Best way to go?

Intriguing citizens to investigate what is behind smart city technologies

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Abstract

The topic of smart cities is growing in importance. However, a field study in the city of Malmö, Sweden shows that there is a discrepancy between the ongoing activities of urban planners and companies using analytical and digital tools to interpret humans’ behavior and preferences on the one hand, and the visibility of these developments in public spaces on the other. Citizens are affected by the invisible data and software not only when they use an application, but also when their living space is transformed. Therefore, this thesis in the area of interaction design focuses on methods to make invisible issues, which are hidden in software and code, visible. One of these issues is the subjectivity of data and of underlying decisions that are presented as neutral facts in a user interface.

By Research through Design, this thesis examines ways of triggering discussion about smart city issues and balancing transparency and readability in visualizations. The literature suggests that transparent design makes different perspectives on an issue visible so that users are able to clearly state their position and join the debate (Schoffelen, Claes, Huybrechts, Martens, Chua, & Vande Moere, 2015). In addition, distributing the information across different layers and thereby supporting the readers’ engagement with the information step by step makes the visualization more readable (Schoffelen et al., 2015).

In this thesis, a specific solution is developed: a public, tangible, and interactive visualization in the form of an interactive signpost. The final, partly functioning prototype is mountable in public places and points in the direction of the most beautiful walking path. The design refers to a smart city application that analyzes geo-tagged locative media and thereby predicts the beauty and security of a place. The aim is to trigger discussion about the contradictory issue of software interpreting the beauty of a place. Through its tangible, non-digital, and temporary character, the interactive representation encourages passers-by to interact with the prototype. Furthermore, citizens are able to share their perspectives and change the direction of the signpost’s arrow. A linked website provides insights into the background information of the software of the smart city application. The user testing of the final prototype in the city of Malmö confirmed the potential of the interactive arrow to function as a mountable toolbox that makes people reflect, but also collects diverse opinions.
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# Table of Contents

1 INTRODUCTION .......................................................................................................................... 7

1.1 RESEARCH FOCUS AND OBJECTIVES .................................................................................. 10

1.2 STAKEHOLDERS ....................................................................................................................... 11

2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW ................................................. 11

2.1 UBQUITOUS COMPUTING AND INTERNET OF THINGS ...................................................... 11

2.2 MOBILE DEVICE AND LOCATIVE MEDIA ............................................................................. 13

2.3 ROLE OF THE INTERACTION DESIGNER .............................................................................. 15

2.4 EXAMPLES OF DESIGNS INFLUENCING THE WAY OF NAVIGATING ............................. 16

2.5 DESIGN GUIDELINES .............................................................................................................. 19

2.5.1 TRANSPARENT AND READABLE DESIGN ........................................................................ 19

2.5.2 DESIGN GUIDELINES FOR PUBLIC AND SITUATED VISUALIZATIONS ...................... 20

2.6 RELATED WORK ..................................................................................................................... 21

2.6.1 TRANSPARENT DATA VISUALIZATION ............................................................................ 22

2.6.2 URBAN RECOMMENDATION SYSTEMS .......................................................................... 22

2.6.3 DEMOCRATIZING DATA .................................................................................................... 23

2.6.4 TANGIBLE INPUT AND OUTPUT ...................................................................................... 25

3 METHODOLOGY ......................................................................................................................... 25

3.1 FIELD RESEARCH .................................................................................................................. 25

3.2 SEMI-STRUCTURED IN-DEPTH INTERVIEWS ........................................................................ 26

3.3 DESIGN PROCESS ................................................................................................................... 26

3.3.1 DESIGN MODIFICATIONS: PAPER PROTOTYPING ....................................................... 27

3.3.2 PROTOTYPING FOR THE FIELD: BEHAVIORAL SKETCH ........................................... 27

3.3.3 USER EVALUATION ........................................................................................................... 28

4 FIELD RESEARCH: EXPLORING THE PROBLEM DOMAIN ................................................. 28

4.1 EXPLORING THE FIELD IN THE CONTEXT OF Malmö ....................................................... 28

4.2 SEMI-STRUCTURED IN-DEPTH INTERVIEWS ....................................................................... 30

4.2.1 MEETINGS WITH CONNECTORS SOCIETY ................................................................... 30

4.2.2 MEETING WITH THE SALES DIRECTOR OF THE COMPANY MODCAM ..................... 32

4.3 DESIGN WORKSHOP .............................................................................................................. 33

4.4 SUMMARY ............................................................................................................................... 34
## Design Process

### 5.1 Design Exploration of Graphical User Interfaces

#### 5.1.1 Design Modifications of Navigation Applications

#### 5.1.2 Evaluation

### 5.2 Design Exploration of Public Visualizations

#### 5.2.1 Process

#### 5.2.2 Design Decisions

### 5.3 Prototyping

#### 5.3.1 Technical Specification

#### 5.3.2 Data Selection

### 5.4 User Evaluation

#### 5.4.1 Observations

#### 5.4.2 Interviews

#### 5.4.3 Results

## Discussion and Conclusion

### 6.1 Research Findings

#### 6.1.1 Interactive Signpost as a Public Visualization

#### 6.1.2 Balancing Readability and Transparency in the Designed Prototype

#### 6.1.3 Results

### 6.2 Knowledge Contributions

#### 6.2.1 Novelty

#### 6.2.2 Relevance

### 6.3 Future Directions

### 6.4 Conclusion

## References

## List of Figures

## Appendices

### Appendix A: Design Workshop

### Appendix B: Design Modifications

### Appendix C: Design Exploration
1 Introduction

Consider a city where everything is measured and crowdsourced and machines make decisions for us. Everything is optimized and efficient. Software interprets human preferences and behavior, but how it does this is invisible and mysterious. Only a few people have the knowledge to understand and fix possible errors. Some machines intrusively manipulate how people behave. Thus, these people influence other people and alternative behavior is not acted out (Figure 1).

Now, consider an alternative scenario, where people have the knowledge to understand the processes of measuring, crowdsourcing, analyzing, and interpreting data. Furthermore, it is possible for everybody to see beyond the layer of a simplified interface in order to understand how the different machines work. Citizens can offer feedback and thereby control these systems. Different perspectives become visible and valuable. Hence, cities remain places where people are confronted with the different and strange (Figure 2).

Through the developments of ubiquitous computing and the Internet of Things, sensors and software are increasingly becoming invisible and embedded in our environment (Chapter 2.1). Simultaneously, analysis and decision-making processes are becoming more and more automated and complex through automatic computing (Chapter 2.1). All in all, from the outside it is difficult to understand the inner processes. Designing opaque artifacts of which only the input and output are visible is also known as blackboxing (Latour, 1999) (Figure 3). All in all, the first described scenario seems to be becoming a reality. Nevertheless, there are different approaches to realize the second scenario, but this is not an easy task and takes time.

One problematic aspect is the increasing trust in smart city applications and data, while smart city technologies come with implications that are invisible from the outside. For instance, demographic and ambient data are used to interpret human behavior and preferences (Chapter 2.2). Thereby, it is assumed that data represent a trustworthy image. However, depending on how the data are collected, analyzed, and presented, they can support different kinds of views. Thus, demographic and ambient data cannot be accepted as neutral and indisputable facts (Chapter 2.3). Furthermore, with the help of locative data, machines should interpret likeability, beauty, and security of places, even if the data are shared by citizens without the intention to rate a location. In doing so, an objective opinion about subjective topics should be formed (Chapter 2.4). Consequently, the dividing line between subjectivity and objectivity seems to blur.
This thesis investigates the topic of navigation as a subset of human behavior and preferences in smart cities. Humans use their spatial knowledge when navigating a familiar space. This knowledge is gained by exploring the unfamiliar space and studying secondary sources, such as maps (Golledge, 1999). Both the secondary sources and the way of exploring unfamiliar spaces might change because of digitalization. Currently, there are already different kinds of navigational applications that for instance calculate the greenest, the most walkable, and the brightest path (Chapter 2.4). Furthermore, the field study and literature review conducted in this thesis show that urban designers, researchers, and companies investigate digital data collection methods to interpret the crowd flow in cities (Chapters 2.1, 2.2 and 4.2). The outcomes of sensors interpreting human behavior might influence systems that then again affect the smart city citizens’ way of navigation (Figure 1). Consequently, navigation is one example of human behaviors that can be affected by smart city technologies.

By designing a prototype of a public and tangible visualization in the form of an interactive signpost, this study explores how to contextualize the back information of a navigation application and how to capture passers-by’s attention. The arrow of the signpost points to an area with the greatest number of geo-tagged data that according to the research by Quercia, Aiello, Schifanella, & Davies (2015) describe places that are perceived to be more beautiful and safe. The goal of their research is to develop an automated and cheap method to crowdsourcing the walkability of a place. This method is developed for an application that calculates the most beautiful walking path (Chapter 2.4). The application and its backstories are one example for contradictory issues that come with smart city technologies. The aim of the prototype is to make these backstories visible on location and to evoke discussion, on the one hand, about debatable aspects that are hidden in the code and, on the second hand, about the need that citizens and users distrust smart technologies and engage in the realizations of a smart city such as in the second aforementioned scenario (Figure 2). The design of an interactive signpost was chosen so that the medium of the representation could reflect the usage of the addressed software, namely a route recommendation. The background information of the underlying method how the geo-tagged data is collected and the collected data is made accessible on a website to which the prototype links. Furthermore, citizens are able to share their perspectives both on location and online.
Fig. 1: Scenario 1: Only a few people know how to control the complexity of automated and intelligent systems.

Fig. 2: Scenario 2: The smart citizens have tools to control and communicate with the smart city.
1.1 Research focus and objectives

As navigation is a focus of this thesis, one objective of this thesis is the design of applications using urban data to influence pedestrians’ behavior. The used data sets are generated by people either through voluntarily measuring, crowdsourcing, or sharing geo-tagged data online (Chapter 2.4). In the design process, underlying information is often simplified, cleaned out, and displayed in an objective way (Chapter 2.3). Therefore, at the beginning of the design exploration, I investigate how to redesign graphical user interfaces (GUI) and thereby make the underlying processes visible (Chapter 5.1). The question is whether it is possible to indicate the subjectivity of the information and make other perspectives visible.

Besides, this thesis examines how to trigger discussion about contradictory issues that are hidden in software and code in the context of a city in Sweden. To make processes understandable and accessible and thus transparent for citizens, information needs to be displayed where the data are relevant (Vande Moere & Hill, 2012). Therefore, the main objective of this thesis is intriguing citizens to investigate what is behind smart city technologies with the help of public visualizations. The format of a public visualization is chosen in order to reach the common citizens in their everyday lives and to focus their attention on an issue they otherwise would not deal with. When making a contradictory issue visible and accessible, the visualization should be both transparent and readable. Therefore, another research focus is to find a balance between readability and transparency. The literature suggests that a transparent design visualizes backstories and different perspectives and offers the user the possibility to trace the source of the information so that hidden issues become visible (Schoffelen, Claes, Huybrechts, Martens, Chua, & Vande Moere, 2015). According to Schoffelen et al. (2015), a first step of readability is to enable the user to engage with the shown information (Chapter 2.5.2).
All in all, this master thesis focuses on how issues behind designed smart city data and software can be made visible in order to trigger discussion and thereby balance transparency and readability in their visualization.

1.2 Stakeholders

The topic of this thesis involves different groups: designers, companies behind smart systems, urban planners, and citizens. For this thesis, interaction designers provided insights into blackboxing in the design process and how to develop a readable and transparent design. The collaboration with other interaction designers was needed as each designer sees the material in a different way and constructs a unique design world (Schön, 1992). As part of the field research, the sales director of the company Modcam, which develops an intelligent camera system, was interviewed (Modcam, n.d). Furthermore, a local non-profit organization called Connectors Society, which sees itself as a Department of Public Spaces, was involved in the whole process of this thesis (Connectors Society, n.d). Through its interest in different kinds of data collection methods for planning public places, the organization could offer feedback from an urban planner’s and designer’s perspective. Finally, it is citizens who are the most affected by automated systems and sensed data-based decisions. Therefore, citizens of Malmö were also involved in the evaluation of the final prototype, the interactive signpost. The main aim of this thesis was to gain a deeper understanding of the problem domain. As this thesis was only a short-term project, citizens were only involved to a limited extent.

The following sections provide an overview of theory and potential design solutions and introduces related work. Afterwards, the methodology is presented. Chapter 4 then summarizes the results of the field research in order to gain a deeper insight into the context of this thesis. The design process of the final prototype is presented in detail in Chapter 5. Finally, the discussion and conclusion relate back to the theory and the research focus, and clarify whether this thesis contributes to the area of interaction design.

2 Theoretical framework and literature review

2.1 Ubiquitous computing and Internet of Things

Concepts that have been essential for software and hardware to become increasingly invisible for the end-user are ubiquitous computing and the Internet of Things (IoT).
Weiser’s (1991) concept of ubiquitous computing describes technology that is interwoven with the material of everyday life. Knowing the user’s situation, such as location, should enable technology to work in the background and thus to demand less active attention by the user. Furthermore, computers are leaving their traditional form of being in a case and are designed for a specific task (Weiser, 1991). The technical evolution of sensors and wireless communication has increased computers’ knowledge of the user and made ubiquitous computing a reality (Vande Moere et al., 2012).

In the case of IoT, technology is integrated in physical objects. “Connecting physical things (...) through a network will let them take an active part in the Internet, exchanging information about themselves and their surroundings” (Bandyopadhyay & Sen, 2011, p.49). Urban IoT products are designed for the urban space and to make the smart city vision a reality. Therefore, urban IoT infrastructure and gathered data should be used to provide new services, optimize the infrastructure of the city, support authorities in the decision-making process, and inform citizens about the city’s current status (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014). By enabling smart cities to immediately adapt to the circumstances, it should become possible to handle problems of the growing and chaotic cities (Townsend, 2013). In his foreword, Townsend predicts that instead of urban managers and planners, dashboards and predictive models will manage cities in real time (Foth, 2009).

According to Roberts (2014), all tracked data and modern technology can be used to improve the decision-making process, if we find ways to solve challenges such as incompleteness and uncertainty of the information and the inability to make good and fast decisions. For instance, during the Northeast Blackout of 2003 in the United States and Canada, quick reaction was needed, but the operators were missing essential information (from the system) about what was happening to be able to make a decision. Therefore, Roberts believes that a self-healing function should be implemented following the concept of automatic computing (Roberts, 2014). Automatic computing was termed by an IBM researcher and refers to seeing computer systems as biological systems (Rokosz, 2003).

Different research projects by both universities and companies demonstrate that sensing and analyzing data and invisible automatic computing are increasingly becoming part of decision-making processes and urban planning. For instance, the company Siemens envisions that, initially, the collection and analysis of data will support decision-making. Then, by 2060, it will be normal for it to function totally autonomously (Gold, 2015). This shows how important it is to find methods to visualize and democratize what is happening inside the black box. An
example of a project on which universities, municipalities, and companies are working together is the *Array of Things*, which is a network of boxes equipped with sensors that are mounted on street lamps in Chicago (*Array of Things*, 2016). By combining the information tracked by sensors on our body and in the environment, a new level of information gathering has been reached (*Wired*, 2014, 00:15). Consequently, for a data-based decision-making process, not only data tracked by sensors embedded in the environment are relevant. Much information about people’s behaviors and preferences can also be gained using mobile devices, as described below.

2.2 Mobile device and locative media

Mobile devices play an important role in urban IoT. On the one hand, mobile devices can be used to interact with physical objects and the whole system. On the other hand, through GPS tracking, context-related data can be gathered (Zanella et al., 2014). So-called locative media describes media and information mapped to a specific location (Greenfield & Shepard, 2007). Locative media is used among others for wayfinding applications, for adding digital content to a physical space, and for supporting social interaction (Gordon & de Souza e Silva, 2011). By geo-tagging invisible traces in varying forms of media, others can again retrieve the information and gain new insights into a place (Humphrey & Liao, 2013). Through locative media and mobile devices, the space itself changes. The dividing line between physical and digital space becomes blurred (de Souza e Silva, 2006).

Because annotative locative media offers the user new possibilities of adding and exploring information about a specific place (Nitins, & Collis, 2013), it becomes important when interpreting people’s behavior and preferences. Therefore, research is exploring ways to gain social and cultural insights into the usage of a place using geo-tagged media. Hochman and Manovich (2013) focus on *Instagram* pictures geo-tagged in cities. In their study, they explore ways of visualizing the pictures in order to gain a better understanding of people’s activities at a specific place at different times (Hochman et al., 2013; Figures 4 and 5). Besides this, there is also research about potential visualization tools developed for spatial planners. The tool *FlowSampler* should help to gain knowledge about the flow of people based on geo-tagged social media data (Chua, Marcheggiani, Servillo, & Vande Moere, 2015). However, according to the researchers, it is crucial to know that not all perspectives are represented and that irregular posts carry too much weight in the visualization. For this reason, the tool enables the urban planners themselves to explore the visualization by changing the settings of the interface (Chua et al., 2015; Figure 6).
All in all, the amount of collected data and the use of digital data in the analysis of human behavior and preferences are growing. One use case is the flow of people and the usage of urban spaces. However, locative data present a subjective view of things. Furthermore, other kinds of data are not objective either. At the interaction15 conference, Danielle Malik quoted a data scientist from Facebook as stating, “you can make data say anything you want it to” (Interaction Design Association, 2015, 14:23). This becomes problematic when using data to interpret but also to influence human behavior. For instance, Shen, Tsutomu, and Tsukamoto
(2016) investigate how to control the crowd flow in case of an event by changing information presented on navigation applications. According to Hannah Arendt (1958/1998), “the trouble with modern theories of behaviorism is not that they are wrong but that they could become true” (p.322). If the output of machines reading human patterns and behaviors influences the human behavior, which then is read again by machines, the feedback loop could become a vicious cycle (Figure 1).

Due to the subjectivity of data, it is important to understand what is truly happening and what effects it could have. This becomes increasingly difficult when working with invisible and automated processes. Therefore, this thesis examines how to make aspects of the smart city more transparent and visible. The next chapter discusses why it is a designer’s task to contribute to the discussion, and how invisibility and blackboxing are defined.

2.3 Role of the interaction designer

The role of an interface is to translate and mediate between the human and the complex machine (de Souza e Silva, 2006; Krippendorff, 2006). However, Latour (2008) criticizes that through the digitalization, the feature of an artifact is hidden in codes and software and these artifacts are “complex assemblies of contradictory issues” (p.4). The user is only in contact with the outer shell, the interface. The complexity behind stays invisible. Townsend (2013) argues that even if the algorithms of smart city software make decisions about issues in everyday life, most people do not know that they exist. According to him, “today assumptions are being encoded into algorithms into an increasing array of decision-support tools that inform planners and public officials as they execute their duties” (p.297). This is confirmed by different examples from the industry and research (Ehrenberg, 2015; Chicago Tribune, 2016, 2:29). For instance, in the smart system *Array of Things* the analysis of tracked images happens immediately inside the box, and only the analysis is stored. Latour (1994) coined the term blackboxing as “a process that makes the joint production of actors and artifacts entirely opaque” (p.32). When trying to look inside the black box, each element is another black box on its own (Latour, 1994).

In spite of the complex system behind them, interfaces should communicate how data are used (Interaction Design Association, 2015). Mattern (2014), columnist for the online journal *Places* and Associate Professor of Media Studies, argues that it is the right of the urban citizens to know what is happening inside the smart system and maybe even to have a share in it, as this has a big effect on politics and citizens themselves. According to Townsend (2013), there need to be legal tools and education for citizens to understand and control computer models.
Latour (2008) asks designers to develop a visualization tool that makes contradictory and controversial issues visible. Latour (2005) argues that a different view on facts and objectivity is needed. Instead of trying to see only indisputable facts, the whole thing should be considered. Thereby, it is important to acknowledge different perspectives and to not universalize (Latour, 2005).

2.4 Examples of designs influencing the way of navigating

For this thesis relevant subset of human behavior and preferences is the topic of navigation. According to Zuckerman (2011), cities are places where, in contrast to the digital world, people are confronted with the different and strange. However, as the way of navigating the urban space becomes increasingly data-driven, the digital bubble is becoming part of the physical world. Companies and organizations such as Array of Things mention that gathered and analyzed data can be used to calculate, for instance, the path with the most pedestrian activity, or the brightest path (Wired, 2014, 1:44).

Another argument regarding the topic of navigation is that when we choose one route, we leave another and thus miss out on other places, people, stores, and restaurants. Presently, locals base this decision on natural skills and abilities and memory-based spatial knowledge (Golledge, 1999). This knowledge is gained by actively exploring the space or studying secondary information sources, such as maps (Golledge, 1999). Both ways might change through digitalization, however. The importance of companies being visible on online maps underlines the influence of these maps. Companies such as PinMeTo earn money by ensuring that a company’s pin on different online maps is always updated and visible (PinMeTo, n.d.).

The following introduces different implications and issues regarding smart city applications. To this end, currently available applications from the urban context have been chosen that use different kinds of data sources. They either represent the city space or suggest routes based on the gathered data. These applications also served as sources for the screen-based design modifications and the tangible visualization described in Chapter 5.

The data sources for many navigation applications are platforms such as Facebook, Google, and Yahoo. For example, the application Likeways, which should support urban strolling, is based on Facebook data (Traunmueller, 2015). In this application, the more Facebook likes a place has, the greater the importance of the place is. Depending on how fast the user wants to get from A

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1 He refers to Heidegger’s text “What is a thing?” and explains that “the old world ‘Thing’ or ‘Ding’ designated originally a certain type of archaic assembly” (Latour, 2005, p.12).
to B, the route includes more or fewer places (Traunmueller, 2012). Likeways recommends places that are most present on the social platform Facebook. Thus, applications such as Likeways increase the pressure on stores, restaurant and places, which are dependent on customers, to be present on social platforms. Furthermore, the risk is high that these applications support the most commercial and famous places, e.g. international coffee houses, and cause users to miss beautiful but unknown spots with local stores (Figures 7 and 8).

Also in case of crowdsourcing data, different politics are involved. Crowdsourcing is an online method of collecting the input of a crowd or community. Some argue that the benefits of crowdsourcing are that it is democratic and supports innovative solutions. Negative aspects might be that it systematically supports the same group of people (Shepherd, 2012). Inspired by existing research, the developers of Walkonomics (Figure 9) defined different categories in order to rate the walkability of a street based on open data, for example “smart and beautiful”, “fear of crime”, and “fun and relaxing” (Walkonomics, n.d.-a). According to the developers, automatic systems can make mistakes; therefore, it is possible to additionally crowdsourceratings. The developers argue that in contrast to automated processes, crowdsourced data provide an accurate image of the human perspective, and errors are less likely (Walkonomics, n.d.-a). In the current stage, there are only a few ratings in the same cities in the application. Moreover, some ratings are questionable, for example if the comment field reads “test” or “rwerwerwe” (Figure 10). Consequently, it is easy to manipulate the crowdsourcing results in order to benefit from a higher walkability rating. For instance, the walkability of a street influences the value of estates on the street, and thus the outcomes of the application have a high impact on processes in the city (Cortright, 2009). That the defined categories for the rating are subjective illustrates the discussion on whether street art counts as “smart and beautiful” or is considered vandalism (Walkonomics, n.d.-b).

Mistakes in reading, collecting, and using data can lead to a false, misleading image of things. Malik draws on the example of a street bump reporting application (Interaction Design Association, 2015). On the visualization, there are no street bumps reported in some areas, but in reality it is only the usage of mobile phones that is lower in these areas. Moreover, the information of one data point tells a different story than the data set as a whole (Interaction Design Association, 2015).

Not only the selection of data sources but also how the algorithm interprets the data influence the perspective on the represented information. The developers of Walkonomics have started collaborating with researchers who predict the happiest path in an urban space based on geo-
tagged *Flickr* and *Foursquare* data (Davies, 2015; Quercia, Schifanella, & Aiello, 2014). The starting point of this research was a study on the visual factors that lead people rate a place as beautiful or not. On a crowdsourcing website, users are shown pictures of two randomly picked places in London and are asked to indicate which one is more beautiful, quiet, or happy (Quercia, Hare, & Cramer, 2014). Based on the findings of the study, the researchers are investigating ways to automatize the crowdsourcing process based on geo-tagged social media pictures (Quercia, Schifanella, & Aiello, 2014). Through this new way of crowdsourcing, collecting and analyzing data should become cheap and scalable (Quercia et al., 2015).

Besides the characteristic of beauty, safety is also subjective, as it is perceived differently depending on the person. Quercia et al. (2015) base their interpretation of the data on debatable research findings that suggest that there is more crime in areas with many potential victims. Therefore, according to Quercia et al. (2015), crime is more likely in places where more women take pictures than men do. Based on this, places where more men have tagged a *Flickr* image than women have are rated as safer than streets where more women have geo-tagged images (Quercia et al., 2015). However, the user of the application only sees the suggested route; how the questionable analysis of the images works completely unclear.

All in all, these applications show that politics are involved when designing an application. Therefore, users should be able to form their own opinion. According to Malik, it is the role of designers to educate, inform, and support users in making informed decisions (Interaction Design Association, 2015). However, it is challenging to visualize underlying processes in the interface. This is particularly the case if the aim is also to keep the visualization readable. In this vein, the next section tries to explain how an interaction designer could contribute to a more transparent yet readable interface. The learned design guidelines were applied to prototypes that were developed later in this study.
2.5 Design guidelines

2.5.1 Transparent and readable design

Related to this study is the work of Schoffelen et al. (2015) on possible design solutions to visualize an issue both readably and transparently. They define visualization as “any perceivable representation of issues that have direct evidence in the form of abstract data, i.e. data that does not possess physical or perceivable shapes or forms” (Schoffelen et al., 2015, p.180). Accordingly, in this thesis, making invisible things visible does not mean designing information visualizations. Furthermore, transparent design clarifies dynamic backstories for the user. As there will always be a subjective decision by the designer, it is not possible to create a neutral interface. Instead, it should be clear for people where the displayed
information is coming from and where they position themselves in relation to it (Schoffelen et al., 2015).

Furthermore, a readable design should encourage people to engage with the visualization, make complex information accessible and understandable, and trigger reflection. In order to keep people engaging with the information for a long time, design visualization should explain different backstories step by step (Schoffelen et al., 2015). Readers should be able to make sense of each layer of the visualization, so that they continue reading. The first step to participation is to catch people’s attention. Then, the reader should stay motivated to try to understand the visualized perspectives. Finally, new and unexpected thoughts and reflections should be triggered, so that the reader can join the debate (Schoffelen et al., 2015).

To increase the amount of visualized perspectives, Schoffelen et al. (2015) recommend that other designers provide varied ways to react to the information shown, such as writing, speech, and video. Furthermore, narratives seem to make an issue easier to understand (Schoffelen et al., 2015).

According to Vande Moere et al. (2012), it is necessary to make open data accessible and understandable for citizens, and it is therefore insufficient to share the large datasets on urban data platforms. For instance, in the project Array of Things, the tracked data, a map of the installed so-called nods, and the specification of the hardware are accessible online (Array of Things, 2016). Nevertheless, when the citizens pass by one of these sensors or use one of the named applications, what is happening behind the interface is totally invisible. However, the information should be visible in everyday places where the data are relevant (Vande Moere et al., 2012). The following section introduces challenges and recommendations regarding designing public displays.

2.5.2 Design guidelines for public and situated visualizations

According to Vande Moere et al.’s (2012) design guidelines, public and situated visualizations should follow three main characteristics of being situated, informative, and functional. The situatedness of a display is defined as being contextual and showing local relevant information. Secondly, a display is informative if it gives feedback and thereby works as a “factual mirror, which must dynamically change according to the activities of inhabitants” (Vande Moere et al., 2012, p.41). Informative also means showing insightful and consistent information (Vande Moere et al., 2012). An insightful visualization shows more than retrievable facts such as time schedules. The design challenge is that the visualization must show a meaningful and complex issue but also make it understandable (Vande Moere et al.,
Finally, a display is functional if it is made for a large audience. In addition, a functional visualization should show objective and trustworthy information. It should be opportunistic, participative, and persuasive, and should fit aesthetically in the environment. Opportunistic means that it is optional for the user to engage with the visualization, and that it does not demand anything from the user to retrieve the information (Vande Moere et al., 2012). Consequently, there needs to be a balance between attracting people to engage and being opportunistic.

A challenge when designing public displays is to overcome display blindness (Müller, Wilmsmann, Exeler, Buzek, Schmidt, Jay, & Krüger, 2009) and interaction blindness (Ojala, Kostakos, Kukka, Heikkinen, Linden, Jurmu, & Zanni, 2012). Display blindness describes the phenomenon that people tend to ignore a public display as they assume it only shows uninteresting advertisement (Müller et al., 2009). In interaction blindness, urban dwellers do not recognize the opportunity to interact with a display and hence do not use it (Ojala et al., 2012). An approach to solve these problems is to use a tangible design. According to Ullmer and Ishii (2001), the task of so-called tangible user interfaces (TUI) is to physically represent and control digital information. In different research projects on public displays, tangible components are used to interact with a public visualization (Claes & Vande Moere, 2015; Behrens, Schieck, & Brumby, 2015; Koeman, Kalnikaite, Rogers, & Bird, 2014). In a field study investigating a display with either tangible or non-tangible elements, the result was that tangible modalities support a longer and more active engagement, as well as interaction by multiple people. A discussion about the shown information with urban dwellers supports deeper insights (Claes et al., 2015). Thus, tangible output systems seem to make citizens engage with public displays. However, it should be possible for citizens to retrieve the information without external support (Claes et al., 2015). Otherwise, the design would lack readability. In contrast, the control and representation of TUIs are embodied in one artifact (Ullmer et al., 2001). In addition, TUIs react to embodied interaction and tangible manipulation (Hornecker & Buur, 2006). The next section presents work examples with and without tangible elements that aim to design a transparent and readable visualization and trigger urban dwellers’ attention.

2.6 Related work

The work examples presented below are attempts to make invisible data and backstories visible in the public space. Therefore, the involved researchers or designers are trying to solve
a similar problem as I am in this thesis. In the next sections, positive and negative aspects of the designs are summarized.

2.6.1 Transparent data visualization

Schoffelen at al.’s (2015) street signs with infographics are an example of a visualization of an issue in a public setting using different layers of information (Figure 11). As the information was divided across four different signs in four adjacent streets, the reader could engage step by step with the shown information. The displayed statistics addressed a current discussion in the neighborhood. In order to gather a variety of perspectives on the topic, qualitative data were collected beforehand using semi-structured interviews and detailed social and field studies (Schoffelen et al., 2015). In contrast to other examples developed by the same research group for exhibition spaces, less information was presented on the street signs to trigger passers-by’s attention. Thus, transparency was decreased. By displaying the information about the streets on location, the visualization was contextualized. This supported conversations among local urban dwellers. Furthermore, Schoffelen et al. (2015) took advantage of the value of the medium by visualizing backstories about the street on the equivalent street sign.

2.6.2 Urban recommendation systems

Urbanflow is an urban interface concept situated in Helsinki that aims to inform both tourists and locals (Nordkapp & Urbanscale, 2011) (Figure 12). A zoomable map shows recommendations in walking distance and tracked ambient data. Thus, the interface supports wayfinding, but also makes the invisible layer of tracked data visible. Interested users should be able to dig deeper and retrieve statistics about the data displayed on a map. The developers of Urbanflow see the system as a “two-way communication channel between city administration and citizens” (Nordkapp et al., 2011). However, communication with the city administration is limited to reporting issues, such as broken traffic lights. There is no option for the citizens to add varying perspectives with the help of different kinds of media. Consequently, the interface does not make different issues visible. Mattern (2014) criticizes the clean and highly abstracted design. If the user interacts with one layer, the others dissolve in the background. Thereby, Mattern (2014) thinks that the complexity and backstories of the shown information disappear. Thus, even if the concept is an attempt to visualize the invisible data, the different layers do not go beyond the displayed information and the visualization shows data as an indisputable fact.

A similar project is Points, which is a tangible output system and, according to the company Breakfast, “the most advanced sign on earth” (Breakfast, n.d.) (Figures 13). The interactive
street sign uses real-time data to inform both tourists and locals about close events and important locations. The displayed information changes depending on daytime and context. It can be used to display recent tweets, or to promote restaurants and shops (Breakfast, n.d.). However, how the promoted places are selected and which kind of information is left out remains invisible. Moreover, the function to display recent and geo-tagged Twitter posts and to point out their direction is questionable: it is unclear how the posts are selected, and the display does not provide space for feedback. On the different online platforms, only a group of people is represented. Thus, these posts do not show diverse perspectives. Nevertheless, the design of the street sign might trigger more attention than the ordinary form of a screen-based display.

2.6.3 Democratizing data

Datacatcher is part of a research project exploring ways to democratize data (Gaver, Boucher, Jarvis, Cameron, Hauenstein, Pennington, ... & Ovalle, 2016) (Figure 14 and 15). Every few seconds, different kinds of data in the form of short statements are displayed. By presenting location-specific data on location, information is contextualized and the user of the device is able to compare the information with the perceived reality. In addition, in contrast to the other work examples of public displays, the device is mobile and personal. The Datacatcher can be seen as an attempt to make data visible on location. The main research question of this project is, “whether and how people’s engagement with the Datacatchers might reflect issues of inequality and data” (Gaver et al., 2016, p.1599). A scroll button enables the user to display the source of the data, but also to answer a selection of questions (Gaver et al., 2016). However, there is no option to engage with different perspectives regarding the shown statement, or to add reflections to it. One test-user argued that it would be valuable to compare different opinions on the same living area, for instance (Interaction Research Studio, 2015a). Another user was interested in digging deeper into a fact that irritated him (Interaction Research Studio, 2015b). Nevertheless, in some cases the odd and large design of the device triggered discussions among collocated citizens. Furthermore, if the same information had been displayed by an application, it would have been hidden among other mobile phone applications (Gaver et al., 2016). All in all, the Datacatcher is an interesting device for democratizing and visualizing data, but it needs to be developed further in order to gather different perspectives and make the visualization more transparent.
Fig. 11: Public visualization at Musenstraat

Fig. 12: Urbanflow.

Fig. 13: Points displaying social media.

Fig. 14: Two Datacatchers.

Fig. 15: Datacatcher displaying data on location.

Fig. 16: Passers-by interacting with Fair Numbers.
2.6.4 Tangible input and output

The public, life-size information visualization *Fair Numbers* relates to the topic of this thesis as it broaches the issues of objectivity and subjectivity (Koeman et al., 2014) (Figure 16). Noisiness and crowdedness can be perceived differently, depending on the situation and on the person him- or herself. Thus, during a public outdoor event, passers-by were asked to rate the noisiness and crowdedness of the event using non-digital material, namely neon tape and neon Christmas baubles. In addition, the sensed objective data was visualized. Three-level icons showed whether the measurement was low, medium, or high. Some participants touched the objects while thinking and talking, while others expected interactive components. The latter stands in contrast to the phenomenon of interaction blindness. All in all, people were attracted by the texture and shape of the display. The temporary aspect of the installation also triggered participation, as it felt more special and it was clear that the visualization was going to disappear. However, the installation was not self-explanatory, as many people asked for additional explanation (Koeman et al., 2014). Thus, the installation lacked readability. The visualization showed that there are different perspectives of a fact. Nevertheless, it could provide more detailed insights than displaying the information and the user feedback in the form of icons. Overall, tangible design seems to both capture people’s attention and make them participate.

3 Methodology

In Research through Design (RtD), the aim of developing research artifacts is to produce knowledge for the research community, and not a commercial product. The artifacts embody both theory and technical opportunities (Zimmerman, Forlizzi, & Evenson, 2007).

3.1 Field research

Field researchers explore the roles that designs can play in a given context. Therefore, understanding the different stakeholders and the context itself takes center stage (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011). In this thesis, the topic of invisible data in cities was explored in the context of Malmö. The approach of field research was applied throughout the whole process.

A first step was to analyze the current status quo of visible and invisible data and systems in Malmö. For this purpose, a walk was taken inspired by the workshop concept Systems/Layers Walkshop by Adam Greenfield and Nurri Kim (Chapter 4.1). The aim of the so-called Walkshop
is to look for the “appearances of the networked digital in the physical, and vice versa” (Greenfield & Kim, 2011, p.5). According to Greenfield et al. (2011), the workshop can either be taken alone, or preferably with other people. However, it is recommended to go with experts and non-experts on the place. The walk should take place in a defined area (Greenfield et al., 2011). The findings were documented by taking pictures. Afterwards, a selection of pictures were shared and categorized on an online platform. Furthermore, the application Architecture of Radio, a real-time data visualization of the info sphere, was used to uncover and experience invisible information on site (Architecture of Radio, n.d.). For documentation, screenshots of the application and pictures of the place were taken and later overlaid in Photoshop.

Another object of this thesis is the approach that social knowledge about physical places can be retrieved by means of geo-tagged media. Therefore, online pictures tagged with “Malmö” were collected from different online platforms and analyzed. The aim was to explore how locative media could be used to gain a personal and authentic view of outdoor places in Malmö, Sweden (Chapter 4.1). As used in ethnographic studies, data describing ordinary life were gathered (Rogers, Sharp, & Preece, 2011). Ethnography is a method used in social science. Compared to other methods, the researcher sees everything as foreign and does not follow a clear structure (Rogers et al., 2011). In a like manner, the data was collected in this study.

### 3.2 Semi-structured in-depth interviews

For research in the field, it is essential to understand the different perspectives of the aforementioned stakeholders. Thus, semi-structured in-depth interviews, a method of data collection in qualitative research, were conducted (Chapter 4.2). These interviews followed the key features described by Legard, Keegan, and Ward (2003). They consisted of natural conversation, in which the interviewer reacted flexibly to the interviewees’ answers. Visual material as probes and follow-up questions were used to dig deeper into a topic. Finally, the interviews provided new thoughts and knowledge to both the interviewees and interviewer (Legard et al., 2003). Consequently, it is essential not to ask suggestive questions or show with body language whether the interviewer agrees with the answers (Rogers et al., 2011).

### 3.3 Design process

This study used elements of constructive design research “in which construction – be it product, system, space, or media – takes center place and becomes the key means in constructing knowledge” (Koskinen et al., 2011, p.5). Thus, knowledge was also gained during in-between steps (Krogh, Markussen, & Bang, 2015). One of these steps was a design
workshop with interaction designers and interaction design students (Chapter 4.3). The workshop was a way for the researcher to observe the design process as an outsider, and thereby gain insights into the concept of blackboxing. The participants were asked to design a recommendation system and to make the underlying data source visible. Through reflection-in-action (Schön, 1992), it was easier to trigger a discussion regarding how much transparency should be part of a user-friendly interface. As described in Schön (1992), “the sequential, conversational structure of (...) seeing-moving-seeing enables (...) (the designer) to manage complexity” (p.7). For the design task, the participants were paired together. The follow-up discussion involved all workshop participants simultaneously. As the topic was complex, the discussion benefited from the possibility to compare views among each other (Ritchie, 2003).

3.3.1 Design modifications: paper prototyping
To explore different ways to make things visible in screen-based design, a selection of applications for the urban context was redesigned (Chapter 5.1). For designing screen-based experiences, the most common technique is paper prototyping. This means that the designer sketches concepts, and ideas can thus easily and quickly be tested and articulated (Bray & Suri, 2007). According to Schön (1992), seeing-moving-seeing experiments help designers to recognize things that used to remain unseen. Besides this, the results functioned as a probe for semi-structured in-depth interviews with design experts and the Connectors Society (Legard et al., 2003) (Chapter 5.1.2), as a prototype simulates how the design looks and works in use (Rogers et al., 2011).

3.3.2 Prototyping for the field: behavioral sketch
In the last phase of the study, a prototype was developed in order to trigger discussions with citizens about the topic of this research. According to Koskinen et al. (2011), in the field a prototype is typically used to create dialogue with potential users on site. First, the design space was explored using sketches. Two concepts with similar qualities were further elaborated. Based on one of the concepts, step by step a prototype arose: the interactive signpost that was described in the introduction (Chapter 1 and 5.3). This is a common way to develop a prototype from a concept (Koskinen et al., 2011). In order to test the prototype in the field, it was important to simulate how it would work. It is often difficult for laypeople to understand low-fidelity prototypes, which are often only hand-drawn sketches (Rogers et al., 2011). However, the so-called Wizard of Oz technique describes a prototyping technique where functioning software is simulated without the test person knowing it (Rogers et al., 2011). Nevertheless, some of the behaviors of the physical object, such as the turning of the arrow or
the option to add new directions, needed to be simulated. With the help of simple electronic circuits and software, a so-called behavioral sketch (Bray et al., 2007) was created.

3.3.3 User evaluation

The user evaluation was structured into two different phases: observation and unstructured qualitative interviews (Chapter 5.4). The aim of the observation was to determine whether passers-by were willing to stop. This is one of the challenges when designing public displays or visualizations, as passers-by are good at ignoring (Vande Moere et al., 2012). Observations in the field are a useful technique to determine whether the developed prototype works in the real world and how the user would naturally interact with it (Rogers et al., 2011). At the same time, there are many different factors in the field that cannot be controlled, and the researcher must be able to adapt to changing circumstances (Rogers et al., 2011). Therefore, and also to test slightly different versions, the prototype was partly modified between and during the testing. If a pedestrian stopped, the question was how much the person engaged with the shown information, and how much he or she understood it. Interview partners were 15 urban dwellers who stopped and engaged with the prototype, two local and two non-local contacts I invited to come by and to interact with the prototype, and two founders of the Connectors Society.

4 Field Research: Exploring the problem domain

4.1 Exploring the field in the context of Malmö

According to Greenfield et al. (2011), the purpose of a Walkshop is to search for “places where information is being collected by the network” (p.9), “where networked information is being displayed” (p.9), and “where networked information is being acted upon, either by people directly, or by physical systems that affect the choices people have available to them” (p.10). In this study, the focus of the Walkshop through Malmö was to find traces of data, but also to see how the underlying infrastructure was made visible.

It was difficult to find visible marks of the networked city and digital data. A prime example of both places “where information is being collected by the network” (Greenfield et al., 2011, p.9) and places “where networked information is being displayed” (Greenfield et al., 2011, p.9) was the stations in Malmö that count bikers per day (Figure 17). The so-called Cykelbarometer (Malmö Stad, n.d) is a best practice example of a display creating a “sense of participation and belonging” (Vande Moere et al., 2012, p.31). The display also works as a “factual mirror”
(Vande Moere et al., 2012, p.41) as it immediately changes when a biker approaches the counting station. Besides this, there were digital displays showing retrievable facts such as digital and analogue timetables at a bus terminal in Malmö. Public displays, which provide insightful information (Chapter 2.5.2), were missing.

The traditional physical signs of the underlying infrastructure of the city were most visible. Here, the information was engraved in the existing physical elements, such as streetlights (Figure 18), and it was displayed when the underlying network was meeting the surface of the city (Figure 19), such as on a manhole cover. There were no places where people reacted to the shown information. During the walk, the focus shifted towards analogue traces, such as stickers added on physical objects or written and engraved sentences (Figure 20). The growing traces document a “rich communication and interaction through and with objects” (Giaccardi, Karana, Robbins, & D’Olivo, 2014, p.473).

![Fig. 17: Cykelparometer.](image1)

![Fig. 18: Engraved information.](image2)

![Fig. 19: Infrastructure meets surface.](image3)

![Fig. 20: Growing traces.](image4)
Uncovering the invisible network of WI-FI and cell towers using the application *Architecture of Radio* was much more impressive outdoors than indoors. Similarly, the pictures that were overlaid afterwards do not convey the same experience (Figures 21 and 22). Consequently, displaying invisible information in a place and the act of uncovering seem to be more intrusive than to be faced with the information at home. All in all, there were hardly any traces of invisible or visible data and of the networked city in Malmö.

To determine what kind of geo-located information people share in Malmö (Chapter 2.2), digital place-specific traces, which can be found on Twitter, Facebook, and Instagram under the hashtag Malmö, were collected and grouped. I grouped the posts into four main categories: working day, city of Malmö, weather/seasons, and socializing. It seems that people only take and share pictures that show the city if they have a good view and time to stop. Thus, some pictures might represent socio-cultural activities, but there are many urban places in Malmö that are not represented on social media platforms. Gathering data to understand people’s behaviors and pattern, and how data and smart systems shape the urban life, was the topic of the semi-structured in-depth interviews. The results are described in the next section.

### 4.2  Semi-structured in-depth interviews

#### 4.2.1  Meetings with Connectors Society

The *Connectors Society* explores methods to measure the flow of people. The organization often uses pop-up interventions at different places (*Connectors Society*, n.d.). Julieta Talavera, one of the founders of the *Connectors Society*, saw many parallels between my research focus and the organization’s work (J. Talavera, personal communication, April 27, 2016). Spaces transform people’s behaviors and people contribute to the space in a loop. She wondered how an urban space would look that would represent the data that citizens leave back to them, so that they would be aware of how they influence the space.
In Julieta Talavera’s opinion, when collecting data about how people use a space, the analogue and digital are seen as opposite poles at the moment, and it would be interesting to find a way to combine them (J. Talavera, personal communication, April 27, 2016). The aim of Connectors Society’s collaboration with students studying systems and information engineering at University of Virginia was to digitally enhance the analogue tools of measuring. As part of the developed tool, the analysis of analogue collected data is automated using Visual Basic. Thus, the tool should make the analogue measuring of pedestrian and cyclist movements in public spaces more efficient and accurate (students from University of Virginia, personal communication, June 2, 2016). In this case, the user needs to program the computer beforehand what to search for. This might be a disadvantage because sometimes the human sees unexpected things while analyzing data, but it could also be an advantage because the computer cannot be distracted. Julieta Talavera also wonders if the computer can see different things than humans can when searching for patterns (J. Talavera, personal communication, April 27, 2016).

Furthermore, Julieta Talavera believes that crowdsourcing is a good way to organize the city. However, there are many factors that influence the quality of the outcome. The quality depends on whether there is a community behind the crowdsourcing tool and also whether the criteria are made comparable (J. Talavera, personal communication, April 27, 2016).

The relevance of the discussion about valuable data collection methods for urban planners was demonstrated by the event public spaces x data x design on the 1st of June 2016. The event was organized by the Connectors Society, and international experts from different areas were invited. One of the speakers, Sophia Schuff from cititek, a social design consulting office working with urban design, believes that it is necessary to be in a place and to use analogue data collection methods. Otherwise, the research would miss information that sensors cannot track (Schuff, 2016). In contrast, Eric Baczuk from Sidewalk Labs believes in the potential of digital data collection (Baczuk, 2016). The company Sidewalks Labs by Google is redesigning public pay telephones into free WI-FI booths called Link NYC. According to the company, the product solves the problem of the digital divide and can make the management of cities more effective by using anonymized data (Sidewalk Labs & Alphabet Inc., 2016). Furthermore, the researcher Søren Zebitz Nielsen tries to automate the analogue way of analyzing the movement patterns in public places with Geographical Information System (GIS) technologies. He believes that digital solutions could ease the work of urban designers, which does not mean that they are not needed to be in a place and to analyze it with human senses (Zebitz Nielsen, 2016).
All of these opinions show that there are different methods to understand and interpret human behavior in public space, and that digitalization is shaping and changing these methods. Even though this event was public, citizens should have a higher stake in the discussion. Furthermore, Julieta Talavera’s concept of mirroring back data to the citizen is a fascinating approach to making data visible. In addition, her way of thinking about the potential to use machines raises the question of how citizens can control machines if we believe that machines have different abilities than humans, and how humans can judge and base decisions on the outputs of machines. An example of a machine inside of which the analysis happens is the intelligent camera system Modcam. The next section outlines the results of the meeting with Magnus Karlberg, the sales director of the company Modcam, based in Malmö.

4.2.2 Meeting with the sales director of the company Modcam

Because the analysis happens inside the Modcam camera system, no images are stored. Thus, the system can be implemented without compromising privacy (M. Karlberg, personal communication, May 26, 2016). Thereby, the system can be seen as a kind of black box system (Chapter 2.3). Modcam’s work is therefore relevant for this thesis. The meeting with Magnus Karlberg from Modcam was about different use cases and concerns. First, as the hardware is similar to that of a mobile phone, it becomes affordable for different kinds of customers to implement the system. In Malmö, there are already different kinds of Modcam systems used, of which I was not aware. Through contact with customers, Magnus Karlberg recognized that members of the younger generation want to base their decisions on data, whereas members of the older generation prefer to trust their feeling (M. Karlberg, personal communication, May 26, 2016).

Moreover, how much the analysis is processed depends on the customer (Figure 23 and 24). Some prefer to receive concrete recommendations, while others base their decision on a heatmap showing the measured activity. Possible errors by the system are visible on a heatmap. For instance, the camera tracks an active spot where it is not possible to walk (M. Karlberg, personal communication, May 26, 2016). However, when I tested the camera indoors in collaboration with the Connectors Society, it was sometimes difficult to understand which area the heatmap actually showed. Furthermore, without support from an expert, it is possible to make different kinds of mistakes when installing the camera in the environment. In addition, errors are more likely if more systems interplay. For instance, the light system of a school changes the color, quality, and amount of light depending on the tracked activity, or the sound system of a concert hall adapts to the measured values (M. Karlberg, personal
communication, May 26, 2016). At the current stage, the camera system is used for indoor spaces. However, a researcher is considering using the Modcam in an urban context. The aim would be to gain insights into transport behavior in the underground based on the camera analysis (M. Karlberg, personal communication, May 26, 2016). Furthermore, the Connectors Society plans to test the Modcam outdoors.

All in all, this shows that it is becoming easier and cheaper to implement systems that not only measure but also analyze and even interpret information. This implies that even if a person does not have an understanding of what is measured and how, he or she can use these systems. In addition, the finding that people increasingly prefer to base their decision on data confirms the statement in UrbanIxD’s manifesto that it is becoming difficult to trust one’s own judgment when instead everything can be measured or crowdsourced (UrbanIxD, 2014).

![Fig. 23: Counted visitors per day.](image1)

![Fig. 24: Heatmap showing the measured activity.](image2)

![Fig. 25: Given scenario and crowdsourced data sets.](image3)

![Fig. 26: A final paper prototype and post-its documenting design decision.](image4)

### 4.3 Design workshop

The goal of the workshop with design experts was to observe the design process as an outsider. The interest was in how design decisions influence the filtered view of a developed prototype. An additional aim was to explore ways to make data visible on a mobile interface.
and to discuss transparency and readability as parts of user-friendliness. The designers were asked to develop a lo-fi prototype for a given scenario of a student searching for the best spot to eat lunch outside around the university (Figure 25). Besides this, detailed information was provided regarding a selection of data sets, namely the wind situation, sensed sunlight, and a webcam picture showing tracked objects. The choice of data sets was left up to the designers. Furthermore, the participants were asked to document each design decision they took (Figure 26) and to try to make them visible in the interface. The latter triggered a discussion about user-friendliness. More details regarding the task, the provided data sets, the process of the workshop, and the results can be found in Appendix A.

One of the design teams developed a recommendation system and based the decision regarding the underlying data sets on crowdsourcing. However, during the design process, one of the data sets was omitted based on assumptions about the users’ preferences. In the final screen-based prototype, the abstract values were represented by gradient visualization of the parameters. In contrast, another design team’s aim was to provide the user with a direct feeling of the selected spot instead of representing the recommendation in numbers. The team developed a box that translates the measurements of noise, wind, and temperature into sensable output.

In brief, the workshop was only scheduled for two hours and I tried to keep the task as simple as possible. Nevertheless, it was demanding to find a solution between abstract and direct representation. As it seems to be in the nature of designing to simplify, it is challenging to make hidden details visible. Another learning outcome of the workshop was to see crowdsourcing from a different perspective. Thus, to justify the opinion of the majority of people, the opinion of the minority and therefore perhaps more diverse perspectives are excluded. Finally, the discussion about user-friendliness related to the research question regarding finding a balance between readability and transparency.

4.4 Summary

With regard to the research topic, one learning outcome of the field research is that most existing data and smart systems are invisible in Malmö. Furthermore, urban planners are interested in different data collection methods to understand users’ behavior in public spaces. At the same time, especially in the urban space, the number of systems collecting and analyzing data such as Modcam and Link NYC is increasing. However, from the outside, what happens inside is not visible. Nevertheless, especially the younger generation tends to trust these systems and believes that based on data, better decisions can be taken. The designers of
the workshop had different opinions regarding whether making backstories visible is part of a user-friendly interface. Furthermore, it was not possible to create a design solution between abstract and immediate output. All in all, investing more in the topic of making invisible data and backstories visible in the context of urban spaces seems to be valuable. The learning outcomes of the field research and theoretical framework influenced the prototypes of this study, which are presented in detail in the next chapter.

5 Design process

5.1 Design exploration of graphical user interfaces

5.1.1 Design modifications of navigation applications

To explore the design guidelines for developing a transparent and readable design, I tried to redesign three applications. The applications are exemplary for displaying an indisputable fact without the backstories behind, and were partly presented in Chapter 2.4. In addition, the selected examples were developed for the urban context and available to test in Malmö. Given my inside knowledge of Malmö, it was easier to identify possible concerns. Furthermore, it was important to gain insights into the underlying development and design process through publications. The purpose was as much as possible to trace the shown information back to the source on which it was based, to determine how the information was translated in the process from being tracked to displayed on the interface, and to identify which information was left out. More details on the original application and the different concepts can be found in Appendix B.

One of my aims was to find ways to visualize the logic behind the interface, for instance how a route is constructed, and thereby make hidden information visible in the software or code. This was easier if the logic was simple and if detailed background information, sketches, and the developer interfaces were accessible (Figure 27). When more factors influenced how the route was constructed, however, it became challenging to keep the interface readable. Thus, I followed Schoffelen et al.’s (2015) concept of layering the information (Chapter 2.5.1). In the paper prototypes, the user could blend in and out details about the route criteria that were defined in the algorithm, and about the used data sources on top of the map (Figure 29).

As Chapter 2.4 described, the original applications highlight some places, whereas others stay invisible. Therefore, my designs focused on methods to draw attention to other places or alternative paths. One concept was to highlight invisible places in the application itself by
showing the opposite route to the recommended route, or by blending out favored places. In another concept, citizens or activists would have a tool to manipulate the application and thereby make a place visible. In this case, an alternative application would go step by step through the criteria that the place would have to fulfill to be recommended by the original application (Figure 30). Thus, the logic behind the application would gradually be made transparent (Chapter 2.5.1).

The most challenging aspect was the task of visualizing the subjectivity of objective data. A possible solution here would be to collect and visualize different narratives and perspectives (Figure 28) (Chapter 2.5.1). For applications using crowdsourced data, this could be part of the crowdsourcing. However, as the example of Walkonomics shows, this option often remains unused (Chapter 2.4). Moreover, only perspectives by active people would be selected.

In meetings with design experts and Connectors Society, the design concepts were evaluated. The results are summarized in the following sections.
5.1.2 Evaluation

Interaction designer Johan Salo from the companies Do-Fi and Guidly focuses on designing locative media applications. He also recognizes the process of translation in his design process, for instance, when transferring Photoshop sketches to code or using frameworks for displaying information on a map. According to him, the concepts of the paper prototypes are not practical for navigating the city, and are not made for mobile screens because of the amount of information. Furthermore, through the complex and less readable interface, it is likely that fewer people are reached. However, application developers and designers are dependent on customers. For this reason, the routes in his application are not only based on the places described by storytellers, but also follow a frequently visited path (J. Salo, personal communication, April 19th, 2016).

Furthermore, the interaction designers Livia Sunesson and Sveta Suvorina from the company Unsworn Industries think that it is in the nature of the designer to simplify. Some of their work is about supporting municipalities in collecting data regarding how citizens would imagine the future of their city. When inspiring citizens to envision new ideas, it is crucial not to promise things to the users. Therefore, transparency is essential when collecting data. In addition, it is the task of a designer to support people who have ambitions. To this end, the designers suggest collaborating with people who would use the application or counter applications in order to further develop the ideas (L. Sunesson & S. Suvorina, personal communication, April 21st, 2016).

Julieta Talavera (personal communication, April, 27th) also doubts that people are interested in seeing the complexity, as they prefer the simple solutions and do not care about the concerns, especially if the issue feels far away. Nevertheless, she thinks that these concerns must be made visible. For instance, people are aware that their data are tracked, but they do not know...
what this means. According to Kizilcec (2016), who investigates the use of transparency in recommender systems, transparency becomes important when the expectation is violated; otherwise the users trust the algorithmic interface.

All in all, my design modifications triggered insightful discussions about transparency in the design process. Being financially dependent, missing the right tools, designing for a positive user experience, and having the task to design for others all prevent designers from showing complex backstories in an interface. Moreover, my design modifications are partly impractical for everyday life and for navigating the city. Readability is decreased because of the amount of information, whereas some designs are perceived as aesthetically appealing while the real message is not communicated. Thus, the designs seem to only scratch the surface and are still decontextualized from the place where they matter.

Furthermore, these screen-based solutions would stay hidden among other applications and would not reach the common citizen. In contrast, public displays or devices such as the Datacatcher increase the visibility and transparency of information on location, and trigger discussion among citizens (Chapter 2.6). In addition, there are rarely any marks of digital information in Malmö (Chapter 4.1). Therefore, in the next phase of this thesis, potential designs to visualize an issue on location and to trigger discussion are explored. The following chapters describe the design exploration, the realization of one design, and the user evaluation.

5.2 Design exploration of public visualizations

5.2.1 Process

In the exploration phase, the focus was on four different aspects: how and where to display information; what to display; where the display data were coming from; and how citizens could react to the displayed information.

First, the solution for potential places to display information focused on spots that might be relevant for urban flow (Chapter 4.2), but also places where citizens choose a specific path, such as at street corners and street signs. According to Meilinger, Frankenstein, and Bülthoff (2014), when memorizing a certain path, humans try to memorize only the turns and if they do not know where to go, they go straight. Thus, intersections are places where people decide in which direction to go. Besides this, potential users need to have time to stop and engage with the information, such as at bus stops, traffic lights, or benches.
Furthermore, the types of data could for instance be data gathered by systems such as Link NYC or Modcam, but also locative media. How much the tracked information is processed could vary from pure data, statistics, and analysis, up to recommendations. Provocative statements might trigger the most reactions. With the fieldwork, the workshop, and the design modifications in mind, the applications using locative data to identify the most common subjective view of a space seemed to be most relevant for this study. Moreover, the possibility for a “machine” to measure the subjective perception of a space, such as beauty and likability, seems to be intriguing and provocative (Chapter 2.4).

The solutions regarding how to display information and to offer the urban dweller the possibility to react to it are interwoven. Ideas for ways to display information range from simple screens to concepts where the information has to be retrieved in a more playful manner. The latter would conflict with the criteria that functional public displays should be opportunistic, but would help to overcome interaction blindness (Chapter 2.5.2). For the developed design concepts, it was also important to uncover the issue step by step, thereby making a longer time of engagement by the user more likely (Chapter 2.5.1).

Concepts for reacting to the shown information were simple voting systems, but also designs that leave room for feedback in the form of audio, images, or longer written text. Both analogue and digital solutions were of interest. The idea behind the feedback loop was to create a communication system between the smart city system and citizens, and that the citizens would have the role of controlling the smart system. Thereby, data would be annotated with different backstories, and hence varying perspectives would become visible.

Two of the concepts, a kind of kaleidoscope and an interactive signpost, were explored further and are described in more detail below. The descriptions and sketches of the other ideas are shared in Appendix C. The main reason for the design decision was the physical quality of both concepts. The designs would be physical manifestations of the networked city. The tangible design might prevent the so-called display blindness and thus catch passers-by’s attention (Chapter 2.5.2).

**Use case: Kaleidoscope**

The concept inspired by a kaleidoscope would be a device displaying information about the place that the user was looking at (Figure 31). By turning or twisting the whole kaleidoscope or elements of it, the user would go deeper into the different layers of information. The displayed information could be the algorithm, determining the security and beauty of a place. In this case, the first layer would show the resulting evaluation of the place, e.g. beauty. The second
layer would uncover how the algorithm determine the beauty, namely by analyzing security and walkability. The third layer could provide more insights into why a place should be more secure or walkable by displaying images taken at night or pictures with so-called “walkability-related” tags, such as sidewalk, resting, and tree. In addition, the tool could also democratize visualization developed for urban designers analyzing the urban flow based on geo-tagged social media data, such as the FlowSampler (Chapter 2.2). The kaleidoscope could be both a stationary tool attached to a certain place, e.g. on a bridge with a wide view, and a mobile tool such as the Datacatcher (Chapter 2.6). Features of the kaleidoscope could include an option to compare the smart city and smart citizens’ opinions, or to see data that are neglected by the Happiest Route Algorithm (Chapter 2.4). Another idea is to add some kind of communication channel to the kaleidoscope in order to annotate the displayed information.

**Use case: Interactive signpost**

The interactive signpost is also characterized by its physical appearance and uses similar data sources as the kaleidoscope (Figure 32). This signpost would point to the most secure place or more likeable place according to the logic of the applications Likeways and Walkonomics (Chapter 2.4). The sign could be placed on a street corner or somewhere with a wide view, and it could also be attached to an existing street post. Depending on this, the design would stand in a different context. For instance, if the arrow pointed to the beautiful spot and was attached to a street sign indicating the way to different areas, passers-by might relate the topic of beauty to these areas. In order to retrieve or leave information, possible forms of interaction could be by phone or by buttons attached to the sign. For instance, an additional interface such as a mobile phone application or website could provide more information about the location of the tracked data and the logic behind the system, like in the Walkonomics application. Furthermore, citizens should be able to add places that they perceive as more secure, bright, or beautiful. Thereby, a variety of perspectives could become visible (Chapter 2.5.1).

In another concept, the signpost could also point to places that are not part of the physical street sign to which it is attached. The signpost could also be a toolbox that would be used by organizations such as the Connectors Society to crowdsource information or trigger discussions. In this case, the stakeholder would decide where to place the arrow and maintain the data selection. In addition, there could be a function to compare the citizens’ and smart system’s perspectives.
Fig. 31: Exploring the concept of the interactive kaleidoscope.

Fig. 32: Exploring the concept of the interactive signpost.
5.2.2 Design decisions

In both cases, it is unclear where exactly the device is looking or indicating. Consequently, the information would need to be supplemented by a map. In case of the interactive signpost, another solution could be to place an interactive signpost at each corner of adjacent streets so that citizens could follow the most beautiful path in one area of the city. This might only work if the path is clearly defined.

The core of the kaleidoscope is beauty. A positive characteristic is the known way of interacting with a kaleidoscope by turning it. By applying the kaleidoscope aesthetic to the information visualization, the information would be translated. On the one hand, this would decrease transparency because the designer would influence the raw data; on the other hand, the translation would make it obvious that the display was not mirroring the information.

In contrast, the outstanding design characteristic of the signpost is the simplicity of the pointer. Thereby, the design itself could easily become another form of a black box. Thus, it would be relevant to explore how such a “smart” system could be designed in a more democratic and transparent manner. Furthermore, the pointer is a physical object that could be used for both retrieving and storing information. However, how the function of storing new places would actually work needs further exploration.

All in all, the kaleidoscope seems to be good at displaying different layers of information and giving the user a tool to dig deeper. In contrast, in case of the signpost, more detailed information might be hidden in a separate mobile device or online on a website. On the other hand, the design of the interactive signpost takes advantage of the value of the medium by visualizing backstories of navigation applications on a physical signpost. In addition, the signpost could be used to retrieve and react to networked information by using a tangible design. Because of these advantages, the design of the interactive signpost was chosen to be elaborated further and to be user-tested in the streets of Malmö.

5.3 Prototyping

The aim of the prototype was to test whether urban dwellers would pay attention to it, how much they would engage with it, how they would understand it in the context of the outdoor space, and whether it would trigger discussion about smart city data and algorithms. For the latter, the algorithm of the Walkonomics application seemed to be the most provocative. It was important for it to be tested outdoors to reach people who normally not interested in the topic of smart cities. Furthermore, it was necessary to be able to leave the prototype alone in order
to observe how people would react to it from a distance. Consequently, one requirement for the prototype was to be robust and to simulate the function. Finally, to test the prototype in different locations, it needed to be easily mountable and demountable (Figure 37).

The final prototype consisted of a wooden arrow that can be turned manually, but was also invisibly turned by a stepper motor (Figures 33 and 35). The stepper motor was steered by an Arduino board. Arduino is “an open-source prototyping platform based on easy-to-use hardware and software“ (Arduino, 2016). The user could switch the data source on which the direction of the arrow was based. In addition, it was possible to change the direction of the arrow and save that direction. A short description provided an introduction to the project, explained how to use the prototype, and indicated where to find further information. Beside this, the final prototype is mountable to existing street poles. The design of the box with the arrow on top was a way to hold the motor and mount it on a pole while keeping the electronics safe but also close to the motor.

5.3.1 Technical specification

After testing different kinds of motors, a stepper motor was chosen because it is possible to precisely control its position and speed (Earl, 2014). When testing different solutions, cheap servomotors were too weak to steer an arrow designed for outdoor conditions. A toggle switch was used to change between two modes, as there was only one arrow for both data sources. Using a potentiometer and a push button, the position of the arrow could be changed and saved, and in a real use case could be shared online. An alternative would have been to design an application or web site to steer the prototype. However, wireless communication was too complicated to realize. In addition, downloading an application or using a website would be another step that the user would have to take to engage with the prototype.

Retrieving the exact direction of the geo-tagged social media data also made the prototype more complex. However, a QR code and a URL enabled the passers-by to retrieve more detailed information if interested. The linked website informed the users about Walkonomics, as well as about places that were rated as walkable. Furthermore, a map with pinned geo-tagged data clarified where the arrow was pointing, and where and which kind of data was collected (Figure 34). In addition, there was an option to comment on existing marks and to add new ones on the map. Thus, the process of retrieving information was step by step (Chapter 2.5.1). The next section will explain more precisely where the data on the map came from.
5.3.2 Data selection

First, data that would be relevant for the application Walkonomics were gathered. In Malmö, this for instance included geo-tagged Flickr images using the walkability-related terms suggested by Quercia et al. (2015): “sidewalk, footway, street light, clean street, pedestrian, bench, resting, tree, greenery, art, architecture, historical, bike, private, hill, and social” (p.881). The search results were added to a Google map.

However, it was difficult to handle the amount of data manually. Therefore, the search process was automated using Application Programming Interface (API). API provides defined commands with which developers can communicate with the file system and for example access specific data that they can then use for their own applications (Sharpened Production, 2016). An easy solution seemed to be the Java-based programming language Processing (Processing Foundation, n.d.) and the Java library for API programming, Twitter4J (Twitter4J, n.d.) (Figure 36). The collected Twitter posts contained one of the walkability-related tags and were sent from Malmö. However, it was only possible to collect recent posts, and many posts were missing GPS location. This shows how easily information is translated or omitted when designing representations. In the next chapter, the results of the user testing will be described.

Fig. 33: Final prototype mounted at street pole.
Fig. 34: Screenshot of the website showing a map with gathered locative media.

Fig. 35: The electronics inside of the prototype.

Fig. 36: API programming with Twitter4J and Processing.
Fig. 37: Setting up a user testing session.

Fig. 38: User testing: interviews with interested passers-by’s.

Fig. 39: User testing: observations.
Fig. 40: Testing different kinds of wording.

Fig. 41: User testing with the Connectors Society.

Fig. 42: User testing at a bridge in Malmö.
5.4 User evaluation

The user testing took place in several locations, on three days and at different times. Decisive criteria for the selected places were that they had to be frequently used by pedestrians, and that the box had to be visible to passers-by. One location was a junction in the pedestrian precinct where both locals and non-locals pass (Figure 39). The possible directions at the junction included different activities, such as shopping, sightseeing, and drinking coffee or beer. The signpost indicated touristic places, but also places such as the nearest station and the police. The other testing location was on a bridge, which was characterized by a broad view of Malmö (Figure 42). Here, the arrow was mounted on a decorative pole, so the prototype did not relate to other signs.

5.4.1 Observations

External circumstances, the form of labeling, and the pedestrians’ mood all influenced whether people stopped or ignored the prototype. At the same time, the option of interacting with the installation, other people interacting with the prototype, or the sight of me opening the box to fix cables all caught people’s attention. Overall, people who were strolling were more likely to stop. The bridge seemed to be a better location for the prototype. There, the atmosphere was more relaxed and the prototype more visible, because the space is open but also empty. In both places, most of the people who stopped also read through the description and analyzed the prototype. However, only on the bridge did passers-by use the QR code to retrieve more information. In order to interact with the prototype, further explanation was needed more often than not. Nevertheless, a few people interacted with the last version of the prototype without any further explanation. Most of the time, I approached passers-by quickly for interviewing, so sometimes there was no time to interact without any explanation.

For the labeling, it seemed to be important to find a balance between making visible from a distance what the installation is about, and not mentioning too much in order to make people curious. The following question seemed to attract the most attention: “Is it possible to predict the happiest walkpath based on social media data?” (Figure 40). This was also a result of the interviews, which are summarized in the following section.

5.4.2 Interviews

As there was no difference between the results of the interviews with passers-by (16) who stopped because of the prototype and friends (4) who do not have a design background but were asked to come by, the results will be summarized in one section. The interview partners were both locals and non-locals, of different ages (20-70 years old) and genders (Figure 38).
First, the purpose was to understand how people read the public visualization. Most people thought that the arrow pointed to paths and streets close to the sign or within walking distance. Some of the interviewees argued that, in that case, it would also become easier for pedestrians to decide which street was more walkable or beautiful. Some people thought of areas in the whole city. On the bridge, it was more likely that people thought of an area than of a path. One of the interviewees liked the view on the bridge, as it allowed users to look around while thinking about possible places and while reflecting on other people’s results and on the analysis of the geo-tagged data.

Furthermore, the answers about the walkable place or street varied considerably. In the interviews, a few added comments such as “that is only our opinion” or “everyone thinks differently”. Overall, there was a clear mismatch between citizens’ opinions and the tracked geo-tagged social media data. Furthermore, passers-by shared their perspective about predicting the most beautiful walking path based on social media. All in all, the answers emphasized the subjectivity of this topic. Nevertheless, interviewees seemed to be able to identify their standpoint about the visualized topic and also came up with relevant issues.

Another aim of the interviews was to identify possible improvements. After explaining the concept of the installation, the way to interact with it seemed to be clear. Two elderly women, who did not read the description, changed the direction by turning the arrow. This seemed to be more intuitive. The visibility could have been increased by color or size.

In terms of readability, the difference between the “data mode” and the “citizen mode” was explained in a separate description. Nevertheless, for a few persons, this was still unclear after reading the description. In addition, the language was sometimes a barrier. For some users of the older generation, the topic was too complex to understand in English, and some were not familiar with geo-tagged social media data and tags. One of the passers-by suggested adding a map to show the locations to which the arrow pointed. Her companion instead argued that today everybody has a phone and could scan the QR code in order to retrieve more information.

Moreover, both Joshua Ng and Julieta Talavera from the Connectors Society tested the interactive signpost on site (Figure 41). Joshua Ng immediately thought of a potential use case for the prototype: collecting data for the municipality to plan a pedestrian street. Julieta Talavera also thought the prototype was valuable. In addition, she started to discuss where to draw the line between the “data mode” representing the social media data created by people and the “citizen mode” (J. Ng & J. Talavera, personal communication, July, 20, 2016).
5.4.3 Results

To summarize the user evaluation, depending on external circumstances, many passers-by were willing to stop. Some of them were interested in the topic. In the interview, almost everybody could identify a standpoint. Thus, by engaging with the interactive signpost and the background information, new thoughts and discussions around the topic were triggered. However, most people needed guidance to interact with the visualization. Furthermore, only a few people were interested in retrieving more information via the website. The next chapter will discuss how the prototype contributed to this thesis.

6 Discussion and conclusion

6.1 Research findings

The overall aim of this study was to investigate the invisibility of data and software in an urban context. Thereby, the focus was on how issues behind smart city data and software can be made visible and thus balance transparency and readability in a visualization. Both the prototype of the interactive signpost and the small-scale design modifications served to explore potential solutions.

In case of the GUIs (Chapter 5.1), the criticism was that the redesigns were not needed. Despite layering the information, the GUIs lacked readability. At the same time, some of the concerns about the used method of selecting and evaluating data remained invisible. All in all, the design modifications and discussions with the different stakeholders contributed to seeing the bigger picture and identifying further problems. This led the aim of the final prototype to be to make an issue visible with the help of a public visualization and to intrigue people to investigate further into what is behind data and algorithm of the smart city.

The attempt with the interactive signpost was to highlight an issue in a public place and to trigger discussion. Thus, it is important to distinguish between the visibility of the representation on site and the visibility of the issue itself in the representation. Because the interactive signpost visibly represented an aspect related to abstract data, it was a visualization (Chapter 2.5.1). The following will analyze which criteria of a situated and public visualization the design of the interactive signpost fulfilled, and whether the visualization was visible on site.
6.1.1 Interactive signpost as a public visualization

As described in Chapter 2.5.2, a public visualization should be situated, informative, and functional. Firstly, the prototype partly fulfilled the criterion of being functional as it was opportunistic, available for a large audience, and integrated in the environment (Chapter 2.5.2). However, in order to retrieve detailed information, it required the passers-by to visit a website via a link or QR code, and this made the design less opportunistic and excluded people without a phone or without technical skills.

Secondly, the prototype was partly situated (Chapter 2.5.2). It gave immediately feedback, for instance when turning the buttons, and related to the streets in the area. However, the visualization was not specifically designed for one place. Nevertheless, the testing showed that the design was well integrated in different locations.

Finally, the interactive signpost seemed to be informative as it addressed a complex topic. However, the characteristic of providing both insightful and understandable information is related to the topic of readability and transparence, and whether the representation itself makes an issue visible (Chapter 2.5.1).

Depending on external circumstances and location, the tangible and temporary design of the prototype seemed to counter display blindness and interaction blindness as it caught people’s attention (Chapter 2.5.2). If a person stopped and was interested, she or he also interacted with the installation. The latter was only possible if the user understood the interface itself, which depended on readability. This will be evaluated in the next section.

6.1.2 Balancing readability and transparency in the designed prototype

Readability

As described in Chapter 2.5.1, a readable design should make people engage. During the short testing phase, the physical visualization triggered people’s interest. The level of engagement stayed mostly at the phase of interacting with the prototype itself.

Furthermore, a readable visualization supports the user in understanding a complex topic (Chapter 2.5.1). In this study, the design of the interactive signpost made the topic of wayfinding clear, while a short description provided more background information. Depending on the wording, the description, and labeling, passers-by understood the topic of the study. Although, or maybe because, the information was split into different layers that were in different locations, namely physically on site and digitally online, it was difficult to make sense of the background information of the installation without further explanation. The website
was rarely visited, probably because I intervened in order to interview the users. The readability of the website was not user-tested as part of this study.

Finally, readability is characterized by enabling the reader to reflect on the displayed topic (Chapter 2.5.1). As nobody used the online possibility to comment, deeper reflection could only be tested in the interviews. Many diverse perspectives were collected, for instance about the wider effect of using locative media to interpret people’s behavior and preferences. However, it is not clear whether participants were triggered by the prototype or in particular by the conversation.

All in all, the design fulfilled the criteria to make people engage. However, the issue was not made fully understandable. The biggest challenge is to translate complex information that is written as code into understandable text. Besides this, by translating what is hidden in the code into words, the author influences the information through his or her interpretation and perspective. This leads to the topic of transparency, which is examined in the next section.

**Transparency**

In this thesis, transparency is defined as making backstories and different perspectives visible and as offering the user the possibility to trace the source of the information (Chapters 2.5.1). Thus, visibility and transparency are interwoven. In the case of the interactive signpost, background information was made accessible on a website. On the one hand, this solution made the design more transparent. On the other hand, the information was hidden in the digital world, less accessible, and not visible on site.

Nevertheless, people enjoyed changing the direction of the arrow and thereby sharing their opinions. Thus, the design collected different perspectives, even if only to a limited extent (Chapter 2.5.1). The varying answers in the interview showed that the design has the potential to collect varying viewpoints on a certain issue.

However, on site it was unclear how the installation was programmed, e.g. to receive the information. Nevertheless, the website explained to a certain extent how the data were gathered or which information was left out or was not considered. Thus, by making one issue visible using the design of a physical object that should attract people’s attention (Chapter 2.5.2), a design with invisible and opaque elements arose.

**6.1.3 Results**

Overall, the prototype of the interactive signpost balanced readability and transparency. Nevertheless, the visualization was partly lacking in both. Furthermore, it appeared that if one
of them was improved, the other would suffer in quality. By picking subjectivity and objectivity of data as a central topic, a discussable issue was visualized instead of an indisputable fact. The prototype was a compelling attempt to make visible what is normally written down in software. The biggest potential of prototype is to confront citizen with implications and issues that come with smart city technology, using tangible design. At the same time, the digital layer could serve for different use cases, for instance as a public data annotation tool. If and how the prototype contributes knowledge is discussed in the next section.

6.2 Knowledge contributions

According to Krogh et al. (2015), knowledge contribution in the field of RtD consists of the clarifications “how one got there – how the design project drifted through and gained insights unintended by its original pursuit – and what knowledge one developed doing so” (p.40). Therefore, the knowledge contribution of this thesis is not only the learning outcomes of designing the interactive signpost; it is the whole process: the workshop, redesigning GUIs, and seeing the differences between graphical user and physical user interfaces. In addition, knowledge contribution needs to be relevant and novel for a research community, among others (Löwgren, 2007). By comparing the prototype to the introduced related work examples (Chapter 2.6), the novelty of the prototype will be proven below.

6.2.1 Novelty

First, it is novel for a physical object to be an attempt to visualize how an algorithm works in a public place, whereas the displays discussed in Chapter 2.6 visualize input as well as output of a software or measurements. Similarly to the highlighted projects, the transparency of the signpost was decreased in order to trigger passers-by’s interest. However, compared to Urbanflow (Chapter 2.6.2), the information provided by the interactive signpost on site was less detailed if the user did not use the option to retrieve information via the website. Unlike Urbanflow and Points (Chapter 2.6.2), the developed prototype tried to visualize an issue instead of an indisputable fact.

Similarly to the street sign described in Chapter 2.6.1, my design took advantage of the existing infrastructure and layered the information. However, the interactive signpost used both physical and digital layers to visualize, which made it more difficult to continue reading. Furthermore, the prototype used analogue, physical, digital, and interactive elements. Conversely, regarding the selected work examples, only Points and Datacacher use both physical and digital elements (Chapters 2.6.2 and 2.6.3). In contrast to both examples, it is
possible to trace back the information and give feedback using the signpost. Unlike the Urbanflow (Chapter 2.6.2), the feedback is not limited to reporting an issue; it is about collecting different perspectives. As the option to leave a comment online remained unused during the experiment, the feedback by passers-by was not more detailed than in case of Fair Numbers (Chapter 2.6.3), but it was ideally saved immediately on the website. Similarly to Fair Numbers, the design broached the issue of subjectivity and objectivity and could be used temporarily.

The prototype of the interactive signpost was distinct from all of the examples by being easily mountable and demountable. Thereby, the prototype could function as a data annotation tool that is maintained by a non-governmental organization such as the Connectors Society. A test person emphasized that being on site helped them to think of his or her opinion. In addition, by using the signpost common citizens are reached, instead of only engaged people using an online platform or application. Thus, collecting data annotation on site using a physical object seems to be an intrusive method to visualize an issue in a readable and transparent way. Even though the design was built on the learning outcomes of the analysis of related work examples and thus shows similarities, the interactive signpost presents novel insight into making an issue about invisible smart city data and software visible on site. The following clarifies for which research communities this study is relevant.

6.2.2 Relevance
This study is situated in the field of interaction design, which Löwgren (2007) describes as the “act of shaping digital products and services” (p.1). Here, the most intriguing question is how to balance readability and transparency in order to design a user-friendly interface. In this study, sketchy paper prototypes focused on GUIs, whereas the final prototype was a tangible output system. As the final prototype used a tangible object to visualize things in public places, the research contributes to the fields of public displays, visualization design, and tangible user interfaces.

Through the focus on urban context, this thesis is especially relevant for the research community in the areas of urban computing, urban informatics, and UrbanIxD. All three domains focus on the use of technology in the urban context. Urban computing describes research about “mobile and pervasive computing situated within urban contexts” (Greenfield et al., 2007, p.8). Furthermore, the outcomes are relevant for urban informatics, as the designs connect the physical and the digital in an urban context. According to Foth, Choi, and Satchell (2011), “urban informatics is the study, design, and practice of urban experiences across
different urban contexts that are created by new opportunities of real-time, ubiquitous technology and the augmentation that mediates the physical and digital layers of people networks and urban infrastructures” (p.4). In addition, the focus of the community of UrbanIxD is people’s needs (UrbanIxD, 2014). According to the community’s manifesto, a significant contribution to the research community would be “the creation of interfaces that allow citizens to understand and act upon data gathered in cities and the subsequent impact on value and identity” (UrbanIxD, 2014, “The Manifesto”, para. 7).

Furthermore, this thesis contributes to research in the area of Human-Computer-Interaction (HCI). For instance, at the Conference on Human Factors in Computing Systems 2016 (CHI ’16) in San José (CA, USA), disadvantages and advantages of algorithms being part of the decision-making process and how to deal with this in the future were topics of a panel (Lustig, Pine, Nardi, Irani, Lee, Nafus, & Sandvig, 2016). The following summarizes how the research communities could further elaborate the learning outcomes of this study.

6.3 Future directions

In order to improve readability of the public visualization, alternative methods to retrieve more detailed information need to be developed. In addition, the prototype should demand less maintenance but still trigger different perspectives on the issue. Thus, one focus of future studies could be to explore solutions that make it easier for readers to take the next step and retrieve future information with the help of digital tools, but also solutions that avoid the digital layer and make more information available on site.

A subsequent design could take into account that passers-by are interested in what is happening inside the prototype, and the box of the prototype could be partly transparent. Another idea would be to also visualize more on the box, for instance the path that the data take: from the database of the platforms to the prototype. In addition, future research could further investigate how readable and transparent visualization could make understandable what is hidden in code and software, and how to avoid the translation from code to text in the visualization process. Here, it would be relevant to explore different algorithms and ways to visualize them on location.

Furthermore, the concept of crowdsourcing data annotations on site by using physical objects should be explored further. In a future design, diverse perspectives should be collected and shared without using interviews. Furthermore, future prototypes need to be tested during a longer period and also without intervention during the test session in order to gain more
insights into whether and how the prototype itself, the function to retrieve more information and to add different perspectives, and a possible digital layer could be used with less or no maintenance.

In addition, more citizens should be included in the design process in future research, as this was not possible in the short period of this project. For a larger involvement, it will be necessary to invest more time in recruiting citizens, in gaining a common understanding of the topic, and in clarifying the roles in the process and each other’s expectations of the collaboration. It is important that the different stakeholders benefit from the collaboration.

A topic that is relevant to explore further not only in the context of the smart city is the increasing trust in data that similar to the terms display and interaction blindness, could be described as data blindness. Besides, more research needs to be conducted regarding how to make backstories visible in GUls. Even if the interactive signpost visualizes an issue that is normally hidden in the software and reaches out to the citizen, it is uncertain whether the issue ultimately confronts the end-user of the software. Since it was difficult even for an interaction designer to trace back the information, a better way to explore transparent redesigns of an application would be to follow the development of an application during a longer period, and afterwards redesign the application with design workshops together with designers and developers.

6.4 Conclusion

As part of this thesis, a public, physical visualization of an issue that is usually hidden in software and code was developed. Thereby, to evoke discussions on smart cities was the main criteria. In addition, the visualization should balance of transparency and readability. This was achieved with two layers of information and by collecting citizens’ perspectives on the prototype.

The prototype was one of the results of this research on invisible data and processes in a smart city. Digitalization, ubiquitous computing, and IoT decrease the visibility of computers and software (Chapter 2.1). At the same time, mobile devices and locative media increase the amount of knowledge that can be gained about people and places (Chapter 2.2). The boundaries between subjectivity and objectivity blur. Moreover, it becomes common to think that better decisions can be taken based on data instead of trusting one’s gut (Chapter 4.2.2). Processes are increasingly automated. Even for crowdsourcing, researchers look for
automated solutions (Chapter 2.4). Thus, smart city technologies are “complex assemblies of contradictory issues” (Latour, 2008, p.4), which from the outside are invisible (Chapter 2.3).

At the beginning of this research process, insights into the context and problem domain were gained by conducting field research, semi-structured interviews, and a design workshop (Chapter 4). In the public space, digital information and digitally gathering information are nearly invisible. However, different urban planners and companies are interested in new ways of collecting data and using smart systems, such as an intelligent camera systems, to analyze humans’ behavior and preferences. Furthermore, the design workshop led to a discussion about user-friendliness and needed readability. In that same vein, the aim of the developed prototypes was to balance transparency and readability in the interface. For this purpose, the complex information was divided across different levels. In this thesis, the concept of transparency is defined as visualizing different views of an issue and thereby making subjectivity a subject of discussion.

The first results of the design exploration were paper prototypes, which should make the parts of the underlying processes visible (Chapter 5.1). Thereby, the logic behind the interface was visualized, either as part of the application with the use of layers and filters, or as part of an alternative application that should make things visible that are invisible in the original application, such as places. However, the user-friendliness of the designs was decreased and the issues still hidden from citizens. Citizens are mostly affected by decisions made by urban planners and public officials. Furthermore, only citizens have the knowledge to identify gaps between their perceived reality and interpretations by machines, and thus to make varying perspectives visible.

Based on an application that predicts the beauty of streets by using geo-tagged social media, a prototype for a public visualization arose (Chapters 5.2 and 5.3). As part of the user evaluation (Chapter 5.4), it was proven that the tangibility, interactivity, and temporariness of the prototype caught passers-by’s attention. However, to aim for people’s attention led to a design that visualized a disputable aspect of one artifact, but at the same time became a blackboxed, controversial artifact itself. Nevertheless, the prototype was perfectly integrated in the existing infrastructure of the city, and collected diverse perspectives on software predicting the beauty of a place based on geo-tagged social media data. Thus, the prototype triggered discussion about an issue that comes with smart city technologies.
References


PinMeTo (n.d.). We help chains and franchises reach all customers on all relevant platforms. Retrieved from http://www.pinmeto.com/#!


List of Figures

Figure 1 (p.9): Scenario 1: Only a few people know how to control the complexity of automated and intelligent systems.

Figure 2 (p.9): Scenario 2: The smart citizens have tools to control and communicate with the smart city.

Figure 3 (p.10): A black box system (Latour, 1999) in the messy city.


Figure 15 (p.24): Datacatcher displaying data on location. From: Merrill, Sam. (n.d.). Fun in the rain at #BeingHuman15 #RadicalNewcross #datatourist event ... #engage #datacatcher [Tweet]. Retrieved from https://twitter.com/socmerrill/status/665504557531795456


Figure 17 (p.29): Cykelparometer.

Figure 18 (p.29): Engraved information.

Figure 19 (p.29): Infrastructure meets surface.

Figure 20 (p.29): Growing traces.


Figure 22 (p.30): Overlaid images.


Figure 25 (p.33): Given scenario and crowdsourced data sets.

Figure 26 (p.33): A final paper prototype and post-its documenting design decision.

Figure 27 (p.36): The underlying concept of Likeways is visualized in magnetic fields.

Figure 28 (p.36): Annotated measured sound pollution.

Figure 29 (p.36): Different layers should make visible the types of data sources, the data themselves, and the logic behind the analysis.

Figure 30 (p.37): Counter application making a place visible.

Figure 31 (p.41): Exploring the concept of the interactive kaleidoscope.

Figure 32 (p.41): Exploring the concept of the interactive signpost.
Figure 33 (p.44): Final prototype mounted at street pole.

Figure 34 (p.45): Screenshot of the website showing a map with gathered locative media.

Figure 35 (p.45): The electronics inside of the prototype.

Figure 36 (p.45): API programming with Twitter4J and Processing.

Figure 37 (p.46): Setting up a user testing session.

Figure 38 (p.46): User testing: interviews with interested passers-by’s.

Figure 39 (p.46): User testing: observations.

Figure 40 (p.47): Testing different kinds of wording.

Figure 41 (p.47): User testing with the Connectors Society.

Figure 42 (p.47): User testing at a bridge in Malmö.

Figure A1 (p.70): Light sensors.

Figure A2 (p.70): Wind conditions.

Figure A3 (p.70): Webcam tracking.

Figure A4 (p.71): Brainstorming different data sets.

Figure A5 (p.71): Ordering data sets according to relevance.

Figure A6 (p.71): Documented design decisions by team 1.

Figure A7 (p.71): Paper prototype by team 1.

Figure A8 (p.71): Concept and design decisions by team 2.

Figure A9 (p.71): Screendesigns by team 3.

Figure C1 (p.74): Possible ways to display data that the Link NYC would track (Sidewalk Labs et al., 2016), for instance by using an interactive poster or an alternative box that would be put up by activists or hackers. A redesigned form of Link NYC could include a transparent box so that the electronics would be visible to the passers-by. Furthermore, the tracked data would be displayed immediately and there would be different forms of communicating with the smart system, e.g. by recording or leaving a message.

Figure C2 (p.74): Modcam would function as a facility management system in the city. Thereby, the heatmap would be projected on the street. In the urban context, the heatmap would visualize which spaces are unused.

Figure C3 (p.74): Displayed data analyzed by Modcam would show which demographic group of people is using a certain space. Possible places are bus stops and benches.
Figure C4 (p.75): Inspired by the Connectors Society’s collaboration with students studying systems and information engineering at University of Virginia, the automated analysis using Visual Basic would be displayed immediately on site.

Figure C5 (p.75): Visualizing the brightest path according to Array of Things and citizens’ input

Figure C6 (p.75): Another concept of displaying the brightest path according to Array of Things and citizens.

Figure C7 (p.76): Paper prototype: designing a kaleidoscope that could hold a mobile phone as a display.

Figure C8 (p.76): Testing the view of paper prototype.

Figure C9 (p.76): Flickr search results for “sidewalk”, Malmö.

Figure C10 (p.76): A map from Flickr showing results matching “streetlight” and located in Malmö.

Figure C11 (p.76): Retrieving one image with the use of Processing and Flickr API.

Figure C12 (p.76): Processing programming using the Twitter4J library.

Figure C13 (p.77): Interacting with the prototype.

Figure C14 (p.77): Testing the interactive signpost in the pedestrian zone. Prototype is hidden from certain directions.

Figure C15 (p.77): Close-up of the interface.

Figure C16 (p.77): Easily mountable and demountable design.

Figure C17 (p.77): Interviewing a test-user.
Appendices

Appendix A: Design workshop

Task
The participants were three designers from an interaction design master class, and three interaction designers who recently graduated and were already working. The task was to design a lo-fi prototype for a given scenario. The scenario was that a student was searching for the perfect space to eat lunch (see below). Besides this, selections of data sets were provided (see below). Each type of measured data was presented on a map showing the area of the university. Regarding the light sensors, it is shown where the sensors were located and their current measured values (Figure A1). The picture based on the weather forecast map clarifies which details about the weather situation were known (Figure A2). A webcam picture displays where the camera tracks occupied spaces (Figure A3). As the workshop time was limited to two hours, I provided a pre-selection of data. This was already a decision regarding which data were omitted and thus became invisible. At the beginning of the workshop, alternative data sets were brainstormed (Figure A4). Nevertheless, it was left open which data sets the participants would use, how they would select them, and whether they would provide alternative information (Figure A5). The data were not real, as there are no detailed ambient data available for Malmö. I wanted the designers to create a prototype for a space they knew, so that they would not have to conduct field research. I tried to provide information that was as detailed as possible so that the participants would have to decide how and how much they would translate the information. The types of data sets were inspired by interfaces that try to represent the city space based on ambient data (Chapter 2.6.2).

Every time the participants thought they made a decision, they were asked to write the decision on a post-it and number it. Thus, I documented the instances when they thought they made a decision as well as which decisions were taken during the design processes.

Scenario
If there is...
> a public outdoor space at Orkanen
> a user who is searching for the perfect spot to eat lunch
> data regarding the amount of wind (data source: weather forecast)
> the location of people using the space, i.e. “traffic density” (data source: webcam tracking)
> the amount of sunlight (data source: sunlight sensors)
Data sets

Fig. A1: Light sensors.

Fig. A2: Wind conditions.

Fig. A3: Webcam tracking.
Results

Fig. A4: Brainstorming different data sets.

Fig. A5: Ordering data sets according to relevance.

Fig. A6: Documented design decisions by team 1.

Fig. A7: Paper prototype by team 1.

Fig. A8: Concept and design decisions by team 2.

Fig. A9: Screendesigns by team 3.
Team 1 (Figure A6 and A7)

One of the design teams decided to crowdsource what the students at the university would base their decision on to find a spot outside of the university building. The designers preselected the data that they considered the most important. After crowdsourcing, they decided to show the data sets with the most votes: space, sun, wind, and comfort. However, during the design process they assumed that comfort was not important for regular students, as they already know how comfortable a place is. Consequently, the recommendation was only based on data about sunlight, wind, and free space. The abstract values were represented by a gradient visualization of the parameters. The user could decide on which data he or she wanted to base a decision. In addition, the application could learn the user’s preferences.

Team 2 (Figure A8)

Another design team wanted to provide the user with a direct feeling of the selected spot instead of representing the recommendation in numbers. The team’s idea was to build a box to translate the measurements of noise, wind, and temperature into sensable output. The navigation to the spot would be done with a common map. This is the opposite to the abstract output of the first design solution.

Team 3 (Figure A9)

The third design team focused on a playful design and on appealing visualizations of the environment and data. Besides this, it wanted to offer the user a three-dimensional map to make it easier to orientate him- or herself.

A reminder to make visible why these kinds of data sets were selected and to show more detailed information on the interface led to a discussion about user-friendliness. The participants argued that the user is in a hurry and only wants to see where to eat lunch. According to them, more information would decrease the readability and thus the user-friendliness. In addition, they argued that designers do not have time to include varying perspectives and detailed insights.
Appendix B: Design modifications

Likeways (Figure 27)

The application Likeways (Traunmueller, 2015) is a prime example to show how important things are cleaned out of a user interface. In the developer interface, the amount of Facebook likes of a place is visualized by the size of the radius marking the location. The more likes there are, the bigger the radius is. However, in the final version of the user interface, the user only sees the recommended path and a few important places. The concept of my modified user interface was to bring back the circles in the form of magnetic fields. The more likes there are, the bigger the magnetic circles would be. The recommended path could be the result of either magnetic attraction or repulsion. In the case of repulsion, the suggested route follows where fewer or no attractions, such as museum or restaurants, are present on Facebook.

Walkonomics

In the case of the application Walkonomics, the aim was to visualize the paradoxes analyzed in chapter 2.4 regarding the basis of the recommendations. The backstory of the application is complex, and therefore the redesign followed Schoffelen et al.’s (2015) suggestion to layer information. It was possible to blend different kind of information in and out on top of the map showing the calculated path.

First, my redesign involved different layers making visible the types of data sources and the data themselves, such as Flickr images or crowdsourced user feedback (Figure 29). Attempts were made to visualize the logic behind the decision of whether a place is walkable by using overlays. Besides this, another way to make things visible could be to use an alternative application that manipulates the shown information (Figure 30).

SoundCity (Figure 28)

Finally, when redesigning the online dashboard of the application SoundCity (Renouard, 2015), information overlays should make background information about the measurements visible. The information is already partly collected by the current version of the application. In my redesign, the function to add a story to the recorded noise follows Schoffelen et al.’s (2015) suggestion to use narratives to visualize diverse backstories. However, in Schoffelen et al.’s research (2015), the narratives were collected as part of a workshop. By collecting the narratives via the application SoundCity, the risk is high that the user input will be similar to the crowdsourcing function of the Walkonomics application.
Appendix C: Design exploration

Alternative concepts

Fig. C1: Possible ways to display data that the Link NYC would track (Sidewalk Labs et al., 2016), for instance by using an interactive poster or an alternative box that would be put up by activists or hackers. A redesigned form of Link NYC could include a transparent box so that the electronics would be visible to the passers-by. Furthermore, the tracked data would be displayed immediately and there would be different forms of communicating with the smart system, e.g. by recording or leaving a message.

Fig. C2: Modcam would function as a facility management system in the city. Thereby, the heatmap would be projected on the street. In the urban context, the heatmap would visualize which spaces are unused.

Fig. C3: Displayed data analyzed by Modcam would show which demographic group of people is using a certain space. Possible places are bus stops and benches.
Fig. C4: Inspired by the Connectors Society’s collaboration with students studying systems and information engineering at University of Virginia, the automated analysis using Visual Basic would be displayed immediately on site.

Fig. C5: Visualizing the brightest path according to Array of Things and citizens’ input.

Fig. C6: Another concept of displaying the brightest path according to Array of Things and citizens.
Kaleidoscope

Exploring the concept of the kaleidoscope.

Fig. C7: Paper prototype: designing a kaleidoscope that could hold a mobile phone as a display.

Fig. C8: Testing the view of paper prototype.

Interactive signpost

The design process: trying out different ways of collecting data from Flickr and Twitter, and testing the prototype in Malmö.

Fig. C9: Flickr search results for “sidewalk”, Malmö.

Fig. C10: A map from Flickr showing results matching “streetlight” and located in Malmö.

Fig. C11: Retrieving one image with the use of Processing and Flickr API.

Fig. C12: Processing programming using the Twitter4J library.
Fig. C13: Interacting with the prototype.

Fig. C14: Testing the interactive signpost in the pedestrian zone. Prototype is hidden from certain directions.

Fig. C15: Close-up of the interface.

Fig. C16: Easily mountable and demountable design.

Fig. C17: Interviewing a test-user.