can be improved, but also imagination and creativity can be inspired and learning through a new form of interaction can be fostered (Hamilton *et al.*, 2001; Al-Douri, 2010; Yamu, 2015; Kim, 2005).

A simplified version of the common perception process is displayed in Figure 5, which also shows how the process is influenced by the use of 3D modelling: Along with the 3D model, new or rather enhanced information is influencing one's inner image. The newly gained information and the 3D model constitute the basis for further discussion, hence participation, inevitably resulting in a learning process. The final product is an altered vision of reality and future.

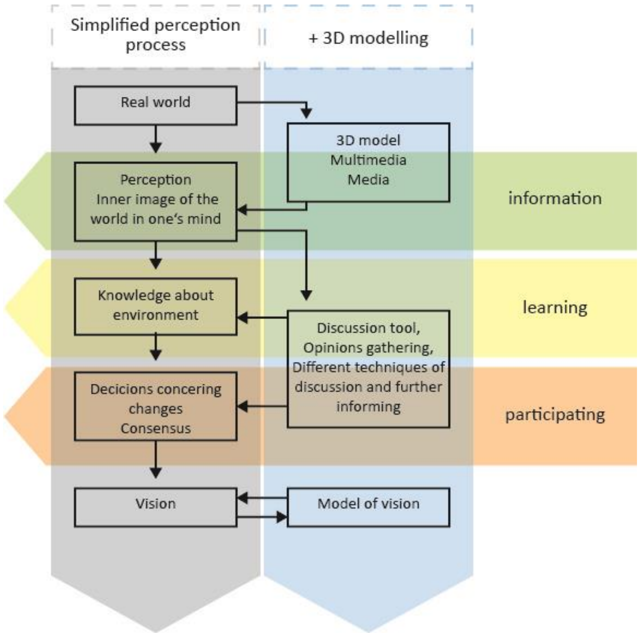


Figure 5: The perception process and effects of 3D modelling in different spheres of concern (after Hanzl 2007, p 290)

Research on the topic of 3D visualisations in regard to planning and urban design diverges in various different aspects. Yamu (2015) for instance brings computer based visualisation techniques through the lens of decision making processes together with complexity and its simplification my means of advanced visualisation. She stresses the superior understanding and the increased awareness of problems through 3D visualisations and highlights the power to motivate people to interact with each other and with the model and emphasises their inspired imagination (Yamu, 2015).

Yet it has to be mentioned that there is supposedly a difference of the effectiveness of 3D visualisations depending on their scale and LOD. Yamu (2015) supports thereby the theory that the most advantages to investigate impacts on the built environment from different angles (top-down, bottom-up) are granted, when across-scale consistent 3D visualisations with different LODs, depending on the various scales, are used.

Wissen Hayek (2011) approached the field with investigating the value or rather effectiveness of abstract and realistic 3D visualisations on a collaborative landscape planning approach and their contribution to each phase of the participation process. Findings of this research assign both abstract and realistic models different strengths and potentials in partly different phases of the participatory planning process (Wissen Hayek, 2011). With differentiating between abstract and realistic models Wissen Hayek (2011) investigates the effectiveness of different levels of realism different LODs respectively.

Figure 6 displays the results of Wissen Hayek's (2011) research, hence the effectiveness of 3D visualisations in various stages of the planning process. The categories information and motivation and collecting information are tasks in which 3D visualisations in both versions show a considerable high potential to enhance the landscape planning process.

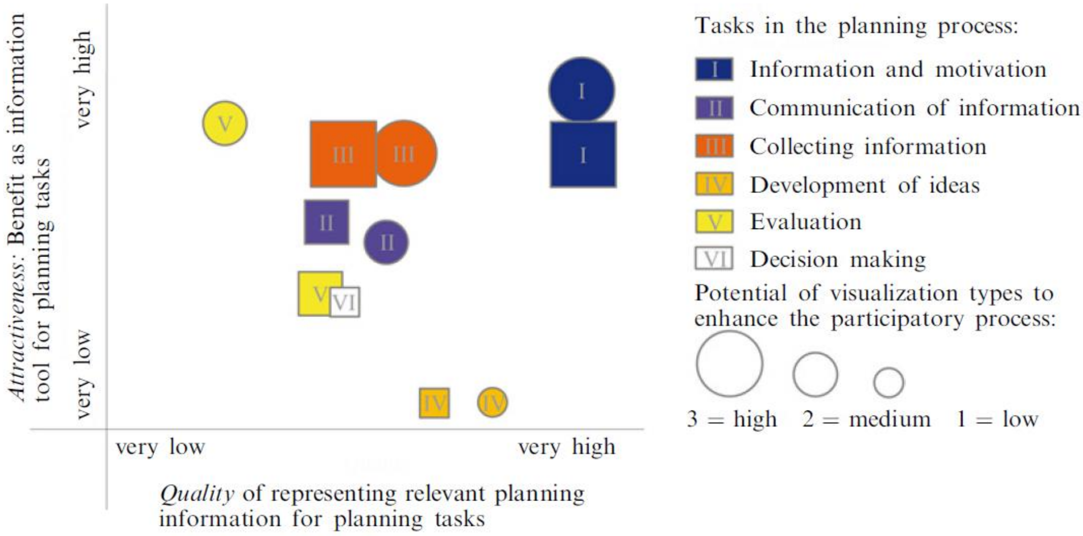


Figure 6: "Portfolio of the effectiveness of 3D abstract (square) and realistic (circle) visualization types for supporting different tasks in planning processes." (Wissen Hayek, 2011, p. 931)

Al-Douri (2010) adds to this and accentuates the ability to "address the complex multidisciplinary nature of most urban [...] plans" (Al-Douri, 2010, p. 95) and the benefit of communicating with participants across the whole planning process as seen in Figure 7. What he calls 'design steps', may be put on the same level as the steps of a regular planning process.

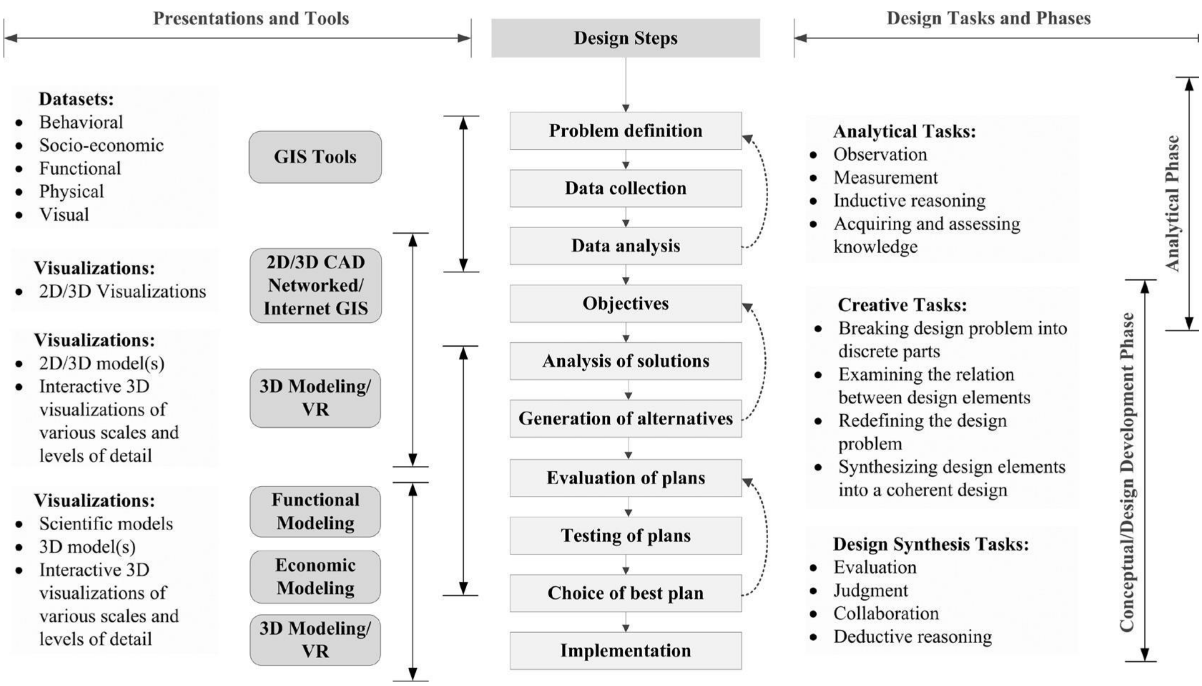


Figure 7: use of 3D visualisation and other support tools across the design process. (Al-Douri, 2010, p. 96)

Al-Douri (2010) investigates and confirms the effectiveness of 3D visualisations concerning their increased "design" content. The term *design content* relates in this context very much to LODs and refers to the increased number of features in 3D visualisations against 2D plans. Probably more important for this study, Al-Douri (2010, p. 75) states that "The effective usage of the modeling [sic!] functions appears to have improved the quality of the decision-making process by increasing designers' cognitive and communication capabilities and providing a platform for communicating design ideas among and across design teams that lead to wider involvement in the decision making."

According to his results the communication function, meaning the interaction fostered by the visualisation (Batty *et al.*, 1998), of 3D modelling was the most effective function ahead of visualisation, analytical and manipulation function (Al-Douri, 2010).

Both Yamu (2015) and Al-Douri (2010) argue eventually for improved collaborative plan- and decision making processes with the help of 3D visualisations. In an improved collaborative planning process, supported by 3D visualisation, actors can alter their visions through interaction and superior comprehension of the plan and its presented information. This effect discloses a learning process and points additionally to the educational side of 3D visualisations (Hamilton *et al.*, 2001).

Hamilton *et al.* (2001) clarify in this sense, that the participation process is synonymous to an educational process, thereby they underline interactive learning and bring up a special example: They justify the need for an improved, more effective planning process by pointing out hot topics such as environmental concerns and more demonstratively the preservation of cultural heritage (Hamilton *et al.*, 2001). By investigating 3D models in cities with a large number of cultural heritage sites, they affirm the illuminating effect of 3D visualisations in regard to the impact of new plans on cultural heritage: "The models [of Edinburgh and Bath] have raised awareness of the rich cultural heritage that these cities offer and are now considered an important element in their conservation." (Hamilton *et al.*, 2001, p. 840) Specifications about the LODs of the regarded models are unfortunately rarely included in these examples and remain an open question. Nevertheless, the educational side of modelling may be seen as the origin of inspiration in participants, the creating of ideas and eventually as improving the basis of communication between experts and laypersons.

Glander and Döllner (2009) bring up the importance of different levels of abstraction in 3D modelling and argue that their individual reduction of complexity leads to easier comprehension hence an superior communication foundation. Glander and Döllner's (2009) main focus is on the reduction of visual complexity with different LODs in 3D modelling. They investigate the matter through the lens of planning processes and outline the specific surplus value coming with it, rather than communication and information display. Further focus of their research lies on better orientation and wayfinding through reduced complexity. The results are various suggestions of 3D visualisations consisting of a blend of different LODs, whereas landmarks are maintained in a more realistic manner, serving as orientation points and other information is displayed in a more abstract way (Glander and Döllner, 2009).

2.3.1 Standardising complexity

Yet, all these stimulating studies, are overshadowed by a fundamental problem of 3D visualisations: The variety of approaches and the manifold and diverse definitions, that is to say the missing standardisation.

Whereas conventional 2D plans follow certain norms, depending on the context, and thereby gaining their legitimacy, attempts to visualise urban plans in a third dimension may follow logic, needs, costs, time, effort and more. Symbolically encoded 2D plans press a complex situation into an effective, standardised medium for efficient bureaucratic planning procedures. However, their communication to laypersons is, as mentioned, insufficient. By adding another dimension, 3D visualisations have a broader range of possibilities to communicate complex situations, whereby still some difficulties arise. The comparability and compatibility but also transferability (Farrell and Saloner, 1985), validity and legitimacy (Pietsch, 2000) of models, research and situations becomes difficult, whereas the bottom line is that all the advantages of standardisation are missing.

In her 2000 article, Pietsch reviews studies about 3D modelling from the past century and draws her attention to the challenges of introducing 3D visualisations on a routine basis. In order to compare the studies and their terminology thoroughly, she defines abstraction as "the selection of information included in the creation and presentation of computer visualisation modelling", accuracy as "the correctness of the information utilised, modelled, and depicted" and realism as "the mimicry of the physical environment in a virtual setting" (Pietsch, 2000, p. 521). Pietsch concludes, that there is neither a common definition nor an agreed application of these three terms. She further advocates the need of a sufficient "degree of detail accepted by the participants" composed of a balance of abstraction, accuracy and realism (Pietsch, 2000, p. 535).

Two important demands form her conclusions have to be underlined: The need for a certain degree of standardization of the used terms and their application, but also the need for an accepted mix of abstraction, accuracy and realism in visualizations. With this call, she acknowledges the complexity of the field and the need for clear guidelines.

2.3.2 Level of Detail

Pietsch's demanded "degree of detail" is a concept very familiar in Geomatics and in 2D plans but rather known as *scale* (Biljecki, 2013). A *scale*, as "[…] the ratio of distances on paper to the distances of the real world objects being mapped" (Thompson, 2009, p. 1) shows a certain degree of detail. Transferred to 3D modelling the term *scale* is not frequently referred to, but the term *Level of Detail (LOD)* is most commonly used (Biljecki, 2013). These two concepts are closely connected and one may say that each scale of a map or plan equals a certain LOD, whereas in 3D modelling LODs are not unitary defined (Biljecki, 2013). The question, if scale is a dependent variable for the selection of a certain LOD remains open.

The LOD concept, a concept originating in computer science, is focused on reducing the complexity of a model, in order to increase the visualizations' performance. In other words: "[…] geometric datasets can be too complex to render at interactive rates, therefore the solution is to simplify the polygonal geometry of small and distant objects." (Biljecki, 2013, p. 11) Figure 8 displays the main rational of LODs in computer graphics.

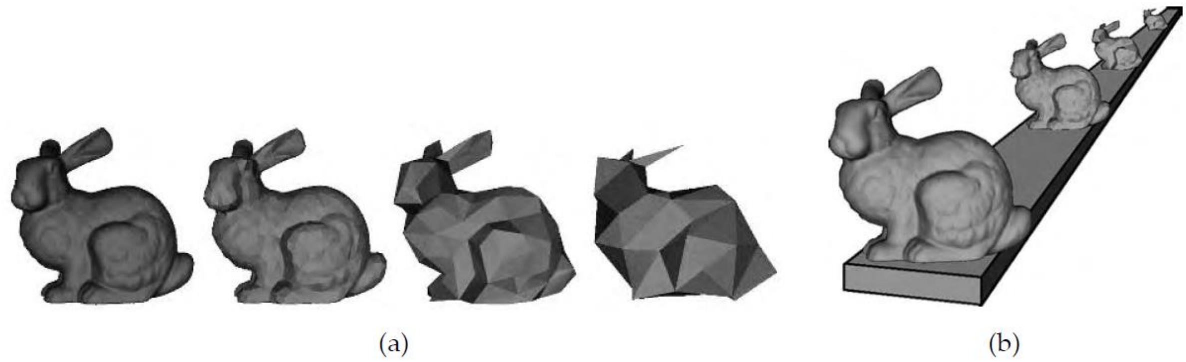


Figure 8: (a) LODs in computer graphics; (b) LODs in relation to a scale (Biljecki, 2013, p. 12)

In computer graphics the distance determines the LOD. The primarily developed discrete LODs are thereby defined for each object individually in connection with a fixed distance to the object, with near objects displayed in a very detailed manner, whereas a coarser visualization is chosen for those in further distance (see Figure 8) (Luebke, 2003).

The later introduced continuous LODs are not specified in advance, but rather continuously extracted at run time from a data set (Luebke, 2003). The newest "View-dependent LOD extends continuous LOD, using view-dependent simplification criteria to dynamically select the most appropriate level of detail for the current view." (Luebke, 2003, p. 10) This also means, that the displayed object can be shown in different LODs at the same time, with nearer features being displayed in a higher LOD, than elements being further away (Luebke, 2003).

2.3.3 A jungle of LODs

The abbreviation LOD can refer to a myriad of concepts and definitions, with all of them sharing the idea of defining an incremental spectrum from basic to mature visualization, idea, concept or object. At the same time all of them represent attempts to create standardized categories and bring a structure to 3D modelling. Eventually, the LOD concept found its way into the building industry and planning, where a considerable share of the jungle of LOD concepts and definitions can be found. Some definitions and related work was already briefly discussed in chapter 1.4 whereas the following elaborates on additional selected definitions.

The American Institute of Architects (AIA) for instance specifies LoD as the *Level of Development* and defines five main LoDs. However, the distinction to the *Level of Detail* concept is stated explicitly in their guidelines: "Level of Detail is essentially how much detail is included in the model element. Level of Development is the degree to which the element's geometry and attached information has been thought through – the degree to which project team members may rely on the information when using the model." (BIMForum, 2015, p. 12)

Meanwhile, the Building Information Modelling Forum (BIMForum, 2015) added another level in their LOD definition, resulting in six Levels of Development (LoDs 100, 200, 300, 350, 400 and 500 as seen in Figure 9).

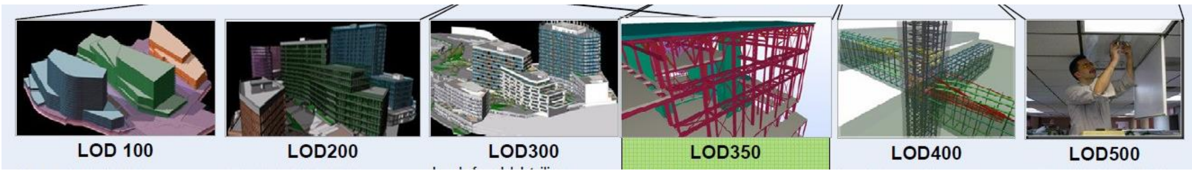


Figure 9: Levels of Development according to BIMForum (2015) with new LOD350 (modified after Docplayer, 2015)

LoD 100 as the lowest level represents a concept and LoD 200 a schematic design. LoD 300 shows the design development, whereas LoD 350 includes first construction specificities. LoD 400 is an accurate model for construction purposes and LoD 500 represents a model of the finished and already constructed object. (Biljecki, 2013; BIMForum, 2015)

Whereas these LoDs have a very technical component and are predominantly used for architecture and construction purposes in regard to planning Biljecki (2013) discusses three different LOD concepts: CityGML, BLOM and VERTEX

Among these three, City Geography Markup Language or CityGML is the widest spread and applied concept (Biljecki *et al.*, 2013). It provides a exchangeable standardized format for 3D city models, while specifically giving attention to "semantic and thematic properties" (Open Geospatial Consortium, 2012, p. 9)

The Open Geospatial Consortium (OGC) (2012, p. 9) claims that "The aim of the development of CityGML is to reach a common definition of the basic entities, attributes, and relations of a 3D city model. This is especially important with respect to the cost-effective sustainable maintenance of 3D city models, allowing the reuse of the same data in different application fields."

Biljecki (2013) concludes from the CityGML LODs that LOD0 cannot be considered as an actual 3D visualisation, as it is a 2D illustration including height as an attribute. Furthermore, he states, that in most cases the difference between LOD2 and LOD3 refers only to openings in buildings as well LOD4 merely being an upgraded LOD3 including interior objects. He reminds that CityGML LODs can be mixed in a visualisation and therefore the standard is based on an object view rather than a scene or scenario. Accordingly, other urban elements, such as street lights, signs, trees and vegetation in general are not simplified, hence are not subdivided in specific LODs. (Biljecki, 2013) CityGML LODs are already extensively elaborated in chapter 1.4, therefore not further illustrated at this point.

Blom, a Norwegian based company, principally involved in the "acquisition, processing and modeling [sic!] of geographic information" also developed a LOD standard, with four categories, similar to CityGML LODs (see Figure 10). BlomLOD1 consists of a building block model comparable to CityGML's LOD1. BlomLOD2 includes roof shapes and colours and BlomLOD3 is enriched with textures from a standard library, which are approximated to the real textures. BlomLOD4 substitutes the standard textures with photo realistic textures of facade and roof. (BLOM, 2012)

Substantial differences between the CityGML standard and the BlomLODs are not only the explicit use of textures and the missing category, comparable to CityGML's LOD0, but also that CityGML uses three different geometries (in LOD1,2,3), whereas BlomLOD's basically work with two geometric shapes (in LOD1 and LOD2).

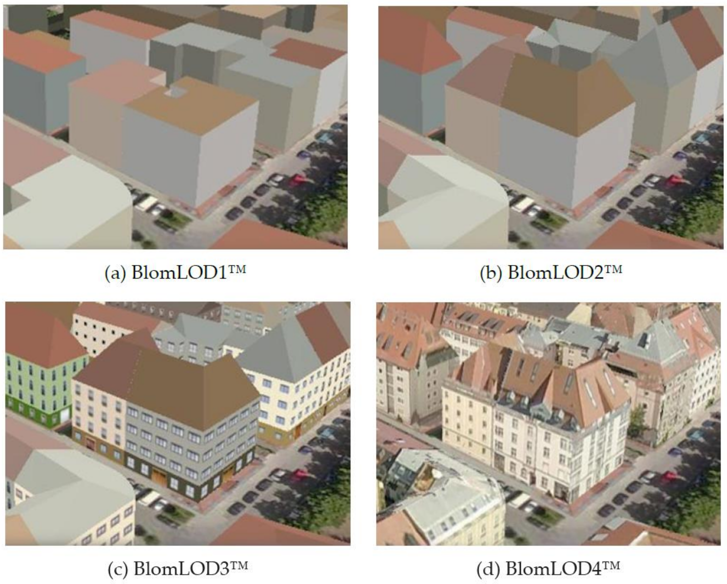


Figure 10: Four different LODs according to Blom's definition (Biljecki, 2013, p. 18)

Biljecki (2013) points also to the London based company *Vertex* and their conception of LODs. Vertex advertises especially its accuracy, acquired by high resolution areal imagery. Vertex describes their LOD model as "low urban massing model [...] [including] simplified but geographically accurate building shapes and accurate unseparated terrain". LOD2 enriches the LOD1 model with terrain specificities, whereas LOD3 is already a highly detailed model including land use information and "[...] all man made structures visible in areal imagery [...]". The information wealthiest level, LOD4, adds facade details to the model. A comparison between the four LODs of Vertex can be seen in Figure 11. (Vertex Modelling, 2016)

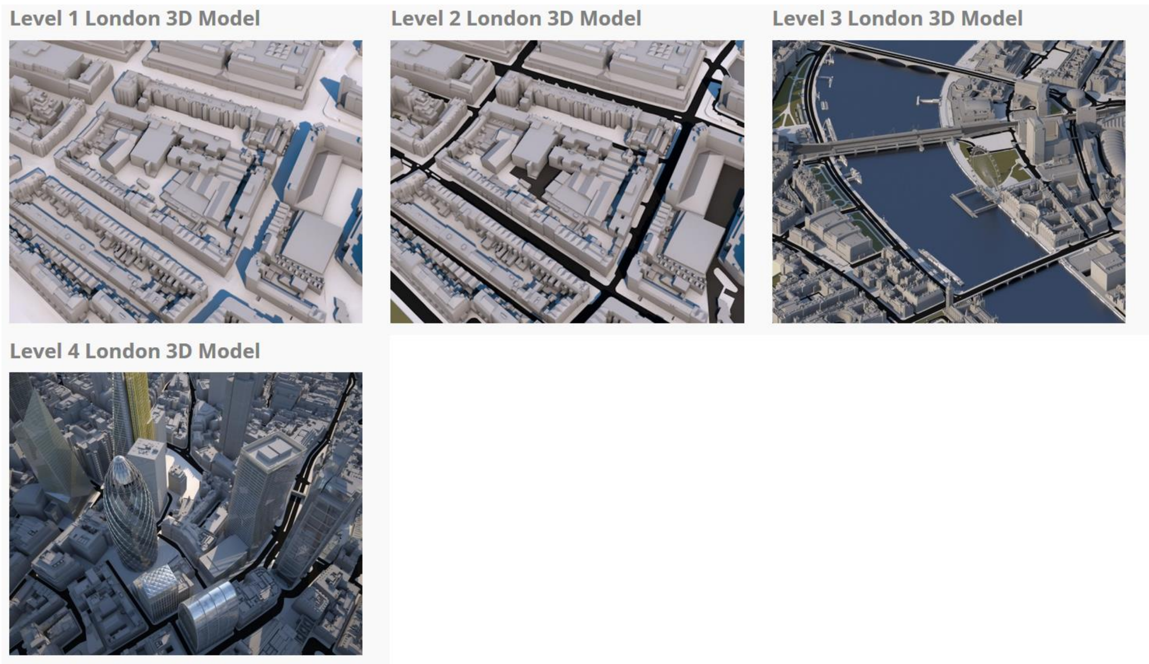


Figure 11: London model in LODs according to Vertex Modelling (Vertex Modelling, 2016)

2.3.4 Critiques: Complexity in just five levels

The different interpretations of LODs, the diverging definitions and the partly conflicting views give the LOD concept at large an experimental and premature character, although some approaches are extensive and detailed. Especially diverging interpretations comparing for instance Forberg (2007), Glander and Döllner (2009), Lemmens (2011), Goetz (2013) and Biljecki *et al.* (2013, 2014, 2016) call for a critical and considered handling of the topic.

Predominantly, Biljecki *et al.* (2013, 2014, 2016) investigate the LOD concept according to CityGML very critically and point out weaknesses, but they also develop and improve the CityGML LODs further.

A pivotal weakness to overthink the CityGML standardisation are the five categories, the complex urban environment is simplified into and the ambiguous definition of the same (Biljecki *et al.*, 2016a). As illustrated in Figure 12 an object in LOD2 can be carried out differently, while still maintaining the status of the same LOD. Whilst the left representation of LOD2 gives more detailed, eventually more valuable information about appearance or volume, the left model in the same category simplifies the object more and thereby leaves this information out (Biljecki *et al.*, 2016a).

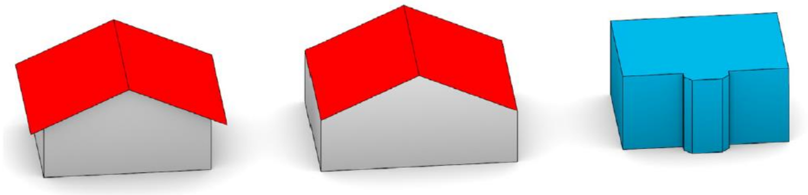


Figure 12: Comparison of two variations of LOD2 models on the left and an LOD1 model on the right, revealing the spectrum of deviation within LOD2 (Biljecki et al., 2016a, p. 26)

The resulting ambiguity is a product of the excessive flexibility of the CityGML concept (Biljecki *et al.*, 2016a; Biljecki *et al.*, 2016b; Stoter J. *et al.*, 2014). Biljecki *et al.* (2016a, p. 27) relate the problem to the missing minimal requirements: "The description [of OGC regarding the CityGML LODs] actually specifies the upper limit of each LOD, and not the minimal restriction for each, i.e. it restricts what can be a part of each representation. For instance, LOD2 cannot contain openings, but it is not stated that LOD3 must contain openings."

Biljecki *et al.* (2016a) further claim that this ambiguity led to other works such as (He *et al.*, op. 2012), He *et al.* (2012), and Besuievsky *et al.* (2014) criticizing the CityGML LODs more indirectly with treating them as umbrella categories and developing further specified versions of LODs. The list of related research, introduced by Biljecki *et al.* (2016a), criticizing the LOD concept at large, but also specifically the CityGML standard as well as the literature developing the standards further is manifold. The variety of criticism, but also new approaches stand for the disunity of academia and practice and again underline the need for further research and most of all the importance of a joint effort of academia and practice. At the moment numerous researchers such as Biljecki (2013, 2014, 2016a, 2016b), Stoter J. *et al.* (2014), He *et al.* (2012), Besuievsky *et al.* (2014) are investigating new approaches concerning the LOD concept, whereas everyone is bringing in new procedures, enlarging the conglomeration of ideas and eventually leaving the concept even more instable than before.

Nevertheless, the new approach of Biljecki *et al.* (2013, 2014,2016a,2016a), shortly introduced below, not only introduces the most recent ideas, but also claims to integrate other researches and outcomes into their approach: "This series [of newly proposed LODs] is a result of an exhaustive research into currently available 3D city models, production workflows, and capabilities of acquisition techniques." (Biljecki *et al.*, 2016a, p. 25) With this they include also the current possibilities of acquisition and creation methods regarding the LOD concept.

As a suggestion to alter the current CityGML standard, Biljecki *et al.* (2016a), develop a set of 16 LODs, extending every category with three sub categories. With specifying and assigning the most common elements of buildings, they limit the freedom of modelling and define minimal criteria to be fulfilled for their LODs. The detailed elaboration of their proposal exceeds the scope of this work, but Figure 13 and Table 2 illustrate their vision and regarded specifications for each level very concisely. It is important to mention that suggestion for LOD3 by Biljecki *et al.* (2016a) are not following the traditional LOD logic but rather represent opportunities to categorize LOD models from different acquisition methods which in fact belong to LOD3. For instance LOD3.0 represents a category for a model from an aerial survey and LOD3.1 represents its terrestrial counterpart (Biljecki *et al.*, 2016a).

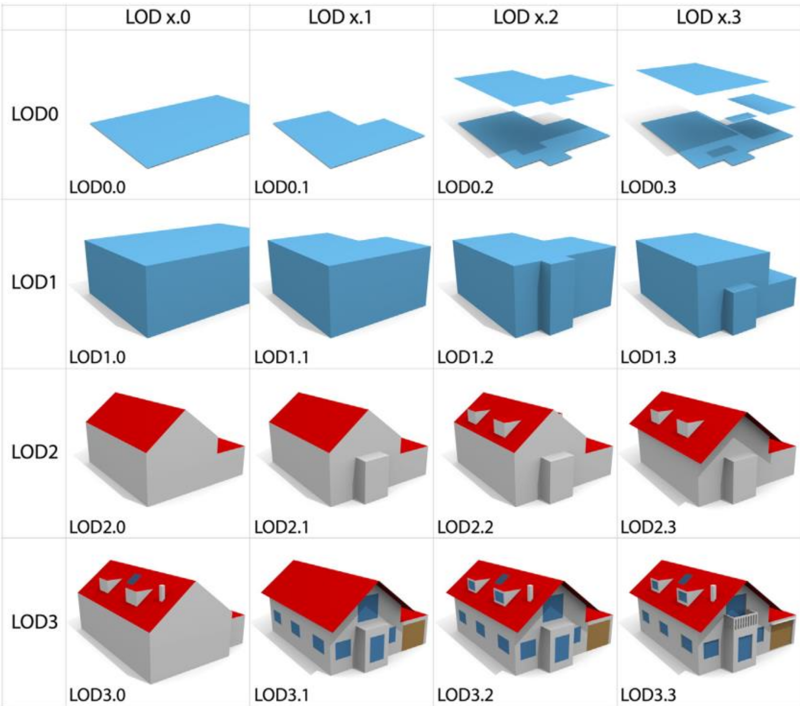


Figure 13: redefined LODs (Biljecki et al., 2016a, p. 28)

Table 2: Specifications for the redefined LODs, seen in Figure 13 (Biljecki et al., 2016a, p. 30)

Table 1
Specification of the refined levels of detail fitting the current CityGML 2.0 LODs.

Requirements	Refined levels of detail															
	0.0	0.1	0.2	0.3	1.0	1.1	1.2	1.3	2.0	2.1	2.2	2.3	3.0	3.1	3.2	3.3
Individual buildings		•	•	•		•	•	•	•	•	•	•	•	•	•	•
Large building parts (>4 m, 10 m^2)		•	•	•		•	•	•	•	•	•	•	•	•	•	•
Small building parts, recesses and extensions (>2 m, 2 m^2)			•	•			•	•		•	•	•	•	•	•	•
Top surface[a]			S	M	S	S	S	M								
Explicit roof overhangs (if >0.2 m)												•		•	•	•
Roof superstructures[b] (larger than 2 m, 2 m^2)											•	•	•		•	•
Other roof details (e.g. chimneys >1 m)													•		•	•
Openings (c) (> 1 m, 1 m2)													R	W	•	•
Balconies (>1 m)														•	•	•
Embrasures, other façade and roof details, and smaller windows (>0.2 m)																•

[a] Applicable only to LOD0.y and LOD1.y: S — single top surface; M — multiple top surfaces if the difference in height of the extruded building elements is significant (larger than 2 m).
[b] It includes dormers and features of comparable size and importance (e.g. very large chimneys).
[c] R — only openings on roofs; W — only openings on walls. In R, openings on dormers are not required.

Commonly used, but sparsely mentioned in literature are mixed LOD visualisations or hybrid models, which contain different LODs at the same time (Biljecki, 2013; Biljecki *et al.*, 2016a). Their common use for architecture or urban planning competitions, and other commercial purposes is most likely explained by the inevitable focus of specific elements or buildings when visualised in greater detail. However, in order to investigate different LODs separately, also separate and consistent LOD models have to be investigated and this category can be disregarded for now.

2.4 Depending on…

During the research process it became evident that context dependencies are a crucial element of 3D modelling. This chapter provides a very concise introduction to the concept of context dependency and its understanding in this paper. The Oxford Dictionaries define the term *context* as "The circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood." The earlier described concept of standardisation represents the urge of unification and centralisation. On the contrary the concentration on the "[…] circumstances that form the setting […]"that is to say a context depended view on 3D modelling strives for individualism and decentralisation. Consequently, standardisation strives to create a central common denominator for every situation its applied in. A context dependent view however, emphasises the uniqueness of every situation.

3 Methodology

The following chapter illustrates and explains the followed methodology, the used methods and steps taken to answer the previously defined research questions. Knowledge was acquired in a variety of steps and ways which are precisely elaborated. Interviews were conducted as one of the first empirical steps to complement, proof and generate new knowledge around the topic. Secondly, the term effectiveness in regard to the topic has been operationalised in an individual step. On the basis of this operationalisation 3D scenarios were investigated. 3D models with different LODs are used as the testing basis and are complimented by a questionnaire testing and evaluating the tangibility of every LOD in the related scenario and its presented information. Operationalisation, criteria and analysis was largely conducted following the methods of Wissen (2009).

3.1 Research paradigm and methods

The literature presented in the previous chapters makes it clear that 3D modelling is a valuable part in participation and planning processes. It seems to be a mutual consent that the various positive effects coming along with a 3D visualisation enhance interaction and understanding of the presented situation among all stakeholders. Nevertheless, a clear differentiation between models and different stages of realism seems to be missing. 3D visualisations across LODs are commonly used in various researches, but only rare cases differentiate LODs and their effects intentionally.

This research is focused on revealing the connection of different abstract visualisations of urban situations and their varying understandings of stakeholders. As displayed previously in Figure 5, it is assumed that the vision of people can be altered by 3D modelling, leading to newly formed knowledge of viewers, hence an altered discussion and decision basis. An additional assumption is, that different gradients of abstraction, LODs respectively, shown in the visualisation can have different effects on the viewer's perception and vision. Thus, actors are undergoing an altered perception process influenced by 3D visualisations, leading to a new information basis and via an education process to a newly constituted participation process. The 3D model consequently helps to bridge the gap of communication between different parties in the planning process.

These alterations of the perception process are connected on the one hand with the tools effectiveness and inferentially with the processes efficiency.

Another focus lies on the collateral discussion on standardisation. A standard defined as "A level of quality or attainment" or "Something used as a measure, norm, or model in comparative evaluations" (Oxford Dictionaries, 2016) may be seen as a necessity to increase *inter alia* quality, compatibility, exchangeability, security and comprehensibility. Consequently, standardisation of LODs in 3D urban modelling is seen as an influential factor on the effectiveness of the tool and the processes efficiency.

In depth literature research, as elaborated more precisely in the following, constituted the first method to gather information and a sound theoretical basis for this research.

Secondly, qualitative interviews were chosen to specifically reach experts in the field and academia. This method made it possible to tap experiences from different cities in different countries as well as from academic experts and set these experiences in relation. They were also important to complement the third chosen method, online surveys.

Online surveys provide an easy method to reach a number of willing participants, interested in planning processes. Similar to a planning process, in which actor participation also depends on the willingness of stakeholders. O'Leary (2004) describes this process of specifically asking for volunteers interested in the topic as *volunteer sampling*, not to be confused with *convenience sampling*, which simply describes the most convenient sampling method for the researcher.

Goal was to reach a variety of interested people, preferably from different countries to compare similarities between interview and questionnaire data. An online questionnaire, as an easy and flexible method to distribute over far geographical distances provides this possibility. Additionally, surveys in general provide an excellent way to gather standardized data. Consequently, they provide a well-fitting format to question the effectiveness of LODs on a comparable scale. Fricker (in Fielding, 2010) summarises these advantages compared to paper based surveys and other methods as lower costs, less effort to administer, better response rates and greater accuracy.

The triangulation of these methods made it possible to investigate and discuss the data and topic at large in a more comprehensive way that is to say from different perspectives.

3.2 Literature research: Previously on 3D modelling

The preparation of this research consisted of in-depth literature review of various, modelling focused articles across the past decade. Chapter 2 elaborated the basic knowledge on the topic of visualisation techniques, examined specific papers on 3D modelling in planning and furthermore established cross references between the researches. Research on planning theory in relevant categories such as communication, participation, power, complexity and visualisation was used to establish a theoretical background tailored to the topic and research question. Links between planning theory and practice were drawn, crucial elements for this research highlighted and research gaps outlined as a substantiation of this research. Following the steps of Burzan *et al.* (2008) the research process includes as one of the principal steps the specification of the topic and definitions of relevant terms. By consulting relevant literature, chapter 1 and 2 narrowed the focus of this research and elaborated fundamental terms and concepts. Important to mention here is that literature on 3D modelling is manifold and varies enormously. Terms and concepts were defined and elaborated either in the most acknowledged way by academia or in the most important way with regard to this research.

3.2.1 Operationalisation of effectiveness and criteria

On the basis of literature research the terms effectiveness and efficiency were operationalised as a necessity in order to be measured (Niekerk, 2015a). This subchapter describes the results of this operationalisation and presents the research criteria developed within this rationality.

Usually, the term *effectiveness*, in regard to a certain tool or method, points to the question if this tool or the method fulfils its objectives and if the expected results are achieved (Niekerk, 2015a). This corresponds to “Usability performance metrics such as satisfaction, efficiency and effectiveness (SEE) [which] are employed to assess how easy the product or system is to use. Satisfaction refers to a user’s attitude or preferences about the system, efficiency refers to how quickly the tasks are completed, and effectiveness refers to whether or not a task is successfully completed." (Çöltekin *et al.*, 2009, p. 6)

Consequently effectiveness is related to methods, tools or instruments used in the planning process, whereas efficiency corresponds to the process itself (Niekerk, 2015b). In order to make the term *effectiveness* more graspable in the given context of this work, this chapter provides an investigation into the requirements of 3D visualisations.

Firstly, 3D visualisations have to be attractive to be used and secondly provide a certain quality. Wissen (2009) uses these two dimensions as umbrella categories to investigate multiple tasks of 3D visualisations in planning processes and their effectiveness. Six of these tasks according to Wissen (2009) were chosen.

Wissen (2009) describes these six tasks as related to communication in planning processes, which can be supported by 3D visualisations. Although she is elaborating on landscape planning, a look back at chapter 2 shows, that the supported tasks are comparable to the urban planning context. These tasks, their target group and the relevant information are shown in Table 3.

While scrutinising the selected tasks it becomes evident that, naturally, the bridge, built by 3D visualisations, between laypersons and experts has two sides. The visualisations' target group reveals which end of the bridge is important and if the information flow is one sided or both sided. For instance, the task informing and motivating is aimed to attract so far not interested citizens and is therefore more one sided. The communication of planning relevant information, from expert to layperson, concentrates on already participating people, whereas the evaluation of the situation is important for both, experts and laypersons. Furthermore, it is important that laypersons as well as experts feel enabled to make suggestions, bring in their own, local knowledge and eventually make an informed decision. (Wissen, 2009)

It is crucial that the amount of information presented in the visualisation should not only exceed the information given in commonly used 2D plans or even the previous category of LODs, but also the information should be better understandable through the advanced visualisation. The 3D model should clarify the situation for participants and thus alter their vision of the given situation. As a platform of communication and an effective tool, the 3D visualisation should additionally motivate stakeholders to participate in the process and discuss the model and should inspire to come up with new ideas and suggestions.

Table 3: Tasks in the planning process supported by 3D visualisations (after Wissen, 2009)

Tasks	**Aiming at**	**Relevant information**
Information & Motivation	passive, currently not participating people	Contextual information and relations of local circumstances and developments
Communication of Information	Laypersons	Spatial and functional relations, influences on spatial structure and quality
Evaluation of the situation	Laypersons, experts	Alteration of vision, scenarios, consequences
Developing ideas	Laypersons, experts	Alternative ideas, suggestions
Decision making	Laypersons, experts	Solutions, agreed alternative ways

Table 4: additional criteria (model specific)

Additional model specific criteria influencing the effectiveness of the visualisation
1. **Vegetation**
2. **Water features**
3. **Light and shadow**
4. **Sky**
5. **Colours**
6. **Basemap**
7. **Roof details**
8. **Façade details**

In order to determine the overall effectiveness of different LODs in the planning process, the tasks supposedly supported by 3D visualisations have to be examined with varying LODs. Eventually, this reveals not only the effectiveness of the LOD at large, but also the individual LODs effectiveness in the numerous tasks. In other words, it states which LODs are beneficial in individual tasks and additionally shows the disadvantage and possible malfunction of a certain LOD for a specific task. (Wissen, 2009)

Consequently, the successful support of the listed tasks by a certain LOD determines its effectiveness. Along with Wissen (2009), the two mentioned dimensions are important to look at, when investigating these tasks. The first dimension, the attractiveness of the LOD, describes how attractive the use of a certain LOD is and if its use is beneficial for communicating information. The second dimension after Wissen (2009), the quality dimension, which is more influenceable than the attractiveness dimension, rates the LOD according to its quality of showing and communicating planning relevant information. These dimensions embedded in the criteria development process are seen in Figure 14.

Wissen (2009) develops criteria for each dimension and the individual tasks in the planning process, which was seen as an inspiration for the criteria development of this research. Yet, in this research these two dimensions are seen as intertwined resulting in criteria standing for the overall effectiveness of the visualisation. This alteration was necessary to make this research as well as the online survey more concise, while still taking both dimensions into account. The criteria can be seen in Table 3.

Next to these criteria, visualisation specific criteria, seen in Table 4, were tested. Specific and tailored survey questions about these criteria gave additional knowledge about which specificities in a visualisation determine its effectiveness.

Efficiency on the other hand, roughly defined as the relation of input and output, may be defined by the time, effort or money invested in the planning process in order to reach its successful completion. As the investigation of multiple planning processes would exceed the resources available for this research, interviews with planning departments in multiple cities are meant to give insights into the efficiency of planning processes in cities using multiple LODs of urban situations.

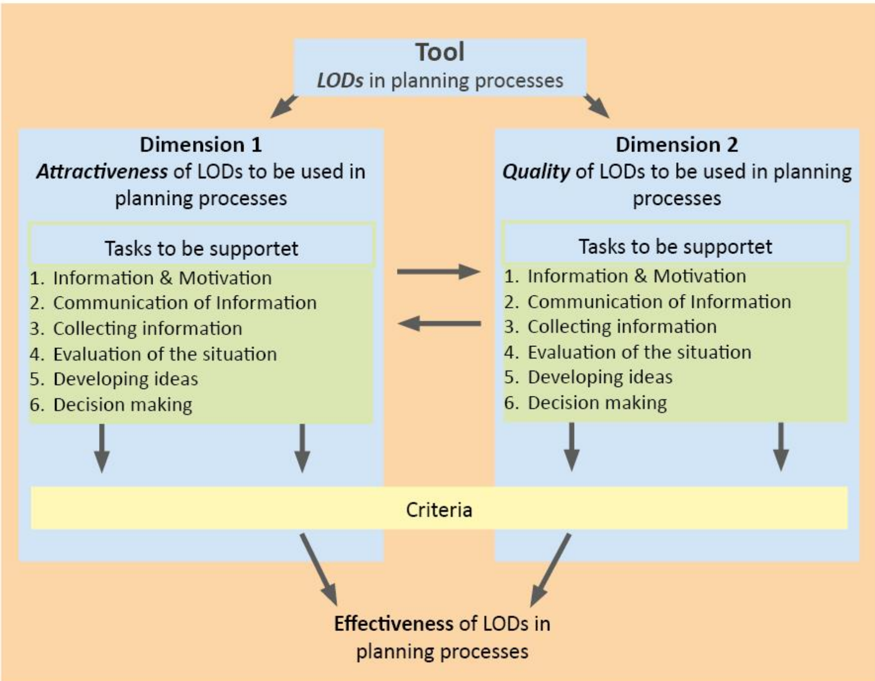


Figure 14: Relation between LODs, the dimensions of attractiveness and quality, the supported tasks of 3D visualisations in planning processes and their criteria as well as the tool's resulting effectiveness (after Wissen, 2009)

Table 5: Criteria per tasks for quality and attractiveness dimensions (after Wissen, 2009)

Tasks / **Criteria**	Informatio n & Motivation	Communic ation of informatio n	Collecting informatio n	Developing ideas	Evaluation of the situation	Decision making
Attract interest/ attention						
Identification with the places character						
Understanding the content of the image						
Differences in perception related to scale/details						
Identify problems and create an opinion						
Basis of further discussion						
Inspiration for new ideas						
Added value of roof structure for understanding						
Identification of different building types						
Overall attractiveness						

3.3 Methodological design: Investigating complexities of the social world

Moving from the research question to answers requires defining the steps needed, hence the elements of a well fitted methodological design (O'Leary, 2004). Crucial thereby is to link the problem situation, the research question respectively, to appropriate methodological approaches (O'Leary, 2004). The methodology, as the manual of which methods to use and how to use them (Häder, 2010), can be derived from the problem statement and the intention of the research as indicated in Figure 15 (O'Leary, 2004).

Figure 15 furthermore depicts the modus operandi between the theory chapter and the results chapter and thereby connects the previously introduced perception process, altered by 3D models and the criteria developed in the previous subchapter. It uncovers the perception process leading to the actual problem situation, the approach of this research to answer the derived, explorative question and connects this question to the mentioned criteria.

As the objective of this research is of explorative nature, i.e. to find out more about the tangibility of different LODs in 3D models and their effectiveness in the planning process, a phenomenological perspective after O'Leary (2004) was adopted. She described phenomenology as the "[…] individual's 'lived experience' of a particular 'object'" which is based on a view that is constructed and (inter)subjective, striving to know "[…] how individuals go about making sense of their direct experiences." (O'Leary, 2004, p. 122). Correspondingly this means the investigation of the different understandings of deviating LODs in 3D models in urban planning, that is to say how people make sense of what they see in a specific urban scenario.

3.3.1 Questionnaire

As planning processes with participative elements, such as the investigated scenarios, are open to a wide range of different people and participation depends on voluntary involvement, *volunteer sampling* (O'Leary, 2004) was chosen as a well-fitting sampling format, following the same reasoning. *Volunteer sampling* relies on peoples willingness to participate in the research and belongs therefore to the group on non-random sampling methods (O'Leary, 2004). As such participants had the choice, comparable to participation in planning processes, to opt-in, i.e. to take part in the survey (Fielding, 2010). Random-sampling methods however would ask participants actively to enter the survey, but they have the choice to opt-out, i.e. decide to not participate (Fielding, 2010).

The questionnaire was developed as an online survey and as such Fricker (in Fielding, 2010) calls it unrestricted self-selected survey. This category, particular for web-based surveys, is open to anyone and "[..] may simply be posted on a website so that anyone browsing through may choose to take the survey, or they may be promoted via website banners or other Internet-based advertisements, or they may be publicized in traditional print and broadcast media." (Fielding, 2010, p. 205)

The questions, all regarding the effectiveness of either LODs at large, a specific task or detail, could be answered in an ordinal scheme from 1 to 5 or from extremely effective to not effective at all respectively, thereby ranking the individual importance of criteria. This format represents a *unipolar likert question*, thus an ordinal answer scheme. In contrast to a *bipolar likert question*, which has a distinct midpoint representing neutrality and answers can fall either on the one side of the spectrum or the opposing antonym, a *unipolar likert questions* asks for a distinct amount, of for instance effectiveness, with incremental gradations in-between and no conceptual midpoint. (Krosnick and Fabrigar, 1997)

Participants had to answer a set of personal questions before starting the actual survey. These questions included gender, age, their nationality as well as their current residency, their knowledge about planning processes and whether or not they have a professional planning background and if they were familiar with the target area of the scenario. Questions 1 to 4 (see appendix B) investigated the effectiveness of the Vienna 3D model without changes to the model (see Figure 17). Questions 5 to 8 investigated the Viennese case by showing scenes of the Karlsplatz (see Figure 18) and question 9 contained elements investigating the effectiveness of nature elements such as trees as well as other details including façade elements, roof details, the underlying map, water features, sky, light and shadow and colours. Additionally, this section questioned participants about their preferred LOD of the proposed changes in the Karlsplatz scenario, the surrounding buildings as well as the St. Charles church. This particular question gave participants the possibility to click on one of these categories and choose either a higher LOD or indicate that the shown LOD2 is sufficient for the scenario. With this feature results from the more general questions regarding the LODs effectiveness were concretised to different areas of the model.

The survey, designed in Qualtrics (see Appendix B), was distributed on October 10th via Facebook and Mail and ended on November 15th 2016. Urban Planning related organisations and other participants active on Facebook where asked to distribute the survey further as well as previously interviewed contacts received a personal invitation to participate. During this time 177 respondents were recorded.

3.3.2 Expert Interviews

As elaborated before, 3D visualisations are a communication platform that works both ways, from expert to layperson and vice versa. In order to get a more detailed picture of the current use of 3D models in the communication of urban plans additional expert interviews were carried out.

By using triangulation (mixed methods), i.e. combining quantitative and qualitative methods, these interviews made it possible to investigate the topic from a different perspective and gave the chance to analyse the results of the survey from another angle (Lamnek, 2010). Additionally, they concretised and supported the formulated theory that the effectiveness of 3D visualisations varies according to their LOD.

Quantitative social research represents thereby a method of testing hypotheses and seeks the generalization of theories with the help of large amounts of data. Qualitative social research on the other hand rests upon the paradigm that reality is socially constructed and generalization is not prioritised. Therefore, subjective interpretation in a context dependent view is crucial to gain new theories from the data. In other words, quantitative social research is testing theories, whereas qualitative social research is generating theories (Wissen, 2009). Mixing these methods brings the research question and data into a new perspective and allows to investigate the matter on different levels (Wissen, 2009).

Expert interviews are directed to a specific target group (Lamnek, 2010). They see the respondent as an expert, hence a source of descriptive information and facts derived from his/her experience and knowledge in a certain, special field (Lamnek, 2010). They also reveal the interviewee's opinion on the investigated matter and thereby reveal certain behaviour and rationality. In the context of 3D models, these interviews reveal how they are used and why they are used in this way.

The interviews were carried out as semi-structured, one-on-one interviews, without fixed but flexible predesigned questions and were held between June and August 2016. The qualitative expert interviews, embedded in step two of the conceptual model, can be seen in Figure 14.

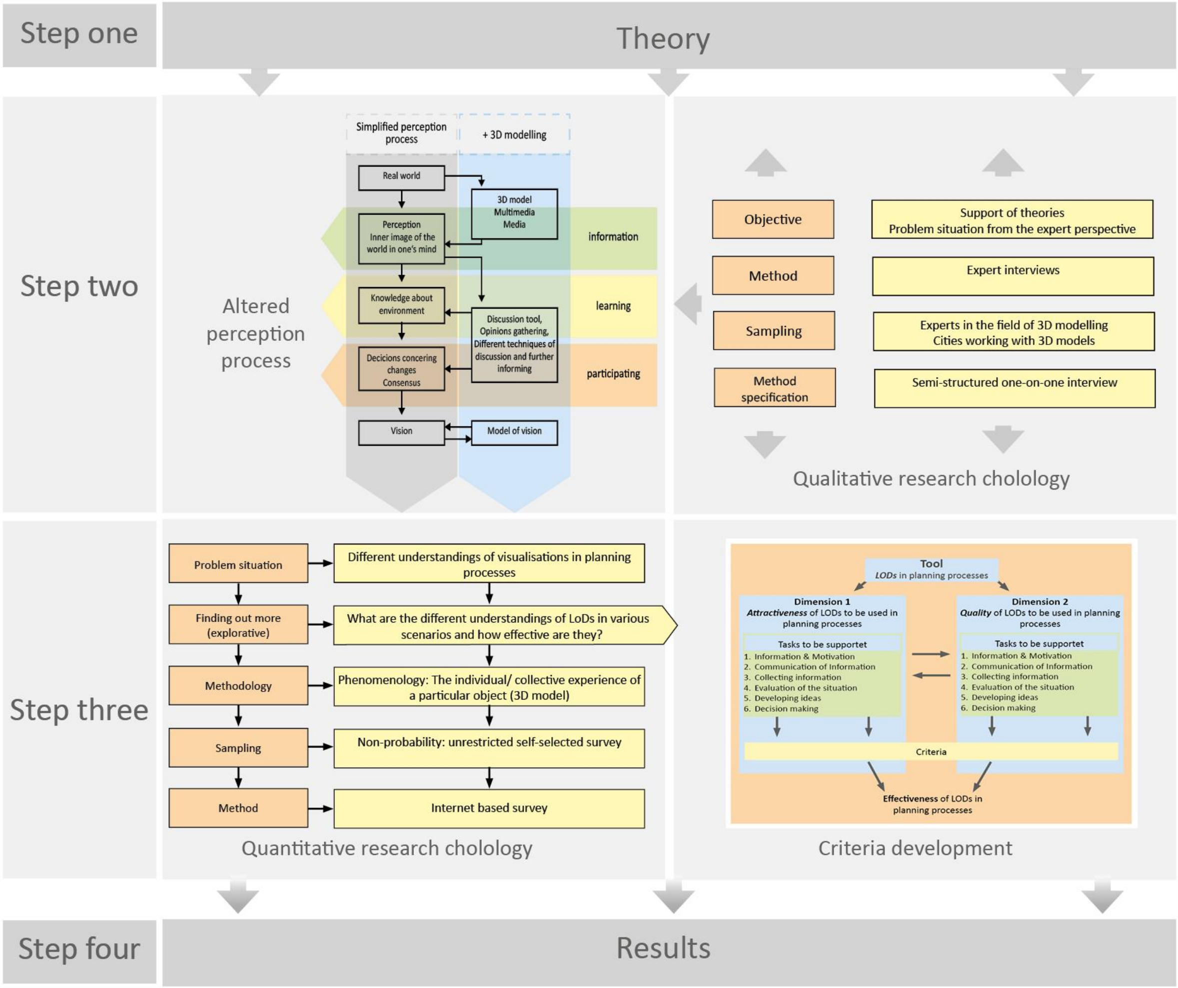


Figure 15: Conceptual model: Workflow and Research method (after Hanzl, 2007; O'Leary, 2004)

3.3.3 3D Scenes & Scenarios

The scenes used to investigate the effective use of different LODs vary between images from the existing model without any changes up to and altered scenario. In order to investigate more areas of application different scales and different purposes for the images where chosen.

For instance, changes in height development in an urban environment, which are generally difficult to be understood for laypersons in 2D plans are shown in one of the scenes. Especially in a situation with distinct topography, 3D models in different LODs are expected to communicate the changes more effectively.

Structural change and the preservation of cultural heritage are further examples. Structural change can either mean a new development or a restructuring process of an area within the city, bringing potentially considerable changes in urban patterns with them.

The preservation of cultural heritage requires a good understanding of developments in in the surrounding of a protected construction. 3D models are estimated to be a good basis for discussing context sensitive development. In all cases the question remains how much detail has to be included? The generated scenes contain elements of all these topics.

The 3D city model of Vienna was chosen as a testing basis for this work. Austria's capital commonly uses three different LODs (1,2,3), seen in Figure 15, for different planning purposes (Dorffner, 2015).

The Karlsplatz area, partly seen in Figure 15, was provided by the city of Vienna for testing purposes and functions as the basis for the investigated scenes. So far only this area is developed in LOD 1,2 and 3. As seen in Appendix B, the investigated model was designed without coloured buildings or textures to make the model the most objective testing basis possible.

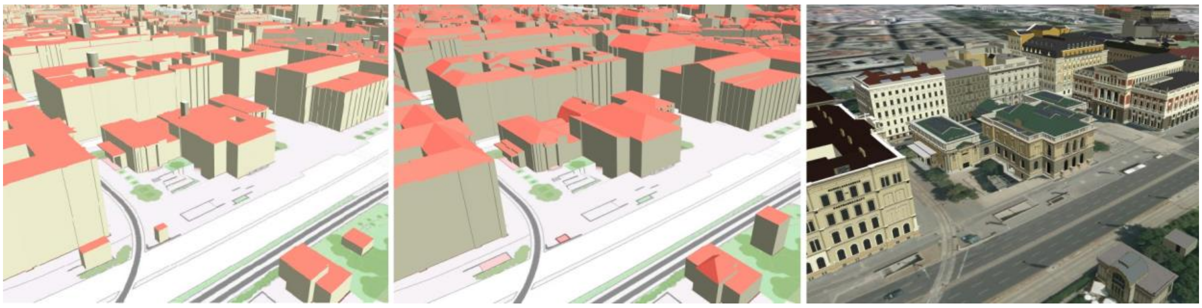


Figure 16: Examples for LOD1, LOD2 and LOD3 from the Vienna 3D model (Dorffner, 2015, pp. 20–23)

Vienna is a city with numerous buildings from the Gruenderzeit, the end of the 19th century. These commonly lower build constructions are nowadays often raised and lofts or attic apartments are added. Therefore, changes in height development not only effect planned fallow lands or other development areas, but can distinctively influence the cityscape as a whole. The Karlsplatz (location seen in Figure 17) consists of various distinctive and historically important buildings including the St. Charles church, the technical University of Vienna and the Kuenstlerhaus (seen in Figure 16) and is surrounded from apartment houses largely dating back to the Gruenderzeit. Some of these buildings were already elevated or roofs were changed. Selected buildings are shown in different LODs in order to make the test persons familiar with the model as well as to investigate the models specificities (see Figure 18). As models are acquired differently, LOD characteristics can vary from one model to the other. Vienna's model, also modelled according to CityGML, differentiates two main geometries, one in LOD1 and one used for LOD2 and LOD3, whereas the geometry in LOD3 is refined. Scenes of the existing model were meant to reveal this model's strengths and effectiveness in each LOD.

The St. Charles church on the Karlsplatz is a very distinctive baroque construction seamed with considerably lower buildings mostly dating back to the Gruenderzeit. Its front opens up to a square with an adjacent park which puts the church in a very prominent scene. An existing modern building complex right next to the church, hosting and insurance company and the Vienna museum, is planned to be elevated (APA-OTS, 2016). This current situation was perceived as a good example and scenarios in different LODs where tested for their effectiveness in this setting. (see Figure 19 and 20)

This scenario focuses additionally on the aspect of cultural heritage in the development of a new building in an area with a high density of cultural heritage structures or buildings. This focus is aimed at showing the integration of a new or rather altered building into the existing pattern and appearance of the city and the effects of a new construction on cultural heritage and its perception.

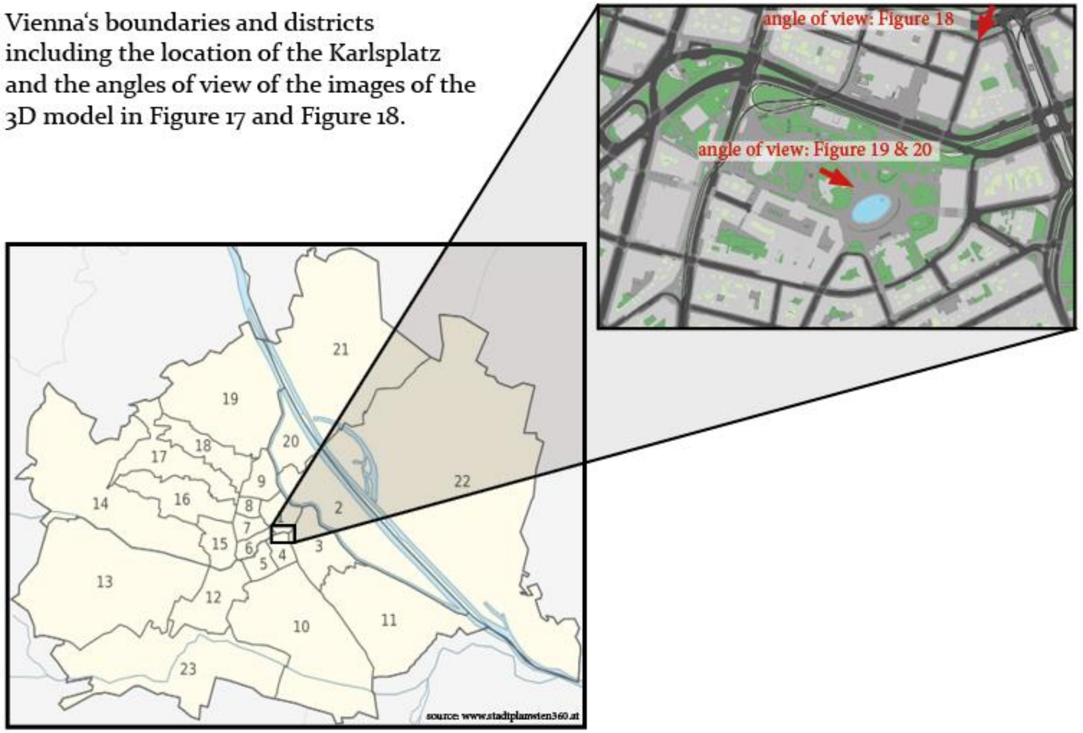
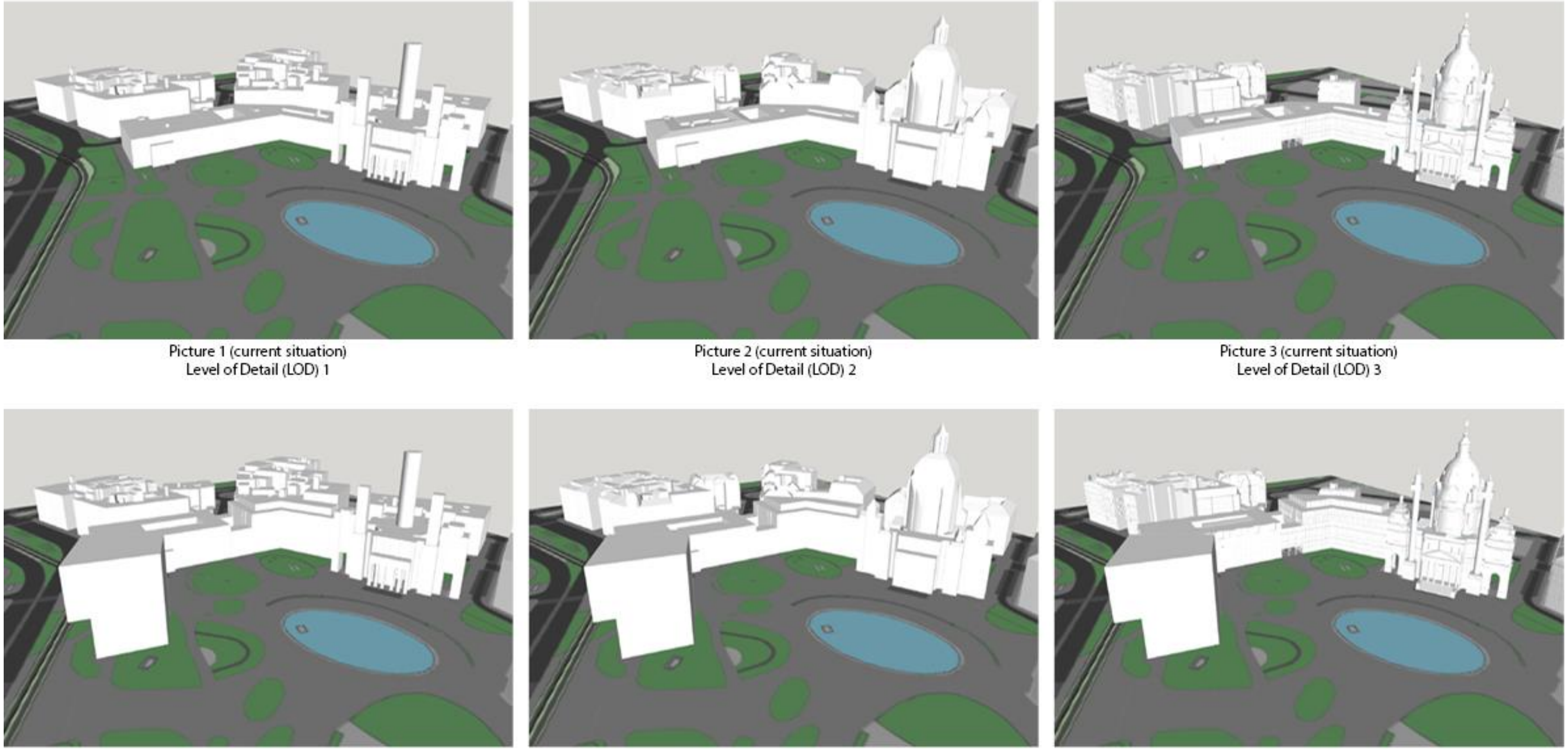


Figure 17: Location of the Karlsplatz in Vienna and angles of view of the images of the 3D model in Figure 18, 19 and 20. (own source)

Figure 17: Tested set of images: Vienna City model without changes; View: Kaerntner Ring/ Schwarzenbergplatz towards Karlsplatz. St. Charles Church in the background (own source)



Picture 1 (current situation)
Level of Detail (LOD) 1

Picture 2 (current situation)
Level of Detail (LOD) 2

Picture 3 (current situation)
Level of Detail (LOD) 3

Picture 1(possible scenario)
Level of Detail (LOD) 1

Picture 2 (possible scenario)
Level of Detail (LOD) 2

Picture 3 (possible scenario)
Level of Detail (LOD) 3

Figure 19: Tested set of images: Vienna City model Karlsplatz scenario; View: Karlsplatz/ St. Charles Church (own source)

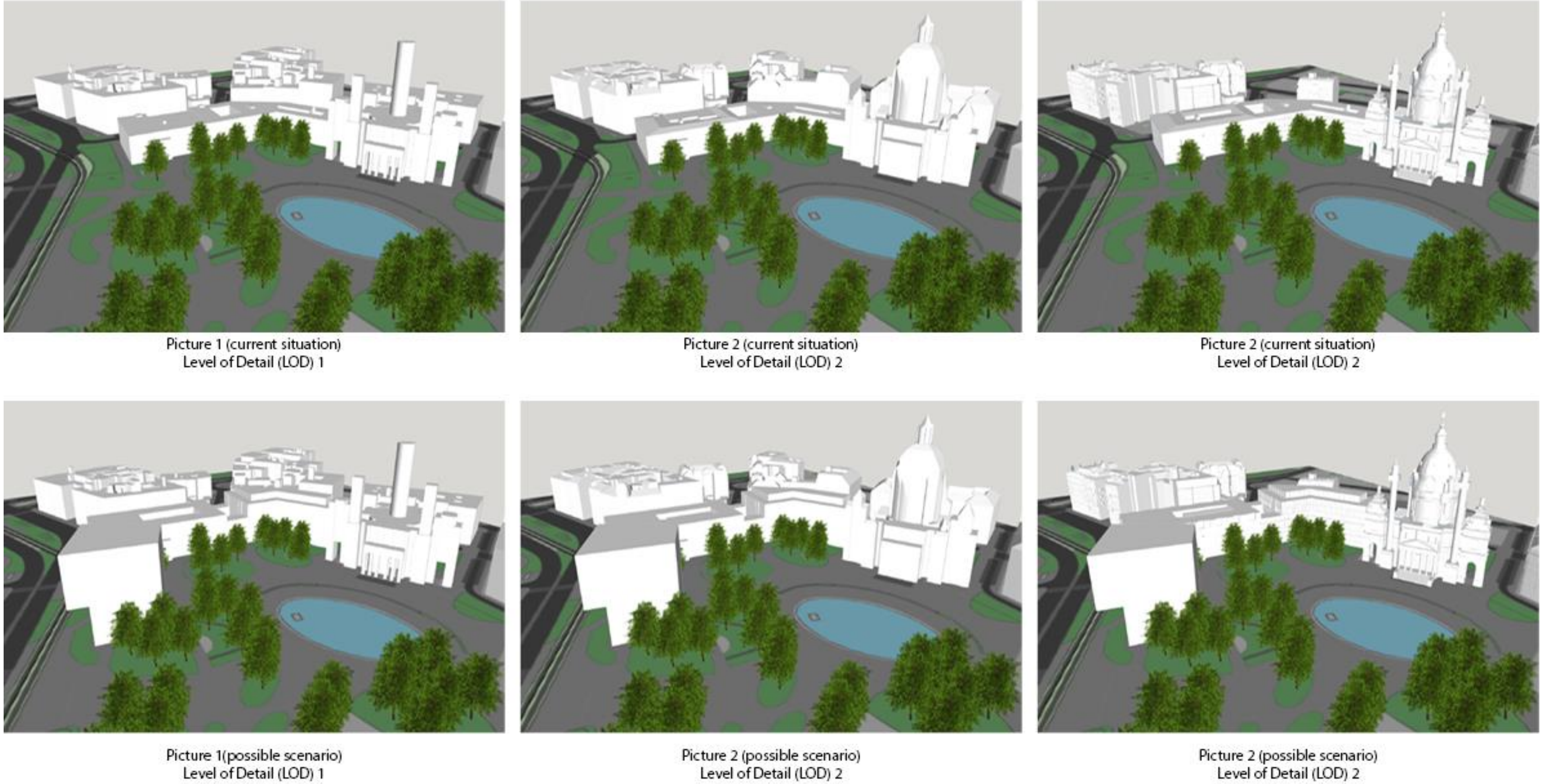


Figure 20: Tested set of images: Vienna City model Karlsplatz scenario including trees; View: Karlsplatz/ St. Charles Church (own source)

3.4 Data analysis

The chosen methods of gathering data, survey and interview, lead inevitably to quantitative and qualitative data. A mixed method approach was needed to further proceed with this data, whereas utility analysis and grounded theory were chosen as appropriate approaches. In contrast to single qualitative or quantitative data, the necessary steps being data reduction, data display and drawing conclusions or verifying the data had to be carried out twice, for qualitative and quantitative data individually. Additionally, the integration and relation of both results had to be conducted at some point during the analysis. A parallel analysis design was chosen, meaning quantitative and qualitative data were analysed individually and were only combined in the last step. (see Figure 21) This step represents the major benefit of mixed methods, as separate methods and data strings can be combined, related to each other and compared. This allowed to discuss results and data from different perspectives. (Kuckartz, 2014)

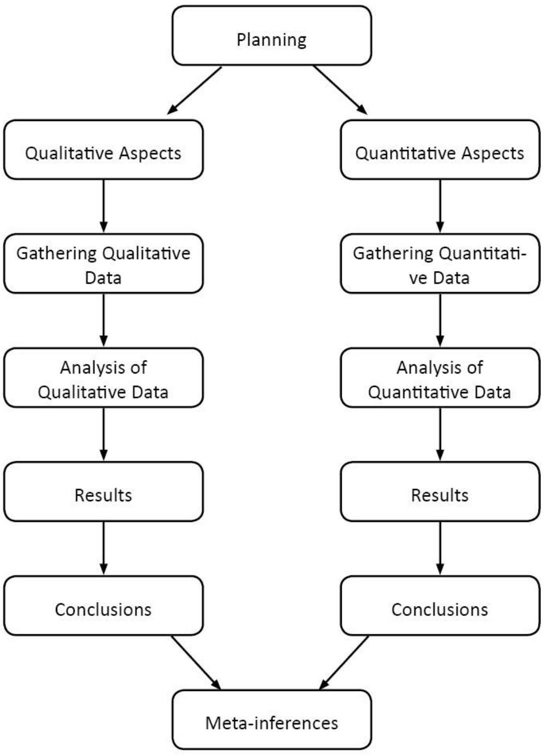


Figure 21: Mixed Methods parallel design with data integration in the last step (after Kuckartz, 2014)

3.4.1 Questionnaire data analysis

Amongst others utility analysis, as a method to rank the utility or effectiveness of various options (Scholles, 2005), was applied in order to analyse the quantitative survey data. The variables introduced in chapter 3.3 were converted in survey questions which offered answers in an ordinal scale scheme from 1 (e.g. very effective) to 5 (e.g. not effective at all) for each individual criteria. Although the questionnaire offers also different answer schemes such as *excellent* to *terrible*, depending on the question, all of them measure the goodness of fit of the LODs in the defined variables. Thus, to avoid different labelling in the analysis only the scale *very effective* to *not effective at all* was used.

To calculate and visualize the response numbers and percentages per answer possibility in either different variables, tasks or in total per LOD, Microsoft Excel was used. This simple analysis was conducted to show the distribution of answers across each answer option and each variable. Consequently, this analysis gives already valuable insights into the LOD preferences of participants and eventually ranks the LODs according to their overall effectiveness.

As a first step data from Qualtrics was exported to Excel, refined and visualized. In a second step these values were accumulated according to Table 5 to calculate numbers and percentages per task in the planning process. Total values for each LOD were accumulated in a third step and resulted in an overview of how often LOD1,2 and 3 were chosen either as being extremely effective, very effective, moderately effective, slightly effective of not effective at all.

Qualtrics offers a graph generating tool which was also used to analyse the data. Simple graphs about individual answers and distributions were used. Especially the individual design of question 9 with various formats of answers possible was analysed with the Qualtrics graph tool.

Additionally, survey data was exported to SPSS in order to statistically analyse the data. This part of the analysis was conducted to reveal possible influences of gender, age, familiarity with either planning processes or the area as well as backgrounds on the answer distribution. In SPSS the data was filtered and only complete data sets, i.e. participants who finished the entire questionnaire, were used. A descriptive analysis was generated to have an overview over the reduced data set. Next to this the *chi-square* test was applied to find out influences of for instance gender on the answer schemes. As *chi-square* tests are only reliable if the expected values in at least 80% of the table are bigger than 5 and the overall sample size is relatively small also a *fischer's exact test* was conducted (McDonald, 2009; Rasch, 2010).This test allows expected values to be lower than 5. Only results with a p-value, the value showing the statistical significance, of lower than 0,05 were processed. With this value being lower than 5% a statistical significance with at least 95% can be guaranteed (McDonald, 2009; Rasch, 2010).

3.4.2 Grounded theory

In contrast to the qualitative content analysis (Mayring and Fenzl, 2014) which analyses qualitative research material with previously defined codes, grounded theory is based on a concept-indicator model. This means that codes are generated in an inductive process: While scanning the data, codes are appointed to described phenomena. These codes function as indicators for a certain phenomenon, hence an underlying concept that is meant to be revealed. Indicators are summarized and condensed in a further step and result in the mentioned concept. (Cremer, 2008)

As the effectiveness of LODs in 3D models is hardly investigated and knowledge as well as opinions on LODs diverges, a theory generating approach, such as grounded theory was chosen to analyse the expert interviews. The interviews with experts using 3D city models in their daily work, was expected to bring especially new insights into the experiences with the different LODs, the standardisation approaches and wishes to make the use of 3D models more efficient. Consequently, instead of predefining codes and testing a hypothesis, indicators and concepts were generated out of the gathered data delivering new theories about the efficient use of LODs in planning processes. Theories given in chapter 2 function as the basis for further investigation, whereas this grounded theory approach is meant to critically question and challenge these theories and at the same time is meant to come up with new theories about the investigated matter. Additionally, results from this analysis were combined with the results from the utility analysis in order to verify, compare and relate the different data strings. (Cremer, 2008)

Nine interviews were consensually recorded and transcribed, whereas one interview was followed with notes as a recording was not permitted. Seven interviews were conducted with experts from planning departments or land surveying departments in Switzerland, Germany and Austria and additional three interviews were conducted with researchers in the field. With the exemption of one English interview, all other interviews were held in German. Transcripts were analysed with the program Atlas.ti following the previously mentioned grounded theory logic. As a first step, abstract notions serving as codes were assigned and in-vivo-codes, being original wordings, standing out for a distinct phenomenon, were tagged.

On the basis of these codes, Interviews were compared and additional codes assigned. In a further step codes were summarized in overarching phenomena.

4 Results

This chapter presents the condensed results from interviews and questionnaire. The interview results are explained and set in relation whereas the quantitative data from surveys is just presented in numbers and graphs. Interview results are thematically structured and summarized. Survey data is displayed according to the analysis method.

4.1 Expert Interviews

The effective use of 3D visualisations is not only related to the used LOD, but also on other factors influencing not only the effectiveness of LODs, the efficiency of the planning process, but also the developmental progress of 3D visualisations in urban planning at large. Amongst others these include structural and organisational problems, missing trust in 3D models as well as insufficient skills and knowledge in 3D modelling. The conduced interviews made it very clear that reducing these external influences and strengthen the use of 3D in urban planning is a matter of time, generation changes and working modes. Nevertheless, numerous advantages of 3D models were listed, which give insights in their current main use. Interviews also showed that cities have LOD preferences when working with 3D visualisations in regard to their most effective use. As a matter of fact, according to the Interviewees the effectiveness of visualisations is highly depended on the LOD. However, opinions and experiences with different LODs in planning processes diverge between cities and between cities at large and researchers in the field. Interviews resulted in statements arguing for the preferred use of high LODs (LOD2+, LOD3 and even LOD4 respectively) as well as arguments for the preferable use of low LODs (LOD2, LOD1 and even LOD0). Between these opposing views are statements about the importance of the situationally dependent use of either low or high LODs.

4.1.1 The developmental brake of effective 3D usage

3D is a still evolving technique and obstacles for its use, let alone its effective use are yet manifold. Costs of developing, maintaining or using 3D models are hindering cities to either generate them, or to expand their use. Interviewee 11, Giorgio Agugiaro, a researcher at the Austrian Institute of Technology (AIT), stresses the advantage for Vienna of even having a 3D model in LOD2 and underlines its uniqueness in the Austrian context. Apparently "[…] there are no other Austrian cities besides Linz [and Vienna] owning a 3D model in LOD2." (Interviewee 11, 2016, Appendix A, own translation)

Reasons for the sparse use of 3D models or their ineffective and inefficient use can be found in the apparently weak confidence in 3D visualisations as well as missing skills when it comes to the generation of 3D images. "Certainly, the biggest disadvantage is always the acceptance [of 3D models] from citizens and politics, they are always sceptical about technologies. Because everything technological, or everything one can't see from the beginning on, can be manipulated." (Interviewee 1, 2016, Appendix A, own translation) Additionally Interviewee 1 (2016, Appendix A, own translation) states: […] if we are using an image for a public or political discussion, with the visualisation coming from and shown by an architect, it's very often […] criticised [..] because he obviously wants to sell his product, and therefore we try to use these pictures very defensively in public." Interviewee 8 (2016, Appendix A) adds to this and mentions that Zurich is only using 3D visualisations for the communication between experts, as concrete pictures are coming along with a high risk of major discussions.

What was referred to earlier as missing 3D skills constitutes a problem with various origins and effects. Interviewees from all cities reported on a clear allocation of competences in which land surveying departments generate, maintain and work with 3D models and as such establish a service provider relationship with planning departments. In a well-organized and informed structure, this system might be beneficial and even more efficient, but currently this system is one source of inefficiency of the process and ineffective use of LODs. Interviewee 1 (2016, Appendix A, own translation) states that "[…] if they [the 3D programs] are not used and exercised regularly, a drawer [from the planning department] is not gaining momentum to handle this program in a way we request it."

In this regard interviewee 5 states that urban planners do not have the resources to work with 3D next to their usual work and interviewee 2 underlines that additional experience and knowledge about 3D computer programs would be needed to work with 3D more intensively within planning departments (2016, Appendix A)

Whereas further statements regarding the reasons for the distribution of duties are sparse, it became clear, that it led not only to a sparing use of 3D models for planning processes, but also to less knowledge about 3D programs and also specifics, such as LODs in planning departments. In regard to the lacking knowledge about the effective handling of 3D images, Ulrike Wissen, a researcher at the ETH Zurich Department of Civil, Environmental and Geomatic Engineering stated that a new generation "[…] with better knowledge about all possibilities and which is able to deliver all this to practise [is needed] but further education is required until these competences are reaching practice." (Interviewee 9. 2016, Appendix A, own translation) Giorgio Agugiaro (AIT) adds to this and questions the knowledge of urban planners about the possibilities and potentials of 3D models and underlines the infancy of 3D in urban planning. (Interviewee 11, 2016, Appendix A)

This missing knowledge about 3D in general and LODs specifically leads also to an unclear reasoning or uncertainty regarding decisions about characteristics of 3D visualisations. Ulrike Wissen noticed during her work that, "[…] practice doesn't really know what they want, what they should request and to what expenses […]" (Interviewee 9, 2016, Appendix A, own translation)

Moreover, traditional 2D drawings as well as physical models are still very popular choices and 3D is to a lesser extent seen as the next step, replacing physical models, but rather as additional support slowly finding its way into planning processes. In line with this, Interviewee 2 (2016, Appendix A, own translation) advocates the use of both models: "[…] I think it's problematic, if one is merely working with the digital model, whereas I am personally an assertor of both, the digital and physical model, as both have their very specific qualities and the physical model can't hold a candle to the digital model and vice versa." Interviewee 6 (2016, Appendix A) explains that one of their two fields of application for the digital 3D model is curiously to print plaster buildings for their physical model in order to keep it updated.

As a result of the current use of 3D visualisations, Interviewees reported no significant changes in the planning process but rather about an additional tool which is sometimes applied. Interviewee 5 (2016, Appendix A, own translation) for instance answered to the question whether 3D models changed the planning process with: "I wouldn't necessarily say it changed, but it was complemented with a modern tool […]"

Interviewee 1 (2016, Appendix A, own translation) summed up: "[...] you can turn and rotate a 3D model on the computer and even look orthogonally at it, in the same way when you have a normal city model, [...] but currently it's not the element we are looking for, because we can't actively work with it and because we have to purchase it from another department, that's probably why our use of such pictures is very modest."

4.1.2 Deploying digitalisation – advantages of 3D

Physical city models were called "representative" (Interviewee 6, 2016, Appendix A, own translation) and beneficial for a different perspective and perception as a result of the arbitrary view coming with it (Interviewee 2, 2016, Appendix A). On the other hand, 3D models were praised for being faster to modify and very valuable for certain tasks such as the visualisation of visual axis and different angles, the two-hour shade[3] and various analyses including noise pollution:

"It is a tool for testing different new and spatial situations, but also existing situations and one of the tremendous advantages is [...] that you can look at the 3D model from different perspectives [...]." (Interviewee 2, 2016, Appendix A, own translation)

"[...] the digital model is an additional tool, and specifically in regard to the planning process a tremendous advantage, because when you are referring to a new plan, and that involves efficiency and possibilities, one can quickly check different scenarios with the help of the digital model [...] also renderings and offline images, which can be produced, checked and decided upon quickly." (Interviewee 2, 2016, Appendix A, own translation)

Interviewee 1 (2016, Appendix A) reports that the city of Basel is using their 3D model to verify models coming from external planners or architects and to review dimensions and volume in the context of the city in order to avoid manipulated 3D images. The city of Basel is also currently using the 3D model in a court procedure to establish a profound reasoning for the reconstruction of a hospital and for better visualisation purposes in front of court.

Interviewees made it clear that visualisations in 3D establish a comprehensible decision support, for experts as well as laypersons. Nevertheless, cities are still careful with 3D images, as a result of missing experiences with citizens and with different applications as well as the risk of misunderstandings: "Especially for laypersons, being not very familiar with the subject matter, it [a 3D visualisation] is certainly more demonstrative, therefore I can better communicate the plans. This is certainly an advantage, especially when plans are already very concrete and it is only a matter of visualising and communicating the real plans [...]. If we are talking about what we are doing at the moment, which is trying different development scenarios, the risk regarding the communication is much higher, because we are producing pictures, of which we know that they are never going to be realised like that [...]." (Interviewee 8, 2016, Appendix A, own translation)

Interviewee 2, while underling the advantages of physical as well as digital models, points to possible future solutions and potentials: "[...] maybe the fast progressing technology will help us, thinking about 3D goggles or the like, where I can walk through space, but we are still in a

[3] Two hour shade: The shadow of a newly planned building is not allowed to stay on any neighbouring building for more than 2 hours during a day.

transition, in which fields of application, to work with the digital model, are getting better." (Interviewee 2, 2016, Appendix A, own translation)

Questions regarding the availability of different LODs in cities created a very diverse picture of use and expectations on LODs. These questions mostly triggered also discussions about the use of different LODs. The following subchapters will present results regarding the preferred levels of detail. Generally, the availability of more LODs was seen as an advantage. The choice out of more LODs helps to react on specific needs, different stages or discussions in the planning process and provides different amounts of data for either weaker or stronger computers: "One has a different range of alternatives, [...] to react properly on either the target audience or the project." (Interviewee 2, 2016, Appendix A, own translation)

4.1.3 The attractiveness of details

Statements promoting the general use of high LODs ranged from the clearer identification and orientation in visualisations with a higher LOD to the superior display including more precision and thus communication potential in contrast to distracting and outdated LOD1 displays. Interviewee 1 and 7 (2016, Appendix A) argue for the most realistic visualisation possible. On the one hand because abstract visualisations require interpretation skills, whereas realistic visualisations are more easily understandable for laypersons. For instance, in the context of height development Interviewee 10 advocates LOD3 "because it gives me a sense of the type of the building;. I could understand why some buildings are shorter than the others." (Interviewee 10, 2016, Appendix A) On the other hand, Interviewee 7 argues, that complex reality cannot simply be reduced, as complexity is an inseparable characteristic of an urban system and people may be confronted with the same kind of complexity in a visualisation as in their daily lives (Interviewee 1, Interviewee 7, 2016, Appendix A).

High LODs are also important to show distinctive characteristics of constructions and urban situations and the more architectural complexity, the more detail is needed to properly communicate and visualize the construction. Especially buildings serving as points of interests (POI) or historical constructions are important to be displayed realistically, as either these constructions are not identifiable anymore or even distract when displayed in a low LOD (Interviewee 1, Interviewee 5, Interviewee 7, Interviewee 11, 2016, Appendix A). Interviewee 1 goes further and states that "if we are merely showing mantles of buildings, we disqualify the citizens of being able to do it and simultaneously say that he/she is neither able to read nor understand architecture or facades. But in the end they are the ones judging the existing city or cityscape [...]" (Interviewee 1, 2016, Appendix A, own translation)

"[...] take LOD1 for example, which is essentially the footprint of a building including an average building height; you can't find an actual customer for this anymore" (Interviewee 4, 2016, Appendix A) LOD1 is outdated. Especially cities commercially distributing their 3D models claim that LOD1 has reached its expiration date, inevitably promoting more details in visualisations.

Interviewee 2 (2016, Appendix A), although generally advocating more abstract visualisations, acknowledged the help of a higher LOD when communicating with laypersons, as a result of the better comprehensibility coming along with a more realistic visualisation.

Interviewee 1 and 7 (2016, Appendix A) underline this statement with highlighting the complexity of some architectural designs, naming for instance daedal designs of Zaha Hadid, clarifying that more architectural complexity also calls for more detailed visualisations.

4.1.4 High LOD – Level of Distraction

Opposing to devotees of highly detailed visualisations stand statements claiming more details lead to more distraction from the actual discussion in a planning process. Interviewee 2 (2016, Appendix A, own translation) calls this a "tightrope walk" as details may help laypersons in understanding the visualisation but on the other hand they provoke strong opinions and instead of a participatory mindset the feeling of confrontation, even opposition, with an already completed plan arises. Furthermore, details may take away the flexibility of changing to or let alone discussing other options.

As mentioned before, 3D visualisations are sparsely used amongst others for the reason, that they can lead to major discussions when falsely interpreted or because they are simply distracting from the actual issue. Opposing to earlier statements, promoting more detail, Interviewee 2 (2016, Appendix A, own translation) explains that especially high LODs distract laypersons: "Having a certain degree of abstraction is enormously important for urban planning, otherwise discussions take place, which we don't want to have, and it leads to discussions, which we shouldn't have in certain levels of detail."

Interviewee 1 (2016, Appendix A) agrees with this and adds that especially details distract when the discussion is primarily about volumes of buildings and not their appearance. In this regard he also points to a problem with scenario planning in 3D. Scenarios are merely possibilities and basis for discussing options, but detailed visualisations distract from the thought of what is possible to thinking about how it could be implemented, from exploring options to their implementation planning. In other words, the more detail a visualisation has the grater the distraction to discuss these details instead of the big picture.

Interviewee 1 (2016, Appendix A, own translation) reflects on several projects and states that the use of different LODs could be a solution, using a lower LOD to discuss volumes and a higher LOD for façade details: "Sometimes it is very difficult, taking the Zaha Hadid project, which was a photorealistic visualisation from the beginning on, consequently one saw how the project was going to look like, which was a metal façade with hardly any windows located in the old town on a popular spot. [...] people said that this building is just not acceptable and they were probably not even talking about the volume, which was admittedly quite big, but primarily people were scared to accept this picture or to say that there is going to be a silver, glittering façade at this place [...] if it would have been a building with a more conservative façade design, the discussion would have probably ended differently, and only the volume would have been discussed."

Interviewee 2 (201,6 Appendix A) draws a clearer picture of their preferences and describes their model as "rough geometrical structures with roof shapes" also showing land uses such as streets, water and greenery, consequently a LOD2 model with an underlying map of the city.

4.1.5 Context and purpose dependency

"One has to determine one's goals specifically and only afterwards it has to be decided which visualisation is needed." (Interviewee 9, 2016, Appendix A, own translation)

The different opinions and experiences with either high or low LODs, already point towards different situations, in which different preferences prevail. Thereby interviews resulted in two main views: LODs in a visualisation depend on its purpose and second LODs in a visualisation depend on the context it is used in.

Although previous chapters show tendencies of practice towards either low or high LODs in their visualisations, various statements also point towards a more context and purpose dependent use of LODs. Although interviewee 1 and Interviewee 2 (2016, Appendix A) generally advocate the use of high LODs, they see the advantage in the availability of more LODs in reaching acceptance of projects across all stakeholders. Different LODs in different stages of the planning process could help to overcome the previously elaborated problems with either high or low LODs. In short a context and purpose dependent application of LODs could be the solution.

Ulrike Wissen states that "the different LODs are very good applicable and can support [planning] processes, but depending on the detailed question or on the chosen instrument to either collect information or communicate information, one has to decide what would best answer the purpose." (Interviewee 9, 2016, Appendix A, own translation)

She strongly advocates the purpose and context dependent use of all available LODs and underlines that there is not *the* one planning process, hence that the uniqueness of each planning process also calls for tailor made 3D visualisations. Scale also shouldn't play a role in the choice of the proper LOD as multiscale approaches should be favoured, whereas upscaling and downscaling shouldn't have an effect on the LOD. Rather looking at problems in consistent LODs across different scales can provide valuable insights and new perspectives. In this line she argues for more collaboration in planning processes including 3D visualisations, from the beginning on, specifically a cooperation of academia, practice and general public in creating the 3D model. She sees this process of "co-designing" as a crucial step to reach a good product and planning process in the end. (Interviewee 9, 2016, Appendix A)

According Ulrike Wissen, but also Giorgio Agugiaro and Filip Biljecki the usual modus operandi in computer science, i.e. more abstraction with more visual distance, can be dismissed and such general rules cannot be applied to urban planning. Ulrike Wissen reports from a planning processes regarding wind turbines, which required models using a higher scale, but as it is a matter of (urban) landscape, details were included, naturally. Giorgio Agugiaro as well as Filip Biljecki emphasise the dependence of LODs on individual applications of the 3D model similar to Ulrike Wissen. (Interviewee 9, Interviewee 10, Interviewee 11, 2016, Appendix A)

Ulrike Wissen (Interviewee 9, 2016, Appendix A) adds to this that landscape planning knows the LOD concept, but it is not applied specifically to 3D models. Visualisations are created only according to the situation and their specific use, but at the same time a standardisation, such as the LOD concept attempts to reach, could proof to be useful.

4.1.6 A question of standards

Yet, there has to be made a clear distinction between standardised LODs and a standardised use of LODs. Whereas the first gives guidelines regarding the specificities of LODs, the latter would appoint different applications or uses to certain LODs. A main question of this research is, if a certain LOD is more effective than another, consequently if suggestions for the specific use of LODs can be made, or rather existing suggestions can be verified.

The already existing guidelines about peculiarities of individual LODs have, as a matter of fact, an important role in this discussion. Interviewees knowing about applied standards in their jurisdiction reported from the prevailing use of CityGML as modelling standard (Interviewee 4, Interviewee 6, Interviewee 7, 2016, Appendix A). German Interviewees reported additionally about a specific German wide, yet CityGML conform, standard every city has to fulfil, when creating a 3D model in order to exchange and approximate nationwide 3D models. (Interviewee 4, Interviewee 6, 2016, Appendix A). Standardisation in this regard was welcomed across all interviewees naming quality, compatibility, exchangeability, security and comprehensibility as the main advantages: "It [standardisation] makes communication easier and ensures a shared understanding." (Interviewee 3, 2016, Appendix A, own translation) "It is helpful when working with foreign planners" (Interviewee 1, 2016, Appendix A, own translation) It is statements like these that specifically pinpoint advantages of standardised LODs.

However, a difficulty with current standardisation attempts and revisions is, that two separate perspectives on the matter exist. One from the urban analysis perspective in which standardized LODs ensure a certain quality and precision of the analysis and the other one from a communication and visualisation perspective, which sees different LODs as different platforms of communication and information. This ambiguity becomes apparent when looking at Interviewee 6 (2016, Appendix A, own translation): "[…] for me there always have to be two models, the one being the intelligent one […] including objects with attributes, which can be analysed and the other one is the beautiful one [for communication and visualisation purposes]." Also Filip Biljecki and Giorgio Agugiaro see their expertise more in the field of analysis and underline the difference between these two perspectives (Interviewee 10, Interviewee 11, 2016, Appendix A). A clear standardisation could combine these, currently opposing perspectives.

Strict regulations and standards also ensure a faster processing, thus a certain quality of the 3D data and model, which makes it more efficient (Interviewee 4, 2016, Appendix A). Also software supporting these standards in their application would profit and presumably gain a new quality criterion (Interviewee 9, 2016, Appendix A).

Interviewee 2 (2016, Appendix A, own translation) sees an advantage in standardisation because "I can make a distinction with it, which Instrument I want to use for a planning process […]." In other words, the precision of the standard would help differentiating between different models or rather LODs.

Although a context and purpose depended application of different LODs is vital, it is equally important to have certain standards for LODs and what can and must be included. Whereas Interviewees from cities at large have a very limited knowledge about standards in 3D visualisations, mostly as a result of the allocation of competences, all academic interviewees criticised the existing standards:

Ulrike Wissen (Interviewee 9, 2016, Appendix A, own translation) sees an advantage in a sound standardisation amongst other reasons because it makes research comparable but at the same time she reminds that "[…] currently there is no such thing as *the* standard, telling what's actually included in LOD1 to 3." She also reminds that standardisation potentially means models would have to include features or details that are not needed in a given situation, hence an increased workload.

Gorgio Agugiaro (Interviewee 11, 2016, Appendix A) acknowledges that current CityGML guidelines are not perfect, whereas Filip Biljecki goes further and specifies that "[…] there are two main critiques: Fist it's not precise enough, take […] for example LOD2, it is defined only as a simple model with roofs, but the standard CityGML doesn't specify [..] if the dormers on the roofs have to be modelled or not. That is the first problem and the second problem is, you can have a lot of combinations that are the same LODs according to CityGML […] you can have LOD2 with dormers and one without dormers and one is more complex than the other, but CityGML doesn't have a mechanism to distinguish the two." According to both researchers the CityGML standard is currently revised to solve these problems. In line with this, cities report of very divers interpretations of LODs in the same category and state that some LOD2 models also contain more information than required, which is referred to as LOD2+ (Interviewee 2, Interviewee 3, Interviewee 6, 2016, Appendix A).

Whereas all interviewed city representatives from the three countries individually prefer certain LODs, a common ground, consequently a generally more effective LOD, cannot be defined. The different opinions and circumstances in cities combined with statements from academic experts, underline again the context and purpose specific use of LODs. In this regard Gorgio Agugiaro (Interviewee 11, 2016, Appendix A) explains that best practices and established rules from trial and error might be good in certain cases, but certainly no general standards, whereas he emphasises again the application dependent use of LODs. Ulrike Wissen (Interviewee 9, 2016, Appendix A) adds to this and brings the thought of co-designing 3D visualizations with participants further, but acknowledges the possible need of a "communication manager" informing all stakeholders, including officials, about the available possibilities, applications and basics of visualisation techniques. This would have the potential to give new insights and knowledge to practice and could improve the trust in 3D visualisations and their application.

4.2 Online survey

This chapter encompasses the results of the quantitative data collection by means of an online survey. First demographic details about the respondents group are elaborated which are further used as independent variables in the statistical analysis which follows as the second part. In the third part results from more specific questions in the survey are explained. The fourth part of this chapter elaborates in a very condensed version on the results of the statistical analysis of the survey data. In the following the terms first set of images is used for tested images showing the Vienna model without changes and the term second set of images is used to describe the tested Karlsplatz scenario.

4.2.1 Respondent group in detail

In the time of October 10th and November 15th 177 respondents were recorded split in 54.24% male respondents and 45.76% female respondents. Figure 22 shows the age ranges of participants in the survey, indicating that mostly people between the ages of 18 and 34 were reached.

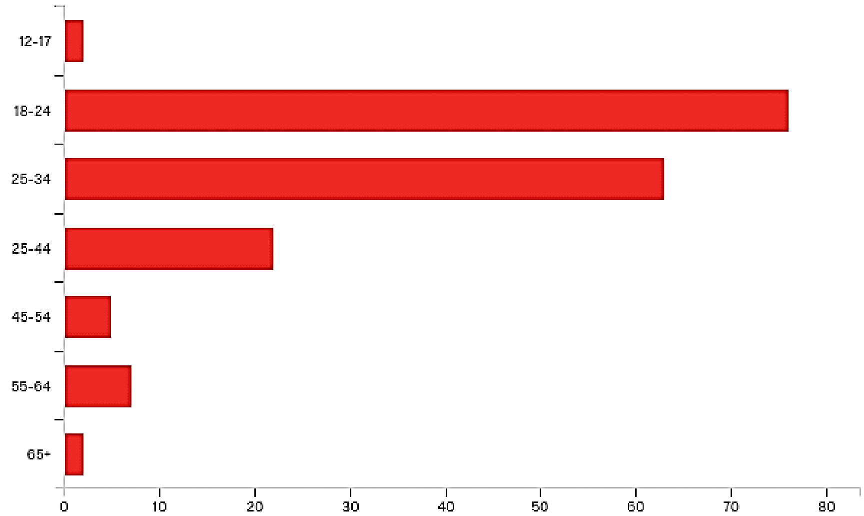


Figure 22: Age range of participants in the questionnaire (own source)

With 76.27% of the respondents a vast majority indicated to be familiar with planning processes and with only 6 respondents less and 72.88% of all respondents correspondingly, also the vast majority has some kind of professional planning background. The target area (Karlsplatz, Vienna) was known to about half the participants with 49,15%.

The main respondent groups were located in Austria (40.48%), the Netherlands (26.19%) and Germany (14.88%) and the main nationalities participating also from Austria (41.57%), Germany (18.67) and the Netherlands (17.47%).

4.2.2 Results for Questions 1-8 (variable questions)

Figure 23, 24 and 25 (see also Appendix D) show the percentages of how many respondents rated LOD 1,2 and 3 either as *extremely effective, very effective, moderately effective, slightly effective* or *not effective at all*. Total values cannot be given for individual variables since also respondents who have not finished the entire questionnaire but answered a considerable share of them are included in this analysis. Thus, the total amount of respondents decreases across the survey and only relative percentages can be meaningfully compared.

For the LOD1 images of the Vienna model without any changes the biggest share of the participants decided for *slightly effective* and *moderately effective* in all the criteria. Nevertheless, a considerable share of the respondents also chose for *very effective* especially when it comes to understanding the content of the image.

The two biggest categories for the LOD2 images shift one step up to *moderately effective* and *very effective*, leaving the category *slightly effective* only with low percentages between 10% and 15%. The results for LOD3 images show again a shift of percentages upwards the effectiveness scale. The biggest proportions of participants can now be found in the categories *very effective* and *extremely effective*, leaving the accumulated percentages of most of the other categories under 20%.

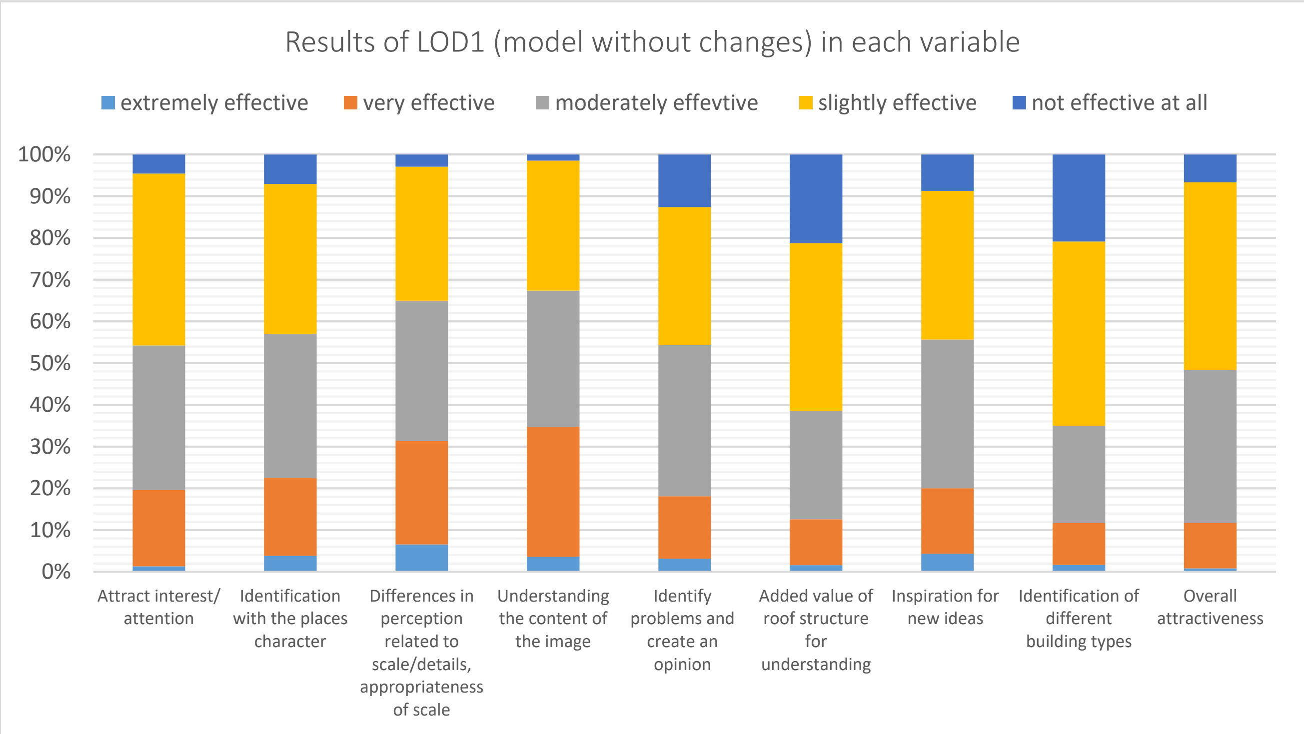


Figure 23: Percentages for each potential answer per variable for LOD1 in the Vienna model without changes (own source)

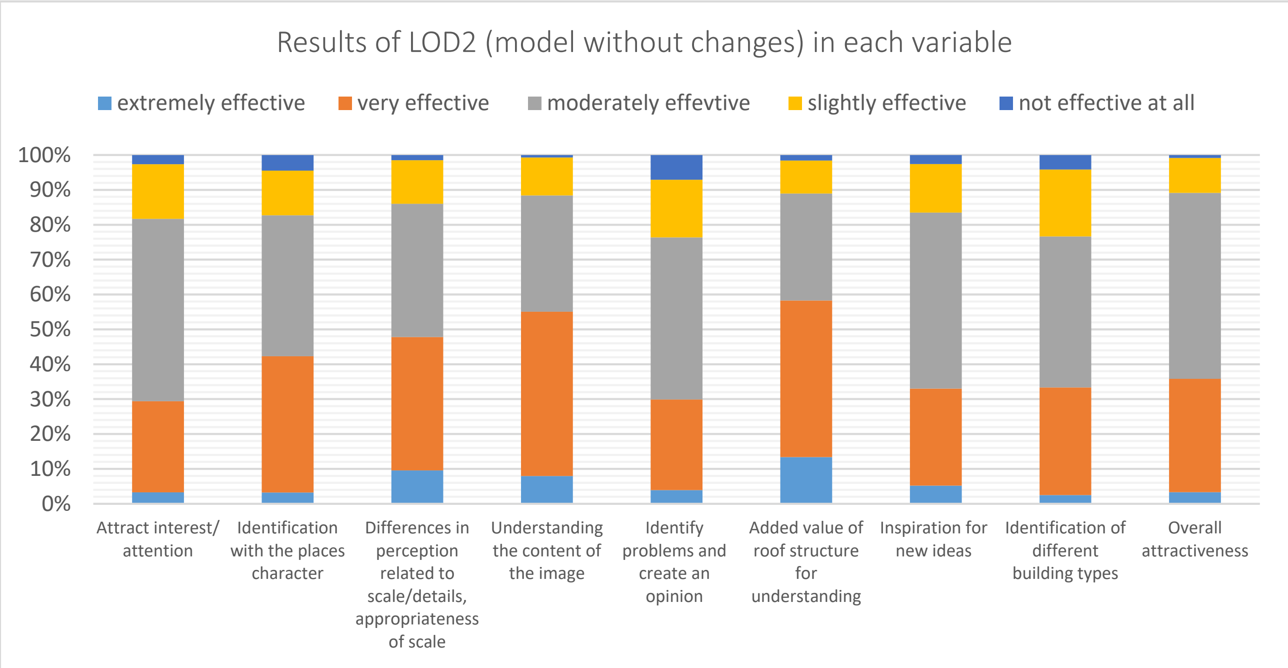


Figure 24: Percentages for each potential answer variable for LOD2 in the Vienna model without changes (own source)

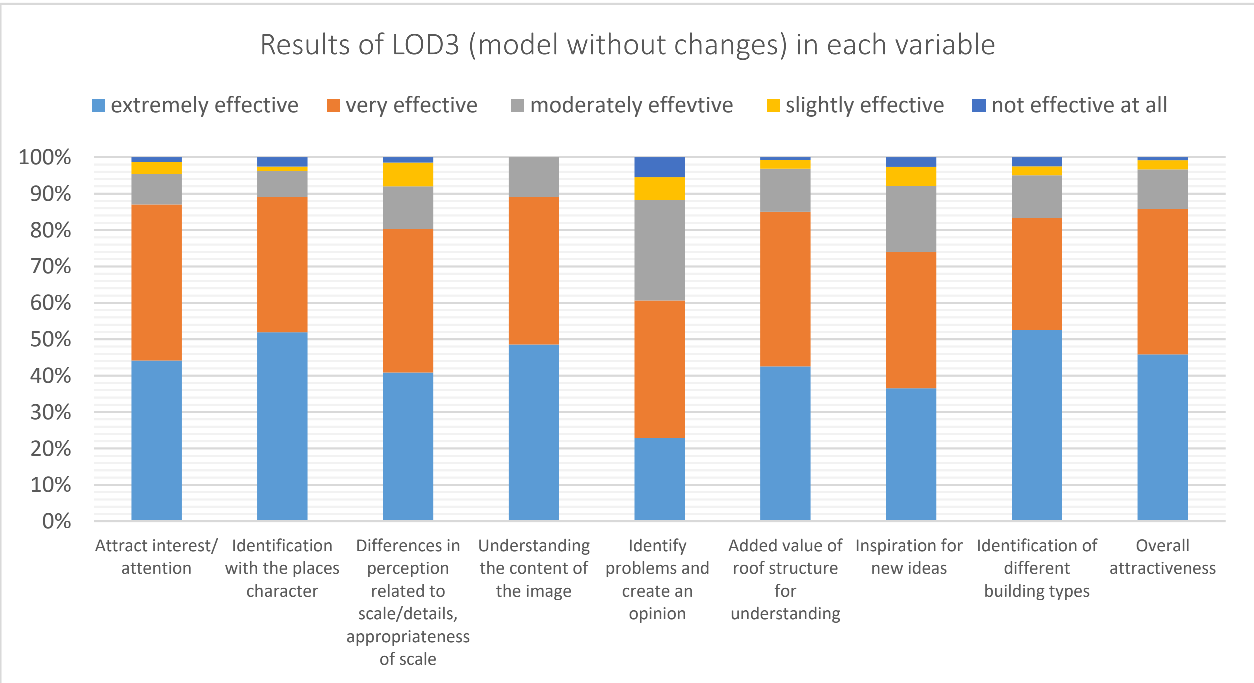


Figure 25: Percentages for each potential answer per variable for LOD2 in the Vienna model without changes (own source)

Results for the Karlsplatz scenario in the individual criteria show the same overall trend with minor differences in percentages (see Appendix D, Figure D4, D5 and D6). Also here LOD1 is mostly rated as *slightly effective* and *moderately effective*, LOD2 as *moderately effective* and *very effective* and LOD3 as *very effective* and *extremely effective*. The results for the Karlsplatz scenario LOD1 image also show that the option *not effective at all* was chosen more often than in questions showing the model without changes. Whereas the share of respondents choosing *not effective at all* for LOD1 in the model without changes lies between 2% and 10% the same category for the Karlsplatz scenario counts mostly for 10% to 20% with some of the shares being even higher.

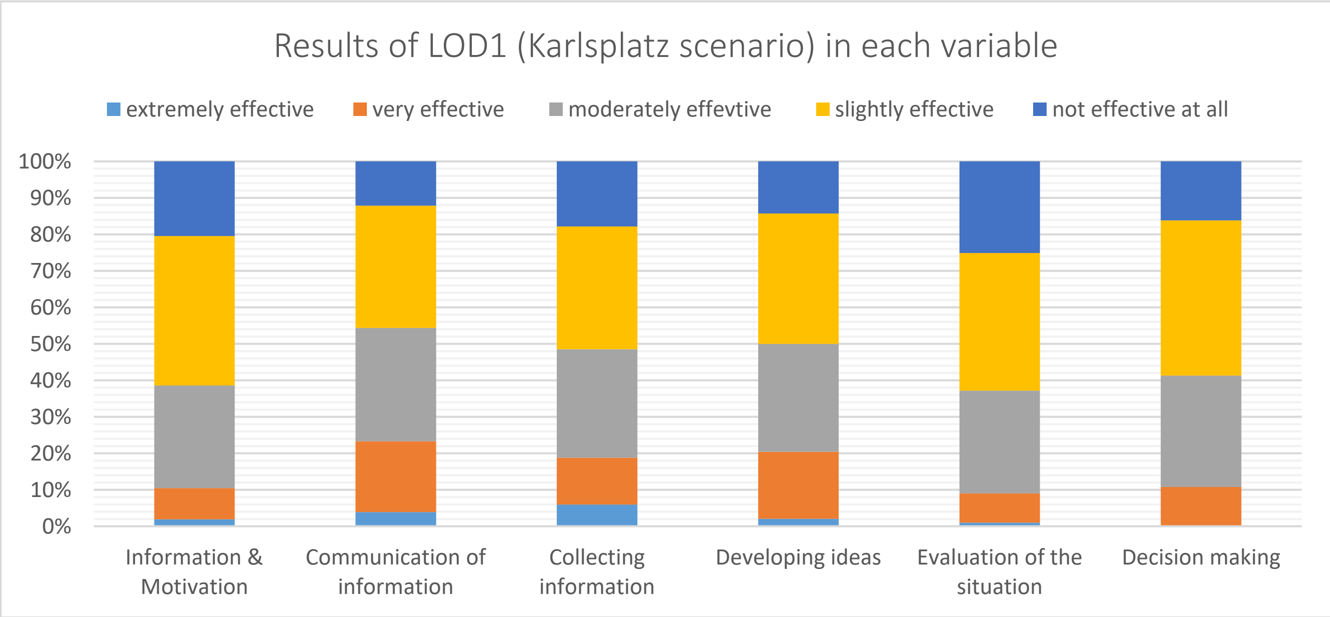


Figure 26: Percentages for each potential answer per task of the planning process for LOD1 in the Vienna model including the Karlsplatz scenario (own source)

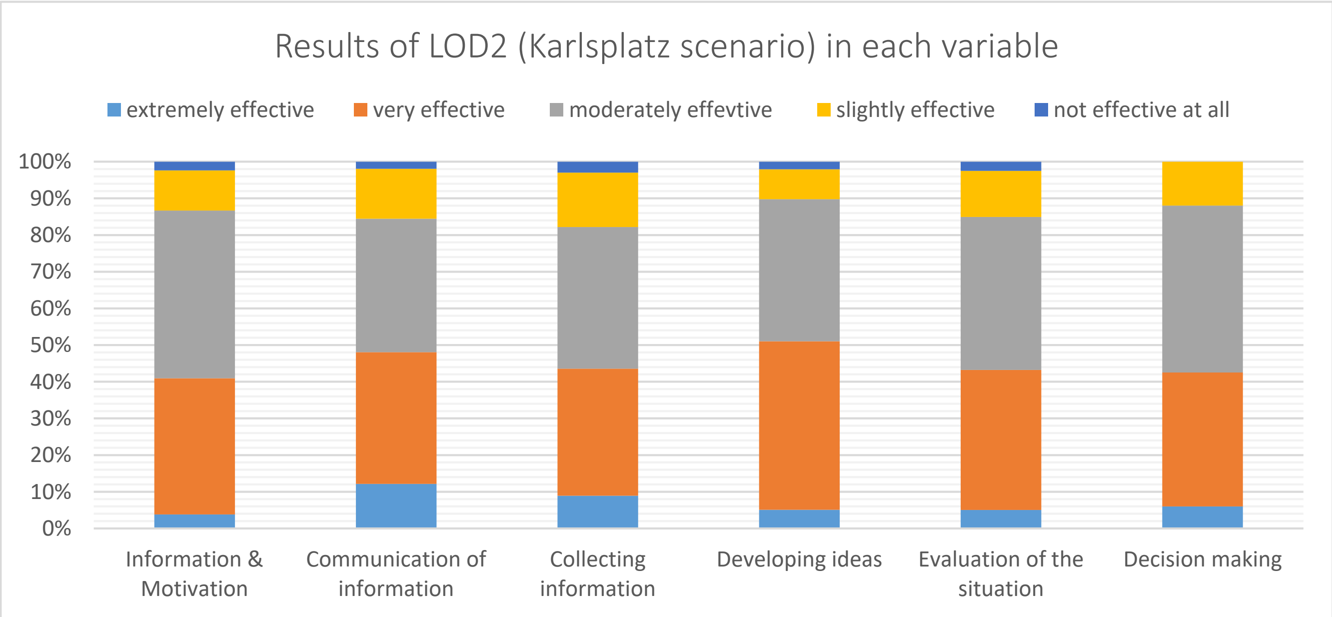


Figure 27: Percentages for each potential answer per task of the planning process for LOD2 in the Vienna model including the Karlsplatz scenario (own source)

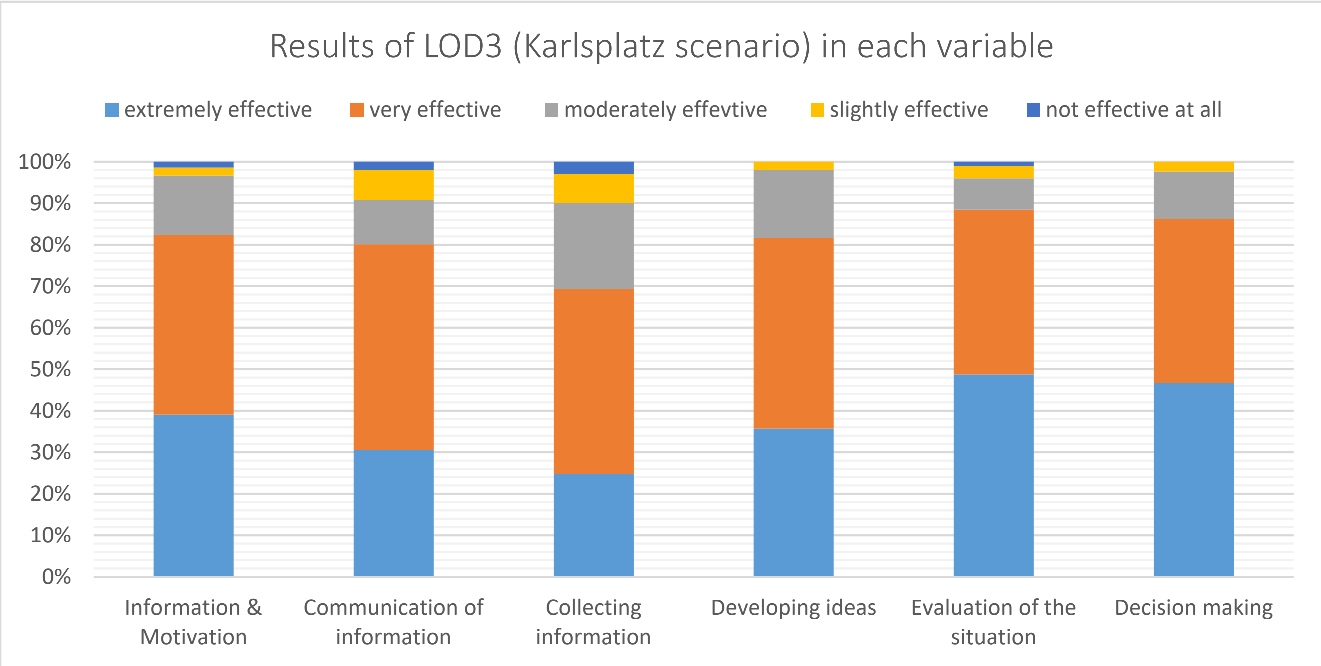


Figure 28: Percentages for each potential answer per task of the planning process for LOD3 in the Vienna model including the Karlsplatz scenario (own source)

The total numbers of respondents for the individual criteria, when accumulated according to table 5, result in the values for the defined tasks in the planning process, which can be supported by 3D models. Following the same rationality as the Figures explained above, Figure 26, 27 and 28 show results for images of the Vienna model including the Karlsplatz scenario in the defined tasks of the planning process. The overall picture of the results resembles, as a matter of fact, the previous displayed results per variable. The higher the LOD the bigger the shares of responses in the upper categories of the effectiveness scale. Also here visible are the considerable high values for the category *not effective at all* for LOD1 and additionally the accumulated percentages of the categories *not effective at all* and *slightly effective* mostly being over 50%.

Figure 29 summarizes the results for all questions regarding the variables. Consequently, the chart illustrates the percentages for each potential answer per LOD for the entire questionnaire. It is clearly visible that percentages in the categories *not effective at all* and *slightly effective* decrease with higher LODs whereas the shares in the categories *very effective* and *extremely effective* increase with higher LODs. The category *moderately effective* peaks in LOD2 and decreases from about 40% to merely 12% in LOD3.

Although the overall picture ranks LOD3 as the most effective visualisation, followed by LOD2 and LOD1, it is important to mention that LOD1 was rated at least *very effective* in 18% of the choices and at least *moderately effective* in about 48% of the overall choices across the questionnaire.

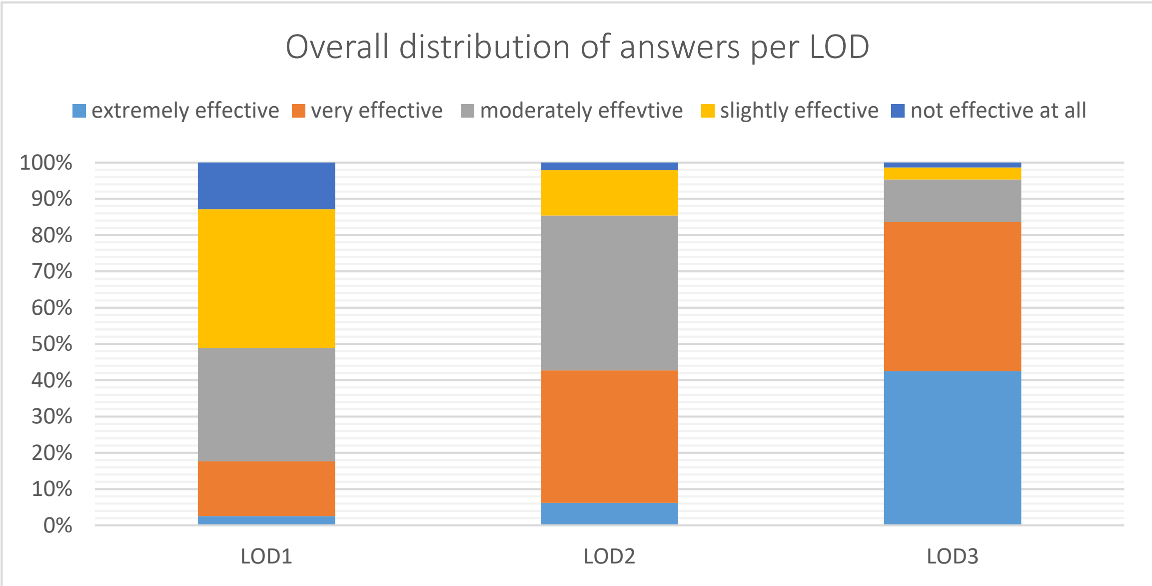


Figure 29: Percentages for each potential answer per LOD for the entire questionnaire (own source)

4.2.3 Results for question 9 (detailed question)

The first sub question of question 9 investigated the preference of trees in the visualisation. With 79 respondents and 82,29% of all answers given to this question, the vast majority voted for the integration of trees.

The second sub question investigated the importance of trees in LOD1,2 and 3 and if they are improving the sense of scale and proportions. In all the LODs at least 50 percent of the respondents considered trees as a *very important* feature in the visualisation to understand scale and proportions better. For LOD1 54% considered trees as an at least *very important* feature to better understand scale and proportions. For LOD2 66% and for LOD3 74% see trees as at least *very important* for the same reason. Figure 30 shows the complete distribution of responses on the effectiveness scale per LOD.

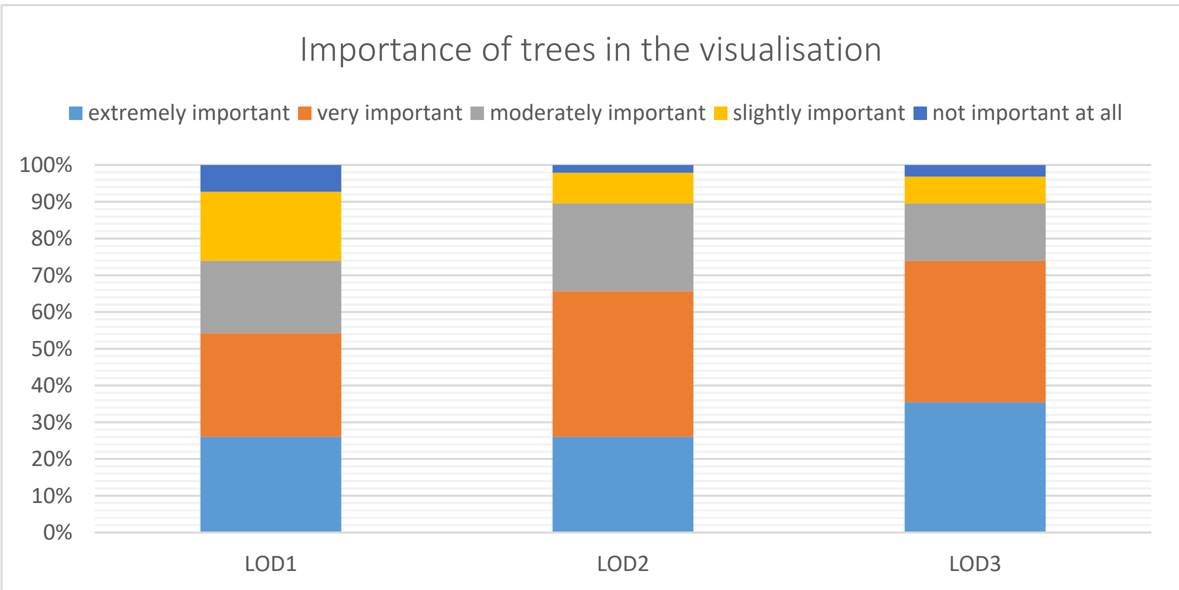


Figure 30: Importance of trees in the visualisation per LOD (own source)

The third sub question asked participants to categorize different details either as being helpful in understanding the visualisation or as being distractive. None of the listed details is entirely considered as either being helpful or distractive. Only details such as roof simplification and the sky are categorized by more than 50% as being distractive. All other details listed are helpful for understanding the 3D visualisation according to over 50% of the respondents. Nevertheless, also 29 participants from the 97 respondents who answered this question, 30% respectively, considered roof simplification in LOD1 as helpful in understanding the visualisation. The top five helpful details to at least 80% of the respondents are the *façade details of the newly planned buildings*, the *roof details*, *trees*, the *underlying map* as well as the *façade details of the surrounding buildings*. The rest of the results is displayed in Figure 31, which illustrates the percentages of participants categorizing all the listed details either as helpful or distracting.

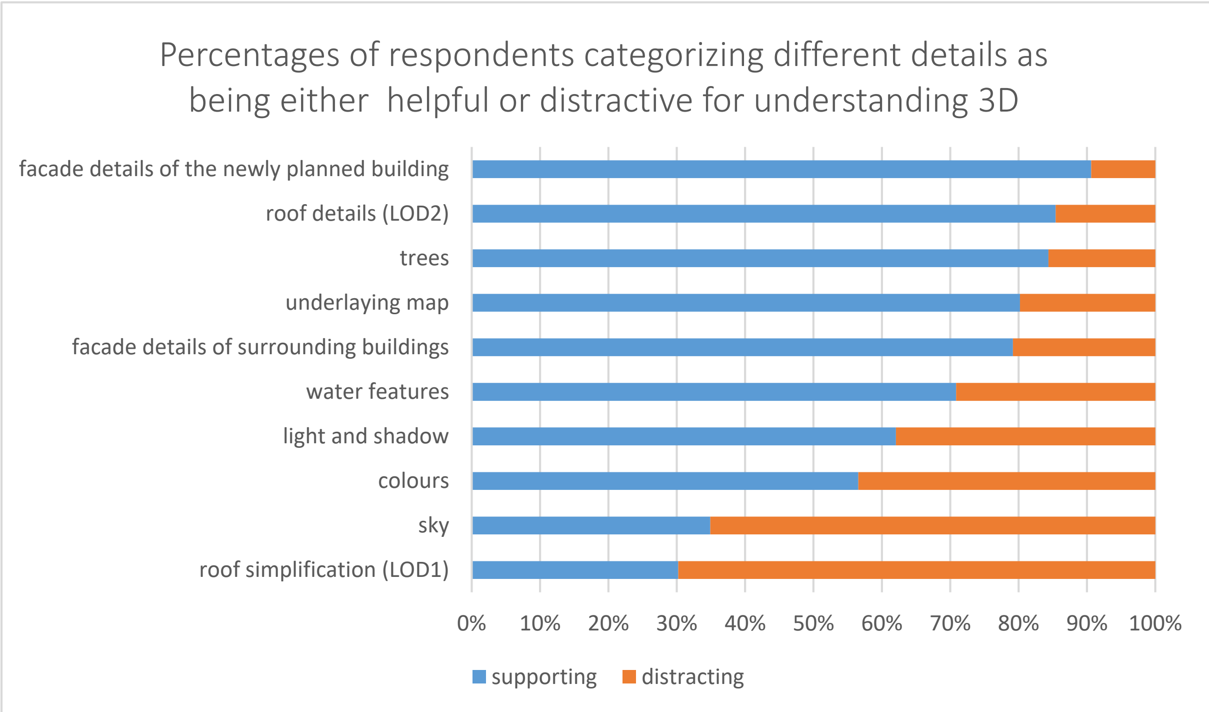


Figure 31: Percentages of respondents categorizing different details as being either helpful or distractive for understanding 3D visualisations (own source)

The fourth sub question provided a LOD2 image of the Karlsplatz scenario and asked respondents to click on either the *St. Charles church*, the *newly proposed changes* or the *surrounding buildings* in the area. One click on the chosen building indicated that participants would prefer more details than LOD2 and two clicks indicated that LOD2 was seen as sufficient. Figure 32 displays the results of this question. For the buildings with proposed changes in the scenario 84,38% of the respondents prefer more details, LOD3 respectively. Also 75% indicated to prefer more details for the visualisation of St. Charles. The surrounding buildings in the background are seen as less important and the majority of respondents. 59,38% are satisfied with the shown LOD2.

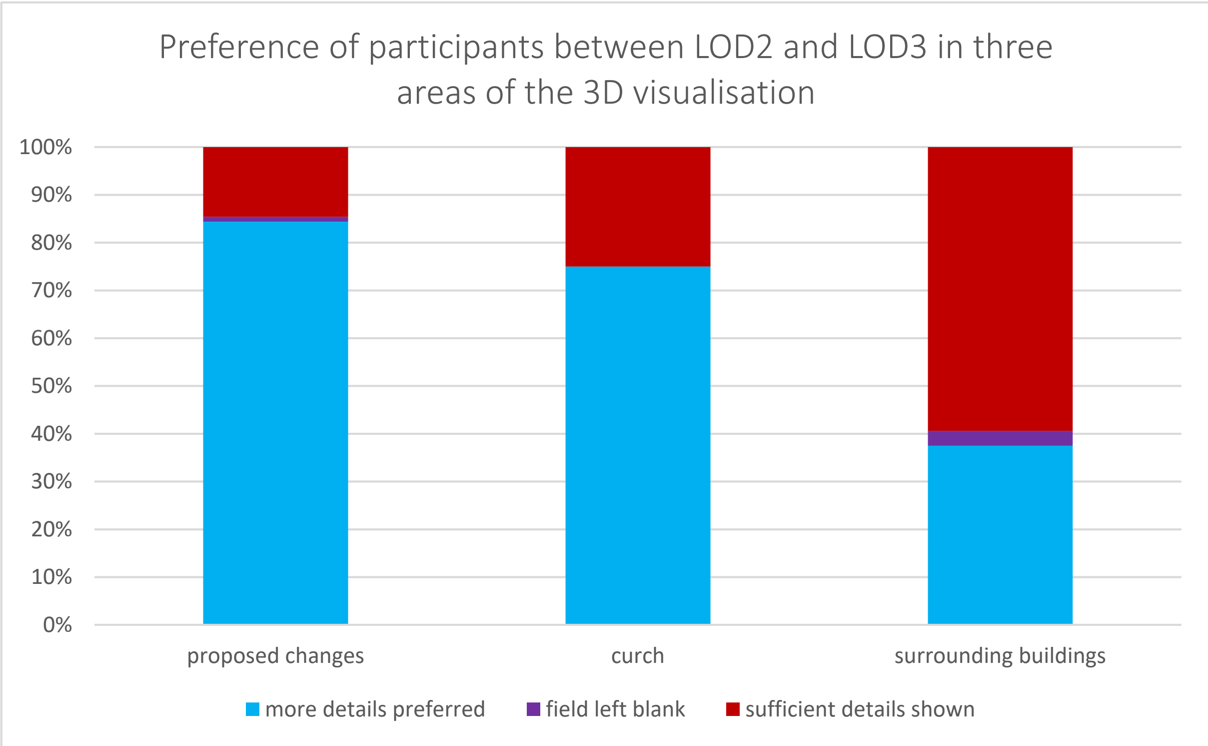


Figure 32: Preference of participants for either LOD2 or LOD3. LOD2 served as a reference for this question. "More details" means LOD3, "sufficient details shown" stands for LOD2. (own source)

4.2.4 Crosstabs - Dependence of variables

In order to investigate the dependence of either demographic variation or knowledge about planning and/ or planning processes as well as the location of respondents, cross tables were generated and *chi square* tests as well as *fishers exact* tests were conducted. These tests reveal the dependence between variables. Only selected, significant results and the most important result tables are presented here. The entire analysis can be seen in Appendix E.

Overall there are no clear dependencies of either gender, age, knowledge or background of planning as well as location and nationality on variables across all LODs. Nevertheless, numerous individual answers regarding LOD1, 2 and 3 are connected.

4.2.4.1 Gender

For the first set of images testing Vienna's 3D model without changes gender appeared to be significant, according to the *fishers exact* test, only in the overall attractiveness of LOD1 (see Figure 33). According to these results women rate LOD1 higher as men do. Whereas 16,3% of the female respondents rated LOD1 as *good* only 2,3% of the male respondents did the same. However, 13,6% of the male respondents rated LOD1 as terrible compared to none of the female respondents. In the second set of images testing the Karlsplatz scenario LOD1 results showed the same significance. 13,5% of the female respondents rated LOD1 as *good* compared to none of the male respondents and 20% of the male respondents rated LOD1 as *terrible* compared to only 10% of the female respondents.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	13,296[a]	4	,010	,004		
Likelihood Ratio	16,720	4	,002	,003		
Fisher's Exact Test	13,265			,005		
Linear-by-Linear Association	6,953[b]	1	,008	,009	,005	,003
N of Valid Cases	93					

a. 6 cells (60,0%) have expected count less than 5. The minimum expected count is ,47.

b. The standardized statistic is -2,637.

Figure 33: Chi-Square and Fishers Exact test for the variables "gender" and "overall attractiveness" of LOD1. (own source)

For the second set of images gender also appeared to be significant for the appropriateness of scale in the shown image of LOD2 (see Figure 34) as well as the importance of roof structures in LOD2. Regarding LOD1 gender was a significant variable for the development of ideas. Male respondents rated the scale of the image generally better fitting to LOD2 as women: 20,5% of the male respondents found the scale of the shown picture *extremely appropriate* for LOD2 whereas only 4,1% of the female respondents thought so. On the contrary 18,4% female respondents compared to only 6,9% male respondents found the scale as *somewhat inappropriate* for LOD2.

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7,842[a]	3	,049	,049		
Likelihood Ratio	8,324	3	,040	,047		
Fisher's Exact Test	7,678			,051		
Linear-by-Linear Association	4,751[b]	1	,029	,031	,019	,009
N of Valid Cases	93					

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,20.

b. The standardized statistic is 2,180.

Figure 34: Chi-Square and Fishers Exact test for the variables "gender" and "appropriateness of scale" of LOD2. (own source)

Men rated LOD1 mostly (38,6%) as *neither good nor bad* when it comes to the development of ideas whereas the biggest share of female respondents (49,0%) rated LOD1 as *somewhat bad*.

4.2.4.2 Age

Also the age of participants turned out to be significant. For LOD3 in the first set of images, age was significantly influencing the understanding of the content, the potential of developing ideas, the possibility of identifying different building types and the overall attractiveness (see Figure 35).

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	24,497[a]	10	,006	,007		
Likelihood Ratio	17,302	10	,068	,054		
Fisher's Exact Test	16,352			,042		
Linear-by-Linear Association	,000[b]	1	,998	1,000	,534	,056
N of Valid Cases	93					

a. 13 cells (72,2%) have expected count less than 5. The minimum expected count is ,11.

b. The standardized statistic is -,003.

Figure 35: Chi-Square and Fishers Exact test for the variables "age" and "overall attractiveness" of LOD3. (own source)

For the second set of images age influenced LOD1 when it comes to identifying problems and building types. Also the ability of LOD3 to attract interest, to identify the character of the place, building types and the overall attractiveness was influenced by age.

When looking at all answers with the biggest share of respondents, a noticeable pattern is visible across almost all variables. Participants between 18 and 24 mostly chose the second best answer, participants between 25 and 34 the best answer, those between 35 and 44 again the second best answer and those between 55 and 64 again the best answer. Only in the second set of images the shares of participants between 18 and 24 and between 35 and 44 for the best and second best answers are equal. In other words, the scenario led to more participants in the mentioned are ranges choosing higher answers on the scale.

4.2.4.3 Knowledge about planning processes

Participants familiar with planning processes rated the appropriateness of the scale for the image showing Vienna's model without changes in LOD3 better as those not familiar with planning processes. Furthermore, participants with knowledge about planning processes rate the same pictures as better for the identification of house types. For the second set of images no significance of knowledge about planning processes is visible for the same variables.

For the second set of pictures participants with knowledge about planning processes rated LOD2 better in attracting interest (see Figure 36) as well as identifying the character of the place than those without knowledge about planning processes.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	8,567[a]	4	,073	,075		
Likelihood Ratio	10,154	4	,038	,050		
Fisher's Exact Test	9,108			,039		
Linear-by-Linear Association	,747[b]	1	,387	,460	,237	,081
N of Valid Cases	93					

a. 5 cells (50,0%) have expected count less than 5. The minimum expected count is ,47.

b. The standardized statistic is ,864.

Figure 36: Chi-Square and Fishers Exact test for the variables "familiarity with planning processes" and "attracting interest" of LOD2. (own source)

Additionally, for participants without knowledge of planning processes the roof shapes in LOD3 (second set of pictures) are significantly more important than for those without planning processes.

4.2.4.4 Professional planning background

Also a professional planning background appears to be significantly influencing the importance of roof structures in LOD3 (second set of images). Participants without planning background rated the roof structure as more important than planners did.

Planners on the other hand rated LOD1 in the same set of pictures overall better as a basis for discussion than non-professionals (see Figure 37).

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	8,199[a]	3	,042	,040		
Likelihood Ratio	10,722	3	,013	,019		
Fisher's Exact Test	8,383			,033		
Linear-by-Linear Association	,826[b]	1	,363	,371	,219	,069
N of Valid Cases	93					

a. 2 cells (25,0%) have expected count less than 5. The minimum expected count is 2,84.

b. The standardized statistic is ,909.

Figure 37: Chi-Square and Fishers Exact test for the variables "professional planning background" and "basis for discussion" of LOD1. (own source)

4.2.4.5 Familiarity with the target area

For the first set of images the familiarity with the target area is significantly influencing the understanding of the content of the images in LOD2 and 3, as well as the character of the place (image in LOD3; see Figure 38), the identification of the roof structure (image in LOD3), the identification of building types (image in LOD2) and the overall attractiveness (image in LOD2). Respondents not familiar with the target area rated LOD3 as better for identifying the places character than those knowing the Karlsplatz. Respondents familiar with the Karlsplatz rated the roof structure in LOD3 as more important, the identification of building types in LOD2 as better as well as the overall attractiveness of LOD2 as higher than their counterpart.

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	8,683[a]	3	,034	,022		
Likelihood Ratio	11,696	3	,009	,012		
Fisher's Exact Test	8,328			,025		
Linear-by-Linear Association	1,443[b]	1	,230	,249	,147	,058
N of Valid Cases	93					

a. 4 cells (50,0%) have expected count less than 5. The minimum expected count is ,90.

b. The standardized statistic is -1,201.

Figure 38: Chi-Square and Fishers Exact test for the variables "familiarity with the target area" and "identification of the places character" of LOD3. (own source)

For the second set of images the familiarity with the target area is significantly influencing the attraction of interest and the understanding of the content in LOD3. In both variables respondents familiar with the target area rate the pictures higher than those unfamiliar with the Karlsplatz.

The familiarity with the Karlsplatz is also significantly important for the preferred LOD of the surrounding buildings in the Karlsplatz scenario (see Figure 39). Respondents familiar with the area mostly see LOD2 as sufficient for the visualisation whereas respondents not familiar with the Karlsplatz wish for more details, LOD 3 respectively.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6,033[a]	1	,014	,019	,012	
Continuity Correction[b]	5,028	1	,025			
Likelihood Ratio	6,069	1	,014	,019	,012	
Fisher's Exact Test				,019	,012	
Linear-by-Linear Association	5,969[c]	1	,015	,019	,012	,009
N of Valid Cases	93					

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 16,26.

b. Computed only for a 2x2 table

c. The standardized statistic is 2,443.

Figure 39: Chi-Square and Fishers Exact test for the variables "familiarity with the target area" and "preference of more detail for surrounding buildings" of LOD2. (own source)

4.2.4.6 Current residency

For the first set of images the current residency of respondents is significantly influencing the appropriateness of the scale for LOD1, the understanding of the content of the image in LOD3 (see Figure 40), the importance of roof structures in LOD3, the ability to develop ideas with LOD3 and the overall attractiveness of LOD3. Regarding the scale respondents in the Netherlands rated it as more appropriate than those in Germany and Austria. The ability to understand the content of the image in LOD3 is rated best by respondents in Austria followed by those in Germany and then the Netherlands. The importance of the roof structure and the overall attractiveness of LOD3 was rated highest by respondents in Austria followed by those in the Netherlands and Germany. Only in terms of developing ideas, respondents in Germany rated LOD3 higher than those in Austria and the Netherlands.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	48,180[a]	30	,019	,025		
Likelihood Ratio	39,029	30	,125	,047		
Fisher's Exact Test	40,349			,020		
Linear-by-Linear Association	6,305[b]	1	,012	,011	,006	,000
N of Valid Cases	89					

a. 43 cells (89,6%) have expected count less than 5. The minimum expected count is ,10.

b. The standardized statistic is 2,511.

Figure 40: Chi-Square and Fishers Exact test for the variables "current residency of the respondent" and "understanding of the content of the image" of LOD3. (own source)

For the second set of images the ability of understanding the content in LOD1 was significantly influenced by the location of the respondents. Respondents in Germany rated it the highest followed by respondents in the Netherlands and Austria. The roof structure in LOD3 was seen as important mostly by respondents in Austria, followed by those in the Netherlands and Germany.

The location of the respondents also significantly influenced the importance of the preferred LOD of the surrounding buildings in the visualisation (see Figure 41). The majority of respondents in Austria and Germany rated LOD2 as sufficient whereas respondents in the Netherlands wish for more details.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	20,715[a]	15	,146	,052		
Likelihood Ratio	25,201	15	,047	,059		
Fisher's Exact Test	19,493			,048		
Linear-by-Linear Association	6,020[b]	1	,014	,014	,007	,000
N of Valid Cases	89					

a. 27 cells (84,4%) have expected count less than 5. The minimum expected count is ,37.

b. The standardized statistic is 2,454.

Figure 41: Chi-Square and Fishers Exact test for the variables "current residency of the respondent" and "preference of more detail for surrounding buildings" of LOD2. (own source)

4.2.4.7 Nationality

The nationality of participants influenced statistically significant the identification of problems in LOD3 and the importance of the roof structure in LOD1 and LOD3 (first set of images). The majority of the Dutch respondents rated LOD3 better than Germans and Austrians when it comes to identifying problems with the help of the visualisation. However, the majority of the Austrian respondents saw the roof structure as more important than Germans and Dutch respondents.

For the Karlsplatz scenario nationality influenced the ability to attract interest, the importance of the roof structure, the development of ideas and the overall attractiveness (see Figure 42) (images in LOD3). For attracting interest and the ability to develop ideas respondents from all three nationalities rated LOD equally effective. Only respondents from Austria used the entire range of possible answers. Dutch and German respondents are only recorded in the upper half of the answer scheme. Regarding the importance of the roof structure as well as the overall attractiveness respondents from Austria and the Netherlands have the same opinion, whereas the majority of Germans see roof structures as a bit less important and they see LOD3 as slightly less attractive than Austrians and Dutch respondents.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	54,871[a]	39	,047	,182		
Likelihood Ratio	47,866	39	,156	,004		
Fisher's Exact Test	61,994			,007		
Linear-by-Linear Association	,070[b]	1	,791	,795	,406	,001
N of Valid Cases	65					

a. 54 cells (96,4%) have expected count less than 5. The minimum expected count is ,03.

b. The standardized statistic is -,264.

Figure 42: Chi-Square and Fishers Exact test for the variables "nationality of the respondent" and "overall attractiveness of the image" of LOD3. (own source)

5 Conclusion – manual for the most effective 3D model

"In theory, theory and practice are the same, in practice they are not."

Albert Einstein (RuhaniRabin, 2016)

3D modelling is still trying to find its proper place in urban planning. The effectiveness of 3D models in urban planning needs insights from theory and practice to be sufficiently understood and further developed. Understanding the effectiveness of 3D models in urban planning means recognising the complexity of communication and interaction of stakeholders and the rejection of a rigid, inflexible, one-size-fits-all approach. It turns out that the effectiveness of 3D models can be discussed with the help of two different, yet interconnected questions: Firstly, how are 3D models embedded in the governance system of urban planning? And secondly, how are 3D models carried out and does their appearance effect their success? The toolbox of planners, the view on planning and the social requirements on planning have been changing over the past decades, but apparently the (governance) system lacks behind. Standards for visualising 3D models in urban planning are (theoretically) existent and currently revised, but their translation into urban planning practice is still behind and the use of 3D visualisations pressed into the old, inappropriate governance system.

This chapter discusses the introduced research questions in the light of quantitative and qualitative research results and concludes with suggestions for a possibly more effective use of 3D modelling in urban planning.

5.1 The root of the dilemma

In order to understand the effectiveness of 3D models in planning processes and to eventually make suggestions for improvement, the root of the dilemma, their current use in planning practice has to be investigated. Consequently, this sub chapter discusses and answers the following research question:

How are 3D visualisations currently used in practice and are there obstacles for the effective use of 3D models?

When looking back at the difficulties of the research process, which are partly reflected in the results of the interviews, the question appears whether planning practice is ready for another dimension. 3D visualisations are rather new to planning and slowly infiltrating the system. Interviews have shown numerous obstacles, including not only the low trust in 3D models, but also the missing knowledge about 3D modelling. Obstacles like these still hamper the success or effectiveness of 3D in urban planning.

The benefits of 3D models are acknowledged in every interviewed city and different, very individual applications of 3D visualisations can be found. The communication with laypersons via 3D visualisations is still marginal. Instead city authorities rather use 3D to either test other 3D models for manipulation, to establish an argumentation line or to look at scenarios from different perspectives. Additionally, 3D gives the flexibility to quickly add or change details. Nevertheless, city authorities still rely on physical models in addition to digital 3D models as both have specific strengths and weaknesses which can counterbalance.

Discussions based on 3D models are an effective way to participate citizens. Moreover, 3D models are more effective than 2D blueprints and surely more flexible than physical models. Nevertheless, 3D is used very modestly for participation purposes according to interviews. The remaining question is how it is possible that 3D models are not used more often and more successfully?

Planning practice is simply scared of 3D visualisations and their possible effects on people's opinions. On the other hand, citizens are scared of being manipulated by the other side, the creators of 3D models respectively. The result is mistrust on both sides combined with a controversial opinion on 3D models. According to the interviews conducted, this matter can be reasoned in two ways: Firstly, planning practice lacks knowledge about the details of 3D visualisations and their application. Secondly, 3D models are predominantly used in a trial and error approach without a clear strategy as a result of the first reason.

Trial and error approaches hardly create sufficient knowledge about the effective usage of 3D models. Additionally, urban planning departments of some cities are mere users of 3D models made by others without knowing what exactly they are using. The current generation of urban planners struggles with the application of this new and not fully established tool. Urban planners of today do not have to fully embrace 3D modelling, but they have to give it (more) space to evolve in order to evolve along with it.

Future generations of planners, however, need to have at least comprehensive knowledge about 3D models and their application. In a best case scenario urban planners will even be skilled in generating 3D models. In such a scenario the knowledge gap between the producers and users of 3D models can be bridged. This also contributes to solve the problem of cities currently having difficulties in managing their expectations regarding 3D visualisations and deciding in the kind of visualisation needed. In other words, a generation gap is evident – it is a question of time and new generations of planners until 3D visualisations are fully accepted and applied. By then, also the methods used to generate 3D data are estimated to be easier, as well as hardware and software are predicted to be more sophisticated and less expensive than today.

What the future of more effective 3D modelling in urban planning could look like, is discussed in the following chapters.

5.2 Everything - From pure simplicity to rich complexity

This sub chapter focuses on the question *how the effectiveness varies between LODs* and *whether a specific LOD is more effective than a different.*

Although LOD3 is the winner of the online survey with the biggest share of people rating it as *very effective* or even *extremely effective* across all tasks, interviews call for these results to be seen from a different perspective. On the one hand, a high LOD might be very attractive and effective for understanding the visualisation as a whole, i.e. good for effective communication. On the other hand, very detailed models with the possible semblance of a finished unchangeable design might provoke strong opinions and give away the freedom of discussing other options. They are therefore ineffective in terms of participation.

Concerning the communication of information from planners to laypersons, LOD3 might be very effective, as it contains highly detailed information. In case, however, is meant to be a participation and discussion platform, the effectiveness of the LOD depends on the matter in discussion.

This is also reflected by almost all survey results. The entire range of possible answers was used across the questionnaire. This indicates that, although the biggest share of respondents rated for instance LOD3 in different variables as *extremely effective*, still a considerable share of respondents also rated it as *moderately effective*, *slightly effective* or even *not effective at all*. Consequently, even in a clear setting as in the questionnaire the effectiveness of the visualisation could still be improved.

When, however results for the 3D model without changes are compared to the Karlsplatz scenario it becomes clear that opinions changed. The Karlsplatz scenario with a clearer purpose of the 3D visualisation impaired for instance the respondents' opinion about LOD1. In the scenario more respondents chose *not effective at all* and *slightly effective*. Consequently, the purpose of the 3D model changed the perception of the respondents.

Similarly, one of the respondents in the online survey remarked "that [the] level of details depends on the message I want to communicate" (see Appendix C)

The majority of the respondents wished for more details for the buildings showing proposed changes, whereas a fourth of the respondents rated LOD2 as sufficient for the St. Charles Church. Almost 60% also rated LOD2 sufficient for the surrounding buildings, although these buildings are historically important too. This leaves the impression that there is a strong focus of participants for details on the actual changes when 3D is used in a scenario. Furthermore, more detailed models of POIs such as St. Charles also could have an advantage, but details of surroundings are not necessarily wanted or even effective.

These results can be summarized in two main statements: Firstly, the LODs effectiveness depends on the purpose it is used for, e.g. communication of information or participation or getting people to discuss. Secondly, it depends on the context it is used in, e.g. an unmodified view of the city or a specific development scenario as well as the presence of landmarks.

The diverging opinions on the effectiveness of either high or low LODs highlights the importance and need of the entire range of LODs- from pure simplicity to rich complexity. Results from interviews point out the fact that different LODs are needed in different contexts and purposes. Moreover, the need for individual models is clearly reflected be the answers given in the survey. When it comes to LOD3 and LOD1 participants opted for poor and high effectiveness respectively.

What is more, the variety of people participating in a planning process can influence which LOD is needed. Interviews for instance strengthen the survey's results indicating POIs such as the St. Charles Church should be displayed highly detailed (LOD3). Respondents familiar with the Karlsplatz perceive LOD2 as sufficiently detailed for surrounding buildings, whereas those not familiar with the area mostly preferred more details in this category.

Interesting to mention are also the results of the statistical analysis. The influence of either age, gender, nationality or previous knowledge on the answer seems to be significant only with changing LODs. While factors such as nationality or previous knowledge are not significant in certain LODs and respondents equally preferred either low or high LODs, they become influential when details increase. As a consequence, opinions between Austrians and foreigners, planners and laypersons, but also those respondents knowing the Karlsplatz and those who do not know the Karlsplatz diverge. These criteria become significant mostly in LOD3 images.

Now, if all LODs are important and all factors affecting the effectiveness should be accounted for in a planning process, how do planners know which model to use in which situation? In other words, w*hat are the future possibilities to improve the effectiveness/ efficiency of 3D models?*

5.3 System change

Participation can have many faces; however, it constitutes a mandatory element of modern planning practice. The communicative turn fired the coup on the term government and governance has taken over ever since. Governance as a means to reconstruct the steering forces of, in and on planning gives rise to forms of interaction and cooperation to give stakeholders a say in the development of their surroundings. It has been neglected though that not only the understanding of planning changed, but also the methods underwent changes with which planning manages. In short, planning as a profession evolved over the past but the governance approach of urban planning practice did not.

Rigid institutional designs and governance modes have to change in order to fully tap the potential of new techniques and introduce a new planning and participation process!

Urban planning processes legitimately gave room for different participation approaches, but the visual nature of these approaches is still based on very solitarily taken decisions. The use of 3D models can be one of these decisions. In order to use 3D models as a more open participation approach, that is flexible and responsive to stakeholders, the planning process has to be redefined. The effective use of 3D visualisations requires an approach that is highly dependent on context and purpose regarding its modelling and design. This can be translated to co-designing 3D models as a driver of co-creating new governance structures.

5.4 Going co-creation

"A smart city will be a city whose community has learned to learn, adapt and innovate"
(Caragliu *et al.*, 2011, p. 68)

Co-creation is the answer to the future needs of planning in 3D, viz. the answer to context and purpose dependent effectiveness of different Levels of Detail. In a process of co-creation, users of 3D models as well as stakeholders in the planning process work together on the 3D model from the start. In other words, the start of the planning process is simultaneous with the start of the co-creation process.

Regarding the definition, the terms co-creation and co- design are often used in a synonymous way to universally describe a collaborative process of creation. Similar to Sanders and Stappers (2008) this work sees co-design as a part of co-creation. Co-design is thus seen as "collective creativity as it is applied across the whole span of a design process" (Sanders and Stappers, 2008, p. 6) i.e. actively creating the 3D model. Co-creation however, is framed in a broader sense and refers to any creative process which is collectively pursued. Hence, co-design can be seen as an instance of a co-creation process.

By collaborating in the development of the visualisation stakeholders decide which model is necessary and useful for them in the given situation. A highly individual, tailor made and area/stakeholder-based approach can be created. The trust in 3D models and the fear of possible manipulation can be set aside with stakeholders having a say in the development of the model. A process of co-creating a 3D model can also respond to the criticism on either high or low LODs. Discussions can be led during various stages of the process including various LODs in different scales. Volumes of buildings can be discussed for instance in an early stage using simple and easy to generate LOD1 models. Later, the same situation can be discussed in a more detailed version when it comes to e.g. facades. In addition, this procedure also gives room for understanding the effect of facades and building details on the appearance and opinions of building volumes.

Furthermore, a co-creation process can be seen as a learning opportunity for academia, practice and civil society, i.e. such a process can be combined with a learning circle. As previously discussed, co-design is seen as a part of co-creation. In the process of co-designing the model academia, practice and civil society are working together *pari passu*. The co-design process in turn is part of a bigger learning circle for the process/system/ approach it is embedded in. (see Figure 33)

In an iterative process the co-designed 3D model as well as the insights of the co-design process can be used by planning practice to discuss the model with civil society which gives further insights to academia about the context and purpose dependent application of 3D visualisations. The most valuable use of the insights, however, is for redefining the governance system around planning. This newly created knowledge incorporates theories as well as approaches and can, as a further step, be translated in to practice. The planning process and governance approach as such also receive context dependent feedback. Consequently, processes and approaches can be shaped in a more adaptive manner. Figure 33 illustrates what such an approach of governance co-creation and 3D co-design could look like.

A co-design approach enables communication between experts and laypersons to be more interactive as it has the potential to bridge communication difficulties from the start of a project. Eventually a learning process leading to adaptive governance structures can be the result.

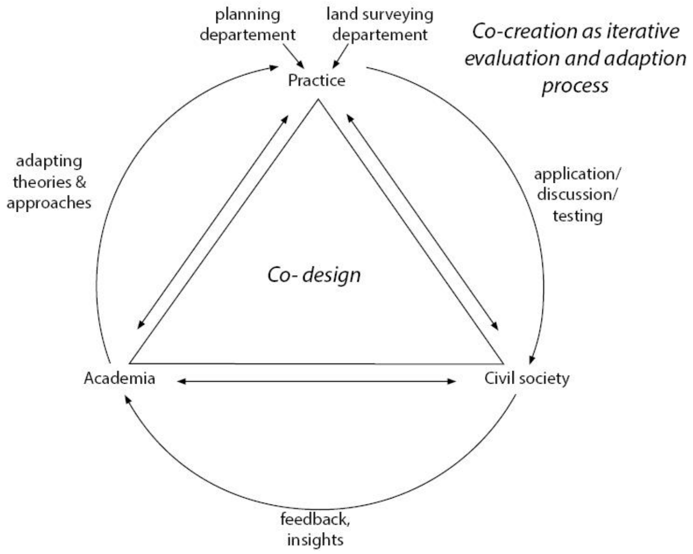


Figure 43: Co-creation as iterative evaluation and adaption process for governance structures including co-designing as participation method for the use of 3D visualisations in urban planning. (own source)

5.5 Standardisation – The rules of the game

What role does standardisation play in the current and future use of 3D visualisations?

To find a common denominator in diversity seems a hard endeavour. Consequently, standardisation and context/ purpose dependent 3D visualisations seem contradicting at first sight. As already mentioned there are two different views on standardisation: The standardised use of LODs and standardised LODs.

The first view on standardisation can be disregarded in this work, as the combination of quantitative and qualitative results showed that there neither is the most effective LOD in general nor in particular. The effectiveness of LODs rather depends on the context and purpose of the model.

Standardisation in terms of defining LODs in urban planning is a very important issue to ensure their effective and efficient use even beyond the urban planning field. The possibility to categorize 3D models into LODs makes it possible to compare models, gives security in form of objectivity and less room for misunderstandings. Interviews confirmed what literature already pointed out: The current standards need to be more concrete. In addition to defining what each LOD can contain and the upper limit of these specifications, minimal requirements are needed to determine the transition point from one LOD to another.

Standardisation still has a long way to go before one generally acknowledged standard for LODs is defined and the current jungle of LODs is sorted out. German cities turn out to have a lead when it comes to the standardisation of their 3D models according to the nationwide, yet City GML conform standard. Furthermore, future standardisation approaches or redefinitions have to consider perspectives and expectations on standardisation from the viewpoint of visualisation, communication and analysis. Up to now, LOD specifications are investigated mostly because of acquisition methods, precise spatial analyses, or workflow, LODs are, however, rarely examined due to reasons such as communication which results in a lack of knowledge about their effectiveness. Moreover, the possible need for further subcategories remains unclear. Despite the fact that LODs miss out information about effectiveness, the concept is redeveloping constantly. A clear and uniform path is yet barely visible.

This research advocates a more integrated view on standardisation in which 3D models are not reduced to tools for analysis, but their use in communication and participation is incorporated.

The more precise definition or standardisation of LODs also contributes to the comprehensibility and traceability of a 3D model. One of the survey respondents for instance was bothered by the fact that the church portal of St. Charles was modelled in more detail in LOD1 than in LOD2. The rationality behind this specific detail of the Vienna model is not yet traceable.

Concluding from the research process and its results standardisation is an important contributor to the effectiveness of 3D models and LODs as long as the standards only define how the LODs can and should be modelled instead of dictating their usage, viz. standards should constitute a framework defining the rules of the game.

5.6 The reinvented planner

The previous chapters argue for a more effective purpose and context specific 3D model in a fitting governance structure and standardised framework conditions. What is missing is the role of the planner on the way to the most effective 3D model. Planner is a very versatile term and subject to interpretation. Depending on the planner having an academic or practical background his work comprises different spheres of activities.

Ulrike Wissen for instance brings up the need for a "Medienkompetenz", a sort of manager and facilitator providing background information about possibilities and options to the parties of the process of co-creation. Including this manager another planner or task for a planner could be added to the system, in addition, to the academic planner and the planner in practice. This planner has to manage the co-creation and co-design processes. With knowledge about 3D modelling and planning, this "new" planner could be the bridge between the currently divided competences of model producer and model user. In this process the planner is the enabler of new scopes of decision making in a collaboratively oriented, yet discursive process aiming at balancing out different interests. The knowledge, needed to discuss and solve a planning issue, however, comes from all three parties involved. Only this ensures the inclusion of academic knowledge from research, knowledge about practical application and legal frameworks as well as equally important local knowledge from citizens.

6 Reflection

This chapter reflects on the research process and elaborates on some shortcomings in the theoretical and methodological approach as well as practicalities and gives suggestions for future research.

6.1 Theoretical reflection

There is no clear method or standard set of rules behind 3D visualisations rather many theories, methods and rules that are rarely interconnected. The theoretical framework was thus built up chronologically elaborating the theories needed to understand and further develop the effective use of 3D visualisations in urban planning processes. Furthermore, the objective was to relate these theories and show the historical trajectory of the introduction of 3D visualisations into planning and generate a new theory about their current and future use. The premise of this research is that every city owning or building up a 3D model also wants to use it in the most effective way, also in participation processes and not only for spatial analysis puirposes.

As a result of the many different theories around 3D visualisations it is hard to build up a fitting framework and connect to a common thread. Instead selected theories, especially about standardisation approaches, were introduced and compared, which only gives a limited view on the diversity of theories and ideas in the field.

6.2 Methodological reflection

Investigating 3D models and making links between practice and academia admittedly resulted in some hurdles for the unobstructed flow of this research. On the one hand academic research has many foci and very specific yet manifold perspectives on the matter, which makes it challenging to compare and set into relation. On the other hand, cities and practice in general are difficult to talk to because either the departments in charge of the 3D model lack the knowledge of its application in urban planning or the department of urban planning lacks knowledge of the technical specificities and the background of the model. This horizontal cooperation which rather resembles a service provider relation sheds a very economic perspective on the use of 3D models which only considers the wishes of the consumer, with the consumer i.e. the planning department mostly not knowing what they are buying.

Interviewees from three different countries were chosen to get a diversified picture of the use of 3D visualisations. The open invitations to municipalities to get interview partners resulted partly in people knowing more about the use of 3D models and others who knew more about their acquisition and details. Thus answers across these two blocks were unevenly detailed depending on the person's background within the administrative structure of the municipality. For future research two interviews per municipality one from urban planning department and land surveying department would provide better insights and a more equal distribution of information from answers.

The online surveys consisted of different parts with different shortcomings. Firstly, the 3D model missed certain information because they were either not available or the used program was not able to process them. These problems could have been solved with more time but the limited extent of this research made compromises in this regard necessary. This lead to missing information of the digital elevation model and a number of buildings which got lost in the conversion process of the model. Although shortly discussed, manipulation with 3D models was not matter of this research. For this reason, also colours of roofs, buildings or even textures where left out of the tested model. The objective was to keep the visualisation as simple as possible and open for suggestions.

Secondly questions in the survey were developed according to variables from previous researches from Wissen (2009), Wissen Hayek (2011) and Wissen *et al.* (2008). The formulation of these variables/ questions remained in a very technological terminology making them difficult to understand for laypersons.

The online survey resulted in a considerable number of responses whereas the majority had a planning background and only a small amount of laypersons could be reached. Amongst other reasons, this is certainly the result of a language barrier and demanding questions. Most of the participants don't have English as native language which makes it difficult for especially for laypersons to be confronted with specific terms in the survey. As a result of the chosen variables also the questions had very specific foci and turned out to be very demanding for respondents not familiar with planning processes. To really attract laypersons for future questionnaires about 3D modelling questions need to be simpler and the survey much shorter.

A very time consuming and more practical problem constituted the combination of provided 3D data formats and the used 3D program SketchUp. SketchUp supports a various data formats, whereas the PRO version allows to import even more formats. Nevertheless, some data was not compatible and I had to convert data, which led to a cumbersome workflow and also the forced abandonment of certain data details, which got lost in the conversion process.

Additionally, 3D data, if available, is currently not easy to obtain from cities as the data is either very expensive, only partly available free of charge or subject to very specific terms of use.

7 Outlook

Visualisations are a common element in planning processes. However, they are mostly used to sell and rationalize a development. Interactive collaboration by means of a 3D visualisation is yet an uncommon method. Finished architectural designs displayed in LOD3 or LOD4 do not leave room for opinions, suggestions and changes. As a result, 3D visualisations are connected with manipulation and mistrust, leaving the impression 3D visualisation are not an effective medium for participation purposes.

The theory about co-creation/ co-design opens up a different perspective, thereby a new field for future research with many possibilities. The use of different LODs across different scales can have major advantages and give new, also inter-regional perspectives during a participation process. However, future research might consider a more interactive research method such as workshops and the cooperation with a suitable planning process to investigate the possibilities further and determine specific strengths, potentials, but also weaknesses of the suggested approach. Eventually the acceptance of 3D visualisations across all actors can be improved by co-creation/ co-design processes.

The exact setup of the co-creation/ co-design process remains subject to interpretation and research as well as the role of a facilitator during the process. Although the suggestions relate to the use of 3D models in planning processes, the idea of a process of common (applied) creativity, i.e. co-creation and do-design, can be applied to any participation method. It represents a general call for the change of the governance system towards a more flexible structure allowing to efficiently tap knowledge from different sources in an interactive process.

The access to different sources of knowledge constitutes an important element in this process to reach tailored solutions for local circumstances. The interaction of the different sources of knowledge and the mutual learning from each other in a co-design and co-creation process composes another field of research for the future.

Regarding the specificities of LODs and standards, future research has to consider the many critiques on standardisation attempts and develop not only an urban analysis perspective, but also a visualisation, communication and participation perspective on the matter. With a comprehensive perspective on 3D visualisations and LODs and their potential uses, researches can be easier connected and continued.

8 Summary

- In the future, more planners with knowledge about 3D modelling and acquisition methods are needed. The missing knowledge about the application of 3D models is currently one of the most present problems. This work suggests a new system in which knowledge, the model and the governance system are co-created/ co-designed in order to react to individual needs.
- Although the quantitative data of this research shows LOD3 as the superior level of detail, interviews as well as detailed answers form the survey conducted question these results. Despite LOD3 being superior in terms of communication of information, due to its information richness, a reduction of complexity can have major advantages. Especially during the starting phases of projects simple visualisations can contribute to keep the focus of the discussion on simple issues such as volumes, heights, distances to other buildings et cetera. By adding detail to the visualisation the discussion can go into more detail ending in the façade design. Different planning processes might need different approaches from the start, depending on the context and the issue discussed.
- Thus, it is important to consider the uniqueness of every planning process and the constellation of actors involved. Including all actors in a co-creation/ co-design process from the very beginning can acknowledge this diversity and result in a tailor made approach for the situation.
- Thereby, co-creation, already seen as a governance approach redefines itself and recreates the governance approach depending on the feedback it gets from the process and possibly extends the scope of planners to creation/ design managers.

Last but not least:

"Technology is not the answer to problems of participatory planning – learning by doing and wanting to do good quality participation matters" (maptionnaire, 2016)

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