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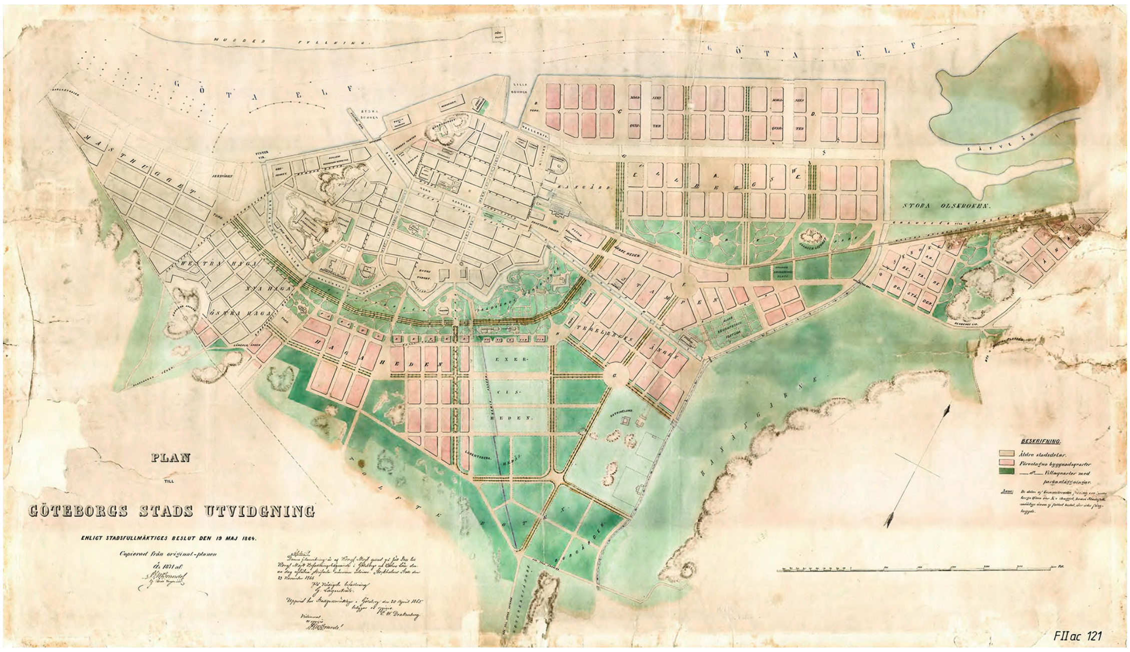

Urban Sketching

Guidelines for Designing a Sketching Interface for Early-Stage Urban Planning

Master's thesis in Interaction Design and Technologies

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Gothenburg, Sweden 2019

MASTER'S THESIS 2019

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Cover: A development plan for the city of Gothenburg, Sweden, from 1871: grey-brown represents currently developed areas, pink is proposed building areas, and green is proposed residential areas with parks. The image is public domain.
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Abstract

While the process of urban planning uses sketching and analyses to a large degree, no guidelines exist for how to design an interface which combine the two. In this master's thesis, 17 guidelines for how to design a sketching interface for early-stage urban planning are presented. These have been created by the means of literature review, in-depth interviews with urban planning experts, as well as the development three prototypes that have been evaluated by both human-computer interaction experts and urban planning experts.

Keywords: urban planning, sketching, sketch analysis, VirtualCity

Sammandrag

I stadsplaneringsprocessen används både skisser och analysverktyg utförligt, men det har hittills inte funnits några riktlinjer för hur ett verktyg som kombinerar detta bör utformas. I det här examensarbetet presenteras 17 riktlinjer för hur ett skissverktyg för den tidiga stadsplaneringsprocessen bör utformas. Dessa har tagits fram genom literaturstuider, intervjuer med stadsplaneringsexperter, samt genom framtagandet av tre olika prototyper som har testats av både experter inom människo-datorinteraktion och stadsplaneringsexperter.

Nyckelord: stadsplanering, skissa, skissanalys, VirtualCity

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Furthermore I would like to thank everybody who participated in the user studies and evaluations, as this work would not have been possible without you. I would also like to thank Barrie James Sutcliffe and Philippa Beckman for their help in voice-over and proof-reading, and David Frisk for creating and maintaining the LaTeX template used in this report. Finally, a large thank you to Helena Gästrin, for always believing in me.

Erik Öhrn, Gothenburg, March 2019

Contents

1. Introduction

While new simulation tools for urban planning and architecture are being developed, some aspects of urban planning are still static in nature; they don't allow for immediate input (Ben-Joseph, Ishii, Underkoffler, Piper, & Yeung, 2001), and require expertise to use (Maquil, De Sousa, Leopold, & Tobias, 2015). One such aspect is the initial rough sketch of an area to be developed. As stated by a city planner interviewed during the project (2018-09-25) the sketches are often made using pen and paper and require substantial work to be converted into the digital versions, needed to run simulations and create more intricate sketches. In order to enable better interaction between stakeholders and with these sketches, I propose guidelines for developing a digital sketching solution.

1.1 The VirtualCity@Chalmers Project

Cities are incredibly complex creations, with advanced and seemingly chaotic relationships and data. In order to enable a sustainable approach to creating, maintaining, and developing cities, new simulation tools are being developed for use by city planners, architects, city officials, and even the general public (Mueller, Lu, Chirkin, Klein, & Schmitt, 2018). As a goal in facilitating a better understanding of city planning, digital twins of cities have started to be developed, using data and mathematical simulations to convert a city into a digital copy. By creating a digital twin of a city, stakeholders can analyze the current situation in a city, in regards to for example wind flow as visualized in Figure 1.1, and use this knowledge for their coming decisions.

In order for this kind of application to be called a *true virtual city*, the research project VirtualCity@Chalmers has created six properties that should be addressed. According to the project, a virtual city is:

- Realistic, shown as a 4-dimensional (space and time) virtual experience of the city
- Interactive, and supporting multi-user interaction
- Simulated, based on a mathematical models of the city
- Integrated, and synchronized with real-time data from the city
- Scalable from building level to the whole city

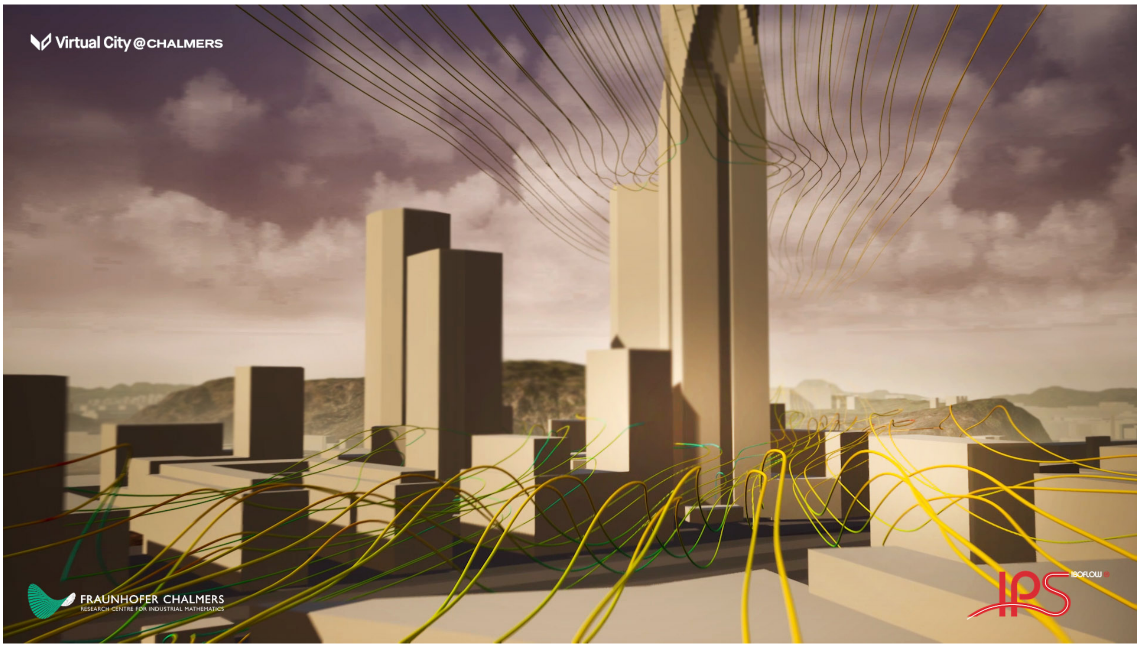


Figure 1.1: Wind flow around the proposed high-rise building Karlatornet in Gothenburg, Sweden, visualized as colored streamlines: this is one of the applications of VirtualCity@Chalmers's current application. The flow is calculated using IPS IBOFlow and a point cloud, based on the work of, among others, Ingelsten, Mark, Edelvik, Logg, and Österbring (2016). Image used with permission.

- Open, as in driven by open data and models

As of now, while city-wide simulations do exist (VirtualCity@Chalmers, 2018), no project has fulfilled all six of these properties. Chalmers University of Technology, together with the City of Gothenburg and the Fraunhofer-Chalmers Research Centre for Industrial Mathematics, aims to create the first such platform, starting VirtualCity@Chalmers in early 2018 (Naserentin & Olsson, 2018). This project aims to provide a comprehensive digital twin of the two campuses of Chalmers University of Technology as prototypes, with the whole of Gothenburg as an end goal.

As a part of this, members within the VirtualCity@Chalmers team have raised concerns regarding the current state of the urban planning process. Several stages require expert knowledge and are non-collaborative in nature (Maquil et al., 2015), and issues have been raised regarding the difficulty to communicate urban planning ideas to other stakeholders (Ben-Joseph et al., 2001). This thesis aims to address such issues, with a set of guidelines for how to design an urban planning sketching interface. In order to do this, interactive prototypes will be created and evaluated.

1.2 Research Problem

Before the official start date of this thesis, a prestudy was performed to get a better understanding of the domain and what problems might lie therein. The study found that some urban planners are frustrated with the work process regarding sketching. One urban planning expert stated in an interview (2018-09-25) that “since the initial sketch is done by hand, additional work needs to be performed to make it digital”, a step she said is vital for further development. Furthermore, the sketch can’t be changed easily, and there is no analysis or simulation available. Although she and her colleague, another urban planning expert present at the same interview, would like a tool which could be used for this initial sketching and provide them with analysis in real time, they fear that there might be opposition towards complicated software solutions. They reported a belief, however, that showing analysis and simulation in this early stage could help with the further process, and also be used as a visualization tool toward other stakeholders.

VirtualCity@Chalmers (2018) states that one of the requirements of a true virtual city is that it should be *interactive*, which they define as being “intuitive, accessible, and [that it] supports multi-user interaction”. Considering these points, along with the ones made by the urban planning experts interviewed in the prestudy, it could be highly beneficial to design a user-centered interface for initial sketching, both for city planners and for the research project.

As of now, there are no solutions which combine virtual cities, initial sketching in urban planning, and sketching software. The main problem is thus how to design an intuitive and usable solution for the urban planners, so that they can use modern simulation techniques to facilitate their work flow.

1.3 Research Question

Based on the state of sketching, urban planning, and simulation software, my driving question is:

What should be considered when designing a sketching user interface for city planning?

To help answer this, and to limit the scope of the project, I have the following research questions (RQ):

- RQ1: How should a sketching user interface be designed to facilitate the ideation phase of an urban planning project?
- RQ2: How can collaboration between users be facilitated in a sketching user interface?
- RQ3: How can sketch analysis facilitate the ideation phase of an urban planning project?
- RQ4: How should objects be created and manipulated in a sketching user interface?

1.4 Aim

The goal of this thesis is to create a set of guidelines, designed to help future researchers and designers when creating a sketching interface for urban planning, especially for early stage ideation and exploration.

I will create these guidelines primarily by designing, implementing, and evaluating a sketching user interface, which in turn will be based on literature review and interviews with experts and presumed users. While the prototypes created in this thesis will not be fully-fledged software implementations, it is envisioned that the final product (to be created in the future) will be connected to the VirtualCity@Chalmers project. Therefore the interface will take into consideration their vision of how users should be able to interact with a virtual city. The guidelines will therefore largely focus on how simulation and analysis can facilitate early-stage urban planning.

1.5 Scope

Since projects like this one can require substantial work, limitations and a scope need to be set. The simulation and models themselves are under development by VirtualCity@Chalmers, and while I will use their expertise to help understand which analyses that might be viable I will not evaluate the simulations or their visualizations.

Urban planning has many different varieties of sketching, which are used in a multitude of scenarios and by different stakeholders. In order to answer the research question and sub-questions, I will focus on the initial rough ideation and sketching phase, where buildings, parks, roads and more are drawn.

The collaboration part of this thesis will focus on non-simultaneous collaboration, that is, that the users collaborate but do not necessarily sketch at the same time. Some guidelines will mention simultaneous collaboration, but this will not be rigorously evaluated due to a relatively low number of test subjects in each evaluation session.

1.6 Ethical and Legal Considerations

Accessibility can be seen as a vital point for this project. Far from everyone is proficient at sketching, and potential users might thus be reluctant to use the interface. Others might not feel comfortable with technological solutions instead of the traditional urban planning methods, and others still might prefer working alone instead of in a collaborative manner. Physical accessibility is, too, an issue to be addressed: the project envisions a design which should not require more dexterity than ordinary pen-and-paper sketching, and therefore users with reduced mobility should not face additional issues when using a sketching interface similar to this.

Furthermore, as a consideration of this thesis itself, care must be taken in considering test subjects and other participants contacted to gather data and evaluate the interface. Their time and insights are valuable, so they should therefore be treated with due care and respect. Any confidential information they give as well as their names and the names of their workplaces are concealed in order to protect their privacy, as recommended by Lankoski and Björk (2015).

There are also legal considerations: stakeholders might not be able to share their material due to contracts or non-disclosure agreements. This has been somewhat mitigated by keeping the research more abstract in nature, and avoiding collecting sensitive data about specific projects. As another legal consideration, later stage plans and simulations can serve as legal documents, which is another reason to limit the focus of this thesis to early-stage sketching.

2. Theoretical Background

To gain a deeper understanding of the domain of digital twins and sketching, a number of concepts have been researched, with findings shown in section 2.1. Concepts related to the design process and its methods are shown in section 2.3, which also aims to give an overview of how research in design can be conducted. Related works are also examined, and shown how they are similar to the research in this thesis.

2.1 Background

Brief explanations of urban planning, digital twin cities, and sketching are given in this section.

2.1.1 Urban Planning

Cities today are rarely created organically; instead, as stated by Castree, Kitchin, and Rogers (2013), they are meticulously planned in the process known as urban planning. While urban planning dates back to antiquity, modern urban planning is linked to the urbanization and industrialization of the 19th century (Encyclopædia Britannica, 2016). Following the accompanying population growth of cities and the social and environmental issues arising from this, reforms were needed and sustainable growth became a central goal in the planning.

As urban planning now concerns entire cities with potentially millions of affected people, stakeholders range from city planners and architects to politicians and the general public. This broad range of stakeholders is not problem free, raising issues around the role of citizens in regards to city officials, and public versus private sector interest (Encyclopædia Britannica, 2016). It is therefore necessary to involve more stakeholders in the process than just the planners (Maquil et al., 2015).

To facilitate the plans and goals, modern tools such as geographic information systems (GIS) are used to show the urban development area and propose changes (Encyclopædia Britannica, 2018). These can analyze maps and simulate various flows using cartographic models, as well as produce new maps and tables for the urban planners.

2.1.2 Digital Twin City

With simulation technology steadily progressing, more advanced and complete simulations of an artifact can be created. A "digital twin" is a copy of an object made via simulations and analyses. This methods dates back as early as the *Apollo* space program, in which a twin of the space vehicle was made and left on earth to mirror the one in space (Boschert & Rosen, 2016). By creating a twin of the object, simulations and models can be run from data from the real object and always reflect the state of the physical version (Boschert & Rosen, 2016). Scaling up the digital twin from a small artifact to an entire city creates a digital twin city, or virtual city.

2.1.3 Sketching

Sketching as a mean of communicating a design is an essential tool in the design process, dating back to the medieval period (Buxton, 2007). Buxton (2007) explains in his book *Sketching User Experiences* how sketching is used early in a design process as a tool to quickly generate, store, and show ideas, and how it can be used to invite feedback and suggestions for change. This sets it apart from advanced renderings, for which the direction to pursue is more set. Indeed, one of the goals of sketching is to convey a design which is open to suggestion and critique.

He furthermore argues that sketching is inherently coupled to design thinking, and others agree. In a 2007 study of sketching in engineering it was found that sketching is heavily linked to design cognition, and might play a large part in design thinking (Yang & Cham, 2007). It has also been claimed that sketching in 2D is as common and natural as handwriting (Arora, Habib Kazi, Grossman, Fitzmaurice, & Singh, 2018), which could suggest that this technique is viable for artists and non-artists alike. However, the skill of interpreting sketches differs between, for example, professionals and students (Buxton, 2007). If a sketching user interface is developed for use by both experts and non-experts, communication between these two must be facilitated to bridge this gap. However, the guidelines in this thesis are target toward a tool for urban planning experts, not the general public, which means that more advanced topographies (such as speciality areas and road types) will be used in the prototypes.

Buxton sets up a number of criteria for sketches, to separate them from more intricate technical plans and drawings:

- Quick
- Timely
- Inexpensive
- Disposable
- Have a clear vocabulary
- Feature distinct gestures
- Have minimal detail

- Have an appropriate degree of refinement
- Suggest and explore rather than confirm
- Feature ambiguity

Explanations for each criterion are provided in appendix A.

One of those criteria is that a sketch is ambiguous. This point is crucial, since the goal of sketching is not about the sketch itself, but rather the conversations that it will trigger. Collaboration on various parts can be essential to the sketching process itself, with conversations acting as springboards for ideas and further development. A study on collaborative drawings by Bly (1988) confirms Buxton's sentiments: that the process of drawings might be as important as the drawings themselves for the overall design process.

This sets the scene for collaborative sketching, in which multiple users contribute to the same sketch. In a design camp challenge hosted by the software company SAP it was shown, albeit informally, that collaborative sketching can be useful to enable several users to contribute during the ideation phase of a project (Fehlau, 2014), although the method works best when creating a small number of sketches. Fehlau's study focuses on collaboration in which the users sketch non-simultaneously on the same sketch. Following the computer-supported cooperative work (CSCW) matrix seen in figure 2.1 this can be classified as a *continuous task*.

For synchronous collaboration, Fehlau suggests a shared sketching area for multiple users, which has previously been discussed by, among others, Bly (1988) and Greenberg and Bohnet (1999). The study performed by Bly agrees that collaboration is indeed useful, since that it is hypothesized that it increases the attention and involvement of the users. Greenberg and Bohnet (1999), analyzing previous work by Tang (Tang & Leifer, 1988; Tang, 1989, 1991), note, however, that it can be difficult to orient the sketches and drawings so that every participant can understand the drawing at large, if the sketch is on a table. As an upside, a tabletop sketch can allow for better conversation, as compared to a wall-mounted sketch area. They also highlight that the group work around a tabletop can be a simultaneous experience: 45 % to 65 % of the activities studied involved simultaneous access.

This thesis will focus on asynchronous collocated collaboration, since this, according to the discoveries made during the prestudy, is the most common way of working in urban planning projects. This can be, for example, that one user creates a sketch, shows it to a colleague, collects input, and continues working on it. The thesis will also cover synchronous collocated collaboration to a degree; however, this exploration is limited due to a relative scarcity of test subjects and is not the focus of my collaboration guidelines.

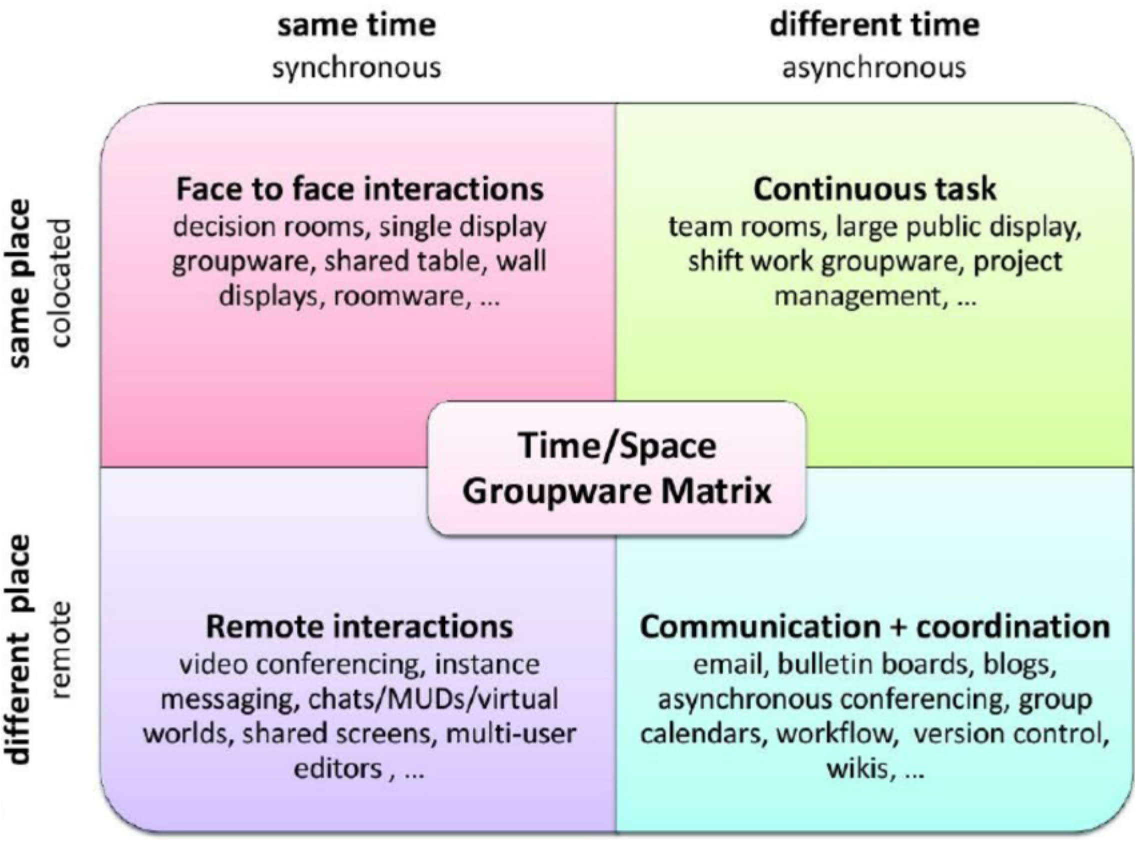


Figure 2.1: The CSCW matrix developed by Johansen (1988) shows the temporal and spatial dimensions of collaboration. This figure is a public domain rendition.

Digital sketching interfaces

Advancements within the last half century have brought sketching to the digital realm (Sutherland, 1964), and with commonplace personal computers now supporting touch-based interaction, digital sketching user interfaces have become more accessible. A touch-based computer such as the Microsoft Surface can in this way be used as an artist's canvas, by utilizing a pen-like tool in combination with the touch-screen (Arora et al., 2018).

As Sutherland (1964) states concerning the very early digital sketching interface *Sketchpad*, that drawing on a computer is only worthwhile if the user gains something in addition to the sketch itself. While this text is over half a century old, Sutherland's statements still provide insights to sketching applications: he theorizes that simulations for the sketches, such as to see whether a circuit diagram would work, could be a viable use case, indicating that simulation and sketching could benefit from being combined.

Sketching in urban planning

Sketching has traditionally been and remains a large part of the urban planning process (Castree et al., 2013). As the urban planning experts interviewed early in this thesis (2018-09-25) state, there are many types of drawings, ranging from early pen-and-paper exploratory sketches shown to a wide variety of stakeholders, to intricate computer-made detail plans necessary for receiving building permissions. They see sketches as a vital part in the early stages of urban planning, something that is agreed upon by an urban planning expert interviewed at VirtualCity@Chalmers (2018-10-08).

2.1.4 Bimanual Input

As most people have a dominant hand they prefer to use in for example sketching, it can be interesting to note how the two hands can collaborate. Even though, as Guiard (1988) points out in "The Kinematic Chain as a Model for Human Asymmetrical Bimanual Cooperation," the movements performed by the hands themselves are just parts of larger actions often involving the arms and upper body, the term "manual" is useful for separating tasks performed mainly by the left or the right hand.

Guiard proposes that a hand is a motor, that is, a device that controls the difference between a variable position (VP) and a reference position (RP). If multiple motors are connected serially, creating a kinematic chain, the VP of the first motor can serve as the RP of the second. Guiard claims that our hands are used in this way in everyday asymmetrical manual activities, due to the often-found dominance of one of the hands.

The non-dominant hand can then serve as a RP for the dominant hand, revising the orientation and position of an object with the dominant hand moving relative to this; for example, Guiard states that it is common that the position of a paper or writing block is adjusted by the non-dominant hand when writing by hand. Related to this, he shows how the non-dominant hand usually performs slower and less precise tasks; the paper can have the same orientation for several seconds before the non-dominant hand moves it, while the dominant hand moves several times per second and with high precision. The non-dominant hand therefore usually moves before the dominant, in order to perform the global part of a movement or action which then can be refined by the dominant hand.

While sketching commonly might be seen as a task that is dominated by the dominant hand, it is therefore important not to discard the role of the non-dominant hand.

2.2 Related Work

There are a number of tools for participatory urban planning, as well as some tools for sketching. A selected number of these are listed in this chapter.

The *MapTable* (Scotta, Pleizier, & Scholten, 2006) is a product that aims to fill a similar gap as the design envisioned in this thesis, and is a way for involving local expertise to plan water management projects. Users can draw a map design on the table, and a simulation is calculated within ten minutes and then shown on the screen. This product is similar to the one envisioned in this thesis in the sense that it is collaborative and involves both drawing and analysis, however, it is made for areas and water management in mind, not buildings and their respective analyses.

In *A geospatial tangible user interface to support stakeholder participation in urban planning*, Maquil et al. (2015) explore how stakeholders can be more involved in the process of urban planning. As a method for participatory planning, this tangible user interface (TUI) enables the general public to visualize and understand a new development plan. The TUI uses tangible tokens in the form of blocks to manipulate a large object-recognizing tabletop display, which enables users to select different map layers depending on which type of data they would like to visualize. Other tokens are used to pan and zoom the map, or highlight specific objects on the map for more detailed information.

As another TUI, the *Luminous Planning Table* (Ben-Joseph et al., 2001) shows simulations such as shadows and wind flow using wire frame buildings and a projected image. One of the main advantages of the table, according to the authors, is the direct simulation and visualization. They compare this to traditional urban planning: if a stakeholder came with a contribution during a briefing, changes would have to been made separately and simulations run at a later stage. The collaboration between users from different fields is thus lifted as a main advantage of this kind of interface.

The *ColorTable* (Maquil, Psik, & Wagner, 2008) takes on an approach which enables even more creation from the users' side. By assigning images to tangible tokens, users can create a scene of different objects by placing the tokens on a table with a projected map. This TUI takes advantage of augmented reality by projecting a mixed reality scene on top of the table, and also shows a separate view of the scene on a vertical screen. The authors underline that although urban planning is a very complex process, tools such as the ColorTable need to use simple interfaces to facilitate stakeholder participation.

A recent web-based interface, *Quick Urban Analysis Kit* (qua-kit) (Mueller et al., 2018), available online at https://qua-kit.ethz.ch/, provides a way for everyday citizens to create their own city design, as well as vote on those of others. Users can drag-and-drop three-dimensional predefined buildings, such as schools, and residential and commercial blocks, onto a map using a touch-screen device or computer mouse. This can the serve as input for the designers and planners who work on a particular area of a city, by showing them what the citizens themselves see as an ideal neighborhood. The designs made by the users can then be analyzed, and used to determine the desired geographical distribution of buildings as well as their volume distribution (Lu et al., 2018).

Out of these, *MapTable* (Scotta et al., 2006) is seen as the interface with most in common to the one envisioned in this thesis, since it covers both sketching and analysis. However, it is limited in use, since it only covers flooding simulation, and not the general urban planning process.

2.3 The Design Process

A considerable body of theory exists concerning how to conduct research in design. A selected number of frameworks and processes that will be used in this thesis are explained here.

2.3.1 Research Through Design

Some problems do not have a definite answer, or a solution that can be described as true or false. These are described by Rittel and Webber (1973) as *wicked problems*, in contrast totraditional “tame” problems with absolute solutions. Rittel and Webber also describe how no attempt at a solution for a wicked problem will be the same. An attempt to solve a wicked problem will, as they call it, be a “one-shot attempt”, meaning that every trial counts.

Gaver (2012) argues that design problems often take the form of wicked problems. He claims that these problems are often underspecified by theory and thus very difficult to falsify, as well as difficult to test and compare in a traditional experimental sense. Trying to establish consensus on how to solve design problems would therefore be harmful, he argues, since design is generative in nature rather than static. Creating and designing is here seen as a way to make progress, and by attemping to solve a wicked problem the collective knowledge is advanced to a new level.

This approach however risks putting design research in a difficult spot in the research sphere, Gaver warns, since claims exist that scientific theories should be falsifiable, refutable, and testable. Contrary to solutions that can be proven *correct or incorrect*, it might be necessary to deem them *better or worse* than previous solutions. In this way, design research can take on an evolutionary approach rather than a black and white one, with theories being modeled and remodeled as new designs are created and evaluated. Thus, theories that are "sometimes right" are the goal (Gaver, 2012), rather than absolute answers.

2.3.2 User-Centered Design

To create a design that that better benefits the users, user-centered design can be employed. Lowdermilk (2013) describes this as a method for examining how effectively a design achieves its purpose, using data and analysis. By involving users and gathering feedback during the design process, usability issues can be found and mitigated, saving resources that otherwise would be needed for amending a broken solution. User-centered design should not, however, be confused with pure usability: whereas usability can be researched and tested for almost any product a user interacts with, user-centered design stems from the field of human-computer interaction and is mostly software-focused.

2.3.3 Design Guidelines

One way to guide designers in their creations and research is to create design guidelines and patterns, showing preferable ways to design an interface (Wesson, 2009). These can then be combined with user-centered design, in order to create designs that follow principles of usability. Koukouletsos, Khazaei, Dearden, and Ozcan (2009) note in a study that while guidelines display some shortcomings compared to patterns, they are still widely used to present recommendations for a design, and many guidelines continue to be relevant decades after their creation.

2.3.4 The Double Diamond Design Process

There are several takes on the process of design, with one being the *double diamond* design process proposed by The Design Council (n.d.). This process consists of four separate stages:

1. Discover: research the topic at hand, by both field studies, literature studies, and other methods to gather data.
2. Define: combine and analyze the findings, and define the actual design challenge.
3. Develop: iteratively develop concepts for the challenge, and test and evaluate them.
4. Delivery: prototype and test the ideas. Deliver the final iteration to the customer or other stakeholder, if it's the final iteration.

These are visualized in figure 2.2, in which the shape of the figure lends its name to the method. The double diamond shape represents the number of ideas in each stage: the diamonds expand during divergent phases (discover and develop), and contract during convergent phases (define and deliver). During divergent phases, different ideas are proposed, and these are refined and filtered during the convergent phases.

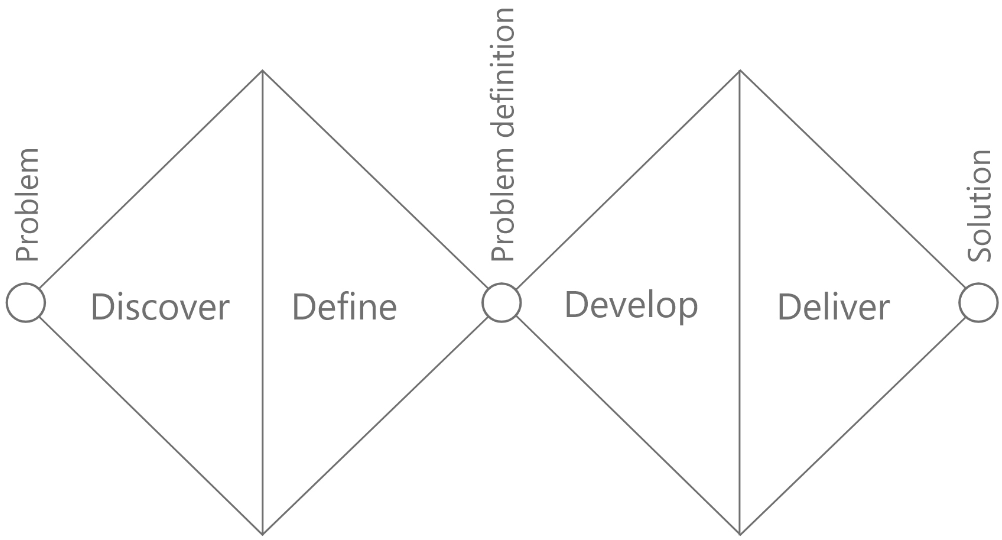


Figure 2.2: An illustration of the double diamond process: two diamonds shapes represent two steps of divergence and convergence, with the four phases written inside the diamonds. This figure is an adaption of the one proposed by The Design Council (n.d.)

Both diamonds can be performed in several iterations, to refine both the problem statement and the solution. To describe the work process of the project I will make use of this: parts of the project consisting of a *discover* and *define* phase will be called *research iterations*, coinciding with the left diamond. Parts consisting of a *develop* and *deliver* phase, coinciding with the right diamond, will be called *design iterations*.

2.3.5 Iterative Design

While it might not necessarily be true that an iteration always improves on the previous designs, designing and refining in cycles generally makes for designs with higher usability, compared to a linear approach (J. Nielsen, 1993). J. Nielsen (1993) shows this in a case study, in which the usability of an interface can improve by 95 % from the first iteration to the last, with an approximate measured improvement of 38 % per iteration.

Authors of several design process frameworks agree that an iterative approach is beneficial: the design thinking framework (Hasso Plattner Institute of Design at Stanford, n.d.), the double diamond framework (The Design Council, n.d.), and the design process proposed in *Universal Methods of Design* (Martin & Hanington, 2012) all highlight the importance iterative refinement of a design.

It should be noted, however, that the iterative process suffers from diminishing returns. As J. Nielsen (1993) describes, large gains in usability will likely be made in the first few iterations, but when the design becomes more polished the gains received for each new iteration drop. In these cases, usability can instead be improved by fundamentally redesigning the interface, and reiterating using the new design.

3. Methods

The thesis work was based on the double diamond design process, due to its clarity in structuring the work in divergent and convergent phases, along with its iterative nature. This was believed to facilitate the project work, and thereby help in answering the research question. The methods used in this project are sorted according to where they best fit into the double diamond design process, and its phases discover, define, develop, and deliver.

3.1 Discover Phase

In this thesis, exploratory research was performed during the three research iterations to collect information about the area of study and build a knowledge foundation, as suggested by Martin and Hanington (2012). During this type of research it is important to focus on understanding the people affected by the study, as well as the context in which the study will take place (Martin & Hanington, 2012). The focus of this research thus lay on the different stakeholders, most notably the perceived end users themselves: urban planning experts. This, Martin and Hanington (2012) argue, will make for a solid groundwork for further research and development in the study.

3.1.1 Interviews

In this thesis it was seen as imperative to collect insights by urban planning experts, who would be the end users of a system designed by the guidelines. Interviews were chosen as a method, rather than for example questionnaires, due to the comparatively low number of primary users of the envisioned design, and it was believed that deep interviews thus could paint a better picture of the domain. Furthermore, as Lazar, Feng, and Hochheiser (2017) state in *Research Methods in Human-Computer Interaction*, different kinds of interviews can be highly beneficial for initial exploration of a research area.

While most of the interviews performed in this thesis were individual, some also took place in groups. This was done for accessing a wider array of experiences and opinions (Wadsworth, 2011), and by taking advantage of communication between the different interview subjects new insights could be gained. Group interviews can, however, be more difficult than individual interviews to conduct, since they require an extra step of note-taking and can generate a much larger set of answers (Wadsworth, 2011).

An interview can take various levels of structure, that is, how much freedom is given to the respondent. *Structured* and *unstructured* interviews are at the opposite ends of a scale, and *semistructured* interviews somewhere closer to the center (Lazar et al., 2017).

In unstructured interviews, the focus lies on the interview subject; the interviewer might have a loose script containing an initial question, but the interview can go any direction (Lazar et al., 2017). This can make unstructured interviews useful for exploratory purposes (Martin & Hanington, 2012), since the interview subject might be more relaxed (Martin & Hanington, 2012). He or she can also focus on what is believed important concerning the subject, as well as educate the interviewer about the domain (Lazar et al., 2017), this enabling deeper understanding of the problem domain, and providing design insights, and other comments that might have been difficult in a more structured interview. However, unstructured interviews require more work and flexibility during the interview itself (Martin & Hanington, 2012), and can require more communication skills to continue the flow of conversation and know what types of answers require further questions (Lazar et al., 2017). Analysis can also be more difficult, since the conversation can touch on a wide variety of topics (Lazar et al., 2017). Unstructured interviews are therefore not chosen as the primary interview method, but will nevertheless be used for early exploration.

In contrast, a fully structured interview follows a predefined script, and can be likened to an administrated survey with a larger opportunity for more fleshed-out answers (Lazar et al., 2017). This more formal type of interview can therefore be easier to conduct as well as analyze (Martin & Hanington, 2012), meaning that they are well suited when comparing answers and evaluating systems (Lazar et al., 2017). The set script does have its disadvantages: even if an interesting subject comes up during an answer, there is no possibility to go off-script, and asking an interviewee to expand or clarify an answer is not recommended (Lazar et al., 2017). Due to their strict nature, structured interviews were limited to the evaluations of the interface at the end of the thesis.

As a middle-ground between these two extremes, semistructured interviews use a predefined set of questions, but allow for further questions and more freedom. By letting the interviewer ask the subject to explain further, or come up with new questions altogether as the interview progresses, these interviews allow for a deeper and broader conversation than structured interviews (Lazar et al., 2017). This type of interview was employed in several stages of the thesis, to gain deeper understanding of the domains of urban planning and sketching.

Similar to surveys, interviews can provide large insights, but rely on often imperfect recall on the subject's side, which might lead to a skewed view of the domain (Lazar et al., 2017). Since they can also be more flexible, and often are on a one-on-one basis, interviews require more time and resources compared to surveys, both in conducting and analyzing (Lazar et al., 2017).

One risk in interviews is biases of different kinds. For example, the way a question is asked during an interview plays a large part: if it's not a simple, straightforward question, it could be seen as obscure, as a trick question, or as a leading question (Wadsworth, 2011), leading to misguided answers. Similarly, the body language, tone, and general style of the interviewer will affect the answers received (Lankoski & Björk, 2015). For example, there could be a need to let the interviewee take their time when answering a difficult or thought-provoking question, which in turn requires the interviewer to be encouraging and not rush the questions (Wadsworth, 2011; Lankoski & Björk, 2015). This was therefore taken heavily into consideration when performing the interviews of this thesis.

The way notes are taken can also affect the answers. Voice recordings can be beneficial to get a complete picture of what has been said and allow for an exact transcript of the interview, but they can also cause people to feel more constrained (Wadsworth, 2011). Manual note-taking was therefore the primary method of recording early interviews, with audiovisual recordings being employed in later interviews where exact transcripts were more vital.

3.1.2 Literature Review

Examining previous works and research can help define a project, by ensuring that the same work has not been done before, and show where the project could fit into the field of study (Wadsworth, 2011). A literature review was therefore conducted during the three research iterations. The main sources for this thesis were the Chalmers and Association for Computing Machinery (ACM) online libraries, and the libraries available at the universities in which I worked.

3.2 Define Phase

In this phase the various observations made in the previous phase will be analyzed and refined.

3.2.1 Affinity Diagram

An affinity diagram can be created in order to discover themes among separate observations, by writing down observations on sticky notes, putting them on a wall, and then clustering them based on shared attributes. Martin and Hanington (2012) argue that connections between observations and overarching themes can be found naturally using this method, which can help designers find insights that otherwise would have been hidden among the observations. Affinity diagrams were therefore widely employed during the course of the thesis, especially in the research iterations to find topics that needed improvement or further exploration.

3.2.2 Personas

Personas are fictional character portraits, intended to personify a stakeholder, for example a member of the core user group for a particular design (Dix, Finlay, Abowd, & Beale, 2004). These consist of characters with their own set of goals, where each goal aims to bring context to the persona and make it more life-like (Sharp, Rogers, & Preece, 2007). In addition to this, each persona will also be described in terms of skill set, attitude, behaviour and other attributes synthesized from the gathered data, as proposed by Sharp et al. (2007). These personas, while imaginary, can be described in high detail (Sharp et al., 2007), and enable a design focus based on more qualitative attributes rather than numbers (Martin & Hanington, 2012).

A persona is not just used in the beginning of a project, but can be used to keep knowledge and insights intact during the process (L. Nielsen, 2013). Since the design process likely leads to new insights during the course of the project, the personas can benefit from being continually updated (Cooper, 2004).

While there will usually be more than one persona in a project (Dix et al., 2004; Sharp et al., 2007), a maximum of three to five is recommended in order to reduce the work needed to create, maintain, and remember them all (Martin & Hanington, 2012). Since this project is relatively small, two personas were created at the start of the project, and updated throughout the process.

It should be noted though, that using personas is not a catch-all method for replacing actual user interaction. A persona can indeed serve as a tool for a user-centered design, but some criticism has been raised that they make designers focus less on interacting with actual users (L. Nielsen, 2013). They should not therefore be seen as a replacement, but rather a complement, to meeting real people. In this project, interviews and other data-gathering research methods were used for interacting with potential users, as were tests of the design, thus mitigating this issue.

3.2.3 Scenario

Scenarios aim for a text-based approach to a user's experience, using personas to create a believable narrative (Martin & Hanington, 2012). As Martin and Hanington (2012) explain, this will help make design ideas concrete, as well as serve as an anchor throughout the design process. As the storyboard should focus more on the general technological solutions used, rather than the technological details, it also helps the designer not to focus too much on technical requirements. Scenarios were used in this thesis to better understand the applications of the envisioned software, as well as how the users work with tools they have access to today. Since the scenarios would be unlikely to be performed as more data was collected, they were, as the personas, updated during the course of the thesis.

3.2.4 Storyboard

To better understand how a design will be used, storyboards were created early in the project process. Storyboards are done by sketching images of a proposed use case. While not limited to design use, with an example seen in figure 3.1, they are used in design projects to help emphasize how a design can be used (Martin & Hanington, 2012), and what impact it can have (Dix et al., 2004). According to Cooper et al. (2014), it is important that not too much time is put into the storyboard, but it is nevertheless very useful for exploring high-level solutions. The storyboards of this thesis were therefore quick sketches, and used to find points that needed to be addressed with further research.

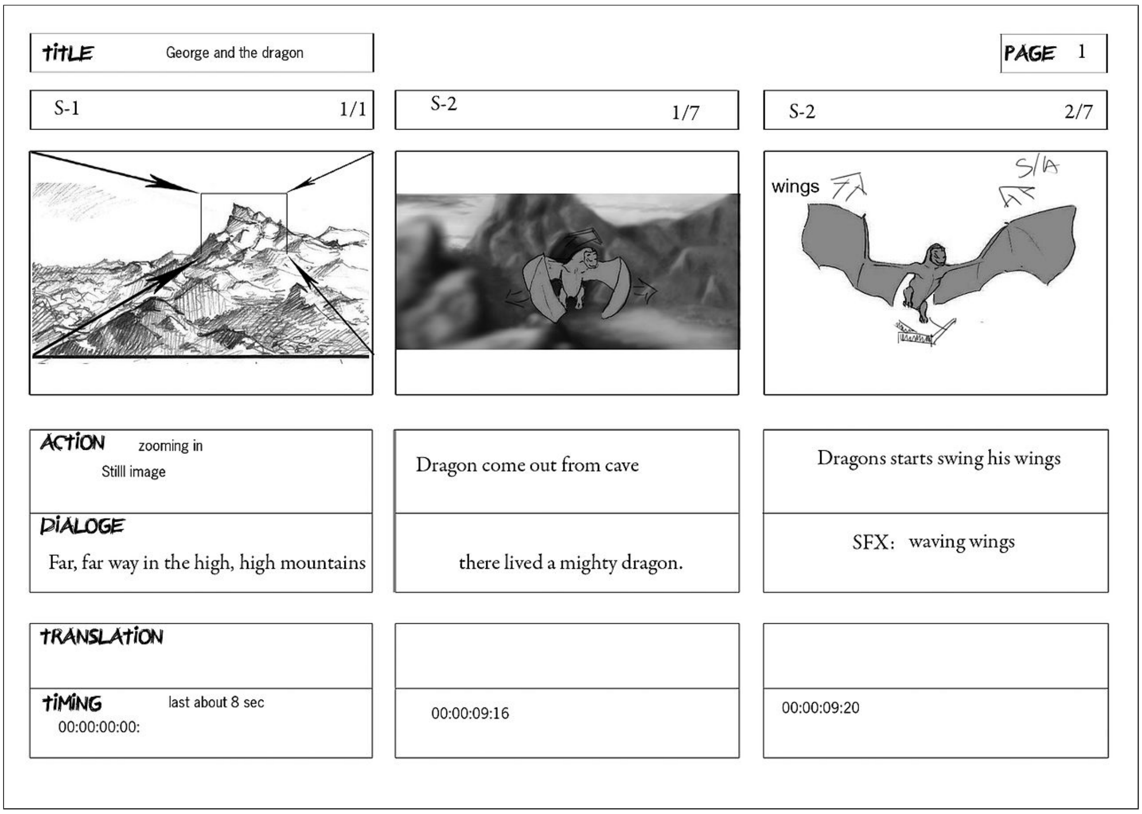


Figure 3.1: A storyboard of a movie scene: the board includes both visual representations of key moments, and additional details such as dialogue and actions. The image is public domain.

3.3 Develop Phase

The main goal of the develop phase is to come up with a set of ideas, and evaluate them to decide which to develop into prototypes.

3.3.1 Brainstorming

Brainstorming was used as a method for ideation, due to the perceived large number of ideas the method can generate (Wilson, 2013). While brainstorming is originally a group exercise (Faste, Rachmel, Essary, & Sheehan, 2013), Daly, Seifert, Yilmaz, and Gonzalez (2016) argue that individual brainstorming is a viable method for novice designers. Indeed, a study has shown that individuals performing individual brainstorming might be more effective than traditional group-based brainstorming (Lewis, Sadosky, & Connolly, 1975).

The brainstorming performed in this thesis was therefore a modified version of the original method, based on the three main phases of brainstorming (Faste et al., 2013) but adapted for individual use:

1. Fact-finding: gather facts and analyze data, and define the problem.
2. Idea-finding: create possible ideas, and select and combine them.
3. Solution finding: verify the solutions and determine which ideas to implement.

3.3.2 Weighted Matrix

Once a set of proposed ideas has been created, weighted matrices can be used to determine which idea or ideas to continue working on. Martin and Hanington (2012) state that this can help make the decision on which ideas to pursue further more grounded in data, as compared to basing it on the opinions of the designer. In order to narrow down the number of potential solutions, the matrix ranks them based on certain key criteria (Martin & Hanington, 2012), depending on the desirable outcome of the session. Weighted matrices were used in this project to better determine which ideas from brainstorming sessions should be implemented.

3.4 Deliver Phase

Ideas were implemented as prototypes and tested in the deliver phase. After this, the process would iterate within the diamond, that is, go back to the develop stage.

3.4.1 Prototyping

In order to gain insights and evaluate different design scenarios, three prototypes were created. Prototyping consists of the development of physical artifacts (or virtual, if the final product is, for example, a software), which are used to test various aspects of the design (Martin & Hanington, 2012). These can take different levels of fidelity, each useful in different stages of a project.

Low-fidelity prototypes can be used in the early stages of a project, where they can be useful for making iterative changes to the design (Martin & Hanington, 2012). These kinds of prototypes, for example paper prototypes, can prove very valuable for gathering feedback from users and be essential parts of usability tests (Cooper et al., 2014). According to Buxton (2007), paper prototyping is well suited for quickly catching design flaws, and is fast to implement; paper prototyping was therefore used as the main form of low-fidelity prototyping.

As a more realistic version of a prototype, a high fidelity prototype aims to emulate a more final look and feel of a product (Martin & Hanington, 2012). Such a prototype was developed during the final stages of the project, to gather data about the interface usability, design, and interaction, as described by Martin and Hanington (2012).

McCurdy, Connors, Pyrzak, Kanefsky, and Vera (2006) propose a different categorization from the more traditional low- medium- and high fidelity prototypes, and instead talk of mixed-fidelity prototypes. They argue that prototypes can take different fidelity in different aspects, and list five dimensions:

- Level of Visual Refinement
- Breadth of Functionality
- Depth of Functionality
- Richness of Interactivity
- Richness of Data Model

A prototype can be of either low, medium, or high fidelity for each of these dimensions. To better describe the prototypes of this thesis, this categorization will be used; however, the three prototypes will still be referred to as the low- medium- and high-fidelity prototypes, since they each have a dominant fidelity type.

Dix et al. (2004) state that while prototypes and iterative development are keystones in the interaction design process, prototyping is not without its caveats. Since iterative prototyping means beginning at a certain point, with a proposed design, and iterating it over time to improve it, there is a risk that a faulty initial assumption can cause the prototype to develop in a wrong direction. Dix et al. (2004) liken this to hill climbing: if you start at a certain point and climb until a high point is reached, it is very possible that this is simply a local maximum, and that higher points exist in uncharted directions. Carefully selecting which idea or ideas to progress into prototypes, for example using weighted matrices, was therefore crucial in this project.

3.4.2 Evaluation

Dix et al. (2004) describe three reasons for performing evaluations:

- To assess the functionality of a system. This is to certify that a system falls in line with the requirements, and that essential tasks can be performed. For example, the performance of completing a certain task by a user can be measured.

- To assess the user experience of a system. This will determine the ease of use and usability of a system, and therefore focuses more on the satisfaction received by using the system.
- To identify specific problems with a design. This is highly related to the above points, with the additional focus on determining which problem points might exist when a design is put to use.

Throughout a project it is necessary to evaluate the findings, for example to iterate the prototypes and update the design guidelines. These evaluations should take place during each iterative step (Dix et al., 2004). This, Dix et al. (2004) argue, allows for issues to be found and changed early on in the process, before too much time has been spent on working in the wrong direction. These evaluations fall into two main categories: expert-based evaluation and user-based evaluation.

Expert based evaluation

Some parts of the process can be evaluated by designers and usability experts, especially early prototypes and design ideas (Dix et al., 2004). In this project, two main methods of expert-based evaluations will be used: cognitive walkthrough and heuristic evaluation. The cognitive walkthroughs will be put to use primarily in the early research iterations, since it was believed that test users would be better put to use in later stage evaluations (Dix et al., 2004). Heuristic evaluation was used before the final user evaluations, to find usability issues that might impede the tests.

As a method for understanding how well tasks can be completed, a cognitive walkthrough uses predefined tasks and actions to step evaluate an interface (Dix et al., 2004). In such an evaluation, a user, which in this thesis was a role-playing designer (used when there is a lack of resources (Wilson, 2014)), steps through the interface defined by the task and action sequences, while an evaluator observes and takes notes using a form. Dix et al. (2004) suggest that the evaluator should for each action answer four questions, proposed by Polson, Lewis, Rieman, and Wharton (1991), and these were therefore the basis of the cognitive evaluations of this project:

1. Will the effect of the action be the same as the goal?
2. Does the user notice that an action is available?
3. When the user has found the correct action, will they know it will give the desired effect?
4. After the user has performed the action, will the user understand the feedback received?

As a second method of expert-based evaluation, heuristic evaluation was chosen due to its low cost and the relatively low level of planning needed (J. Nielsen, 1992). When performing a heuristic evaluation, an interface is evaluated based on a certain set of heuristics. It should be noted that it can be difficult to connect a particular problem into a certain heuristic, and therefore it is necessary to carefully select the heuristics used (Hartson & Pyla, 2012). The heuristics used in this project were the traditional ten proposed by J. Nielsen and Jakob (1994), which are displayed in appendix B. Since an evaluation of this kind should consist of several evaluators to discover the majority of all usability problems (Dix et al., 2004), master students in HCI were employed to conduct them.

User-Based Evaluation

Not all evaluation can be performed without users, since there are insights that can only be gained from those who will actually use the system (Dix et al., 2004). These tests start with hypotheses for various parts of the system, which can then be confirmed or discarded based on the observations during these tests. For example, the user evaluations in this thesis will determine whether the guidelines are viable, by the means of assessing the usability and viability of a system based on it.

This data was collected by think-aloud tests, in which users interacted with the interface while telling an observer their thoughts and intentions. This was done to add more insights to the user's behavior, as compared to simple observation (Dix et al., 2004). Questionnaires were also added for the users to answer after this tests. These provided quantitative data, thereby complementing the qualitative data gathered during interviews and observations.

System Usability Scale

The system usability scale, or SUS, is used to determine the overall usability and learnability of a system (Brooke, 2013). Brooke (1996) describes it in "SUS - A quick and dirty usability scale" as set of ten statements (appendix H), shown to the user immediately following interaction with a system. The user then answers the statements on a five-point Likert scale, preferably quickly and intuitively. The simplicity and free access to SUS has made it widespread in usability assessments (Sauro & Lewis, 2011).

Sauro furthermore writes in a self-published article that the average SUS score is 68 (Sauro, 2011): anything above that number can therefore be seen as above average in terms of usability. However, the scale is not linear, that is, a score of 100 is not twice as usable as a score of 50 (Brooke, 2013).

The SUS was used in this thesis to determine if an interface based on the synthesized guidelines was above average in usability, and thereby helped support the validity of the guidelines.

3.4.3 t-Test and Normality Test

To determine if the true mean of a data set is significantly different from a proposed value, it is possible to conduct a one-sample t-test. A test statistic T, which follows a T distribution, can be calculated as shown in *Introduction to Probability and Statistics:*

Principles and Applications for Engineering and the Computing Sciences (Milton & Arnold, 2003):

$$
\begin{aligned}
X &: \text{a random sample from a normal distribution, with size } n \\
\mu_0 &: \text{an assumed population mean of the distribution of } X \\
S &: \text{the estimated variance of } X \\
T &= \frac{\bar{X} - \mu_0}{\frac{S}{\sqrt{n}}}
\end{aligned}
$$

This statistic can then be used to calculate a p-value based on the T distribution with $n - 1$ degrees of freedom. From this, the null hypothesis H_0 can either be rejected or failed to be rejected. This hypothesis can differ between (1): $H_0 : \mu \geq \mu_0$, (2): $H_1 : \mu \leq \mu_0$, and (3): $H_1 : \mu = \mu_0$, with accompanying alternative hypotheses (1): $H_1 : \mu < \mu_0$, (2): $H_1 : \mu > \mu_0$, and (3): $H_1 : \mu \neq \mu_0$. This is based on a significance level α: the probability of committing a Type 1 error (that is, the null hypothesis is rejected despite it being true) (Milton & Arnold, 2003). A default value of $\alpha = 0.05$ will be used in this thesis, as recommended by Stockburger (2007).

The t-test is only valid if the data is normally distributed (Milton & Arnold, 2003). This can be roughly determined by producing a box plot, or box-and-whiskers plot, of the values: if the plot is symmetrical with few outliers (or no outliers, if the sample size is less than 15), this hints that the data is normally distributed (Elliott & Woodward, 2007). This is visualized in figure 3.2. A more rigorous test is the Shapiro-Wilks test, named after the inventors Shapiro and Wilk (1965). The test has the hypotheses:

$$
\begin{aligned}
H_0 &: \text{The sample comes from a normally distributed population} \\
H_1 &: \text{The sample does not come from a normally distributed population}
\end{aligned}
$$

In their paper “An analysis of variance test for normality (complete samples),” Shapiro and Wilk (1965) describe how a test statistic W can be calculated from a test sample $x_1, x_2, ..., x_n$ as follows:

$$
\begin{aligned}
m_i &= E(x)_i : \text{the expected values from a normally distributed sample} \\
m' &= (m_i) \\
v_{ij} &= cov(x_i, x_j) : \text{the covariances between the samples} \\
V &= (v_{ij}) \\
a' &= \frac{m'V^{-1}}{(m'V^{-1}V^{-1}m)^{\frac{1}{2}}} \\
W &= \frac{(\Sigma_{i=1}^{n} a_i y_i)^2}{\Sigma_{i=1}^{n} (y_i - \bar{y})^{\frac{1}{2}}}
\end{aligned}
$$

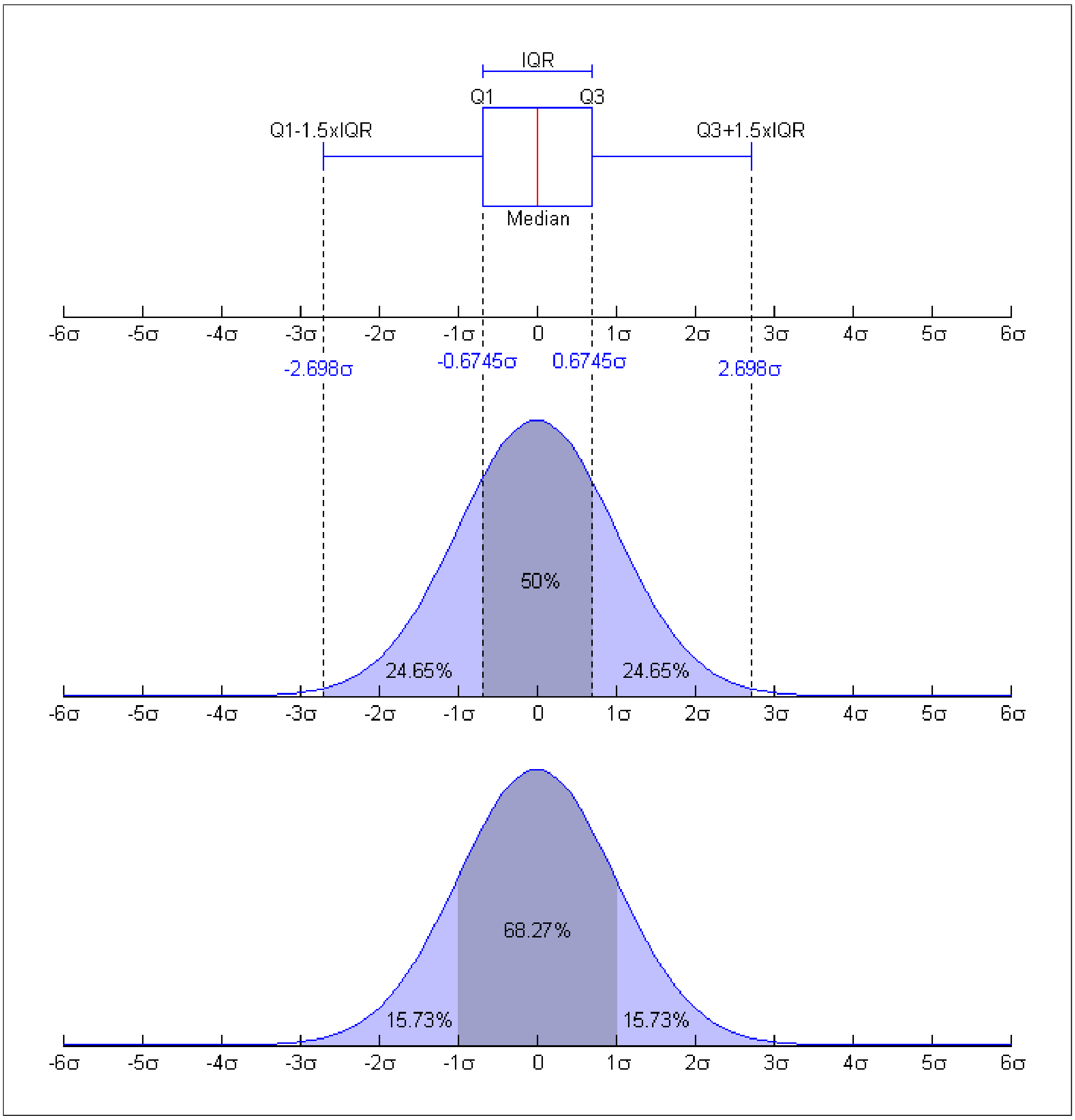


Figure 3.2: A box plot of a normal distributed sample, along with the accompanying probability density function. Figure by Wikipedia user Jhguch, uploaded to https://commons.wikimedia.org/wiki/File:Boxplot_vs_PDF.png with a CC BY-SA 2.5 license (https://creativecommons.org/licenses/by-sa/2.5/deed.en).

y_i is in this case the i:th largest value of the sample; that is, $y_1, y_2, .., y_n$ is the result after ordering $x_1, x_2, .., x_n$. The p-value of this statistic can then be calculated based on the H_0 assumption that the data is normally distributed. This value can then be compared to the set significance level to either reject or fail to reject H_0.

While both the t-test and Shapiro-Wilks test can be calculated as shown here, they are both included in the R language stats package (R Core Team, n.d.-c), which was used in this thesis to determine whether the average SUS score from the user evaluations were above the total average.

4. Process

The project has been performed in six cycles, or iterations: three research iterations, consisting of the *discover* and *define* phases seen in figure 2.2, followed by three design iterations, consisting of the *develop* and *deliver* phases (table 4.1). During these, methods described in chapter 3 have been applied, such as literature studies, interviews, user evaluations, among others. A general time plan of the iterations, including key moments, can be seen in figure 4.1.

Table 4.1: The six iterations of the thesis, showing which phases of the double diamond process that was a part of each iteration. The timelines for each iteration can be seen in figure 4.1.

Iteration	Discover	Define	Develop	Deliver
First research iteration	×	×		
Second research iteration	×	×		
Third research iteration	×	×		
First design iteration			×	×
Second design iteration			×	×
Third design iteration			×	×

A total of nine interview subjects (U1-U8, E1) contributed their knowledge in the research iterations. In-depth interviews were conducted with five expert users: U1-U3 and U7 were all interviewed once, while U8 was interviewed twice. Three shorter interviews were also conducted with an expert on digital urban planning interfaces (E1). Secondary research was conducted by analyzing interviews with three more expert users (U4-U6). Three of the subjects (U1, U4, U5) were stakeholders in the VirtualCity@Chalmers project. How these and other research methods were performed, in addition to insights gathered from them, is explained in sections 4.1 to 4.3.

Since the number of test subjects in each test was comparably low it was decided to focus on qualitative data. For this reason, cognitive walkthroughs and usability tests were chosen as the main evaluation methods. As a way to complement the qualitative data gathered using these methods, the interface was also tested using heuristic evaluation, and a SUS questionnaire was added to the final user evaluation.

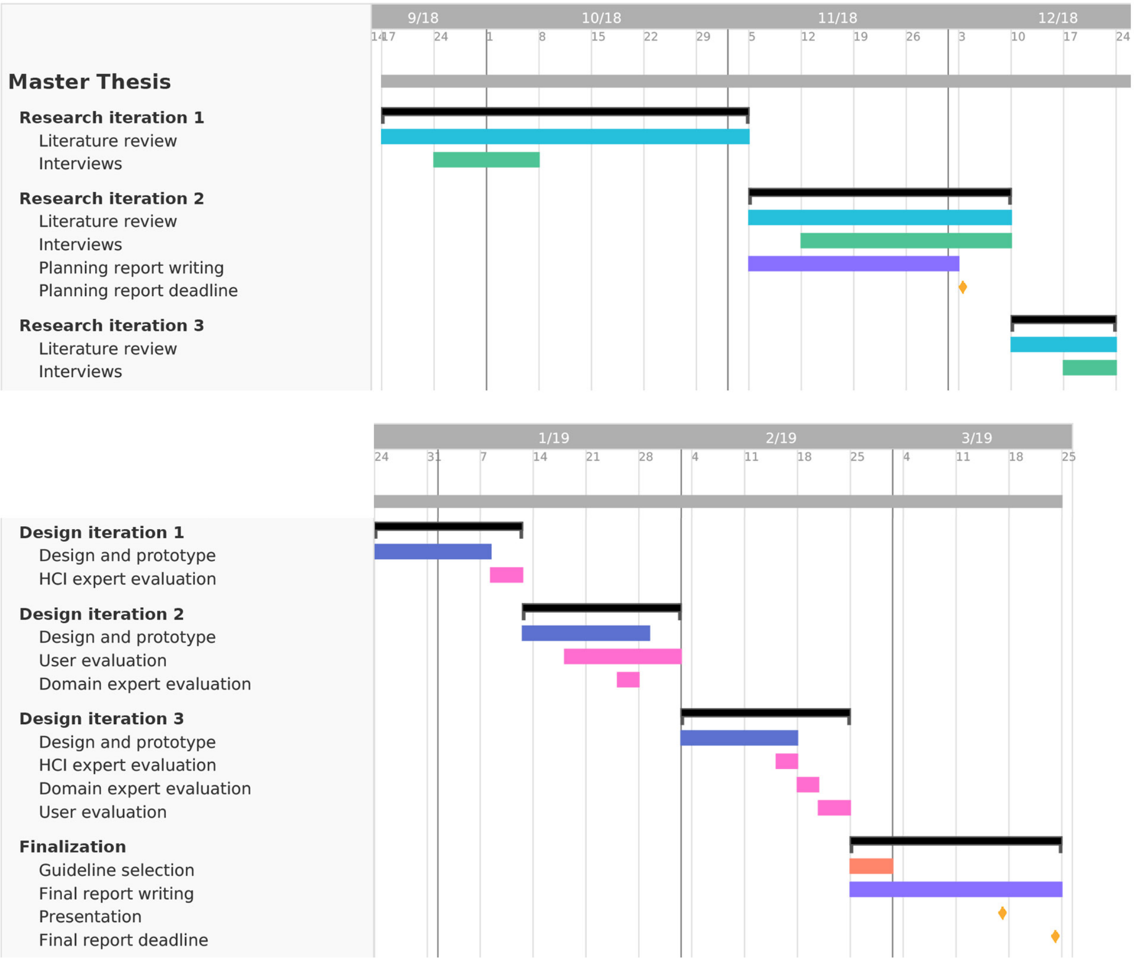


Figure 4.1: A Gantt chart of the master thesis work. Teal: literature review, green: interview, purple: report writing, blue: design and prototype, pink: evaluation, orange: miscellaneous. The iterations are the same as described in table 4.1.

The design guidelines have been evaluated by creating an interface based on them. This interface was created in three iterations, with prototypes, each with a higher fidelity than the previous one, created and evaluated in each iteration. The fidelity dimensions for each prototype are visualized in figure 4.2.

These prototypes were evaluated in a total of 22 tests: in usability tests with five subjects of senior HCI knowledge (all active PhD students in HCI, S1-S5), using heuristic evaluations by four subjects of intermediate HCI knowledge (all active master students in HCI, S11-S14), in user evaluations with eight urban planning experts (S6, S7, S9, S10, S19-S22), and in expert evaluations with one urban simulation expert (S8) and four urban studies researchers (S15-S18). How the evaluations fit in the three design iterations is described in sections 4.4 to 4.6.

Matrices over in which form the participants participated are shown in appendix E.

Finally, the guidelines were rewritten to combine the main insights derived from the thesis. This was done by creating one set at the end of the second research iteration, and updating it four times (at the end of every following iteration). A visualization of

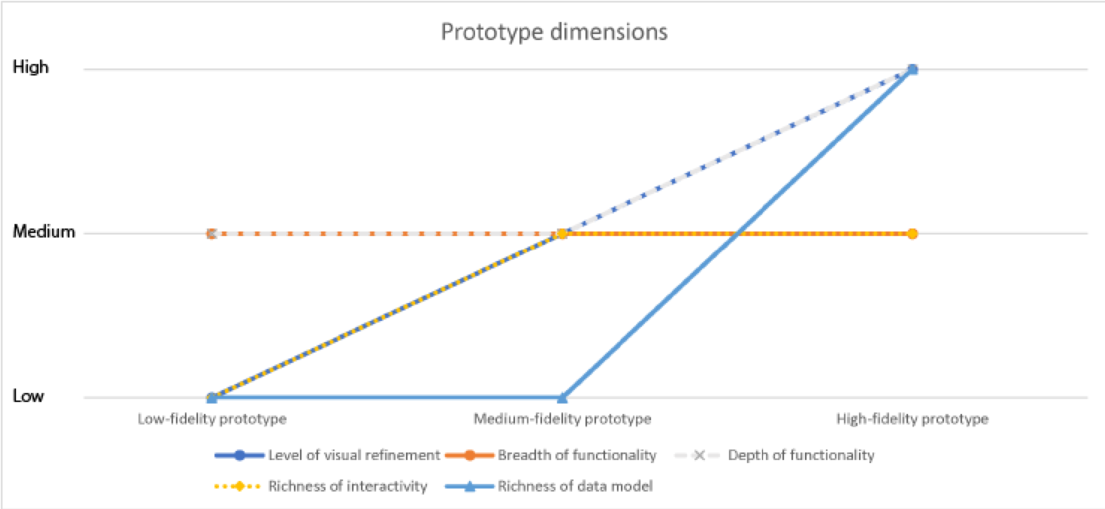


Figure 4.2: The five dimensions of fidelity for each of the prototypes created during this master thesis: the fidelity levels generally go higher as the design iterates.

this is seen in figure 4.3.

4.1 First Research Iteration

Week 36 - 44, Sweden

The first steps of the thesis were taken in a prestudy, in the form of a research iteration, to get an initial image of potential issues and requirements, and to investigate the needs of the target users. This phase took place in Gothenburg, largely together with the VirtualCity@Chalmers team, and served as a basis for the coming work. Based on the data gathered during this phase, the scope and aim of the project could be defined.

4.1.1 Stakeholder Contact

During the phase, several meetings were held with the VirtualCity@Chalmers team, discussing the potential scenarios for the envisioned interface. The team was also consulted for input for the project proposal, before the journey to Singapore.

The professor of the Human-Computer Interaction (HCI) Media Lab at the National University of Singapore (NUS) was contacted during this iteration, to arrange an internship there for the first half of the thesis. This was to both strengthen ties between Chalmers and NUS, as well as to use the experience of the lab members to assist the early parts of the thesis work.

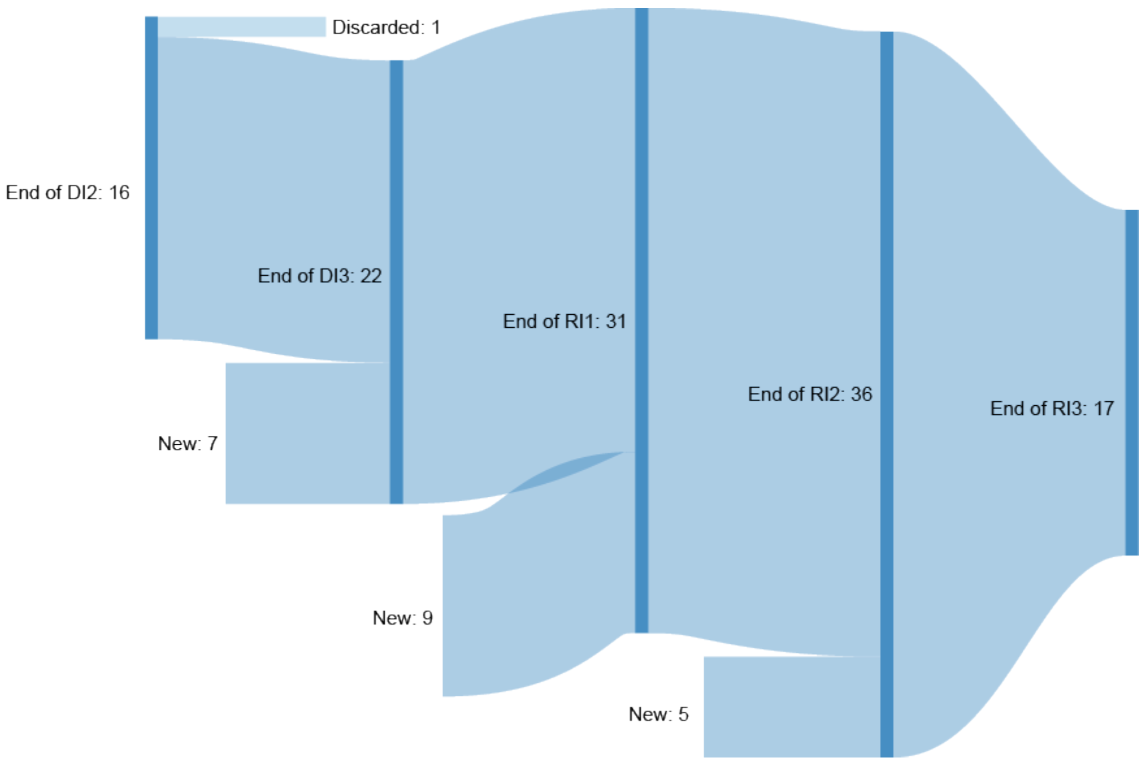


Figure 4.3: A Sankey diagram of the number of guidelines at each update of the set: the vertical dark lines represent each time the set was updated (DI = design iteration, RI = research iteration). The width corresponds to the number of guidelines at each point of the process. Diagram created using SankeyMATIC (http://sankeymatic.com) and Adobe Illustrator.

4.1.2 Interviews

In order to better understand the domain, an architect with expertise in urban planning (U1), who was working with the VirtualCity@Chalmers project, was contacted for an unstructured interview. The interview focused on his experience of urban planning, and his experience and suggestions of different kind of relevant software and hardware interfaces.

Two additional expert users (U2, U3), both working in a private sector urban planning office, were contacted and a group interview was conducted in their office. The goal of this interview was to understand the general work flow of an urban planning project, the software used, the perceived advantages and disadvantages of these, and how viable a tangible user interface (TUI) would be in the early stages (as a TUI was considered the most likely application at this stage).

The interview was semi-structured in nature, allowing for a deeper descent into especially interesting topics, such as the need for sketching. The interviews showed that there was a desire among the subjects to quickly come up with sketches for scenarios, either by drawing free-hand or using tangible tokens, and thereby bridging the gap between the analog (hand-drawn on pen-and paper) and digital (such as creating sketches in Adobe Illustrator) in the early stages of urban planning. However, there was a fear that a TUI would be too imprecise and that it might hinder the creative process.

Further interviews were also planned with the VirtualCity@Chalmers team, but due to scheduling difficulties these could not take place until after I had left for Singapore.

Secondary Research of User Interviews

The VirtualCity@Chalmers team had held previous interviews with expert users (U4-U6), and supplied the transcripts of these for use in this project. U4 and U5 were then working at a municipal urban planning office, and U6 was working in a municipal urban development office. U4 and U5 were also stakeholders in the VirtualCity@Chalmers project. The interviews contained questions highly related to the research topic of this thesis, such as *"What makes you use or not use a tool? (user-friendliness, versatility, cost, etc.)"* and *"What data and features would you like the tool [virtual city interface] to provide you with?"*. This transcript was therefore analyzed, and answers that could be applied to a sketching user interface were collected and recorded.

4.1.3 Literature Study

Papers regarding technical urban planning solutions, the urban planning process, TUIs, touch interfaces, and related works were researched based on keyword searches on the Chalmers Library (http://www.lib.chalmers.se/) and Google Scholar (https://scholar.google.com), as well as suggestions by professor Fjeld. Keywords were at this stage mostly “tangible user interface”, “urban planning”, and variations and combinations of these. The information gathered was recorded as highlight notes, along with reference sources, for use in later iterations.

4.1.4 Chalmers Sustainability Day

A demonstration prototype, in the form of a TUI, was prepared by the VirtualCity@Chalmers team to be shown to the public during the Chalmers Sustainability Day 2018-10-23, and it was planned to use this opportunity to conduct stakeholder interviews for the thesis and observe how people would interact with the TUI. However, it was discovered very late that the TUI could not be moved to the location of the Sustainability Day, and so had to be abandoned.

4.1.5 Altered Focus

Possible technical solutions for a TUI were further researched, including analyzing the hardware available at Chalmers. The available technology was found old and unreliable, and combined with the pain points of TUIs discovered during the interviews, as well as that the related works often were perceived dated, it was decided to focus solely on sketching in the thesis. The research question was therefore altered to allow for this new focus. The change of focus furthermore allowed for a focus on urban sketching, with the ideation phase in particular, instead of the previous focus of both urban planning and architecture.

4.2 Second Research Iteration

Week 45 - 49, Singapore

Based on the prestudy, the second research iteration could start. This iteration was was performed at the HCI Media Lab at NUS in Singapore, with a purpose of creating a solid knowledge base on which to start ideating designs, as well as to create the first set of design guidelines.

4.2.1 Affinity Diagram from the First Research Iteration

The data gathered early in the first research iteration had come from several separate sources: interviews with three expert users, a literature study (including related works), and the secondary research of interviews with three other expert users. In order to find common themes among this research and to understand what needed to be researched in this iteration, an affinity diagram was created.

The notes from the previously mentioned sources were searched for insights, and everything deemed interesting and noteworthy was written on post-it notes, with one

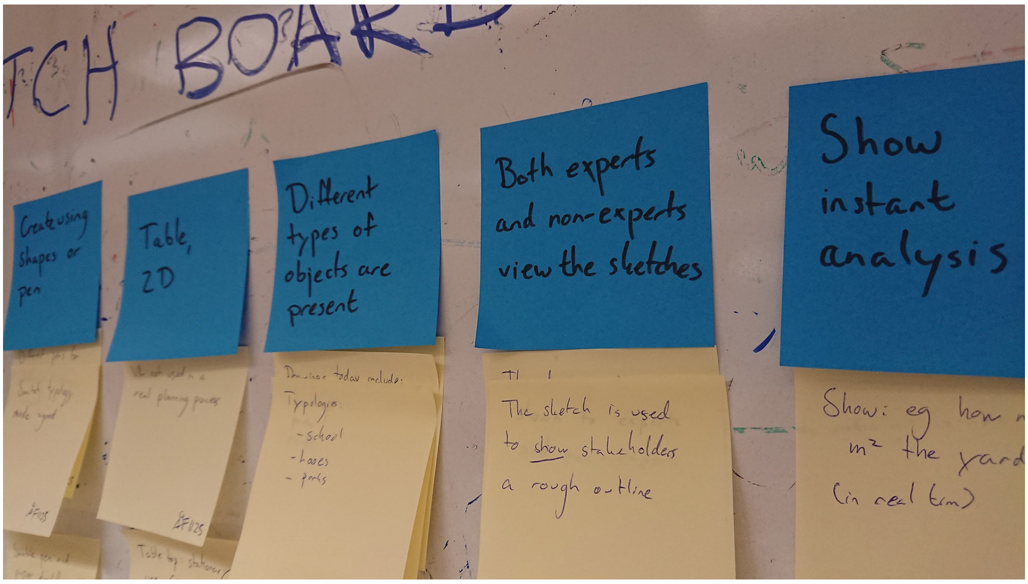


Figure 4.4: Detail of the first affinity diagram: the insights, written on yellow post-it notes, have been synthesized from previous research. They have here been merged and grouped into clusters, with the main insight from each cluster written on a blue post-it note.

note for each insight. Each note also included a source for the insight. This resulted in a total of 81 notes. The notes were then put on a white-board seen in figure 4.4, and by an iterative process of merging and clustering notes based on common themes several insights groups could be created as seen in figure 4.5. The main takeaway from each group was written as a heading, and overarching themes developed for related groups. The notes were then transferred to paper sheets for easy storage and transportation, and the groups and clusters written down digitally. The takeaways from this diagram can be found in appendix C.

4.2.2 Literature Review

Literature such as *Research Methods in Human-Computer Interaction* (Lazar et al., 2017), *Do It Yourself Social Research* (Wadsworth, 2011), *Human-Computer Interaction* (Dix et al., 2004), and *Universal Methods of Design* (Martin & Hanington, 2012) served as guidelines on how to conduct the research required for this thesis. Knowledge and insights gathered from these books and others like them, both physical and e-books, were compiled in guides for myself, and were also the foundation for chapter 3. Other literature, suggested by Professor Fjeld and gathered from the HCI lab physical library, or found by keyword searches on Google Scholar, the Chalmers Library, and the ACM Digital Library (https://dl.acm.org/) was researched to get an understanding on sketching, bi-manual cooperation, and related works (keywords here including "sketching interface", "urban planning sketching", among others). Insights and notable extracts from each of these sources were taken as notes, for use in the planning report as well as in coming research.

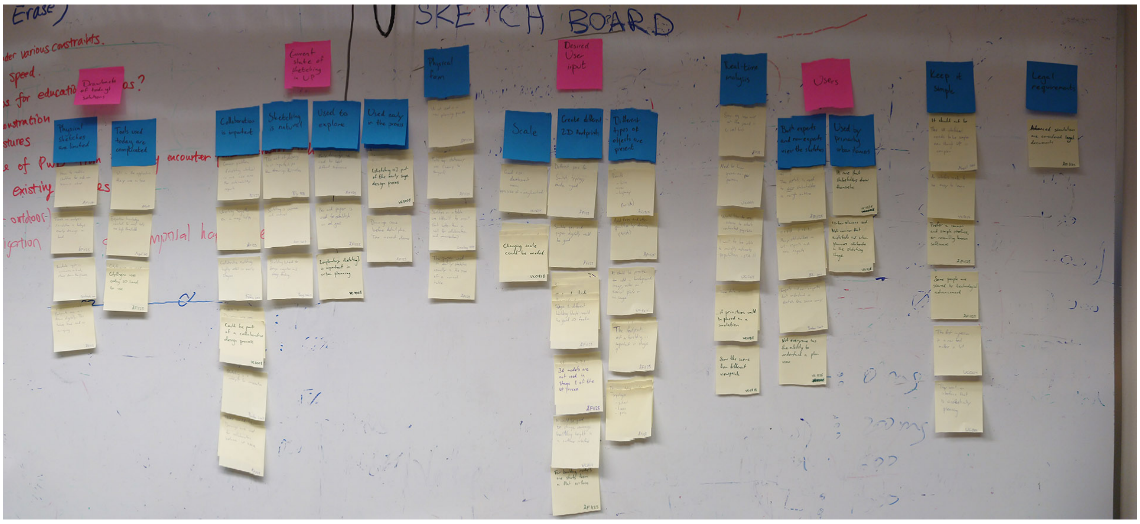


Figure 4.5: The first affinity diagram created in the second research iteration: the insights, written on yellow post-it notes together with a note of their source, have been synthesized from research conducted previous in the iteration. They have here been merged and grouped into vertical clusters, with the main insight from each cluster written on a blue post-it note. The pink post-it notes denote overarching themes among several clusters.

Further suggestions by subjects interviewed during this phase pointed to literature and data related to urban planning, which was collected in order to get a better understanding of the domain. These could be, for example, related works or official information from the Swedish national urban planning agency Boverket (https://boverket.se/). Based on one such suggestion a brief case study of a city district under development, Västra Jakobsberg in Karlstad, Sweden, was conducted, by analyzing its program plan (seen in figure 4.6), detail plan (Karlstad Municipality, 2018), site analysis reports (among others those by Andersson, 2018; Larsson and Nordlander, 2018; Eriksson, 2016), and other relevant data found on the web page of Karlstad Municipality dedicated to the project (Karlstad Municipality, n.d.).

4.2.3 Interviews

The user base for this research was considered comparatively narrow. Since it was therefore seen as probable that the turnout for a questionnaire study would be too low to draw statistical conclusions from, interviews were chosen as the primary data collection method. These were done in order to find pain points in the current urban planning process, to collect requirements for an interface, and to better understand the domain of urban planning.

Researchers in urban planning in Singapore were contacted via email. A meeting was then scheduled with a researcher in urban design interfaces (E1). In the course of the iteration, three unstructured interviews were held with this researcher, with insights collected regarding the urban planning process and software used in the ideation

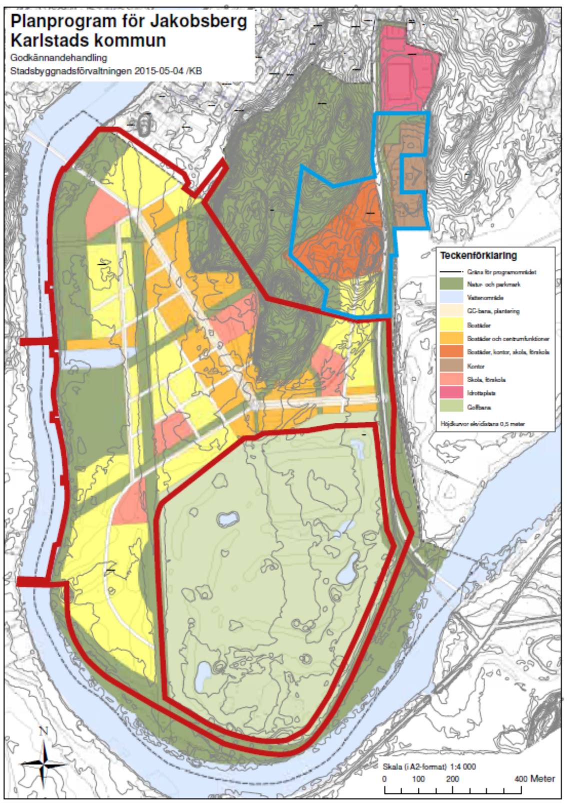


Figure 4.6: An official program plan map of Västra Jakobsberg, a new city district in Karlstad, Sweden, with different areas marked for different uses. The red lines indicates the boundary of the program. Part of *Detaljplan för västra Jakobsberg* (Karlstad Municipality, 2018).

phase of urban planning and design. Lectures by this researcher and a colleague on novel urban design software were also attended, in order to gain a deeper understanding of current software solutions.

A semi-structured interview was also booked and conducted with a researcher in urban planning software and methodology, who also had experience of working in urban planning (U7). This interview was performed to delve deeper into how sketching is used in urban planning, how software is perceived, which pain points exist in the process, and other topics related to sketching and the urban planning process. Example questions from this interview included *“What roles do sketching play in the ideation phase of a project?”* and *“Are sketches mainly done by hand or using software, and why?”*. Notes were taken by hand, in order to not put additional pressure on the interview subject, and later converted to a digital form with interesting points highlighted.

A third subject, an expert user working in a Swedish municipal urban planning office (U8), also agreed to be interviewed via a video call. The following interview focused on the process of recent projects she and her team had worked on, software and sketching tools used, and the collaborative aspect of urban planning. The interview was conducted via a video call, with notes taken by hand, and contained both high-level questions such as *“Can you describe the general work flow of one of your projects?”* and more detailed such as *“What analyses do you usually make in the program plan stage?”*. The notes were then rewritten digitally and highlighted as seen in figure 4.7.

at Jakobsberg, Karlstad växer]. We then create a detail plan and a plan program. Different analyses are made of the site, such as ground structure.
The process is iterative in the beginning. Sketches are made, these are analyzed, more sketches are made, and so one. Sometimes we hire architect firms to do these sketches and analyses.
We go through these together.
We make our own maps using SketchUp, InDesign, Illustrator and Photoshop. And by hand.
It takes a long time to go from inquiry to a final proposition. 1-5 years.
When we are comfortable with our idea and analysis we develop a first proposal. This is shown in a “samråd”, a public consultation. Here, governmental agencies, the county administrative board (länsstyrelse), and the general public are invited. They can give input on the proposal, for further processing.
After this, the urban planners go through the input and compile them into questions that need further work.

Figure 4.7: Highlighted notes from an interview with an urban planner: yellow denotes stages of the urban planning process, teal tools and their uses, and pink stakeholders. Insights collected from these highlighted sections were later written in a separate document.

4.2.4 Affinity Diagram

A second affinity diagram was created later in the iteration. The sources for this diagram included the interviews with three potential users, which had taken place during the iteration, along with further literature studies on urban planning, and research on the plans for the new city district Västra Jakobsberg in Karlstad. The goal was to find common themes about the urban planning process in general, the ideation phase in particular, and the role sketching plays in the early stages for urban planning. A secondary goal was to create themes for interview coding, if that would be deemed necessary in the future.

The process of creating the affinity diagram was similar to the first one described in section 4.2.1, with 72 insights written down on post-it notes. These were merged and clustered in several iterations, with headings and overarching themes created based on these clusters. The results from this diagram can be found in appendix C.

A third affinity diagram was created shortly after the second, with the intent of combining the findings of the two previous ones. For this diagrams, the cluster heading post-it notes themselves served the same role as the insight notes in the previous diagrams, and these were merged and moved into clusters. The resulting themes and merged clusters are shown in appendix C.

4.2.5 Personas

Based on the combined research, two personas were created: the main being the urban planner and project manager Lisa, and the secondary being an urban planner and urban designer called Johanna. Their traits such as gender, age, and work responsibilities were based on the people interviewed in this thesis and the analyzed interviews conducted by VirtualCity@Chalmers. Their goals, pain points, and other attributes were synthesized from the interviews and affinity diagrams. A story describing each was written, highlighting their goals and frustrations in their work, with the main points also listed as bullet points. Some essential attributes, such as software skills and sketching skills, were added on a 5-point scale in order to better separate the personas. Images were then chosen and added to make them more memorable. The resulting personas are shown in appendix D, with the highlights visible in figure 4.8.

Feedback on the personas was gathered from three of the PhD students in the HCI lab, including one specifically researching personas, and they were thus modified and rewritten to better convey the main goals and attributes of each.

4.2.6 Scenarios

To understand the place of a potential sketching interface in an urban planning ideation setting, three separate scenarios were created based on the goals of the personas. These scenarios, seen in table 4.2, were expanded to short stories. Key points from these stories were then written down on post-it notes, and a scenario analysis was then performed for each scenario.

The post-it notes were placed on a white-board, in chronological order. For each note, new post-it notes were created for each: some showing questions regarding that steps, some showing comments, and some showing ideas for how to overcome

Persona: Lisa

Lisa

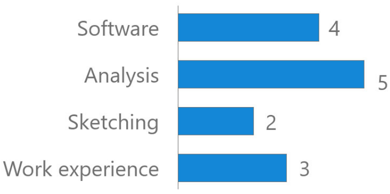
Urban planner, plan project manager

Age: 30 years

Work goals
- Guide her process to completion.
- Create different scenarios with her team and analyze them.
- Discuss with other stakeholders.

Pain points
- Collaboration with other stakeholders can be difficult.
- Too many softwares rely on experts, and they have very unintuitive interfaces.
- The steps from digital to analog to digital takes too much time and effort.
- The public doesn't always understand her work.

Skills



Persona: Johanna

Johanna

Urban planner, urban designer

Age: 25 years

Work goals
- Create several abstract city plan designs quickly.
- Combine the best from each sketch.
- Show her project leader why the final scenario is the best one.

Pain points
- Advanced software is needed.
- The software feels like a hindrance rather than an enabler.
- Too much politics involved in urban planning.

Skills

Figure 4.8: Highlights from the two personas: Lisa (left) and Johanna (right), including age, work goals, pain points, and skills. The full personas are shown in appendix D.

Table 4.2: The three scenarios, along with their main user, with the user being either of the two personas Lisa and Johanna.

User	Scenario
Lisa	Compare and select sketches for further development
Johanna	Create a new sketch based on given requirements
Johanna	Merge two previously created sketches

some of the issues. This resulted in a set of potential issues that needed answering before or while creating the interface. One of these analyses can be seen in figure 4.9.

4.2.7 Storyboards

For each of the scenarios, a storyboard was created consisting of 3-6 images and a short description of each. They focused on the interaction between users and the interface, as well between user and user. These storyboards were very rough, as seen in figure 4.10, but still resulted in several questions and insights: for example, “what is a good physical size of the input area?” and “how can I make sure everyone can see what’s being sketched?”.

4.2.8 First Set of Guidelines

Based on the research performed in this iteration, a first set of sixteen guidelines could be completed. These were still vague in nature, but would come to be concretized during the coming iterations. For each guideline, an explanation was created, and a number assigned depending on which sub-research question it was believed that it would help answer. The guidelines synthesized in this iteration are shown in table 4.3.

- Number of new guidelines: 16
- Number of removed guidelines: 0
- Total number of guidelines after this update: 16

Table 4.3: The sixteen guidelines added in the second research iteration.

Guideline	Explanation
Keep it 2D	Urban planners don’t use and don’t want to use 3D sketches in the early stages. Limit the number of dimensions to two.

Abstraction over details	Sketches in the ideation phase are abstract and rough, with areas drawn rather than individual buildings. Keep the abstraction level high.
Simple analyses are enough	Limit the interface to basic analyses that can be performed in 2D, such as estimated population.
Urban planners sketch, stakeholders view	Urban planners are the main users: design for them. However, other stakeholders might view the sketches, so decide whether a separate viewing mode could be necessary.
Let everyone participate	Collaboration in sketching shines when the users can participate. Don't limit the interface to a single user with multiple onlookers.
Sketch by hand	Many urban planners are familiar with pen-and-paper sketching, and prefer that over software interfaces. Ease the threshold to computerized assistance my allowing sketching by hand.
Draw inspiration from familiar software	The Adobe suite and tools such as SketchUp are common among urban planners. Design icons and layout so that they are recognizable to users of such software. Consider using a canvas-and-palette layout.
Follow the mental model of sketching	While this interface is digital, urban planners still have expectations on how a sketch should behave. Erasing and redrawing should be easy.
Keep it simple	Don't add too many functions. The basis is the sketch, and urban planners desire a simple interface that is easy to learn.
Analyze in real time	Performing analyses that take several minutes breaks the quick flow of sketching. If needed, limit yourself to simple analyses and simulations.
Let users compare sketches	Make it easy to compare two or more sketches based on appearance and key statistics.

Make the input area large	Physical sketches used today often cover an entire table. Aim for the same size in the digital interface, both to ensure familiarity and to enable user participation.
Allow for exploration	If the user does something unintentional, it shouldn't be the end of the world. Enable undo/redo functionality and revision history.
Different objects, different uses	The planners will need to sketch different uses, such as residential areas, parks, schools and others. Allow for different kinds of objects to be sketched.
Allow for sketch combinations	The users might want to combine scenarios. Enable copy/paste functionality.
Details and overview	Allow for zoom functionality, so that users can get a detailed view of a particular area of the sketch.

4.2.9 Planning

The coming works were planned, including deadlines for the iterations and milestones such as the final presentation. These deadlines, shown in table 4.4, were set up to help keep the work on track, but it was understood that they might change if additional research was required. The project was set to be finished at the end of study period 3.

Table 4.4: The deadlines for the various parts of the project, as set in the planning phase, compared to the actual project Gantt chart of figure 4.1.

Activity	**Deadline**
Prestudy (first research iteration)	4 November
Planning report	2 December 2
Second research iteration	9 December
First design iteration	30 December 30
Second design iteration	27 January 27
Third design iteration	24 February 24
Presentation	22 March 22
Final report	24 March 24

Figure 4.9: An analysis of a scenario based on a goal of the persona Johanna: blue notes are steps taken during the scenario, yellow notes are questions that have arisen from each step, orange are comments, and pink are ideas.

Figure 4.10: A frame and description from a storyboard showing a possible scenario for comparing two sketches in a sketching interface, here in the form of a table. The level of detail of the storyboard is made with deliberately low fidelity.

4.3 Third Research Iteration

Week 50 - 51, Singapore

While only two research iterations were planned, as seen in table 4.4, there were still blind spots in the collected data. Most pressing, data about an actual project had not been collected, and data on how sketching could be used in combination with technological solutions was still lacking. It was therefore decided to conduct a third research iteration, consisting of more literature review, a user interview, and updating the scenarios and personas, all leading to an updated set of guidelines.

4.3.1 Literature Study

In order to better understand how sketching can be used in combination with technological solutions, several papers such as “Back to Basics: Sketching, not CAD, is the Key to Improving Essential Engineering Skills” (Hilton, Gamble, Li, Hammond, & Linsey, 2018) and “Digital Sketch Modelling: Integrating digital sketching as a transition between sketching and CAD in Industrial Design Education” (Ranscombe & Bissett-Johnson, 2017) were researched. These papers, recommended by Professor Fjeld as well as found by the means of their interlinking references, provided insights into the role of sketching in conjunction with modern software tools.

4.3.2 Interview

One of the subjects previously interviewed (U8) had mentioned that she would be willing to be interviewed again if needed, and was therefore contacted for a second interview. This semi-structured video-call interview, lasting approximately one hour, was conducted to delve deeper into specific projects she had worked on, and to find out details about the ways she and her colleagues work. For this reason, this interview can be seen as a kind of contextual inquiry: the questions were largely based on how she worked in the project, with many questions on the form of “how did you use that tool in this project?” and “what was your purpose of creating this particular sketch?”. She was not able to show me around her office, negating some of the effect of the contextual inquiry, but was able to send images of her work station, the “creative corner” of the office where most of the sketching takes place, a meeting room, and several other locations. These images were analyzed with regard to her answers and stories, in order to synthesize new insights.

An issue with previous interviews was that some remarks got lost when taking notes and later rewriting the notes to a more comprehensive summary of the interview. This interview was therefore, with the urban planner’s permission, recorded, and later transcribed to plain text.

4.3.3 Updating Personas and Scenarios

The personas were updated slightly, to better match the findings from the interview. Three new scenarios were created, seen in table 4.5, to specify tasks the urban planners perform today. These would be considered a baseline of tasks that should be able to be accomplished with the designed interface. The scenarios were based on interviews held during the research iterations.

Table 4.5: The three present scenarios, along with their main user persona.

User	Scenario
Lisa	Digitally analyze an analog sketch
Lisa	Collect input on a sketch
Johanna	Create a new sketch, based on a previously created one

4.3.4 Updating the Guidelines

Based on the findings in this research iterations, the guidelines were updated. The explanations of the previous ones were rewritten to better fit the new insights, and seven new guidelines, seen in table 4.6, were added to the set. One guideline was in turn removed, as seen in table 4.7.

- Number of new guidelines: 7
- Number of removed guidelines: 1
- Total number of guidelines after this update: 22

4.4 First Design Iteration

Week 52 - 2, Singapore

As a way to test and develop the guidelines, a first design was created. This first iteration focused on ideation of a design, based on the previous findings: selecting an idea, creating a first prototype, and testing it using HCI experts. The aim of this iteration was to create a springboard for further design development, and to test the general viability of the design idea, with a focus on creating new guidelines.

4.4.1 Ideation

As stated in section 3.3.1, there are three parts in the process of brainstorming. Since the first part, “gather facts related to the issue, and analyze any data that might help”,

Table 4.6: The seven new guidelines added to the guideline set in the third research iteration.

Guideline	Explanation
...	...
Provide assistance	Some people aren't comfortable sketching by hand. Allow for other users to help them, and provide tools to make it simpler.
Put the sketch in its context	Connect the interface to a map of the area, with the ability to view different aspects in that map.
Allow for iterative work	Enable cyclical work of sketching and analysis, and make it easy to continue on a previous sketch.
Analysis is more important than looks	These sketches are made for analyses, and it's not important that they look good.
Different analyses, different uses	Make it easy to select which analysis to display.
Early error detection	Warn the user if there could be any difficulties with the sketched plan.
Consider the available hardware	Don't rely on expensive or specialized hardware solutions.

Table 4.7: The guideline removed after the third research iteration.

Guideline	Reason for removal
Let users compare sketches	This guideline was based on a preconception on how urban planners work, but this was shown to be inaccurate.

had been completed in the previous iterations, the ideation phase of this iteration focused on the second part: “come up with, select, and combine ideas”.

The brainstorming was conducted individually, in three sessions, focusing on different parts of the interface. These were based on aspects deemed important to create a first version of the interface, namely:

1. What is the physical design of the interface, including interaction methods?
2. How can areas and other objects be created within the interface?
3. How can the interface provide help with error detection using urban planning analysis?

These sessions each consisted of two 15-minute long sub-sessions, with a break in between each for analysis of the synthesized ideas. In total, 20 ideas for ideation question 1 were created, 23 ideas for ideation question 2, and 20 ideas for ideation question 3. These ideas were then transferred from the post-it notes on which they had been written to a digital spreadsheet.

4.4.2 Idea Selection

The third part of brainstorming is to “verify the ideas and select which set to implement”. While many of the ideas from the brainstorming sessions could be implemented in tandem, several were mutually exclusive: this showed the need of proper idea selection. Furthermore there was a fear that some ideas might hinder the design rather than help it, and these therefore needed to be properly identified and discarded. Weighted matrices were created in this step, to help select the most viable ideas.

One matrix per brainstorming session was created in a Google spreadsheet. The ideas were assigned to one axis, with one column each. As selection methods, the last set of the design guidelines was used, and the guidelines were thus assigned to the other axis. Each guideline was given a weight, to estimate how important it would be for the specific idea category. The weights were on a scale of 1-5 from least to most important, with guidelines removed completely if they were deemed irrelevant for the particular session.

For each idea, a number of 1-5 was assigned for each guideline, seen in figure 4.11, based on how well it was deemed to conform to the specific guideline. This value was in turn multiplied with the weight of the guideline, providing a total conformity sum for each idea. The sums were color-coded to highlight the ideas with highest score.

4.4.3 Low-Fidelity Prototype

Based on the ideas and their corresponding weighted matrices, a first prototype was created. This was made in the form of a paper prototype, in order to find potential design flaws and issues as early as possible. Paper and black markers were chosen, to keep clarity high and the fidelity low so the user could focus on the parts important

Guideline	Weight	Idea =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	17	19	20
Keep it 2D	4		5	3	2	5	5	5	5	5	5	5	5	5	5	5	1	5	1	5	5	2
Let multiple users provide input	3		4	4	4	4	3	5	3	4	2	3	2	2	3	4	3	1	4	1	4	2
Sketch by hand	5		2	5	2	3	5	5	1	1	5	4	5	3	4	1	2	1	2	3	3	5
Follow the mental model of sketching	4		1	3	2	3	3	4	1	1	5	3	4	3	4	1	1	1	2	3	4	5
Keep it simple	5		4	2	1	3	4	4	4	2	3	4	4	3	3	3	1	3	3	2	3	4
Make the input area large	3		1	5	5	2	4	4	2	5	4	2	4	4	4	1	4	2	4	3	2	2
Different objects, different uses	5		5	1	5	5	1	1	5	2	2	5	5	3	4	2	3	4	4	4	4	4
Details and overview	4		2	4	4	4	3	2	5	2	2	5	3	2	3	1	3	4	3	4	2	2
Keep the price down	3		5	1	1	3	4	5	4	1	5	4	3	4	1	2	2	4	3	2	2	1
		Sum	29	28	26	32	32	35	30	23	33	35	35	29	31	20	20	25	26	27	29	27
		Weighted sum	117	110	102	130	127	136	121	87	131	144	145	115	127	79	77	101	102	111	118	116

Figure 4.11: A weighted matrix based on the first brainstorming session: each idea has been given an index 1-20, seen in the top row, and a score based on how it well it corresponds to the guidelines in the left column. The color-coded weighted sum for each idea, seen in the bottom row, is the sum of each score multiplied by the corresponding guideline weight.

for the experiments. The prototype was made in the size of a common A2 paper format, roughly imitating the size of a large screen, and at this point designed for single-user or dual-user use, with the size of the screen allowing for a secondary user to provide verbal and visual input. Inspiration for graphical details and layout was taken from similar sketch tools, such as Adobe Illustrator and SketchUp, the related work described in section 2.2, and UI guidelines such as the ones proposed by Buxton (2007) and Cooper et al. (2014). Divided into the five dimensions of prototype fidelity proposed by McCurdy et al. (2006), this prototype would follow table 4.8.

Table 4.8: The fidelity dimensions of the low-fidelity prototype.

Dimension	Level
Level of Visual Refinement:	low
Breadth of Functionality:	medium
Depth of Functionality:	medium
Richness of Interactivity:	low
Richness of Data Model:	low

Four tasks were selected, which should be able to be completed using the interface, chosen based on the previously created scenarios in tables 4.2 and 4.5:

1. Create a new sketch, and add an area and a road based on a created target sketch
2. Delete an area of a sketch
3. Copy two areas of a sketch, paste them in another sketch, and move and scale them to a new location
4. Determine the simulated traffic noise level at a given part of a sketch

Each of these tasks was broken down into smaller actions, between three and nine each, allowing for a modular paper prototype to be constructed. Since the prototype was created based on allowing these four specific tasks to be fully completed, the result was a shallow but deep prototype.

4.4.4 Usability Evaluation with HCI Expert Subjects

As a means to test the usability of the design, the prototype was put to an expert evaluation. Five HCI experts (S1-S5), none with urban planning experience but all with hand sketching and data visualization experience, were recruited for the task. All of these had previously read through the information sheets of the personas Lisa and Johanna, and were asked to role-play as urban planners during the tests. Before the experiment, each participant was briefed regarding the urban planning ideation process and shown urban planning maps (appendix F), as well as interviewed for their knowledge in areas such as urban planning, sketching, and digital sketching interfaces, using a self-reported value on a five-point Likert scale.

The test took the form of a think-aloud usability test, combined with cognitive walkthrough. The paper prototype was controlled by the means of Wizard-of-Oz, with the setup seen in figure 4.12. In each experiment, the user was assigned the four tasks described in section 4.4.3, one at the time, interacting with the paper prototype using simulated touch and a Microsoft Surface stylus. While thinking aloud, their voices were recorded, with pen-and-paper notes taken if the users did something interesting that was not conveyed by their talking. A protocol for cognitive walkthrough, with boxes for each of the four cognitive walkthrough questions shown in section 3.4.2, was completed as the tasks progressed. The users were free to ask any questions regarding the domain and what was possible to do in the interface, but had to rely on the interface itself to complete the tasks. After each experiment session, a brief structured interview was conducted, to gather any additional comments regarding layout, interaction, and other opinions about the interface.

The recordings were studied closely after the experiments, with any observations deemed interesting transcribed into a document. These observations were then combined with those taken during the experiments, and insights from the cognitive walkthrough report regarding intuitive and non-intuitive steps.

4.4.5 Updating the Guidelines

A total of 324 observations were recorded in the experiments and then cleaned into 194 main observations. An affinity diagram was created from these, seen in figure 4.13, in order to find common themes and insights. Many of these observations were very specific to the prototype, or only mentioned by a single user. Several, however, were mentioned by multiple experiment participants, indicating more pressing issues.

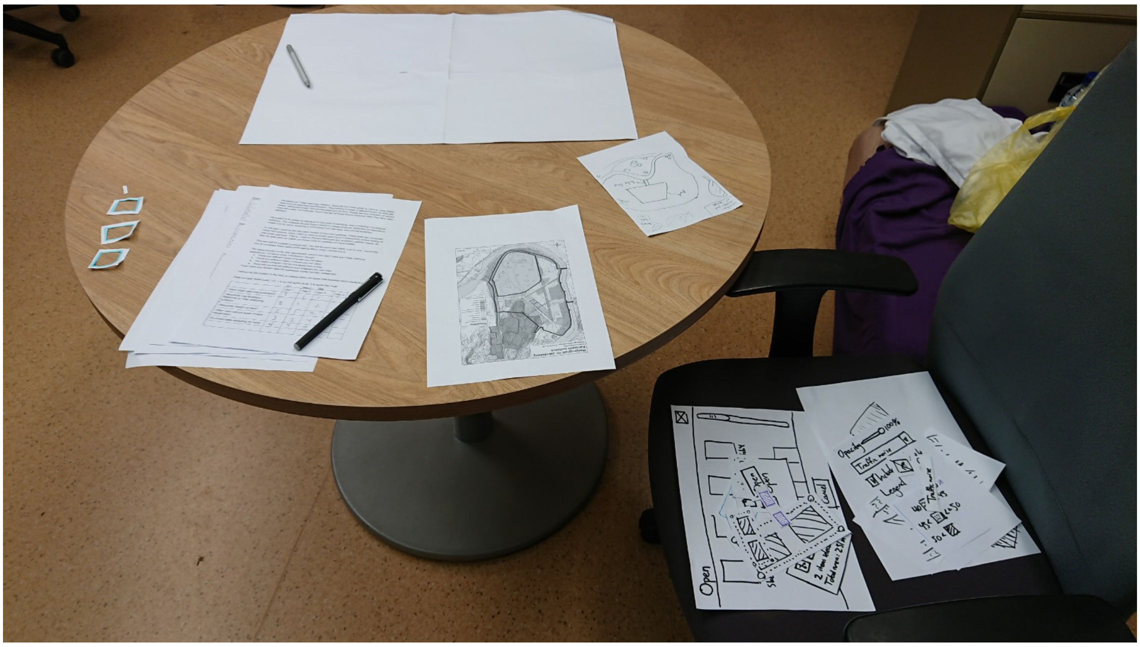


Figure 4.12: The setup for the first paper prototype experiments from the facilitator's point of view: the user interacts with the A2 paper at the far end of the table, while the facilitator determines what is being shown by placing the appropriate paper sketches, a few of which are seen in the lower right and far left parts of the image, on top of it. Meanwhile, forms, at the close left of the table, are completed by the facilitator. A program plan map of Västra Jakobsberg, shown to the users before the test, is also visible on the close right part of the table.

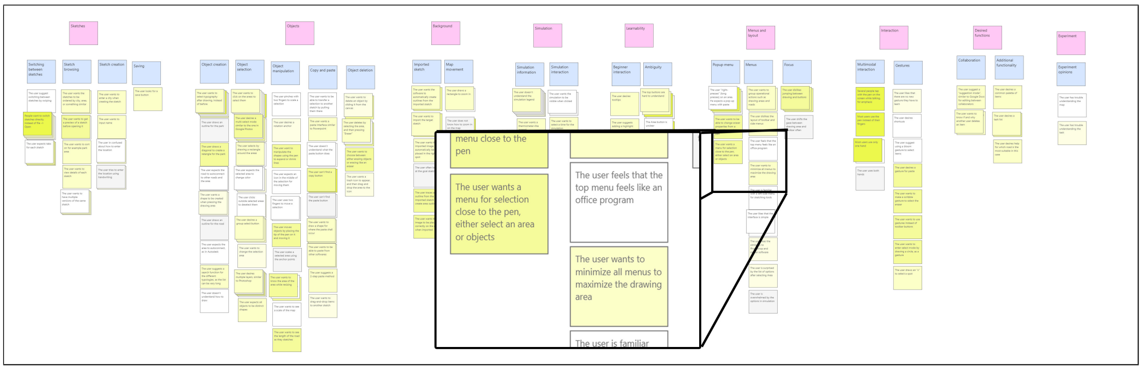


Figure 4.13: An affinity diagram created from the observations provided by the experiment in the first design iteration: 324 observations were culled and merged into 194, each seen here as a yellow or grey post-it note. The shade of the note denotes from which source the observation came. The observations were again merged into 114 insights, which were grouped into 23 categories (blue post-it notes) and 9 themes (pink post-it notes). A box shows a zoomed-in view of a few of the notes.

These merged observations were then gone through one by one, to see how they could support current guidelines, oppose them, propose the creation of new guidelines, or alter previous ones. Additional care was given to the observations or issues mentioned by several participants. With these and previous insights in mind, nine new guidelines could be created, shown in table 4.9, and added to the guideline set. The explanations of previous guidelines were rewritten to make use of the new insights, and several guidelines were altered to combine the new findings with the old. It should be mentioned that several observations and suggestions were discarded, for example that two users suggested adding a task list, as this was seen more as a comment specific to the evaluation and not relevant to the research questions.

- Number of new guidelines: 9
- Number of removed guidelines: 0
- Total number of guidelines after this update: 31

4.5 Second Design Iteration

Week 3 - 5, Singapore and Sweden

In the previous iteration, the focus had been on establishing the basic design concept, as well as evaluating the physical design, layout, and interactivity of the interface. From that iteration, the set of guidelines was updated and expanded. This revision of guidelines was then used for updating the interface design, in a second design iteration, with an aim to evaluate what kinds of objects were needed in the interface, how to create them, and how simulation could assist the ideation phase. This aimed to both evaluate and update the existing guidelines as well as create new ones.

So far, the only evaluation of the interface has been made with HCI experts. While their expertise in user interfaces helped evaluate whether the system was interactive and usable, target users would still have to be consulted in order to find if the interface met their needs. This iteration therefore included four user evaluations, divided into two sessions. Further, an evaluation with an urban simulation expert was conducted, to understand what kind of analyses would be feasible to implement.

4.5.1 Updating the Design

Based on the new guidelines in table 4.9, brainstorming was conducted to ideate changes to the design. This took place in three 15-minute sessions, with an aim to come up with as many ideas as possible to help change the design to better fit the new guidelines. Some ideas were not the result of the new guidelines, but rather changes based on the old guidelines; these ideas were not discarded, but instead acted as further input in the brainstorming. After these sessions, a total of 44 new ideas concerning improvements and changes to the design were created.

Table 4.9: The nine new guidelines added to the design guideline set in the first design iteration.

Guideline	**Explanation**
...	...
Layer the sketch	Users expect all shapes to be distinct, rather than a single 2D sketch. Put each object in its own layer.
Object-based selection	Users behave as if the objects are distinct. Make it possible to select a shape by pressing it, perhaps using a special select tool.
Provide immediate manipulation feedback	Show feedback such as area when re-sizing an object.
Build on hand sketches	Make it possible to import images, such as previous sketches, for the user to reference and trace. Keep these as separate background layers.
Exact information extraction	Make it possible to select a specific point to receive simulation information, rather than relying on just an overlay.
Stylus-central menu	Let the user focus on the drawing area. Provide a menu close to the tip of the stylus when long-pressing, for selecting pen mode, pasting, and other.
Multi-manual interaction	Users will likely mainly use the stylus to interact, but some will use their other hand to access menus. Allow for both stylus and finger sensing capability.
Expert shortcut gestures	Consider implementing stylus gestures, such as erasing or selecting, for expert users. Keep the menus for novice users.
Thoughtful menu grouping	Group object manipulation options close to each other, and high-level options at another place, to help the user find the correct alternatives.

Since some ideas were conflicting, and there was a concern that not all changes would result in an improved design, a new weighted matrix was created. The parameters used in this matrix were how many users in the tests of section 4.4.4 noted the issue, how well the change would correspond the overall design guidelines, and how likely it was deemed that each of the two personas would appreciate the change. This weighted matrix acted as a priority list on which changes to include.

In addition to this, direct feedback from the expert evaluation that was not part of any guidelines, such as the meaning of some icons being unclear, led to several changes in the new design, provided that they did not contradict any of the guidelines.

4.5.2 Medium-Fidelity Prototype

The changes selected from section 4.5.1 were first sketched by hand. Together with the prototype made in section 4.4.3 these sketches formed the basis for the next design prototype, a screenshot of which can be seen in figure 4.14. In order to increase fidelity, which was deemed necessary for showing the interface design to target users, this prototype was created digitally using the design and prototyping tool Adobe XD. This allowed for both higher visual fidelity and better interaction, at the cost of a longer prototyping time. Elements from the Windows UI toolkit (https://docs.microsoft.com/en-us/windows/uwp/design/downloads/) were used, together with icons from Google (https://material.io/tools/icons/), to provide a relatively high degree of visual fidelity. Colors from the VirtualCity@Chalmers web page (https://virtualcity.chalmers.se/) were used as a color scheme for the interface, and typologies and their related colors were taken from the program plan of Västra Jakobsberg (figure 4.6) to be used for the different typologies. The one task involving simulation visualization borrowed its analysis design from the noise level report made for the development of Västra Jakobsberg (Andersson, 2018). A 27-inch computer monitor served as the hardware of the prototype, its size (2010 cm^2) being close to that of an A2 paper (2495 cm^2). Divided into the five dimensions of prototype fidelity, this prototype would follow table 4.10.

Table 4.10: The fidelity dimensions of the medium-fidelity prototype.

Dimension	Level
Level of Visual Refinement:	medium
Breadth of Functionality:	medium
Depth of Functionality:	medium
Richness of Interactivity:	medium
Richness of Data Model:	low

The prototype centered around five tasks, the number chosen to be a combination of covering a large portion of the interface and being able to complete a single user test in approximately 30 minutes. The tasks were selected on three criteria: they should

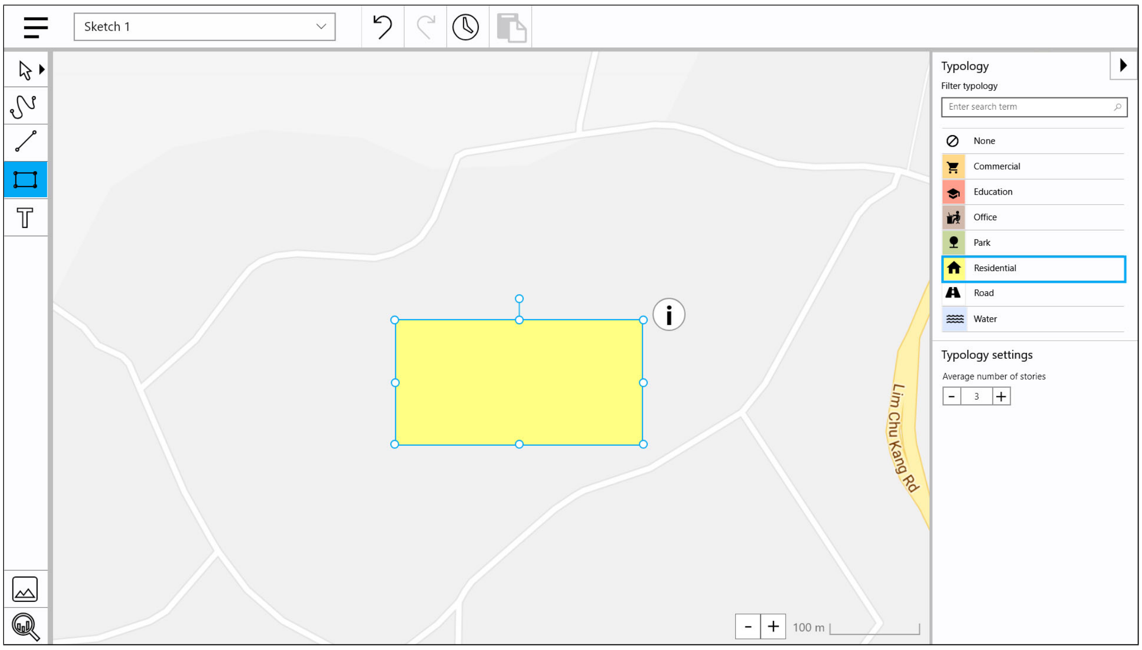


Figure 4.14: A screenshot of the second prototype, showing some of the components of the interface. Compared to the previous version, the prototype has significantly higher visual fidelity.

either test changes made after the previous design iteration, be part of the scenarios in tables 4.2 and 4.5, or help the personas reach their goals.

From this, the following five tasks were selected:

1. Draw a sketch consisting of a residential area and a road, connecting the area to the existing road network (the user got to see a reference picture as an example)
2. Copy two areas from one sketch and add them in a particular location in a second sketch (the user was instructed which items should be copied and where to place them, to ensure that several stages such as multi-selection were tested)
3. Explain to your colleague, for example by leaving a comment, on why you placed those two areas there
4. Retrieve the simulated traffic noise value from a specific point in the sketch
5. Find and open the sketch that has the most park area

The interface prototype was created to allow for each of these tasks to be completed in a step-by-step manner. In order to allow for the user to try to click on various elements, and to make the tasks compatible in several different ways, multiple branching paths were created for each task. An overview of a task showing these branching options can be seen in figure 4.15.

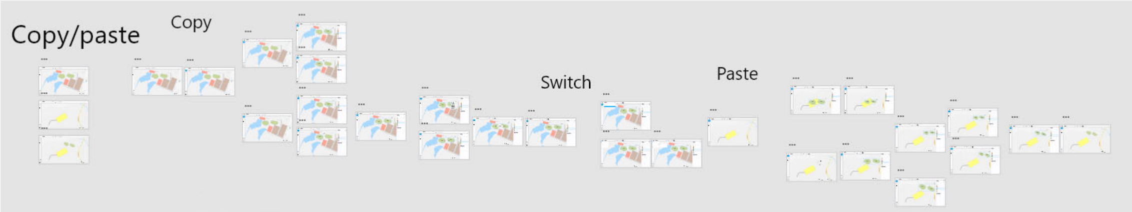


Figure 4.15: The second task of the prototype: copy two areas and paste them in another sketch. Each rectangle is a screenshot of the interface, with the screenshots ordered by approximate time on the x axis. Multiple screenshots on the y axis indicate that the task can branch out, allowing for different ways to complete it.

4.5.3 First User Evaluation Session

Two urban planning experts (S6, S7), both working at a research facility for urban planning in Singapore, were contacted and agreed to evaluate the prototype. Both subjects had previous experience in creating program plan sketches, albeit only S6 had done so professionally. Both S6 and S7 had created such sketches by hand, and S6 also had used software such as Adobe Illustrator to create digital program plan sketches.

The user evaluation took place in the office of the subjects, and used the Wizard-of-Oz setup shown in figure 4.16. Both subjects were introduced to the thesis project, and given background information about the problems it aims to solve. They were also informed by the process of usability testing, the think-aloud protocol, the Wizard-of-Oz technique, and how it was envisioned that they should be able to interact with the interface (using either their fingers, the stylus including its right-click function, or a combination of both). Both subjects were then asked to give verbal consent to be recorded, as well as to participate in the study.

Following this, the five tasks described in section 4.5.2 were performed by one user at a time, with the audio being recorded using a smart-phone and the facilitator making notes of any noteworthy non-verbal cues. While many different paths had been prepared in the prototype, the subjects sometimes strayed off the intended path: in these cases, the user was asked to either explain their thought process and what they expected to be able to do, or the sketch shown to the user was quickly altered in an ad-hoc manner to allow for the new path. After the tests, a brief interview was conducted with each subjects, with them being asked to provide additional feedback on the interface, such as elements they found unintuitive, elements they found helpful, and whether they would like to see any changes. These comments, too, were recorded. The recordings were later transcribed, with particularly noteworthy spoken-aloud thoughts added to a spreadsheet. Observations made by the facilitator were also added.

Both subjects expressed generally favorable views of the interface, and had the opinion that it could help the early stages of urban planning. However, they suggested several alterations, additions, and deletions. For example, S6 was confused over how the different typologies fit in under the line and polygon tools, respectively, and S7 stated that it would be beneficial later in the process to visualize height data. The various statements and thoughts of the subjects, together with observations made during the tests, were considered as changes to the interface and design guidelines, and are analyzed in section 4.5.7.

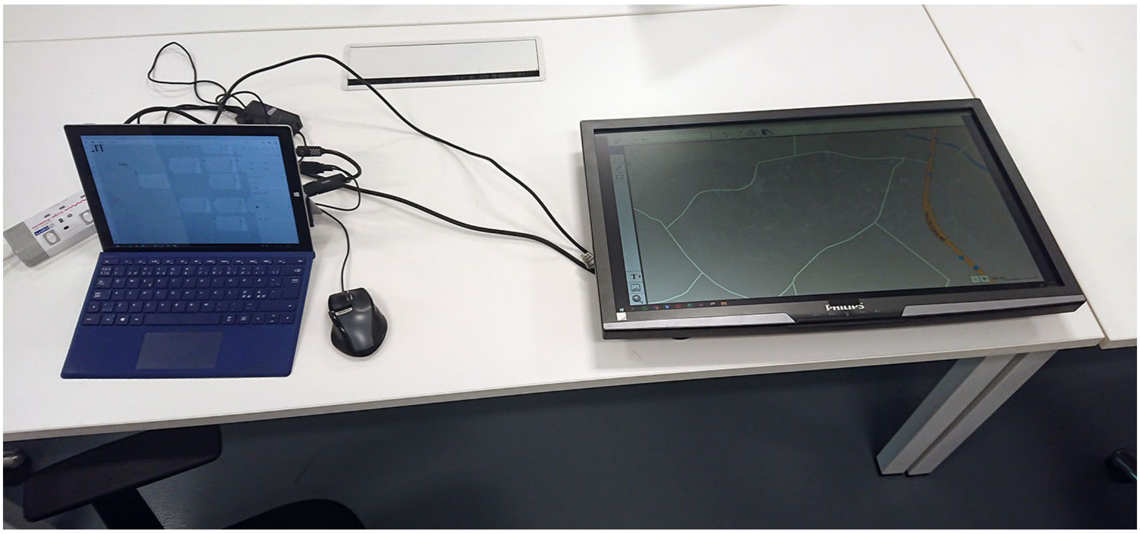


Figure 4.16: The setup of the second prototype: the user sits at the table and interacts with the right-hand screen. The facilitator controls what is shown on this screen from the computer in the left of the image, by selecting one of multiple pre-made interface screenshots or by changing the current view.

4.5.4 Updated Prototype

It was discovered that some aspects of the current prototype did not sufficiently test the guidelines, due to unclear task formulation task or that an insufficient amount of branches for unexpected user behavior had been created. The prototype was therefore altered slightly for the second user evaluation: for example, in one task the user had to rotate two selected areas to match a target picture. However, neither of the previous test subjects noticed the rotation, being too slight from its original position, and this rotation was therefore made more exaggerated (figure 4.17). Additional parallel paths were also added for the task, to consider alternative ways the subjects might take to complete them. No larger changes were made, in order to ensure that the same views and interactions tested by S6 and S7 could still be tested in the second user evaluation session.

4.5.5 Domain Expert Evaluation

To enable data of a higher fidelity in the last prototype iteration, an expert in urban simulations (S8), working with VirtualCity@Chalmers, was consulted. The current interface design was explained to him, and he was thereafter able to provide input on what kind of simulations would be feasible to connect to it given the relatively high

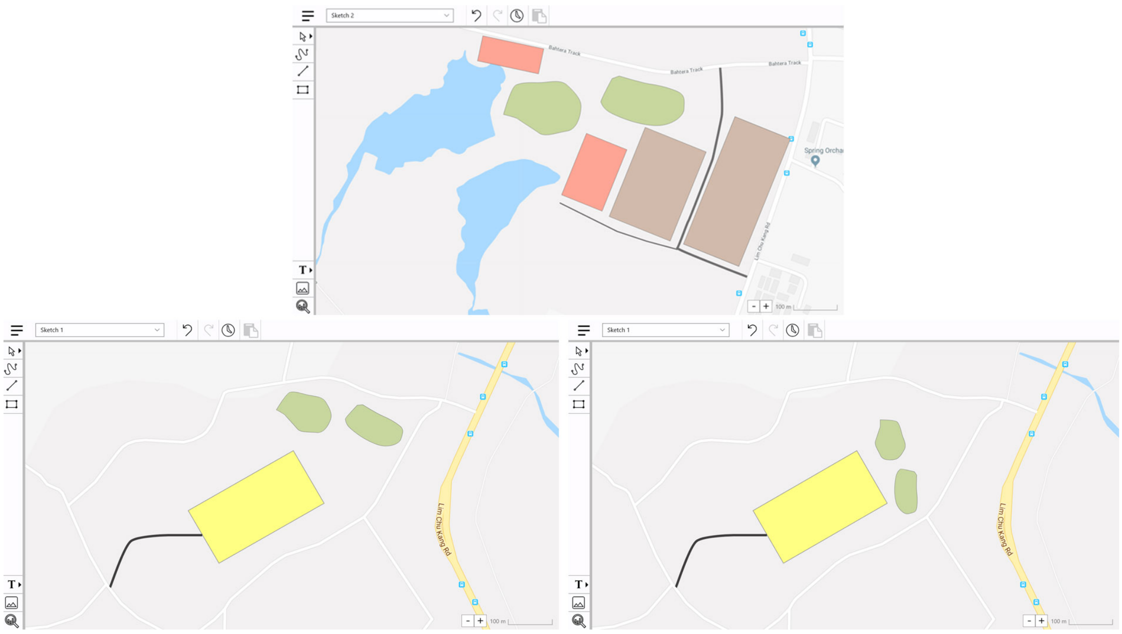


Figure 4.17: In one of the tasks of the medium-fidelity prototype, the user was asked to copy the two green areas of Sketch 2 (top) and place them as indicated in Sketch 1 (bottom left). However, the users had difficulties noticing the rotation of the areas. The position of the green areas in the reference image was therefore altered (bottom right) for the second user evaluation session.

level of the sketches. The expert stated that as of now, only wind simulation would be possible to conduct via VirtualCity@Chalmers, but real-time noise, flooding, traffic, and other simulations would work at this scale and are planned to be implemented at VirtualCity@Chalmers in the future. The interface would also have access to rules such as how many people would fit into a building, the spacing between different houses and between houses and streets, and other similar data.

4.5.6 Second User Evaluation Session

Two urban planning experts (S9, S10), working at a private sector urban planning office in Sweden, were contacted and agreed to an evaluation of the interface prototype. The setup, tasks, and procedure were the same as in the previous user evaluation (section 4.5.3), except for being conducted in Swedish rather than English. Both of the participants had previous experience in creating program plan maps, but only S9 had done so professionally. Both subjects had created sketches by hand as well as digitally, using tools such as Adobe Illustrator, with S10 stating that she more-often sketches using analog than digital tools.

The evaluation took place in the office of the subjects. The observations made by the facilitator and noteworthy observations from the recordings were transcribed and added to the spreadsheet created in the previous user evaluation.

Both subjects expressed mostly positive views of the design regarding object creation and manipulation, but did stress that the connection to both the underlying coordinate system and the simulation needs to be clear for it to stand out against other sketching applications. S10 mentioned, for example, that her work flow would benefit from seeing additional details about the area distribution, while S9 would like to manipulate the background map more than is possible in the current interface. In general, S9 expressed more mixed feedback, however, much of this was regarding implementation details. This might indicate that he thought the interface was more complete than it actually was, and that I therefore did not explain the test clearly enough.

Example on positive feedback

- The interface is very simple and clean.
- The interface is easy to use.
- The stylus-touchscreen solution works well.
- The fast analysis would be very helpful in a real project.

Example on negative feedback

- It's too difficult to see which sketches are open. A tab-like system would be good.
- It's unclear from where the data for the simulation comes.
- Showing terrain on the map is necessary to evaluate road placement.
- There is no setting for more detailed simulation options, which would be needed to get a sense of security on whether a certain object placement would work.
- The "browse sketches" window is unnecessary and just adds confusion.

4.5.7 Updating the Guidelines

133 observations were transcribed from the user evaluation sessions, and were added to a virtual post-it wall in Adobe XD. An affinity diagram (figure 4.18) was created from the observations, to merge similar ones and to find common themes.

This affinity was then reviewed one set of post-it notes at a time, with regard to the current set of guidelines. For each new insight, one or more guidelines could be altered to make use of the new information. Some insights were highly specific to the interface, rather than any of the guidelines, and were also considered too specific to create guidelines from: for example, all subjects had issues finding the copy button in the current interface design. Insights similar to this were therefore considered when updating the interface design (section 4.6.1), but not added to the set of guidelines. Similarly, some observations were highly related to the back-end part of the perceived application (which suggests that some users believed that the prototype was more

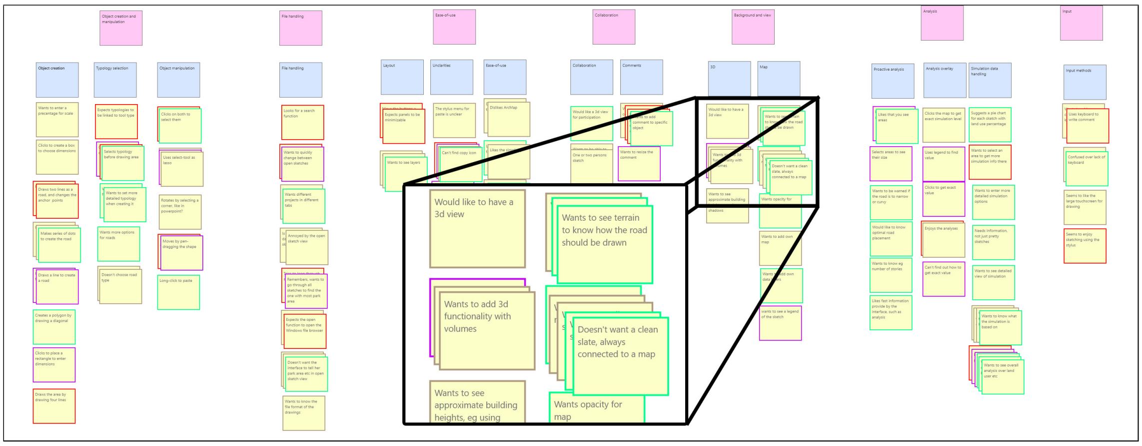


Figure 4.18: An affinity diagram made from the 133 observations made during the user evaluations of the second design iteration. The border color of the yellow post-it notes (observations) denotes in which evaluation they were recorded. The observations were merged into 80 insights, grouped into 15 categories and 7 themes. The box shows a zoomed-in view of a few of the notes.

advanced than was the case), such as the file format that would be used for the sketch data. These observations were also not added to the set of guidelines, as they were not considered to be interface design related observations.

Several guidelines were affirmed by the comments of the subjects, while others had to be rewritten to make use of new information. This could be, for example, that while the urban planning experts mostly work in 2D, they would like to view the sketch in 3D, too, especially for collaboration between different user categories such as urban planners and architects. In addition to the alterations of previous guidelines, five new guidelines, seen in table 4.11, were added.

- Number of new guidelines: 5
- Number of removed guidelines: 0
- Total number of guidelines after this update: 36

4.6 Third Design Iteration

Week 5 - 8, Sweden

The purpose of this iteration is to evaluate the design guidelines synthesized during the previous iterations, by the means of a high-fidelity prototype of an interface based on them. This prototype was evaluated in three stages: first in a heuristic evaluation with four HCI intermediate experts (S11-S14), second in a domain expert evaluation with four researchers (S15-S18), and third in a user test with four urban planning experts (S19-S22).

Table 4.11: The five new guidelines added to the guideline set in the second design iteration.

Guideline	Explanation
...	...
Allow for temporal collaboration	Make it possible to add comments for collaborative use, linked to specific objects. These should preferably be entered with a (virtual) keyboard.
Design for a touch-screen	Use a stylus and a horizontal touch-screen as primary input methods. However, consider adding a keyboard, either physical or virtual, for shortcuts such as Ctrl-C for copying.
3D in a 2D world	Make it possible to change the average building height for building areas, either via a detailed setting menu for the typology, or via a 3D mode.
General analysis	Show general land use division of the sketch, as well as total road length for different road types.
Divide by use, not by tool	Divide the typologies by lines (e.g. roads) and polygons (land use), rather than enabling the creation of areas by selecting a line tool. This can instead be a setting in the polygon creation tool.

4.6.1 Updating the Design

In order to find out how to update the design, a brainstorming session was conducted. This had the new set of guidelines as input, and was performed in three 15-minute iterations. 47 ideas were generated, believed to improve the design based on the guidelines. These ideas were then judged in a simple weighted matrix, based on the perceived benefits they would have for the interface design based on the guidelines, and acted as a priority list on how to update the design. Additionally, several items were changed based on feedback from the user evaluation sessions even though they did not consist of any guidelines, such as the copy button being hard to find: the button was placed next to the paste button, with text added to distinguish between the two.

Inspiration on how to include sub-typologies was taken from the OpenStreetMap (https://www.openstreetmap.org/) editing tool, which was suggested by S7. Other UI decisions, such as the placement of buttons for zoom functionality, were also inspired by this website, with the rationale that is a relatively well-known tool and that no previous research on map button placement had been made in this thesis.

4.6.2 High-Fidelity Prototype

A third prototype was created for the final user and expert evaluations. To achieve a higher degree of interaction, as well as a more refined visual aspect, the prototype was created as a web application using the Vue (https://vuejs.org/) JavaScript framework, along with patterns and add-ons such as VueX (https://vuex.vuejs.org/) and Bootstrap (https://bootstrap-vue.js.org/). Icons and other visual elements were either supplied by databases such as Font Awesome (https://fontawesome.com/), free-to-use Vue components, or created using Adobe Illustrator. This allowed for a higher visual fidelity, which can be seen by comparing figure 4.14 with figure 4.19, and divided into five dimensions of prototype fidelity the prototype would follow the levels show in table 4.12.

Table 4.12: The fidelity dimensions of the high-fidelity prototype.

Dimension	Level
Level of Visual Refinement:	high
Breadth of Functionality:	medium
Depth of Functionality:	high
Richness of Interactivity:	medium
Richness of Data Model:	high

The app was created with separate facilitator and user modes, to be used with a Wizard-of-Oz setup. The facilitator could that way emulate stylus presses made by the user, as well as select images to be shown in the canvas part of the interface

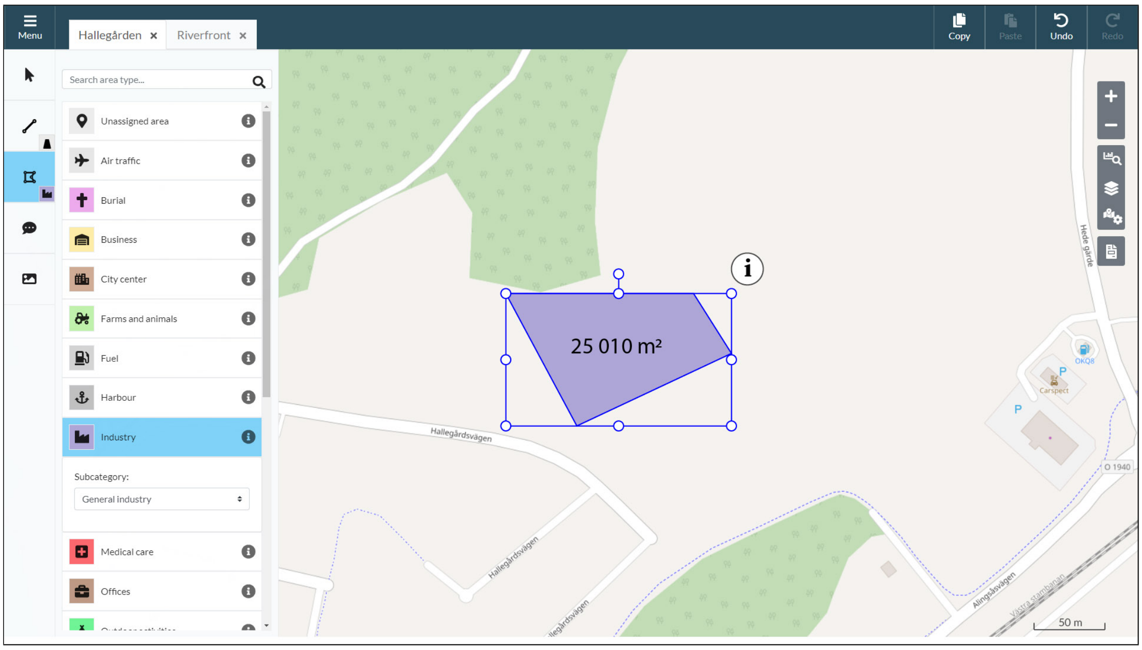


Figure 4.19: A screenshot of the high-fidelity prototype, during the first task in which an industry area recently has been created. Compared to a similar screenshot of the medium-fidelity prototype in figure 4.14 there are some notable changes: for example new icons, a tab system, changed button placement, among others.

(figures 4.20 and 4.21). This was done to mitigate the need to develop a real sketching application, which was deemed not possible to create given the short time-frame.

Unfortunately, due to technical limitations, it was not possible to synchronize drop-down menu presses or tool-tips; for this, the facilitator had to move the mouse over to the user's screen to press and click, adding a slight delay to those operations. Due to time constraints, a complete sketch software was not created for the prototype; however, the interface consisting of menus, tool and mode selections, tool-tips, stylus menus, layer options and more was created with high functional fidelity and was made close to completely interactive. Furthermore, due to material shortages, a 23-inch screen was used in lieu of a 27-inch screen.

To ensure correct object types, Boverket's guide to the Swedish urban planning laws (Boverket, n.d.) was studied. From this, correct land typologies (Boverket, 2018), road types (Boverket, 2016b), and street types (Boverket, 2016a) were added to the prototype, along with the colors used by Boverket and the Swedish transport administration Trafikverket (Trafikverket, n.d.). For the background map, topography data was retrieved from a public online map provided by the Swedish mapping, cadastral, and land registration authority Lantmäteriet (Lantmäteriet, n.d.-b). As Lantmäteriet does not permit distributed use of the map for a resolution of less than 200 meters (Lantmäteriet, n.d.-a) and the resolution for the maps in the prototype were 100 meters, the topography lines were hand-traced from the 200 meter resolution and placed on top of screenshots of free-to-distribute maps from OpenStreetMap. The map locations themselves were chosen to not be directly linked to the cities in which either of the test subjects reside, as to keep the evaluations as unbiased as possible. Map guidelines

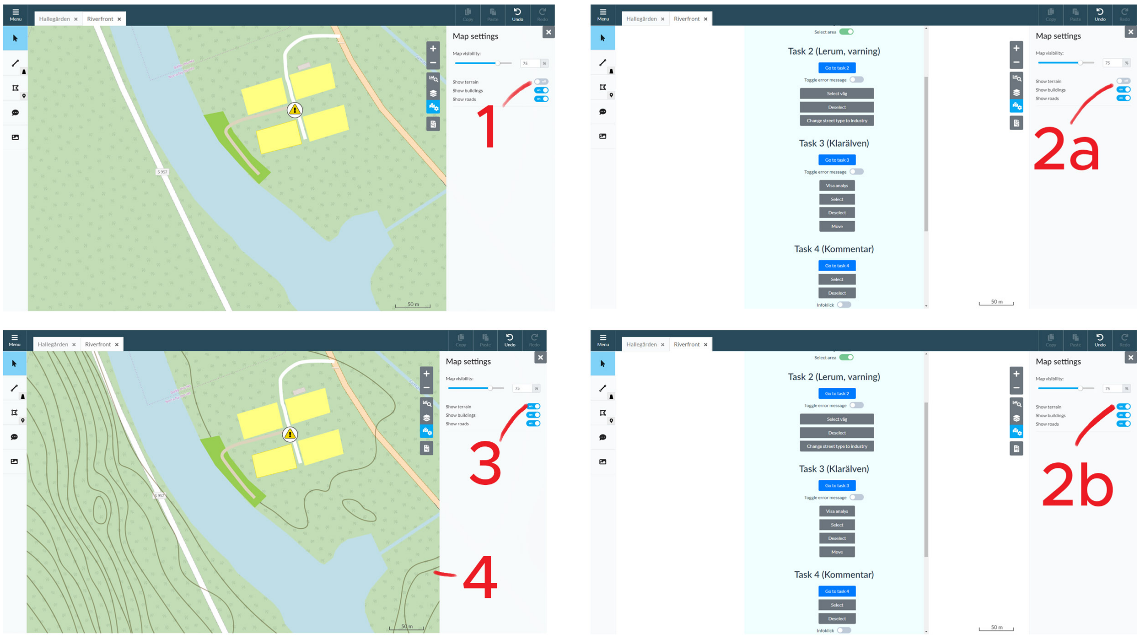


Figure 4.20: Four screenshots of the high-fidelity prototype: the user's view is to the left, the facilitator's to the right. The user presses the "Show terrain" toggle button (1). The facilitator toggles the same button on their screen (2a, 2b), resulting in the button being toggled in the user's screen, too (3). The terrain data layer is then shown to the user (4). This button and the other functionality that make up the palette parts of the interface (for example, the tool menus) are the same in both modes, and are synchronized using VueX and the local storage of the web browser.

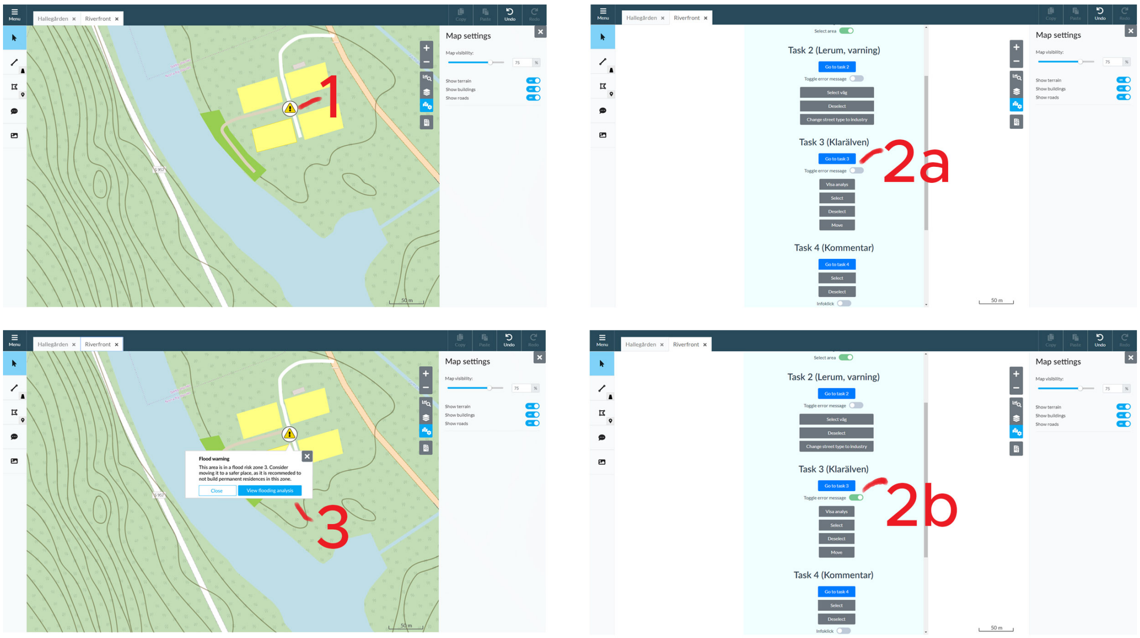


Figure 4.21: Four screenshots of the high-fidelity prototype: the user's view is to the left, the facilitator's to the right. The user wishes to see more information about the warning, and thus presses the warning icon (1). The facilitator toggles a setting on their screen (2a, 2b), which shows the warning message to the user (3). Note that there are several options in the center of the facilitator's view, each relating to something the user can do within the central canvas part of the interface.

from a flooding risk and analysis report (Ivarsson, Offerman, & Valen, 2011) were followed for the flooding simulation overlay, but not overly strict since the simulation visualization is not part of the scope of this thesis.

These decisions, together with simulations deemed feasible by the expert consulted in section 4.5.5, allowed for high data model fidelity; however some of the topography lines were altered to better facilitate the prototype, hinting, for example, where a road should be placed.

Five tasks were selected to be completable in this prototype. These were based on both the previous scenarios developed in this thesis, as well as the interviews that took place at the end of the previous user evaluation sessions. Generally, they aimed to cover the core features of the design, and thereby evaluate the design guidelines.

1. Create an industrial area, and connect it to the road network using a local street. *A reference sketch will be shown to the user, since this prototype does not have high enough interaction capabilities to actually create custom areas and lines.*
2. Find out what the error is, and what a suitable solution would be. Try to solve the issue. *The street will be inappropriate for industrial use, which will be indicated by real-time feedback.*
3. Find out which building areas, if any, risk being flooded. Move these areas to a safer location. *A new sketch, which will be pretended to be made by a colleague*

of the user, will be opened for this task.

4. Make sure your colleague knows why you moved them, for example by leaving a comment.
5. Find out the total residential footprint area in this sketch.

The prototype was designed to allow the user to deviate from the presumed set of actions by a small margin: for example, in a previous user test one subject (S10) asked if there would be topographical lines on the map. A map settings button, with a functioning topographic layer toggle button, and similar items deemed not too difficult to implement were therefore made functional. This was believed to let users explore the interface prototype in a more natural manner.

4.6.3 Usability Evaluation with HCI Expert Subjects

To find errors in the design that might impair further evaluations, four students with intermediate HCI experience (S11 - S14, all second-year students in a HCI master program) were consulted for heuristic evaluations. The evaluators were divided into pairs (S11 and S12, S13 and S14) to be able to discuss their observations. For each of the two sessions, the background, idea, and research topic of the project were explained. The evaluators then received a copy of Nielsen's ten heuristics together with an explanation of each heuristic, as well as forms for entering observations.

Following this, the evaluators were free to explore the interface, with a facilitator, who was the same as the designer of the interface, acting as a Wizard of Oz. The evaluators were free to discuss with the facilitator, for example which buttons were functional and which were placeholders. When any usability error was found, violating any of Nielsen's heuristics, the evaluators wrote it down in the form, and assigned it the relevant heuristic. After this free exploration, the evaluators performed the five tasks of the prototype, again writing down anything that violated the heuristics.

Eighteen observations were made during these evaluations, three of which overlapped between the pairs of evaluators. For two of the issues the designated heuristic differed; however, as the goal was to discover usability errors rather than categorize them, using the usability heuristics as goal, this was seen as an acceptable error. The final distributions of the errors, with account to each heuristic, are seen in table 4.13. The original observations, in Swedish, can be found in appendix G.

Seven of these violations, including two discovered by both pairs of evaluators, were remedied in time for the next evaluation sessions. Some of the changes, for example that a physical keyboard would be a beneficial addition, were seen as too time-consuming to implement. Instead, this formed a basis for observations in coming evaluations, in this particular example the facilitator then observing whether the participants would indeed prefer a physical keyboard.

The issue with the prototype now being a 23-inch screen rather than a 27-inch screen was somewhat put to ease during the session: both pairs of evaluators stated that they believed that the screen size would be sufficient, since it allowed both persons

Table 4.13: Sum of violations, per heuristic, discovered during the heuristic evaluation sessions of the third design iteration. Note that two issues have split heuristics assigned to them, due to differences between the opinions of the evaluators: the asterisks (*) found on two counts show that there is one issue that belongs to either of the two heuristics, and the daggers(†) show the same for the second issue.

Heuristic	**Violations per heuristic**
Visibility of system status	4
Match between the system and the real world	1
User control and freedom	3-5*†
Consistency and standards	5
Error prevention	0
Recognition rather than recall	1
Flexibility and efficiency of use	0-1*
Aesthetic and minimalist design	0
Help users recognize, diagnose, and recover from errors	1-2†
Help and documentation	1

in the pair to view the whole sketch (when they were sitting next to each other) while they could both reach the whole area of the screen.

4.6.4 Domain Expert Evaluation

The interface was evaluated in a pilot test with four domain experts (S15-S18), all working with the VirtualCity@Chalmers project and with the evaluation taking place in the office of VirtualCity@Chalmers. One of the four subjects (S15) had basic knowledge of the urban planning process. Two (S15, S18) reported some experience in sketching, both analog and digital, with S15 being considerably more experienced.

The main reason for performing this evaluation was to test the interface usability and the evaluation method, before testing it on the target end users. That said, the domain experts can be considered tertiary users of the system, after urban planners and urban designers, as they could use a tool for testing and interacting with simulations and models. The goal for these users would therefore not be the creation of a sketch or a map, as with the primary and secondary user groups, but instead the analysis function would be the main feature. Despite the different goals, the same tasks were used, so that the evaluations between domain experts and users later could be compared.

In the beginning of an evaluation, each subject was asked for verbal consent to participate in the evaluation, as well as to their voice being recorded. The subject was then interviewed briefly regarding their urban planning and sketching knowledge. If the user was unfamiliar with program plans, two reference maps were shown (appendix F). Following this, the goal and purpose of the interface and the evaluation were explained, as well as the think-aloud and Wizard-of-Oz protocols, and the subject was free to ask any questions. The interface, the setup of which is shown in figure 4.22, was thereafter gone through, simulating a highlight tour of the interface (for example, showing where different buttons were located and briefly stating their purposes).

The subject then performed the five tasks while thinking aloud, and with the facilitator acting as a Wizard of Oz. Following the completion of all tasks, the subject entered questionnaire determining the SUS score of the interface, either in English or Swedish depending on the preference of the user (the questionnaire can be found in appendix H). The English version used the original questions described by Sauro (2011), while the Swedish used a translation proposed by The City Office in Jönköping Municipality (n.d.). Finally, the subject was free to add any additional comments on the interface.

Several of the issues found in the heuristic evaluation did indeed turn out to be obstructions in this evaluation; most notably, the flooding analysis (figure 4.23) was difficult to interpret, with three out of the four test subjects (S15, S17, and S18) commenting on this. Despite this, the interface received an average SUS score of approximately 87 ($\bar{x} = 86.9, s = 8.3$).The individual scores can be seen in table 4.14.

One issue with the SUS method did appear, however: two subjects (S17, S18) stated regarding the first statement of the questionnaire (“I think that I would like to use this

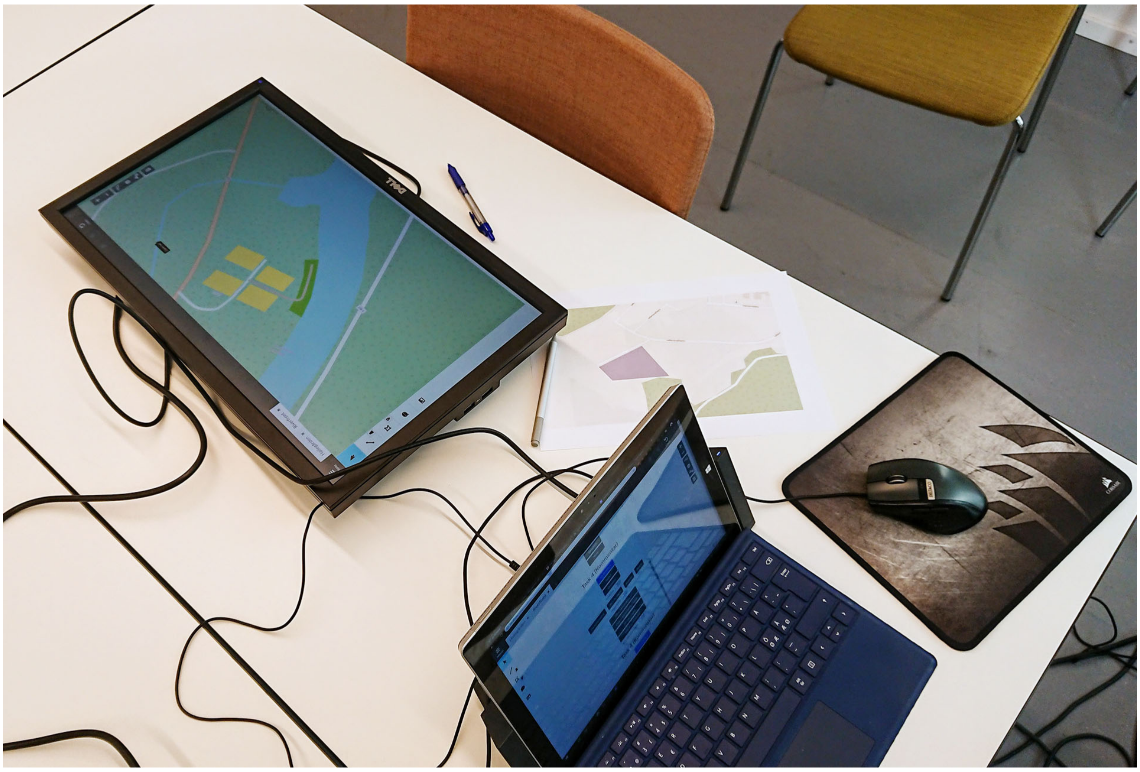


Figure 4.22: The setup of the domain expert evaluation in the third design iteration: the subject interacts with the interface, seen at the top left of the image. The facilitator sits at the bottom right of the image, giving them a full view over the interface to observe the actions of the user. A smart phone, not present in the image, was used to record the voice of the subject while they were thinking aloud.

system frequently.") that the score they provided would be the one they gave if they were working with urban planning. However, they only stated that they answered the first question this way, and as the further nine questions were more about system than domain dependent this could be seen as an exception. S16, on the other hand, explicitly stated that he would like to use this tool to "play around" with various simulations and analyses.

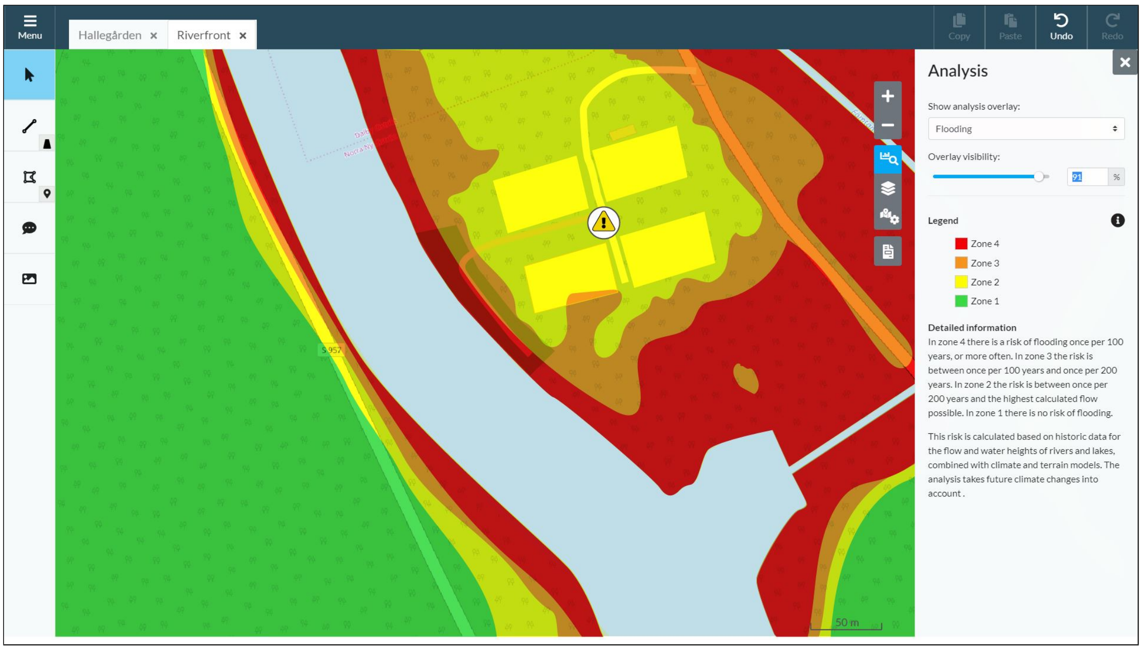


Figure 4.23: A screenshot of the flooding analysis available in the high-fidelity prototype. Due to the blend mode used for the overlay (multiply), the yellow area in the top center looked green, indicating Zone 1 instead of Zone 2. This caused confusion for several of the participants in the domain expert evaluation.

Table 4.14: The SUS scores received from the subjects in the domain expert evaluation of the third design iteration.

Subject	SUS score
S15	87.5
S16	97.5
S17	77.5
S18	85

Despite the issues found that were more inherent to the prototype than the guidelines, most notably the issue with the flooding analysis overlay, it was decided not to alter the prototype further. This was done to better be able to co-analyze the results from the domain expert evaluation and the user evaluation; if the prototype were to be altered, the results would not be comparable.

4.6.5 User Evaluation

The prototype was evaluated with four urban planning experts (S19-S22), with S19 working with the VirtualCity@Chalmers project, and S20-S22 working at a municipal urban planning office. All users had professional experience in urban planning, with a median experience of 3 years (low: 1.5 years, high: 5 years). All subjects also reported themselves as experienced in sketching.

The evaluation took place in their respective offices. The purpose of this evaluation was to get a final opinion on the interface design, and thereby its design guidelines. These urban planning experts are the target end users of the system, and thus their opinions would have a large impact on whether or not the guidelines could be considered viable.

The process of these evaluation sessions was the same as for the domain expert evaluations of section 4.6.4, with one addition: in the end of the evaluation proper, a structured interview was conducted to gauge the subjects' opinions on the interface. A Swedish translation of the questions, used when the subject preferred to do the evaluation in Swedish, can be found in appendix I. The questions in English were:

1. Where in the city planning process do you think this tool would be most useful?
2. How much time, in terms of percent, do you believe this tool could save compared to your normal work flow?
3. Would you prefer to have a keyboard, too, or is the touchscreen itself enough?
4. What is your opinion on the screen size?
5. How well would this interface work for working in pairs?
6. How helpful would it be to receive real time feedback, such as that for the street in the beginning?
7. What was the most helpful function?
8. What was the least helpful function?
9. Is there any functionality that you think is missing?
10. Do you have any additional comments?

The evaluation showed some shortcomings of the interface that had not been considered: for example, S21 mentioned how the role of an urban planner requires the user to always compromise. While there are guidelines from Boverket, Trafikverket, and other stakeholders, these cannot always be followed. As an example, she mentioned that Boverket were updating their guidelines on building construction in flooding-prone areas. The guidelines their office followed at the time of the evaluation stated that residences only can be built where the risk of flooding is once per 200 years or less, but the new guidelines instead have a limit of once per 10000 years or less often. This would exclude, she stated, a very large part of the city they plan, and is therefore not possible to follow. Likewise, some buildings might have been constructed before the 200-year limit was put in place, and removing those houses is not a possibility. While she stated that it could be beneficial to receive real-time feedback from the interface, it risks turning the situation too black-and-white. That said, S21 stated that it could still serve as a guideline in the early phase, but it would be necessary to be able to disable the warnings. If links to different sources for example flooding guidelines, or previous cases, could be added, that would be highly beneficial. S22 agreed with the overall sentiment, stating that the interface must not be too rule-driven, but rather provide suggestions for the users to consider.

Generally, the subjects agreed that the interface would be most suitable for early-stage urban planning in ideation and brainstorming, even though S19 and S22 both noted that it would also have a place in later analytical stages. S20 and S21 furthermore added that it would be a good discussion tool for usage together with other stakeholders.

All agreed that the interface would be suitable for two urban planning experts working as a pair, and that the screen size of 23 inches was neither too large or too small for that task, providing a good view of the sketch with the whole area was still reachable; however, S22 noted that the screen could be made a bit smaller to make the device more portable. None of the subjects believed that a physical keyboard would be necessary, but S19 did desire some sort of shortcuts, either using a keyboard or using stylus gestures, and S21 did welcome the idea of the interface being available for a desktop computer.

The analysis functionality, which in the test consisted of a flooding analysis, was widely seen as the most helpful feature of the interface, along with it being easy to use. The most requested missing functionality was the ability to see the sketch in 3D, with S19, S20, and S21 independently commenting on this. No user could think of any superfluous functionality, except that S19 suggested that the map settings perhaps did not need their own dedicated button.

Finally, three of the subjects (S19, S20, S22) stated that they would like to use this interface relatively frequently, giving it a score of 4 out of 5 on the first SUS statement ("I believe that I would like to use this system frequently"). S21 answered the same statement with a score of 2, but commenting as she did so that the reason she would not like to use it that much is because their municipality has developed highly advanced GIS tools for her and the other urban planners in her office to use. She however held the opinion that it would likely be a useful tool for other offices. The total SUS scores of the evaluation can be found in table 4.15.

4.6.6 SUS Score Analysis

While the SUS scores from the evaluations indicated that the true population mean of SUS scores for the interface would be above the average of 68, it was had not yet shown as statistically significant. A t-test would therefore be conducted, but since this requires input data that comes from a normally distributed sample, the distribution of the SUS scores would first have to be determined.

The scores were first plotted in a box plot (figure 4.24. This plot suggested that the

Table 4.15: The SUS scores received from the subjects in the user evaluation of the third design iteration.

Subject	SUS score
S19	82.5
S20	90
S21	90
S22	85

values of the combined SUS scores were normally distributed, given the symmetry of the box and whiskers, and a Shapiro-Wilk test was conducted to better determine whether this was the case:

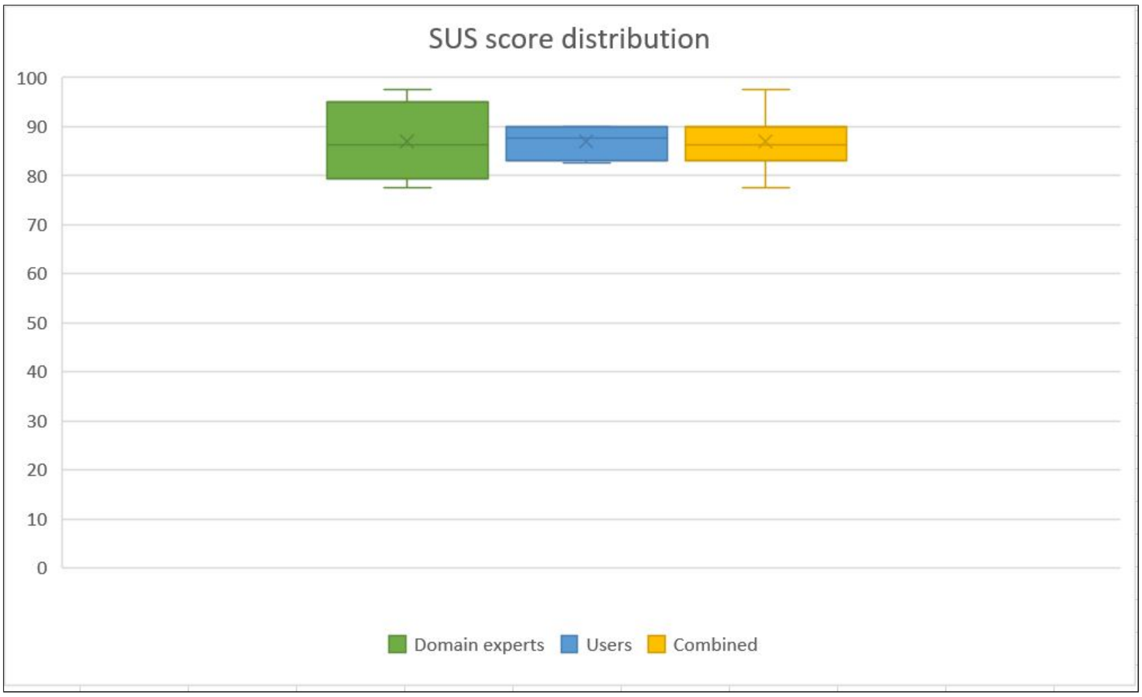


Figure 4.24: A box plot of the SUS scores of the domain experts (green), users (blue) and the combined scores (orange): the boxes contain values from the 25:th to 75:th percentiles of their respective data sets, with whiskers that extend to the local minima and maxima. The central lines represent medians, and the crosses mean values. No outliers (which would be any values further than 1.5 times the length of the box from either whisker) are present in either data set.

H_0 : the data follow a normal distribution

H_1 : the data do not follow a normal distribution

The test was conducted using the R programming language (R Core Team, n.d.-a) as shown in listing 4.1.

```
1 > x <- c(87.5, 97.5, 77.5, 85, 82.5, 90, 90, 85)
2 > shapiro.test(x)
3
4         Shapiro-Wilk normality test
5
6 data:  x
7 W = 0.97194, p-value = 0.9128
```

Listing 4.1: The Shapiro-Wilk test run in R, using all SUS scores as input. The test is part of the “stats” package (R Core Team, n.d.-a).

Given the received p value of 0.9128, seen at row 7 in listing 4.1, H_0 could not be rejected with a significance level of 0.05. It could therefore not be rejected that the SUS scores were normally distributed.

If it could be assumed that the SUS scores followed a normal distribution, a one-sided t-test could be performed to conclude whether the population mean of the interface’s SUS score (μ) was above the average SUS score of 68 by a statistically significant margin. However, as the Shapiro-Wilk test does not prove that the data is normally distributed, merely that there is not enough evidence to say that it is not, this test is to be seen as a suggestion rather than conclusive proof.

For the t-test, a significance level of 0.05 was chosen, with the hypotheses set to:

$$H_0 : \mu \leq 68$$
$$H_1 : \mu > 68$$

The relevant values were then calculated in R (R Core Team, n.d.-b) as seen in listing 4.2. As can be seen in the output code on line 7 of the same listing, the p value was $2.149 * 10^{-5}$, far lower than the selected significance level of 0.05. This implied that H_0 could be discarded, meaning that it was likely that the population mean of SUS scores for this interface was above 68.

4.6.7 Creating the Final Guideline Set

As this iteration was made to evaluate the guidelines, rather than synthesize new ones, no new guidelines were added to the guideline set. A few were rewritten, such as the one detailing screen size, to better reflect the findings from this iteration.

The guidelines were then analyzed based on their descriptions, and it was discovered that many guidelines were similar or overlapped. They were therefore grouped and merged, similarly to an affinity diagram, as seen in table 4.16. The resulting 17 guidelines can be found together with their descriptions in chapter 5.

- Number of new guidelines: 0

```
> x <- c(87.5, 97.5, 77.5, 85, 82.5, 90, 90, 85)
> t.test(x, mu = 68, conf.level = 0.95, alternative = "greater")

        One Sample t-test

data:  x
t = 8.9896, df = 7, p-value = 2.149e-05
alternative hypothesis: true mean is greater than 68
95 percent confidence interval:
 82.89707      Inf
sample estimates:
mean of x
   86.875
```

Listing 4.2: A one-sided t-test run in R, using all SUS scores and a significance level of 0.05 as input. The test is part of the "stats" package (R Core Team, n.d.-b)

- Number of removed guidelines: 0
- Total number of guidelines after this update: 17

Table 4.16: The guideline set condensed into its final version. The table shows all guidelines up to this point, and how they were merged to create the final set.

Original guidelines	**Merged guidelines**
Allow for exploration Allow for iterative work	Allow for iterative work
Sketch by hand	Consider using free-hand sketching or a line tool
Layer the sketch Object-based selection	Created objects should be distinct
2D first 3D in a 2D world Urban planners sketch, stakeholders view	Design for 2D, allow for 3D
Design for a touch-screen Let multiple users provide input Make the input area large Multi-modal interaction	Design for a large touch screen
Provide immediate manipulation feedback	Detailed information on demand

Allow for temporal collaboration	Enable comments
Build on hand sketches (image import part)	Enable image import
Allow for sketch combinations Draw inspiration from familiar software Follow the mental model of sketching Thoughtful menu grouping	Follow sketch application conventions
Details and overview Put the sketch in its context Build on hand sketches (GIS data part)	Include a customizable background map
General analysis	Include sketch statistics
Keep it simple Provide assistance	Keep it simple
Abstraction over details Analysis is more important than looks Different objects, different uses Divide by use, not by tool	Land use instead of buildings
Expert shortcut gestures Stylus-central menu	Provide a stylus-central menu
Early error detection	Provide early error prevention, to a degree
Analyse in real time Different analyses, different uses Exact information extraction Simple analyses are enough	Provide real-time analysis overlays
Consider the available hardware	Use off-the-shelf products

5. Results

The research question of this thesis was:

What should be considered when designing a sketching user interface for city planning?

An attempt to answer this question has been made, with the result being a set of 17 design guidelines. These represent the main findings of the three research iterations and three design iterations performed in this thesis, and are based on the guidelines used and evaluated by the low, medium, and high-fidelity prototypes. Note that while the design and evaluation of the prototypes play a large part in this thesis, they are not part of the result: their purpose was to help create and test the guidelines, which in turn form the final result.

To better structure the finished guidelines, they have been sorted into four categories (sections 5.1 to 5.4) based on the four research sub questions of this thesis from section 1.3. Together, these form an overarching set of guidelines for the creation of an early phase urban planning sketching interface, envisioned to be particularly used by designers who are mostly unfamiliar to the field of urban planning.

5.1 Guidelines for Design and Layout

Allow for iterative work

The planning process is iterative. It could be beneficial to show previously opened sketches, as well as previous snapshots of the current sketch, and provide a way to switch between open sketches, preferably using a tab system.

Follow sketch application conventions

Consider implementing copy and paste, erasing, undo and redo, and similar functionality common in modern sketching interfaces. The Adobe suite and tools such as SketchUp are common among urban planners, and it could therefore also be beneficial to use a similar canvas-and-palette layout.

Keep it simple

The basis is the sketch, and urban planners desire a simple interface that is easy to learn. Make it easy to get started, for example by providing a highlight tour and tooltips for novice users, and tools to help them sketch. Consider limiting the time spent on designing proprietary items, such as a file browser.

Provide a stylus-central menu

Consider a stylus-central menu, for example a flower menu, when long-pressing or right-clicking with the stylus. This will let users maintain their focus on the sketching area. This menu can include tool and type selection, which could require sub-menus.

Use off-the-shelf products

Many urban planners choose their tools due to their low cost or familiarity. Expensive and specialized hardware solutions could therefore be turned down by the users, and off-the-shelf products such as ordinary touch-screens and touch-screen styluses could therefore be better suited.

5.2 Guidelines for Collaboration

Design for a large touch screen

The screen needs to be large enough to get an overview of the sketch, as well as for two persons to view it comfortably sitting side-by-side and working collaboratively. A 23-inch screen might be seen as a well-suited compromise. A stylus for interaction with the screen could prove highly beneficial, but be prepared that the users might use their fingers instead. Stylus gestures can be considered instead of keyboard shortcuts.

Enable comments

Consider implementing comment functionality, linked to a specific object or objects. These should preferably be entered with a keyboard, rather than handwriting, as users likely will find keyboard input faster. The users would likely want the comments linked to their authors.

Enable image import

Many sketches might already be made previously, either by the user or colleagues. By enabling the user to import images for the tracing, you could help them both with collaboration between users and with transitioning from pure pen-and-paper sketches or from other tools.

5.3 Guidelines for Analysis

Display detailed information on demand

You could show basic information, such as area or length, when selecting an object, to help the user get immediate general feedback from the sketch. Consider also showing category when hovering on the object.

Include sketch statistics

Consider showing the total area of each area type, including subcategories, as well as the total length of different line types. This will likely benefit the users when performing cost analyses and further analyses later in the process.

Provide early error prevention, to a degree

Sketches and maps are used to find errors in a scenario, which could be expensive in a later stage. If your simulation allows for it, you might want to warn the user if there could be any difficulties with the sketched plan, such as a road being too curvy. Bear in mind that it could be needed to allow the user to disable this, as urban planners sometimes need to circumvent regulations.

Provide real-time analysis overlays

By providing analyses in the interface, both as an overlay as well as with detailed information extraction, you could help users sketch and analyse quickly and iteratively. You might want to limit these to simpler simulations so that they are able to be run in real-time. The user would likely know where the data comes from, as well as being able to enter their own simulation parameters such as time of day.

5.4 Guidelines for Object Creation and Manipulation

Consider using free-hand sketching or a line tool

Many users are familiar with pen-and-paper sketching, and prefer that over software interfaces. Consider to ease the use of the new tool by allowing them to create objects by free-hand sketching. Note that several users are accustomed to digital sketching tools, and might prefer to create objects using key points and curvature options similar to the line tool in Adobe Illustrator.

Created objects should be distinct

Users expect all objects to be distinct, rather than a single combined 2D sketch. Consider putting each object in its own layer, as well as making it possible to select individual objects by pressing on them. For multi-select, consider supporting multi-press as well as a lasso selection tool.

Design for 2D, allow for 3D

It could be beneficial to initially limiting the number of dimensions to two for sketching. However, some users need to add and view the height of, for example, buildings blocks for proper analysis. Consider adding a 3D mode to view this, something that also could prove beneficial for stake-holder participation. Augmented and virtual reality is, however, not highly desired at this stage, but could be an option for further participatory design.

Include a customizable background map

The interface would likely be benefited by being connected to a map, panable and zoomable, where the location should be possible to be specified by the user. Consider including, for example, terrain lines, to help the user create objects to scale and in the correct position. Another beneficial addition could be to let the user add their own GIS data layers, since each user might have different demands on the sketch.

Land use instead of buildings

Consider aiming for the creation of different land uses, not individual buildings. These could be in the form of either polygons for areas, or lines for roads, paths and similar. You might want to make it possible to select sub-categories, such as an apartment area for a residential area, which can help with more detailed analyses and visualizations. The different areas and lines could also be used as basis for object creation: a polygon tool for areas, and a line tool for lines.

6. Discussion

In this chapter, I discuss what I believe went well, what went less well, and what could be performed in the future with this thesis as a basis.

6.1 Planning

The plan proposed in table 4.4 was mostly followed. One notable change, which can be seen when comparing the table to figure 4.1, is that a third research iteration was added. This was done due to a lack of data on how a particular urban planning project could be conducted, and therefore included more research and interviews (with care taken so that no confidential information was asked for). This, in turn, let to altered and shortened design iterations, and had I remade the project I would probably have structured the research iterations to become a bit shorter and more focused rather than shortening the design iterations.

In the end, each prototype was created to a sufficient level of detail, but the work did become more stressful than it would have been with only two research iterations. However I believe that this third iteration was necessary for the thesis, or the prototypes might have started in the wrong direction, which is one of the dangers of prototyping described in section 3.4.1. Since no parallel prototyping was conducted, this could have led to wrong conclusions and guidelines that would have needed substantial rework following the user tests. While the third research iteration was time-consuming, it became a time-saver for the overall process.

6.2 Methodology and Process

Several different methods have been used in this thesis, to a varying degree of correctness and with varying results. Some steps that could have been done differently, and issues discovered when performing certain methods, are described in this section.

6.2.1 Data Gathering

As discussed in the methodology chapter of this thesis, interviews were chosen as the main research method. I believe this proved an effective way of collecting insights from several urban planning experts and other stakeholders. However, some choices in hindsight should be questioned. One is that only one interview was recorded, while the rest all used manual note-taking. This might have been positive that it allowed for a freer flow of conversation, as proposed by Wadsworth (2011). However, in several instances it was not possible to immediately follow up with transcribing the notes, meaning that it was difficult to remember all the context during the actual transcription. This shows for example during the two interviews with U8, in which the second was recorded. The transcript from the first interview was approximately 1400 words, while the one of the second was approximately 4400 words. This is despite both interviews lasting about one hour. It should therefore be examined how vital it could be to record the interviews, especially if there is only a single person interviewing and the subject is not highly personal or private.

Finally, only the second interview with U8 used some form of contextual inquiry, in that images of the office of U8 were supplied, and questions related to actual projects were asked. It was not until this interview that the actual setting of the sketching interface had been highly considered, apart from a quick remark from U2 that a portable device could be beneficial for showing sketches to stakeholders. I believe the project would have benefited from using further contextual inquiries early in the project, and studies of the actual workplaces of the interview subjects, instead of interviews taking place in a meeting room. If I had remade the data gathering phases of the project, this would indeed be the largest change: attend meetings as a fly on the wall, observe the urban planning experts at work, and ask questions directly related to the tools and methods they use.

6.2.2 Iterative Design

The type of interface changed during the process itself. In the beginning, I envisioned that the final prototype would be a TUI, connected to the VirtualCity@Chalmers simulations. When I discovered that the users didn't desire a TUI at this stage, but rather a sketching interface, the scope was changed. I still believed in a table, but further research showed that a smaller interface would be more desirable. This shows the importance of working iteratively, as I otherwise would likely have gone with my initial assumptions and designed a prototype that no-one would want, as well as involving users in the design process. Regarding the connection to VirtualCity@Chalmers, I decided to focus more on the guidelines and interface design itself, and not put too much time on creating a highly advanced prototype. I believe this decision was correct, as the final prototype proved sufficient for evaluating the guidelines.

Related to this, it could be worth asking whether the idea that was developed in this iterative manner what what the users needed, or merely what they wanted. There is a difference here: while the users did not show a particular interest in either TUI or virtual and augmented reality (VR/AR), it might be so that these tools could help them more in their work than a sketching tool. This could hold especially true in the future, if VR/AR become more accessible and commonplace. Nevertheless, an interface developed using the guidelines from this thesis could likely be iteratively modified to also include future technologies, such as adding an AR mode for a 3D view of the map.

As was shown in figure 4.3, the number of guidelines were at points very large, above 30. At the same time, their explanations often overlapped, due to trying to fit in all new data after each iteration. This made it difficult to properly brainstorm and test ideas, since there were so many guidelines to take into account. In future works, I would recommend merging the guidelines after each new addition, as performed when creating the final guideline set. This would ensure a more streamlined process when prototyping and evaluating. The reason I did not do so is simply that I didn't figure out that the total number of guidelines would be too unwieldy until they actually were, sometime in the later design iterations.

6.2.3 Analyzing the Iteration Results

Affinity diagrams were widely used in this thesis. While I believe they helped me organize the data in a meaningful manner, it should be noted that they were done with me as the only participant. The clusters and hence the guidelines could well have become different should another participant also have been present or produced the diagrams. One way to mitigate this could have been to employ another HCI expert, or hire assistance using for example the Amazon Mechanical Turk (https://www.mturk.com/). It would be interesting to know, after the final guideline set has been completed and let someone else create the affinity diagrams, to see how the biases of the individuals affect the result. The same goes for the merging of the guidelines for that final guideline set: while I as the creator believe that the merges were logical, this is not evident from an objective standpoint. This is one of the dangers of conducting a thesis alone, but which I nevertheless have tried to work around by being structured and working methodically.

6.2.4 HCI Expert Evaluations

Cognitive walkthrough was seen as an effective way to find early usability errors, before testing on actual users. However, while all subjects (S1-S5) had read through the personas, I failed to instruct them to role-play as a specific persona. This led them to tend to role-play as a mixture of the two, which might have made the evaluation less effective. While the cognitive walkthrough was only a small part of the overall evaluations of the interface, it is still worth bearing in mind when examining its results. I also discovered that these HCI experts focused on very different items compared to real users: while they commented primarily on interaction techniques, the urban planning experts focused more on content and functions, and how these relate to the process of urban planning. This is to be expected, after all, the subjects did have their varying fields of expertise, but it also shows that user tests cannot be completely replaced by expert usability evaluations.

This had the side-effect that many of the guidelines in the beginning were more focused on a general interface design rather than urban planning and sketching: for example, one guideline was that the file browser of the operating system should be used instead of creating a proprietary one, while another concerned the placement of menu buttons. These are arguably important for sketching interfaces as a whole, but not only for urban planning sketching interfaces. They therefore distracted from the research question more than they helped answer it, something which could have been avoided by selecting a more narrow set of guidelines or involving end user tests as early as in the first design iteration. In the end, these guidelines were largely merged (to one stating that general sketching application guidelines should be followed), which I believe led to a more concrete set of final guidelines.

Some issues manifested themselves during the heuristic evaluation in the third design iterations. These are most notably (1) that not all issues were discovered, and (2) that some issues were assigned different heuristics. The first issue was discovered during further evaluations, for example that the “sketch details” button was difficult to understand, even though the domain expert and user evaluation subjects did not comment on particularly many issues that the heuristic evaluators had not already found. In order to find more issues, a simple solution would be to find more heuristic evaluators: J. Nielsen (1992) describes how four novice evaluators could find, on average, a little less than 50 % of all usability errors, while double that number could find around 60 %. I believe that this number likely is higher for the heuristic evaluations performed in this thesis, since the evaluators had intermediate rather than novice knowledge in HCI, but it still shows that more issues probably could have been found.

More effectively, usability experts could have been found and used instead. J. Nielsen writes, in the same paper, that four specialists likely can find, on average, close to 80 % of all usability issues present. While it can therefore be determined that it is likely that more issues were present than were found, it is necessary to ask whether it would be worth the higher cost in either performing more heuristic evaluation sessions or finding experts. Heuristic evaluation was chosen due to its low cost and speed of finding errors; if the cost was considerably higher, it is uncertain whether the method would have been used at all (effectively reducing the number of errors found to 0). For the second issue, regarding choosing the “wrong” category, this is a rather common issue among novice evaluators. de Lima Salgado and de Mattos Fortes (2016) show that a majority of the novice evaluators in their study reported difficulties in selecting the proper heuristic, which could lead to conflicts (as it did in this thesis) for which heuristic should be assigned to each issue. Selecting a modified set of heuristics, such as the one de Lima Salgado and de Mattos Fortes propose, might have mitigated this issue. Despite this, Nielsen’s set of heuristics (J. Nielsen & Jakob, 1994) was used due to its use in previous classes in which all of the heuristic evaluators had participated; it was believed that this would make it easier for them to properly perform the evaluation.

Not all errors that were found were corrected. This is in itself an issue, which stems mostly from a tight schedule between the heuristic evaluations and scheduled user tests the week after. Several issues the heuristic evaluators found, that were not corrected in time for the coming evaluations, did indeed prove to be hindrances in the evaluations (most notably the flood analysis overlay). It is likely that I mis-prioritized some of the issues, which could have been mitigated by performing a proper analysis of time the issue would take to fix and how severe it was. As of now the only priority list was that I first and foremost aimed to remedy the issues found by both pairs of evaluators, but I had no concrete plan following that. This is a lapse of judgement that could have been avoided with better planning. One possible solution would have been to include heuristic evaluations earlier in the process, for example in the second design iteration, which would have given ample time to correct issues before creating the third and final prototype.

6.2.5 Domain Expert and User Evaluations

Not only the heuristic evaluations, but the usability tests need further reflection. One apparent issue is that I conducted all of the evaluations as the sole observer. While the tests were recorded and analyzed following the evaluation sessions themselves, and any non-verbal cue was recorded as a note during the test, it is still highly likely that some observations were lost. Jacobsen, Hertzum, and John (1998) found that it is likely that a single evaluator only can find around half of all present problems of an interface. While this is a somewhat better result than using a single evaluator in heuristic evaluation, it is by no means good. This could have been helped by bringing in a second evaluator, but since I conducted this thesis by myself I might have been too set in my ways to also conduct the observations myself and did not therefore consider this. If the usability of the design should be properly evaluated, I recommend redoing the final user test with several evaluators, or the very least let multiple people listen to the recordings. Despite this, I do believe that the tests were satisfactory, as the final evaluations were supplemented with a structured interview and SUS questionnaire.

The majority of the subjects during the user evaluation had not participated in previous user tests. Some of them, most notably U10, seemed to fail to understand that the prototype was solely a mock-up designed to evaluate the interface (or rather, I failed to properly communicate this). He instead asked technical questions, such as the proposed file types, what kind of coordinate systems were used, and similar. This might have been a risk, as some users might have focused more on technical implementations than the usability. It might be worth bearing in mind that those questions to that user, however, could seem very natural; they are vital parts of the process, to ensure that all systems function correctly when used together.

The language barrier also posed an issue during the evaluations. During two of the evaluations of the final prototype I had to help translate text (for example, one test subject though that “flood” meant river). This could have been mitigated by translating the prototype based on the native language of the subject, but this poses another issue: how will the test results differ based on the translation? The translations will likely not be perfect, and could instead hinder the evaluations. If it would have been translated, I would for consistency's sake have to translate it to English, Swedish, Italian, German, French, Czech, Greek, Korean, Mandarin, Bengali, and Sinhalese, to cover all native languages of the test subjects. English was chosen since all subjects had satisfactory knowledge of the language, and it was also assumed that several would have used for example the Adobe suite and other English-language programs.

6.3 Validity and Generalizability of the Results

To ensure that the guidelines were properly evaluated I designed, prototyped and evaluated based on them. This means that the guidelines were validated in discrete steps, with all of them being finally evaluated during the user tests of the third design iteration. It is my belief that this gives them further validity. It is however possible to argue that some guidelines were tested more than others: those developed for the first set were naturally tested more than those synthesized during later iterations, since they all were part of the prototypes. I have combated this by primarily evaluating the *new* guidelines during each evaluation, and not focusing on the old ones.

Furthermore, the guidelines were tested on a wide variety of people: urban planning experts from both the public and private sectors, with experience from Sweden as well as from other countries. I therefore argue that the guidelines will be relatively generalizable over country and sector borders. However, they are, as the scope states, only made for early-stage urban planning. It remains to be tested if the same guidelines can be used for later-stage sketches as well. I believe this will not be the case, since later sketches, according to an interview with an urban planning expert (2018-09-25) will focus more on buildings instead of land uses, which immediately counters the guideline concerning land use over buildings. Some might still be relevant though, for example the screen size and input methods. Further prototypes and evaluations need to be created for this.

As a way to see if the interface designed after the guidelines had a high degree of usability, the SUS score of the interface was determined. The average SUS score of the interface developed in this thesis was approximately 86.9, a 95 % confidence interval for μ had a lower bound of 82.9 (seen at row 9-10 in listing 4.2), which would make it easy to assume that the interface had a very high degree of usability. However, as Bangor, Kortum, and Miller (2008) state in "An Empirical Evaluation of the System Usability Scale," even though a SUS score in the 70's to high 80's is good, one cannot make the assumption that the system will be accepted in the field.

It should be noted that the SUS questionnaires were only a supplement to the think-aloud evaluations and follow-up interviews. Usability was not the primary goal of the thesis, and is in fact not part of any of the research questions. It can however be argued that an interface needs to have high usability to be desirable for the urban planning experts, as several users (for example U2 and U8) highlighted the need of a user-friendly interface.As a main form of evaluation, the opinions of the users were instead woven into the guidelines in every user test. Furthermore, the initial set of guidelines were based on interviews with targeted end users, ensuring that the guidelines are based on the needs of the users and not the whims of the designer. One question is however if the guidelines could be evaluated in some other way, if not using user evaluations and research through design. In hindsight I believe they could have benefited from being shown to an expert designer, or similar person who would have a background of both using and developing guidelines, to evaluate whether he or she would deem them helpful. I however still only believe that this should have been done as a final, confirming step, and not replace the user-centered design process.

One interesting note is that the original research question, before being changed in the end of the first research iteration, related to the design of a TUI rather than a sketching interface. Most of the guidelines could, with a little adaption, actually help answer this question, since they would be very similar to both a TUI and a sketching touch-screen interface. This might stem from the fact that a touch-pad with a stylus *is* a form of a TUI: the stylus forms the basis for the tangible interaction.

6.3.1 Missing Evaluation of Guidelines

One particular guideline was unfortunately missing from the last prototype: the one concerning a 3D mode. What a 3D mode would look like was therefore not tested. It should be noted though that the absence of this mode itself contributed to strengthening the guideline, as three test subjects commented that this was the main missing feature. Furthermore, sun and shading simulations are proposed to be a part of VirtualCity@Chalmers, and these would require some sort of height data to function properly. Therefore, if the simulations need three dimensions to function properly I don't see it as an unreasonable step for the interface to also visualize it in this way. I would therefore like to state that a 3D mode is beneficial to include, but cannot say how it should be designed; this is a project for further research.

6.3.2 Subject Bias

One overarching issue regarding the evaluations, both with domain experts and with users, is that of bias. For the domain expert evaluations in the third iteration I used people from the VirtualCity@Chalmers project as subjects. I had, at that time, shared an office with them for a month, which could lead to a situation where they would try to be nice to me personally, rather than factually evaluate the interface. Indeed, one of the test subjects (S16) asked when performing the SUS questionnaire: “I don't have to be kind to you, right?”. This issue is also present in the user evaluation of the same iteration, since one of the test subjects (S21) was a personal acquaintance of mine, and the heuristic evaluation, given that all S11 - S14 have participated in several university classes that I, too, have participated in. This must be weighed versus the benefit of those evaluations. For example, had I not contacted U21, I likely would have difficulties recruiting enough test subjects for the final user tests, as she helped put me in contact with both S20 and S22. Likewise both the heuristic evaluators and the domain experts of the VirtualCity@Chalmers team showed several issues that needed to be accounted for when performing the final user evaluations, that without those subjects might have gone unnoticed. It was therefore a trade-off between ensuring non-biased data with receiving *enough* data to either support or dismiss each particular guideline.

Similarly, there is a risk that two of the subjects (S17 and S18) misunderstood the SUS-questionnaire in part, and answered the questions in a role-playing way. That is, the first questions they answered as if they were urban planning experts (making statements such as “If I were and urban planner I would probably like to use it fairly frequently”). This could skew the result of the SUS score, and begs the question of whether SUS was a good choice for the domain expert evaluation. I believe that the answer overall is “yes”, as most questions regard general usability and are not connected to a particular field of work, but it is still worth noting that there is a slight bias for the first question for the SUS scores of that evaluation.

6.4 Future Works

By recommendation by my supervisor, I focused on qualitative studies of the users. This was done due to a belief that the time of the urban planning experts was scarce, a belief that was reinforced when I together with the VirtualCity@Chalmers team were searching for interview subjects during the first research iteration. The heuristic evaluation and SUS analysis serve as means of quantitative evaluations, but no comparison to current tools have been made, or tests to determine to what degree this interface can help the urban planners compared to their traditional methods. There is therefore a need to create a tool to test an interface based on the guidelines of this thesis versus, for example, hand sketching or sketching in Adobe Illustrator, to see if the guidelines provide a better tool than currently exists. This could mean creating a real software based on the guidelines, or a high-fidelity prototype using a real touch-screen instead of the Wizard-of-Oz approach used in this thesis.

Another interface, similar in goal and scope but *not* following the guidelines should also be created: by pitting the two interfaces with each other, this could show whether an interface following the guidelines is more usable than one not following them. This would strengthen the viability of the guidelines, and better help future sketching interface designers.

One aspect that furthermore lacks proper evaluation in this thesis is that of collaboration. This was a choice that primarily was made due to a relatively low number of test subjects in each evaluation session, and I instead chose to focus on the three research questions not concerning collaboration. Had I had more test subjects in the design iterations, especially present at the same time and place, I would have likely been able to test simultaneous collaboration and thus synthesize and evaluate more guidelines regarding the collaborative aspect of the interface.

That said, the research question regarding collaboration was not neglected; for example, the size of the screen as well as the comment functionality are highly linked to simultaneous and non-simultaneous collaboration, respectively. However, the fact remains that the interface was never evaluated for team-work, except for the heuristic evaluators working in pairs. I would recommend future designers and researchers to delve deeper into the collaboration aspect of urban planning, using the guidelines of this thesis as a foundation for continued research.

7. Conclusion

A set of 17 guidelines have been presented in this thesis as a means to answering the research question: *"What should be considered when designing a sketching user interface for city planning?"*. They have been created by answering four sub-questions of the main research question:

1. How should a sketching user interface be designed to facilitate the ideation phase of an urban planning project?
2. How can collaboration between users be facilitated in a sketching user interface?
3. How can sketch analysis facilitate the ideation phase of an urban planning project?
4. How should objects be created and manipulated in a sketching user interface?

These are all wicked problems, and in order to make an attempt to solve them a design project was conducted, to both synthesize and evaluate design guidelines. This project has followed the double-diamond process, with three research iterations and three design iterations. During the research iterations, five urban planning experts were interviewed, one twice, as well as several shorter interviews with an expert in urban planning interfaces. Interview transcripts with three other urban planning experts were analyzed. In addition to this, literature regarding both the urban planning practice and sketching guidelines have been researched, with focus on the ideation phases of urban planning and what role sketching plays. Personas and scenarios were also created and updated during the process of the project, to keep the design grounded in the findings from these three research iterations. This research acted as a foundation for the creation, and one update, of a first set of design guidelines.

In the following three design iterations, research through design has been implemented. An interface based on the guidelines was designed, with three prototypes, of increasing fidelity, created in iterative steps. Each prototype was evaluated: the first using cognitive walkthroughs with five HCI experts, the second in a domain expert evaluation with one expert and user evaluations with four urban planning experts, and the third in heuristic evaluations with four HCI master students, domain expert tests with four experts, and user tests with four urban planning experts. The main forms of user and domain expert evaluation have included the think-aloud protocol, observations, analysis of recorded material, structured interviews, and SUS questionnaires. After each evaluation the set of guidelines has been updated and revised, to ensure that they follow the needs and desires of the intended users. At the end of the third design iteration a final set of guidelines was created by structuring and combining the guidelines used for designing the interface. These have all been given an explanation and reasoning on why they should be followed.

The process included some issues, for example a risk of bias when performing the evaluations. Most of these issues stem from conscious decisions regarding the process and methods used, and there could have been larger issues if other decisions had been made. However, several items need further evaluation, most notably collaboration studies as well as qualitative studies to compare an interface based on these guidelines to the current methods of urban planning projects.

In conclusion, 17 guidelines have been presented for use by future designers, created and evaluated by the means of user-centered design, to help design sketching interfaces for city planning.

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A. Buxton's Criteria for Sketches

These are the criteria for sketches proposed by Buxton (2007):

- Quick: a sketch should be fast to make.
- Timely: it can be provided when and as needed.
- Inexpensive: it should be cheap to make.
- Disposable: as opposed to a plan, a sketch can be thrown away (but it does not need to be).
- Clear vocabulary: the style of a sketch follows set conventions.
- Distinct gesture: sketches are fluid and open.
- Minimal detail: don't show details that aren't needed in this stage of the design process.
- Appropriate degree of refinement: the sketch should not show a level of certainty that is beyond the one in the designer's mind at the time.
- Suggest and explore rather than confirm: it should allow for conversations about the design.
- Ambiguity: a sketch is intentionally ambiguous, to allow for different ways to interpret it.

B. Nielsen's Ten Heuristics

These are the ten heuristics described in "Enhancing the explanatory power of usability heuristics" (J. Nielsen & Jakob, 1994).

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

C. Affinity Diagrams from the Second Research Iteration

The first (table C.1) and combined (figure 4.5) affinity diagrams from the second research iteration can be found here.

Table C.1: The main insights synthesized in the first affinity diagram. The table does not include all 81 insights, but instead the group headings derived from clustering and merging these.

Theme	Insight
Drawbacks of today's solutions	Pen-and-paper sketches are limited
	The software used is complicated
Current state of sketching in urban planning	Collaboration is important
	Sketching is natural
	Sketches are used to explore
	Sketching is used in the early process
Desired user input	The scale is small but changeable
	Outlines need to be created
	Different uses will be present in the sketch
Sketch users	Urban planners are sketchers
	Experts and non-experts view sketches
-	Large hardware can be cumbersome
-	Real-time analysis is beneficial
-	Urban planners desire simple interfaces

Table C.2: The insight cluster headings synthesized from combining the two first affinity diagrams, with a total of 153 insights. The headings have been grouped into overarching themes.

Theme	Insight cluster heading
Work process	Rigorous site analyses are made
	The process takes several years
	The process is iterative
	The process is collaborative
	A normal scale is a city district
	The public is involved in several stages
	There are legal requirements to consider
End goals	They have to design for politicians
	A common goal is to improve the quality of life.
Software	Analysis software is complicated
	Some software is comfortable to use
	Urban planners desire simple interfaces
	The scale of a software sketch should be changeable
Physical models	Physical models are sometimes used
	Large hardware can be cumbersome
Sketching by hand	Sketching is natural
	Pen-and-paper sketches are limited
	Plan sketches are often made by hand
Sketching in urban planning	Sketching is used for exploration
	Sketching is used early in the process
Sketch content	Outlines need to be created
	The content is mainly high-level and abstract
Sketch users	Urban planners are sketchers
	Experts and non-experts view sketches
Sketch evaluation	The sketches need to be evaluated
	Real-time analysis would be beneficial
	Advanced evaluations can be outsourced

D. Personas

Two personas were created: one main persona, Lisa, described in figure D.1, and one secondary persona, Johanna, described in figure D.2. They were both based on people interviewed during the research iterations of this thesis, and updated as more subjects were interviewed.

Persona: Lisa

"I like my work, but why are there so many bottlenecks? I want software that's intuitive to use, and find a way to let me and my team communicate our ideas without hiccups."

Lisa

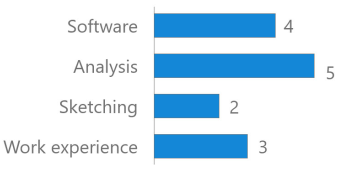
Urban planner, plan project manager

Age: 30 years

Work goals
- Guide her process to completion.
- Create different scenarios with her team and analyze them.
- Discuss with other stakeholders.

Pain points
- Collaboration with other stakeholders can be difficult.
- Too many softwares rely on experts, and they have very unintuitive interfaces.
- The steps from digital to analog to digital takes too much time and effort.
- The public doesn't always understand her work.

Skills



Lisa is one of the senior urban planners at the municipal planning agency. With six years of work experience, she often takes the role of a leader of an urban planning project. In this role, she is responsible for communication with other members within the agency, such as teams of architects as well as managers, and with the public and politicians to get approval for construction to start. She is not just a project manager, however. With experience both from her work and her city planning degree from Linköping University, she does a lot of practical work in the office. This includes going through requirements with the city management, creating sketches and designs, and discussing different scenarios with the other person who is the main responsible planner in a project. While she might not be an expert in all of these areas, she has a good grasp on most parts of the process.

For her work, Lisa employs a variety of tools. She is familiar with the Adobe suite, and frequently uses Photoshop and Illustrator to create scenarios. These programs are relatively advanced, but through repeated use she ahs gained expertise, and nowadays feels that they are rather intuitive. She also uses SketchUp for this phase, which she thinks is even more easy to use. If she just wants to try out a scenario, however, she often uses a pen-and-paper approach to create and discuss a design with her team.

When she wants to analyze the paper sketch, she uses her knowledge of the software tools to convert the sketch to a digital format. This process she feels is quite boring, since it is simple and repetitive work. She believes that there should be an easier way to do this, as she would rather not spend time on what she sees as very tedious work.

Once this step is done, the sketch can be used for analyses and simulations. Lisa does have rudimentary knowledge of CityEngine, a tool used for analysis, but she feels that it takes so long time to create buildings and scenarios in the program, and that the interface is too complicated with too many menus and options. This makes the tool off-putting, and despite Lisa's knowledge of the program she would rather not use it. The main analysis is therefore performed by other experts at the office, or handed over to external consultants.

A large part of her work involves communication with these experts, other urban planning teams, and various other stakeholders. While Lisa is an outgoing person she often think that the communication is lacking. For example, when showing a detail plan of a new area to the public they often ask what she sees as unrelated questions, and different plans have to be made depending on who the recipient is.

Due to the states of both communication and the software interfaces, she feels that her work takes more time than it should. She would rather be home in time for dinner with her husband, than spend another hour digitizing a paper sketch to find out the approximate population density. After all, she thinks that the urban planning process should be a way to help the planners, and to help create a more sustainable city.

Figure D.1: The first persona, Lisa, with goals, pain points, and work tasks.

Persona: Johanna

"Software is cool and all, but I don't want it to stand in the way of my creative process. Despite this, I still need it to understand whether a particular design would work."

Johanna

Urban planner, urban designer

Age: 25 years

Work goals
- Create several abstract city plan designs quickly.
- Combine the best from each sketch.
- Show her project leader why the final scenario is the best one.

Pain points
- Advanced software is needed.
- The software feels like a hindrance rather than an enabler.
- Too much politics involved in urban planning.

Skills

Johanna is the newest member of the office, with a fresh degree in urban planning and design from Lund University. She has only been at the workplace for one year, but did have a one semester internship during her study, in which she participated in an urban planning project in Malmö. At her new job, she is most comfortable with designing and evaluating different urban scenarios. In doing so, she participates in a lot of discussion with the other team members, and sometimes talks to architects and designers to get their opinion on the look and layout of the area. She is sometimes intimidated by the seniority of the others, but really enjoys the collaborative aspects of her work.

To create her designs, Johanna is most comfortable with a pen-and-paper approach. She has used both SketchUp and AutoCAD in the past, however, and still do if she wants to see how the buildings would look in 3D. She especially likes how SketchUp quickly lets her place different objects and create volumes. In addition to these two programs, she is also trained in using the analysis software CityEngine to evaluate her designs based on different requirements such as noise levels or traffic flow.

During her design process, she creates a multitude of scenarios as well as work on them iteratively. The goal here is to combine the best element from each scenario. Here, however, lies a problem: she prefers sketching by hand as she sees at the most intuitive way of creating a design, but there is no way for her to prove that the design works before analyzing it in a computer program. Her workflow therefore goes from digital, when researching requirements, to analog, when sketching, and back to digital for analysis. She understands that it might be quicker to just use SketchUp for sketching, but feels that she becomes too confined by the boundaries set by the software.

To Johanna, the first impression of a software matters a lot. It needs to be intuitive, and preferably good looking. Not surprising, CityEngine with its multitude of boxes, menus, and input fields is therefore far from her favorite program. Still, she uses it, since she needs to show the other team members in what way her design is a good possible solution.

Unrelated to software, she is very disenchanted when it comes to politics. She feels that politicians hinder rather than enable her work, and that too much is going on above her head that in the end impact her process. She entered the field of urban planning to improve the life of everyday people, but feels disheartened when a project might get shut down based on the whims of a politician.

Figure D.2: The second persona, Johanna, with goals, pain points, and work tasks.

E. Participant Matrices

Matrices of the participants in the research iterations (RI) (U1-U8, E1) and design iterations (DI) (S1-S22) are show in tables E.1 and E.2.

Table E.1: The participants of the three research iterations (RI).

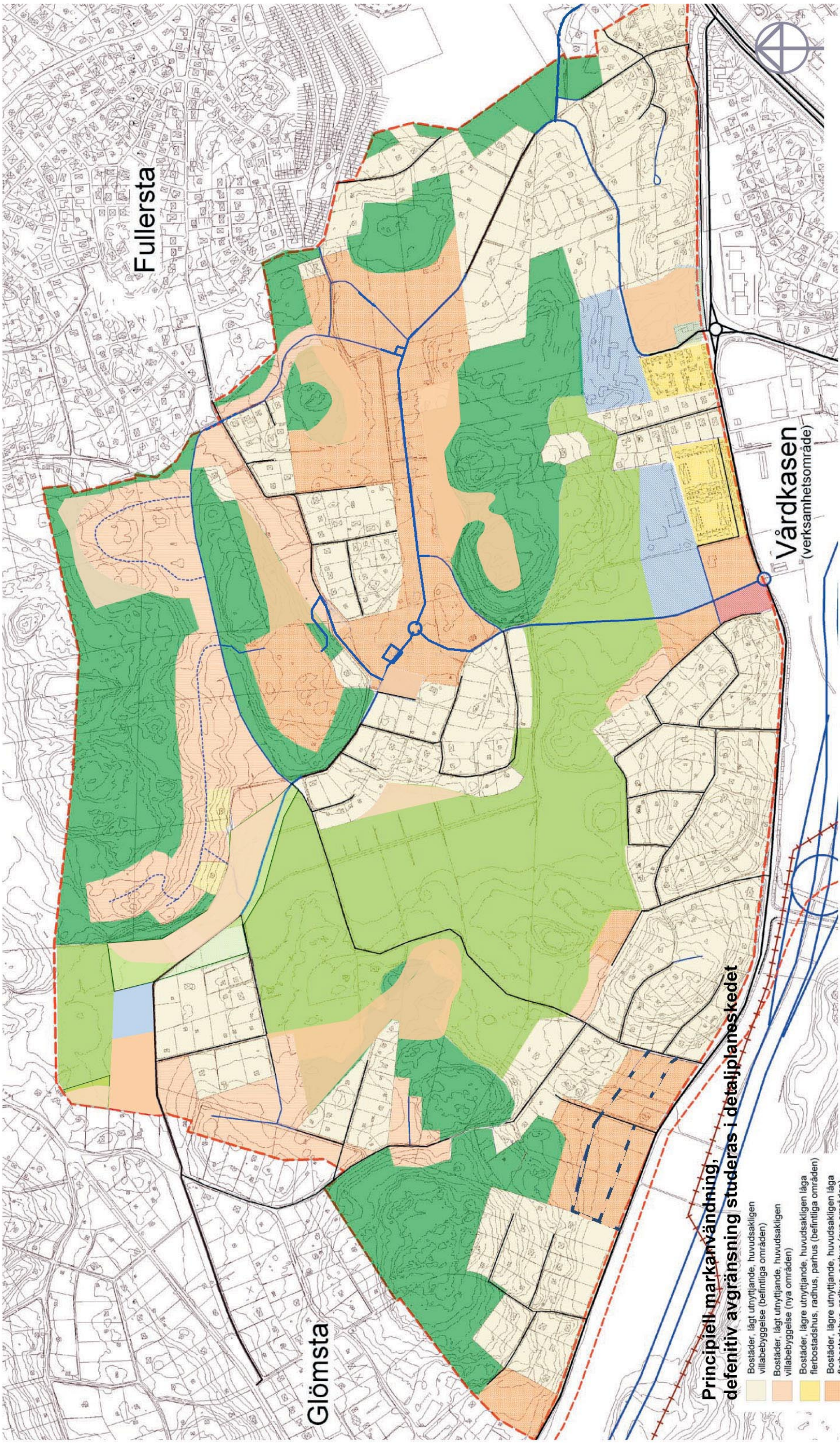
	RI1 interviews	**RI1 secondary research**	**RI2 interviews**	**RI3 interviews**
U1	×			
U2	×			
U3	×			
U4		×		
U5		×		
U6		×		
U7			×	
U8			×	×
E1			×	

Table E.2: The participants of the three design iterations (DI).

	DI1 HCI expert evaluation	DI2 user evaluation	DI2 domain expert evaluation	DI3 heuristic evaluation	DI3 domain expert evaluation	DI3 user evaluation
S1	×					
S2	×					
S3	×					
S4	×					
S5	×					
S6		×				
S7		×				
S8		×				
S9		×				
S10			×			
S11				×		
S12				×		
S13				×		
S14				×		
S15					×	
S16					×	
S17					×	
S18					×	
S19						×
S20						×
S21						×
S22						×

F. Program Plan Maps

These program plan maps were shown as examples during the evaluations, in case the subject was not previously familiar with the method. The first is a program plan map of Vistaberg, Huddinge, Sweden (Huddinge Municiptality, 2004), and the second is a program plan map of Nya Maglarps Strand, Trelleborg, Sweden (Trelleborg Municipitality, n.d.).


Markanvändning Vistaberg skala 1:6000
Huddinge kommun Planprogram maj 2002
Reviderad februari 2004
Fullersta
Glömsta
Vårdkasen
(verksamhetsområde)
0
100 meter
500 meter
Principiell markanvändning,
defenitiv avgränsning studeras i detaljplaneskedet
Bostäder, lågt utnyttjande, huvudsakligen villabebyggelse (befintliga områden)
Bostäder, lågt utnyttjande, huvudsakligen villabebyggelse (nya områden)
Bostäder, lägre utnyttjande, huvudsakligen låga flerbostadshus, radhus, parhus (befintliga områden)
Bostäder, lägre utnyttjande, huvudsakligen låga flerbostadshus, radhus, parhus (nya områden)
Allmänt ändamål
Handel och närservice
Kulturmark
Naturmark
Grönstråkets omfattning studeras i detaljplan
Ny vägsträckning, principiell
Ny preliminär vägsträckning
Befintlig vägsträckning
Reservat framtida snabbspårväg
Reservat framtida kraftledning


0
100
300m

G. Heuristic Evaluation Results

These observations (table G.1) are the results from the heuristic walkthrough performed during the third design iteration.

Table G.1: All observations, in Swedish, as written down by the four evaluators S11-S14, working in pairs.

Observation	Heuristic	Observed by
Informationsknappen vid area behöver implementeras	1	13 & 14
Rita område: behöver tydligare states. Ex dra från ena hörnet för att rita en rektangel, eller rita frihand	1	13 & 14
Svårt att veta vilken typ av väg, område, etc man valt efter man minimerat	1	13 & 14
När man väljer industri, hur vet man att man valt den pennan/verktyget?	1	11 & 12
Ha kvar senaste verktyget även om man klickar [area] samt feedback för vilket som är aktivt	1	11 & 12
Visa valt verktyg + dess inställningar	1	11 & 12
Oklart medöverlappande färger, gult blir grönt över skog. Informera om vilka zoner som är OK!	2	11 & 12
Ignorera varningen gör att den försvinner för alltid	3	13 & 14
Alternativ behövs för att kunna räkna ytor för hand, kanske något sätt att markera alla likadana ytor	3	13 & 14
Hotkeys är nice. Tangentbord generellt för att kunna snabba på arbetsflödet	3	13 & 14
Svårt att få exakt storlek med endast touch	3	13 & 14
Skillnad mellan road och street är oklar	4	13 & 14
Pie chart är otydligt. Fundera på stapeldiagram	4	13 & 14
Kanske tom använda mer stadsplanerarsnack eftersom det inte är för alla	4	11 & 12
[<] onödig om man klickar på [area]. Dra in panelen så det bara blir symboler där man kan se vilken som är aktiv	4	11 & 12
Fundera över placering på undo-knappen, ibland är den inte över artboarden	4	11 & 12
Ändra map-setting-ikonen? Map + kugghjul?	6	11 & 12
Kanske behövs accelerators och favoriter i vänsterpanelen, och/eller tangentbord	7	11 & 12
[...] vid kommentar, vad gör den?	8	11 & 12
[Ignore], går inte att ändra sig	9	11 & 12
Ev hjälpknapp? Mer najs hjälp överlag	10	11 & 12

H. System Usability Scale Questionnaires

These are the questionnaires used in the third design iteration, to determine the System Usability Scale score of the design. The questions are the ones discussed in "When designing usability questionnaires, does it hurt to be positive?" (Sauro & Lewis, 2011), with Swedish translations provided by The City Office in Jönköping Municipality (n.d.).

Please answer each of these ten statements on a scale from 1 (strongly disagree) to 5 (strongly agree). Fill in the dot that is most correct in conveying your feeling.

1. I think that I would like to use this system frequently.

Strongly disagree				Strongly agree
1	2	3	4	5

2. I found the system unnecessarily complex.

Strongly disagree				Strongly agree
1	2	3	4	5

3. I thought the system was easy to use.

Strongly disagree				Strongly agree
1	2	3	4	5

4. I think that I would need the support of a technical person to be able to use this system.

Strongly disagree				Strongly agree
1	2	3	4	5

5. I found the various functions in this system were well integrated.

Strongly disagree				Strongly agree
1	2	3	4	5

6. I thought there was too much inconsistency in this system.

Strongly disagree				Strongly agree
1	2	3	4	5

7. I would imagine that most people would learn to use this system very quickly.

Strongly disagree				Strongly agree
1	2	3	4	5

8. I found the system very cumbersome to use.

Strongly disagree				Strongly agree
1	2	3	4	5

9. I felt very confident using the system.

Strongly disagree				Strongly agree
1	2	3	4	5

10. I needed to learn a lot of things before I could get going with this system.

Strongly disagree				Strongly agree
1	2	3	4	5

Var snäll och svara på varje av de här 10 påståendena på en skala från 1 (håller absolut inte med) till 5 (håller absolut med). Gör en markering i cirkeln som bäst passar in på din upplevelse.

1. Jag tror att jag vill använda systemet regelbundet.

Håller absolut inte med				Håller absolut med
○	○	○	○	○
1	2	3	4	5

2. Jag tycker att systemet är onödigt komplext.

Håller absolut inte med				Håller absolut med
○	○	○	○	○
1	2	3	4	5

3. Jag tycker att systemet är enkelt att använda.

Håller absolut inte med				Håller absolut med
○	○	○	○	○
1	2	3	4	5

4. Jag tror att jag behöver stöd av någon teknisk kunnig person för att kunna använda systemet.

Håller absolut inte med				Håller absolut med
○	○	○	○	○
1	2	3	4	5

5. Jag tycker att de olika delarna i systemet är välintegrerade.

Håller absolut inte med				Håller absolut med
○	○	○	○	○
1	2	3	4	5

6. Jag tycker att det är för mycket inkonsekvens i systemet.

Håller absolut inte med — Håller absolut med

1 2 3 4 5

7. Jag tror att de flesta snabbt skulle lära sig detta system.

Håller absolut inte med — Håller absolut med

1 2 3 4 5

8. Jag tycker att systemet är besvärligt att använda.

Håller absolut inte med — Håller absolut med

1 2 3 4 5

9. Jag känner mig trygg i att använda systemet.

Håller absolut inte med — Håller absolut med

1 2 3 4 5

10. Jag kommer att behöva lära mig många nya saker innan jag bli produktiv med detta system.

Håller absolut inte med — Håller absolut med

1 2 3 4 5

I. User Evaluation Interview Questions

These are the questions asked during the semi-structured interviews that took place in the user evaluations of the third design iterations. There are two sets: one in English and one in Swedish. The set of questions used for subjects performing the evaluation in English was:

1. Where in the city planning process do you think this tool would be most useful?
2. How much time, in terms of percent, do you believe this tool could save compared to your normal work flow?
3. Would you prefer to have a keyboard, too, or is the touchscreen itself enough?
4. What is your opinion on the screen size?
5. How well would this interface work for working in pairs?
6. How helpful would it be to receive real time feedback, such as that for the street in the beginning?
7. What was the most helpful function?
8. What was the least helpful function?
9. Is there any functionality that you think is missing?
10. Do you have any additional comments?

The set of questions used for subjects performing the evaluation in Swedish was:

1. Var i stadsplaneringsprocessen tror du att det här verktyget skulle vara mest användbart?
2. Hur mycket tid, procentuellt sett, tror du att det här verktyget skulle kunna spara, jämfört med ditt normala arbetssätt?
3. Skulle du föredra att även ha ett tangentbord, eller är touchskärmen tillräcklig?
4. Vad tycker du om skärmstorleken?
5. Hur väl skulle det fungera att arbeta två och två i det här interfacet?
6. Hur hjälpsamt skulle det vara att få realtidsfeedback, liknande det som var för gatan i början?
7. Vad var den mest hjälpsamma funktionen?

8. Vad var den minst hjälpsamma funktionen?
9. Är det någon funktion du tycker saknas?
10. Har du några övriga kommentarer på interfacet?