RECOMMENDATIONS FOR THE DESIGN OF COLLABORATIVE MAPPING SOFTWARE TOOLS FOR MAPTABLES

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Cartography M.Sc.

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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the joint Master of Science in Cartography

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ABSTRACT

Nowadays, maptables are being increasingly used in urban development related spatial decision-making processes, in which stakeholder participation has become a central element. The maptable is an interactive tool that supports collaborative planning and facilitates the participation of stakeholders. While most studies of interactive maptable software focus on the involvement of stakeholders and domain experts, the use and usability of maptable software for collaborative mapping have been hardly investigated. The main objective of this research is to develop recommendations on design principles of GIS collaborative mapping software tools for maptables, based on testing and evaluating the usability of the Phoenix software. The second objective focuses on the research methodology: to provide recommendations for the concurrent use of several mobile eye-tracking devices to investigate the usability of maptable software in collaborative mapping in group decision-making processes. The requirement analysis through a Focus Group interview with experts and a mixed-method approach of eye-tracking, thinking aloud, observation and questionnaire, and interview techniques in a task-based experiment provided a complete and wide range of observation data for investigation of the usability of the Phoenix software. Four eye-tracking glasses were used concurrently to investigate the group-decision making processes in collaborative mapping during the experiments. As a result of the investigation, the strong and weak parts of the Phoenix software were outlined. Based on the analysis of the retrieved results the general recommendations for maptable software were developed. The outcomes of the research, the usability test results and recommendations could provide guidelines for further improvements of the maptable software and make them more user-friendly.

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I dedicate this thesis in the memory of my father.

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1. INTRODUCTION

1.1. Motivation and problem statement

Nowadays urban and regional planning are becoming a progressively collaborative activity, in which stakeholder participation has become a central element (Pelzer & Geertman, 2014; Pelzer et al., 2014). The maptable is an interactive tool that supports collaborative planning and facilitates the participation of stakeholders (Figure 1.1). A maptable is a map-based touch table that functions as a Planning Support System (PSS) in combination with components such as data, software, and models. The tool consists of a GIS base for performing database management, analysis, and visualization tasks, but also includes functionalities to support planning tasks such as design, scenario-building, visioning and evaluation (Pelzer et al., 2014).

Figure 1.1 Stakeholders collaborating with maptable (Source: URL1)

The maptable is aimed to support collaboration among small groups of people (from 6 up to 10) so that participants could stand around the table and have a discussion (Pelzer et al., 2014). The maptable is a large-scale horizontal mapping table displaying digital cartographic content. It allows users to interact with a map via touches and gestures. There may also be an additional small screen showing interactive mapping results and outcomes or 3D scenes of the 2D maps projected on the table (Flacke & de Boer, 2017). Maptables are used in different applications of collaborative mapping, e.g. urban planning (Pelzer, Arciniegas, Geertman, & Lenferink, 2015), and spatial planning (Pelzer et al., 2014), but also for other purposes, such as increasing social learning and awareness (Shrestha, Köckler, Flacke, Martinez, & van Maarseveen, 2017), emergency planning (Tena, Díez, Aedo, & Díaz, 2014), renewable energy planning (Flacke & de Boer, 2017), etc.

Most of the maptable applications work with standard GIS-based desktop software (Pelzer et al., 2014). One of the commonly used tools is CommunityViz Scenario 360 software, which is an interactive ArcGIS extension, that complements ArcGIS with an analysis tool and a decision-making framework (URL2). However, the software, that is specifically created for maptables is the Phoenix software by Geodan (URL3). The software was developed for the touch table context, to be operated with touch control. The software shows geospatial mapping data and contains additional drawing functionalities, such as sketch tools, a geo ruler, a buffer tool, adding notes, etc. (Phoenix 1.2.0, n.d.).

While most studies of interactive maptable software focus on the involvement of stakeholders and domain experts, the use and usability of Phoenix and other maptable software for collaborative mapping have been hardly investigated (Flacke & de Boer, 2017). The research problem is that no GIS software specifically created for maptables is available yet (except Phoenix).

1.2. Research objectives and questions

1.2.1. Research objectives

The main objective of this research is to develop recommendations on design principles of GIS collaborative mapping software tools for maptables, based on testing and evaluating the usability of the Phoenix software.

The second objective focuses more on the research methodology: provide recommendations for the concurrent use of several mobile eye-tracking devices to investigate the usability of maptable software in collaborative mapping in group decision-making processes.

The research results may interest software developers for maptables. Usability test results and recommendations could provide guidelines for further improvements of the maptable software tools and make them more user-friendly.

1.2.2. Research questions

To achieve the research objectives, the following research questions need to be answered:

- What is the usability of the Phoenix software?
  - Who are the users, and what are their characteristics?
  - What are the specific requirements of the participatory use of the maptable software?
  - What are the effectiveness, efficiency, and user satisfaction of the Phoenix software for executing a collaborative mapping task?

- What recommendations could be given for the design of GIS collaborative mapping software for maptables?

- Can several mobile eye-tracking devices be used concurrently to investigate group decision processes in collaborative mapping?
  - How can data be collected? How can the collected data be synchronized and analyzed?
  - How are group decisions made?

1.3. Outline of the thesis

The answers to the research questions will be summarized in the last chapter but will be described explicitly in subsequent chapters. The research stages are described in a workflow below (Figure 1.2). The thesis is structured with seven chapters. Chapter one is an introduction with the research statement, objectives, and research questions. Chapter two briefly describes maptables, their applications, collaborative mapping, and group decision processes, and summarizes the literature review of previous and related studies, including already executed user studies. Chapter three presents the methods of the research implementation, which includes requirement analysis, eye-tracking, thinking aloud, video observations, questionnaire, and the interview. Attention will also be paid to the selected case study. Chapter four describes the requirement analysis based on a Focus Group interview with experts. Chapter five describes the implementation of the pilot test and user tests and, explains the technical possibilities of the concurrent use of multiple Tobii Pro

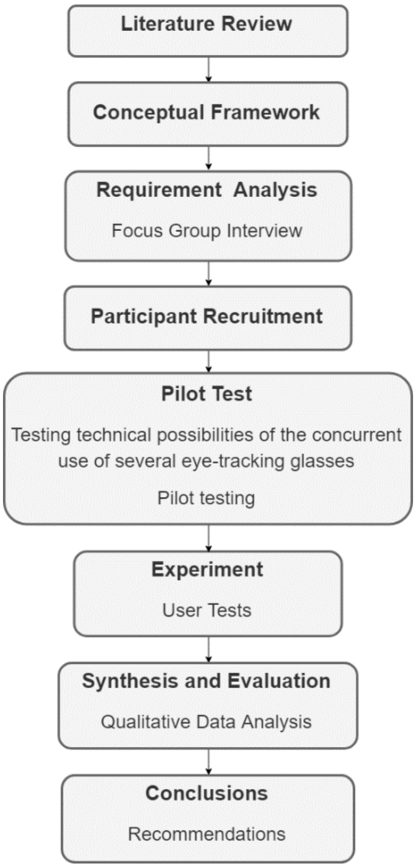


Figure 1.2 Research workflow

Glasses and the recruitment of test persons. Chapter six presents the results of the experiments and the results of the data analysis. Chapter seven summarizes the work that has been done and the answers to the research questions and gives suggestions for further research works.

2. PREVIOUS RESEARCH ON THE USE OF MAPTABLES

2.1. Introduction

Referring to the workflow, as presented in Chapter 1 (Figure 1.2) the first step in implementing research is a literature review. This chapter covers a review of the literature relevant to this thesis research. First, an overview of maptables and their applications will be given. Section 2.4 covers the basics of group decision-making processes in collaborative mapping. Section 2.5 describes the research works that have been done on the usability of maptables and their applications.

2.2. Maptables

2.2.1. General characteristics

The maptable is a table surface with a touch-sensitive computer screen (Bulens & Ligtenberg, 2006; Shrestha et al., 2017). It works with finger multi-touch gestures, a special pen, and a keyboard with a mouse (URL4). The screen is operated with a regular computer (PC) which is usually located under the table (Vonk & Ligtenberg, 2010). The sizes of maptables vary, but in general, they can accommodate a small group of up to ten people around the table (Figure 2.1) (Vonk & Ligtenberg, 2010). For instance, the MapSup maptable is 116 cm in diagonal and stands on four flexible wheels; the screen can be rotated in horizontal and vertical ways and adjusted in height (URL4).

Figure 2.1 Stakeholders collaborating around a maptable

The maptable functions as an instrument between stakeholders and different types of planning tools (i.e., software). It facilitates a broad range of group tasks where maps are the central component (Pelzer, Arciniegas, Geertman, & de Kroes, 2013). The spatial element or the map component of the maptable is a GIS (Geographical Information System) displaying suitable layers that can be overlayed and turned on and off, and on which stakeholders can draw, in this way creating a new map (design) (Pelzer et al., 2013). It uses a GIS base for navigating, map structuring, and visualization of data, and, furthermore, for creating and saving spatial content during the discussion processes (Shrestha et al., 2017). Besides, the horizontal positioning of large interactive screens, such as maptables, supports collaborative activities where participants tend to solve tasks together, compared to vertical setups (Tong, Tabard, George, & Serna, 2017).

Initially, maptables were developed with the expectation that digital maps, in combination with sketch tools, could accelerate the process of designing spatial plans (Bulens & Ligtenberg, 2006). The literature review also revealed other applications of maptables, such as usability evaluation (see section 2.3), but, nevertheless, applications are mostly aimed at spatial planning.

2.2.2. Maptable software tools

As hardware, maptables do not contain any data. However, a typically embedded GIS software package allows for storing relevant datasets (local or distributed) (Bulens & Ligtenberg, 2006). Thus, the maptable performs as a working interface between stakeholders and various planning tools, and most of them characteristically run within the ESRI ArcGIS environment (Pelzer et al., 2013). My literature review revealed several software which are used most often in maptable based workshops, such as CommunityViz, Phoenix, and Urban Strategy. Also, the use of Envision Tomorrow+ has been mentioned, as well as non-domain specific tools, as Google Earth (Pelzer, Goodspeed, & Brömmelstroet, 2015). Also, as part of their research projects, some scholars present customized software for supporting spatial planning processes (e.g. Tena et al., 2014).

CommunityViz by City Explained Inc. (URL5) is a frequently used planning support tool (Pelzer, Arciniegas, et al., 2015). It is a GIS-based planning software and extension of the ArcGIS platform (URL5). It consists of two components: Scenario 360 and Scenario 3D. Scenario 360 expands the quantitative capableness of ArcGIS, while scenario 3D shows interactive three-dimensional scenery of buildup territories and surroundings in half photo-realistic view (Lieske & Hamerlinck, 2015). CommunityViz Scenario 360 allows creating conjectural plots, making and changing suppositions, viewing impacts of changes, decision making, and linking to 3D visualization tools. The software provides a wide range of visualization, analysis, and communication tools for planning (Walker & Daniels, 2011) and helps in decision-making processes in regional and local planning (URL5). However, this tool is designed for single-user software interaction and not for group use on maptables.

Phoenix is a maptable based tool developed by Geodan that visualizes map data and allows to draw and add data for spatial design and collaborative mapping (URL3). Phoenix is mainly created for a touch screen environment (Phoenix 1.2.0, n.d.) and has an intuitive user interface (Dias, Linde, Rafiee, Koomen, & Scholten, 2013). The application uses webservers for the visualization of the map. The Phoenix Prepare Tool helps to assemble the layers for further displaying them in the tool. The sketches created while using Phoenix can be exported to any desktop GIS application (Phoenix 1.2.0, n.d.). The software tools are easy to use; however, it lacks advanced evaluation tools, such as impact models (Dias et al., 2013).

Urban Strategy is a software package based on calculation models developed by TNO (the Netherlands Organization for Applied Scientific Research) (URL6) for supporting complex urban planning sessions (Champlin, Te Brömmelstroet, & Pelzer, 2018). The broad spectrum of models that cover urban dynamics include features such as air quality, noise, traffic intensity, safety, energy production and consumption, urban heat and greenhouse gases (Champlin et al., 2018; Dias et al., 2013; URL6). The software works on a PC and is accessible only for expert operators. Stakeholders can discuss what they see and give suggestions (Dias et al., 2013). The outcomes are shown as maps, graphs, and tables (Champlin et al., 2018).

2.3. Application of maptables

Maptables display the digital content in terms of maps and allows users to interact with it via touches and gestures. Navigation functions such as panning, zooming in and out, let the users maneuver through the area on the map. While navigating, they can apply changes on the map, for instance, allocating different facilities, sketching or annotating (Flacke & de Boer, 2017; Shrestha et al., 2017). Some tools show the immediate outcome indicators of the drawings.

Spatial planning appears in several studies. The planning process of urban zones and city parts is a complex process that generally starts with designers and creative professionals. In order to improve the positive impacts and to reduce the negative ones of the initial ideas, they need to be acknowledged and evaluated. So, the design becomes an interactive process of feedbacks, external reviews, and contributions to the process by and with stakeholders. Stakeholders with different backgrounds can be involved into the process, as urban areas incorporate various prospects, such as economy, movability, security, aesthetics, health and climate issues, etc. (Dias et al., 2013). For instance, four cases of urban planning with tasks aiming at different goals were presented in a study of Pelzer, Arciniegas, et al. (2015). Scholars used maptables in combination with, for example, CommunityViz software as the central element of stimulating negotiation among stakeholders to observe the usefulness in planning practice. As study of Lenferink, Arciniegas, Samsura, & Carton (2016) had a case study of regional planning with site supply for urban development, while a research of Pelzer et al. (2013) used maptables to include sustainability facets in the urban development plan.

Another wide spread application of the maptables is land use planning. For instance, the study of Arciniegas & Janssen (2012) describes a set of collaborative land use planning workshops with respect to a peat-meadow polder in the Netherlands. One more study covers land use and water management in relation to climate change (Eikelboom & Janssen, 2017). Another study (van de Ven et al., 2016) focuses on urban planning in view of climate change, and researchers created a toolbox called the Adaptation Planning Support Toolbox for touch tables to integrate climate adaptation in actual planning. The toolbox consisted of two web-based software tools running on touch enable hardware developed for supporting the planning process: the Climate Adaptation App (climateApp) and the Adaptation Support Tool (AST) guides. The climateApp was designed for informing the participants about potential adaptation measures in the beginning, while AST was a touch-based platform where participants could select and situate those interventions and see the immediate feedback.

A study for emergency planning (Tena et al., 2014) was conducted for risk reduction, i.e., facing an emergency, prioritizing activities, and defining strategies. Scholars developed their computer-based collaborative tool "TIPExtop" for a horizontally placed touch screen. The authors customized the toolbar depending on the roles of participants: advanced toolbar for the coordinator and toolbar for the remaining participants, that contained annotation tools, resources palette, and drawing tools, as well as tools for editing and saving. The central element of the software was a map with the street view and the satellite view, and the coordinator was switching the two views.

Some studies aimed at increasing social learning through stakeholder discussions: increasing social awareness and acceptance, negotiation of stakeholders with different backgrounds, and individual learning. All implemented maptables, covering the initial goal of collaborative discussion with the help of the tool. For instance, one of the recent studies (Flacke & de Boer, 2017) organized a workshop involving local stakeholders in order to increase the social acceptance of renewable energy sources. The workshop aimed to stimulate the discussion, and, as a result, to arrange renewable energy facilities, such as solar panels and wind turbines. Another example of an application field is environmental health issues (Shrestha et al., 2017), where the goal was to stimulate, articulate and map the stakeholders' awareness to come to a shared problem understanding.

2.4. Group decision-making processes

Group decision-making or collaborative decision-making is a process where stakeholders are conjointly involved in making a decision (Ghavami & Taleai, 2017). It has several privileges compared to individual decision-making (Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007). First, it helps to identify and integrate the point of view of each participant, which leads to involvement in the process of decision-making. Therefore, it helps to achieve results of higher acceptance and superior realization of decisions. Second, the process allows linking various experiences, ideas, and perspectives into high-grade decisions. The efficiency of the decision-making process depends on the capacity of combining all the knowledge, viewpoints, and values of involved stakeholders and the process of making the decision itself (Nogueira, Borges, & Wolf, 2017).

The spatial group decision-making process is a model of decision-making that consists of a group of several people whose aim is to resolve which action would be better in accordance to particular spatial issues (Ghavami & Taleai, 2017). Furthermore, Ghavami & Taleai (2017) studied and characterized the model and presented a framework called "the conceptual agent-based framework for simulating spatial collective (group) decision-making processes, or CaféSCP. It contains vital concepts of spatial group-decision making processes (SGDMP), such as spatial influence, group-level influence, individual-level influence, negotiation influence, and performance. First, spatial problems have a unique influence on group decision-making process. For instance, representation of spatial information; spatial complexity problems (the metric properties of space, spatial relation, spatial dependency, and spatial heterogeneity), and scale and time issues have a significant role in effectiveness of the spatial group decision-making process. Secondly, since groups consist of numerous individuals, who are aiming to decide which action needs to be taken regarding a specific spatial problem, individual-level issues can influence the outcomes of group decisions. These issues are: individual cognition – how they acquire the information; personality issues – behavior and actions that individuals can generate during the group interaction; and communicative issues – communicative skills of an individual. Third, group-level issues, such as social cognition, group norms, and group processes influence group decision outcomes. Fourth, negotiation – has significant part in resolving contradictions and facilitating communication inside the group. Fifth, performance measures are the different range of proceedings to use with negotiation process and its outcomes.

Arciniegas & Janssen (2012) described multiple models structuring the decision process of spatial decision-making presented in three stages: identification, development, and selection. Each step of the process involves map use, which can be applied to maptables as well. The first step - identification of the problem - consists of defining the problem, deciding on alternatives and evaluating the criteria, where maps are tool for communication. The second step - exploration of alternatives - uses maps for spatial evaluation and includes preferences of decision-makers, evaluation of alternatives, and expert knowledge. The last step - selection and decision contain trade-offs, evaluation and a consensus plan, where the maptables perform as interactive decision support tool.

Some recent observations (Conniff, Colley, & Irvine, 2017) showed that interaction with maptable in a group can be dominated by one or two users. This phenomenon was also observed in the research of (Nacenta et al., 2012) with an interactive table. Study of Conniff et al. (2017) also revealed easier involvement to process for more reserved participants, when the visual focus is on tool, rather on other participants. However, study of Pelzer, Goodspeed, et al. (2015) concluded that tool should not dominate and suppress the discussion, but yet, participants are encouraged to assimilate the basic ideas of the tool and emerging spatial phenomena. Balancing these two interventions may be significant aspect of a successful workshop.

In the process of decision-making, the impact on outcome policy depends on elucidating the phases where stakeholders are engaged, cooperate, and share their interests. Thus, decision-making consists of not only collecting and analyzing information but primarily includes cooperation and sharing knowledge of various participants with different interests and preferences (Nogueira et al., 2017).

2.5. Studies on the usability of maptables

Most of the studies of maptable based Planning Support Systems (PSS) focus on evaluating the system, the workshop results, and the engagement of stakeholders into planning processes, but not specifically on usability (Flacke & de Boer, 2017; Pelzer et al., 2014; Shrestha et al., 2017). Vonk & Ligtenberg (2010) focused on functionality and usability evaluation of two PSSs which were developed following traditional system engineering and socio-technical methods. The authors suggested improvements and requirements of a PSS for collaborative sketch planning. Lenferink et al. (2016) explored whether facilitation of geodesign and game theory on maptables could stimulate learning among stakeholders and found that it grants added value to the planning process.

The number of studies involving user research of collaborative or participatory mapping with maptable based PSSs is low. The earliest design evaluation studies of specifically maptables (operated by touch pens) were done by Bulens & Ligtenberg (2006) and Yang & Baber (2006), where suggestions were mostly aimed at improvements of drawing. Most of the PSS usability tests have been conducted individually in small groups (Russo, Costabile, Lanzilotti, & Pettit, 2015) or on internet-based public participation (Brown & Weber, 2011; Onyimbi, Koeva, & Flacke, 2018). The research of Rzeszewski & Kotus (2019) focused on evaluating internet-based public participatory mapping by means of usability testing experiment, including eye-tracking. The research results did not focus on group participatory or collaborative mapping, but some aspects of the testing could be useful. A research done by (Champlin et al., 2018) looked for the correlation between the usability of PSS and the satisfaction of the planning process. They evaluated the usability of the Urban Strategy software with 14 statements, related to the aspects of the tool such as transparency, level of details, output clarity, focus, credibility, process organization, and chaperoning. The results showed a positive score of usability and revealed strong correlations between the perception of the process quality and usability.

The literature review did not reveal any publications reporting on research into the usability of the Phoenix software specifically. However, te Brömmelstroet (2016) explored the relation between user-friendliness and usefulness of PSS by comparing different software, including Phoenix. The study consisted of five experiments, and Phoenix software along with Urban Strategy was tested in the last experiment. The user-friendliness and usefulness were evaluated through two short post-test questionnaires. Findings demonstrated positive feedback on the user-friendliness of the tools in general. However, the test users were students who already had experience working with similar instruments.

2.6. Conclusion

The chapter discussed the general characteristics of the maptables and its applications. It also described the general principles of the spatial group decision-making processes. Regarding the usability of the maptable software, the literature review did not reveal the study related to the Phoenix software specifically. Therefore, the following chapter will present the methodology of trying to fill this research gap.

3. RESEARCH METHODOLOGY

3.1. Introduction

To be able to answer the research questions given in Chapter 1, the most appropriate research methods need to be chosen. This chapter presents the methodology and explains the reasons for choosing them. Section 3.2 covers the basics of usability evaluation and the qualitative method of study. Section 3.3 describes the requirement analysis and a Focus Group interview with experts. Mixed-research methods used in the user test workshops are described in section 3.4. The following sub-sections cover the introduction to the workshop sessions and descriptions of the methods: eye-tracking, thinking aloud, video observation, questionnaire, and interview. Section 3.5 introduces a case study selected for the user test.

3.2. Methods of the user research

This research focuses mainly on evaluating the usability of the software. Usability methods are widely adopted by researchers to measure three main aspects, effectiveness, efficiency, and satisfaction in order to congregate information on the quality of the user experience (International Organization for Standardization, 1998; Wang et al., 2019). According to the International Organization for Standardization (1998) usability is a measure to which a product can be used to achieve specific goals with effectiveness, efficiency and satisfaction (SEE) in a specific context of use. Effectiveness is the accuracy and completeness of users while doing the task, or, in other words, reflects the success of the task performance. Efficiency is explained by how much time and effort the user spends on performing a particular task. Finally, satisfaction means the attitudes or preferences of users towards the functionality of the product. These three aspects are equally significant in usability testing, but they are extremely interrelated.

Typically, usability may be tested by observation, questionnaires, and video analysis. These evaluation methods can be maintained with other empirical methods, such as think-aloud and interviews (Çöltekin, Heil, Garlandini, & Fabrikant, 2009). However, apart from the traditional ways of usability testing, evaluators have started adopting psychophysiological approaches (e.g., eye-tracking) to gather more information about users during the usability testing (Wang et al., 2019).

There are different methods of evaluating cartographic products by deriving quantitative and qualitative characteristics (Herman, Rezník, Stachon, & Russnák, 2018). In this research, the focus is on the qualitative research approach, which includes observation techniques. The reason of the choice of these methods is that the involvement of a little number of test participants in a qualitative research approach will already clear insight into the use, user and usability (van Elzakker & Ooms, 2017). After repairing these issues in the next version of the product, quantitative research may be executed that may lead to statistically more valid conclusions on usability.

3.3. Requirement Analysis: Focus Group Interview

Determining the requirements is the first stage in setting up a methodology for developing geo-information solutions (Sluter, van Elzakker, & Ivánová, 2017). The requirement analysis is a structured study of the tasks to be performed with maps or tools, i.e., the Spatio-temporal questions that need to be answered with the help of the tool. User preferences, user characteristics, and the context of use have to be identified attentively. During this step in the research, it is extremely important to identify in detail the purpose of the map product or application (van Elzakker & Ooms, 2017), which, in our case, is the maptable software.

Determining the user needs demands not only knowledge about the users and their problems that need to be solved but also a comprehension of their skillfulness, competence, and decisions that they need to make (Sluter et al., 2017). In this research, the requirement analysis will be performed based on two steps: a literature review (see Chapter 2) and an interview with experts.

One of the challenges in defining the requirements of the geo-information solutions is understanding specific characteristics and their influence on the design that meet the goals and needs of the users. That is why expert knowledge can be a valuable source of information in finding an accessible geo-information solution (Sluter et al., 2017). People involved in the field of participatory planning, and experts who have experience with the software on maptables are able to analyze the user needs and distinguish what can be implemented and how. Therefore, a semi-structured focus group interview with specialists was conducted in order to gather information about the software requirements from the expert side of view. A Focus Group interview will allow experts to have a discussion altogether, and as a result, to come with more ideas than they would generate individually. The outcome can be more abundant in data, compared to individual interviews. The main goal of the Focus Group interview is to gather inside information about what exactly is needed from the ideal software for maptables.

3.4. Workshop sessions: mixed methods

3.4.1. The workshop sessions

The user tests would be conducted as collaborative planning workshops. The groups will be asked to execute the tasks on the maptable with the Phoenix software. The observation of the experiments will be based on a mixed-methods approach, in which several user research techniques were applied, such as eye-tracking, thinking aloud, video observation, questionnaire, and interview. After getting acquainted with the previous researches in Chapter 2, it became clear that most of the user studies have been recorded on video, using methods of thinking aloud, interviews, and questionnaires. The eye-tracking method was applied only a few times, individually with each user. Therefore, all the chosen methods of this research would help to investigate the usability of Phoenix in particular, although the research results may also be used to draw some general conclusions about the use of collaborative mapping software on maptables.

3.4.2. Eye-tracking

Eye-tracking is a technology that allows recording the users gaze movements with an eye-tracking device (URL7). The device records where users look at, e.g., which parts of the software interface they are studying the most. The results can be analyzed for further processing. The eye-tracking devices can precisely record pupil diameter, number, and duration of fixations, and saccades multiple times per second. Fixation is when the gaze is stationary during a certain threshold of time, and a saccade means quick movements of the eyes between the fixations (Çöltekin et al., 2009). In the experiments, Tobii Pro eye-tracking glasses with audio and video recording of the gaze position of the participants wearing the device will be used.

The eye-tracking method has a big potential in disclosing significant usability issues of the software interface. In a qualitative analysis, a video review of the visual scan trajectory and the movements of eyes can provide essential information about the characteristics of attending to different attributes of the interface (Wang et al., 2019). Video recordings of gaze movements allow identifying where the problem areas are and how they could be processed.

Typically, eye-tracking glasses are used individually with one participant at a time, but in this research, several eye-tracking glasses together will be used simultaneously to be able to investigate the group decision-making process. That is one of the research questions described in Chapter 1. In a group decision-making process, this method will reveal how often participants communicate among each other or look at the maptable. By studying these recordings, researchers can offset the cognitive load of users, letting them concentrate on tasks, rather than memorizing the process (Çöltekin et al., 2009), which is required when interviewing participants afterward or asking them to complete a questionnaire.

3.4.3. Thinking aloud

Thinking aloud is a research method where participants speak aloud any thoughts they have as they perform the task (Lea & MacLeod, 2018). In this research, the thinking aloud may be helpful to explain why participants are looking at something on the software interface. This method would allow to understand the logic behind their actions while executing the tasks. Additionally, the method can be useful in studying different approaches in completing the tasks by each participant.

Initially, during test sessions participants should not need any help or direction: they should articulate their inner thoughts just as they are (Lea & MacLeod, 2018). However, sometimes, it is hard for some participants to report their ideas continuously without demonstrations and practice beforehand. It is important to know that the thinking aloud method does not reveal the deeper thinking processes since it can be hard for participants to simplify their thoughts into words because of their complexity. In a qualitative analysis of results considering non-verbal characteristics is important as well, such as tone of voice, etc. (Charters, 2003).

3.4.4. Video observations

The whole experiment, including the post-test interviews, will be recorded on a video camera. This method allows to monitor the process of making group decisions, as well as the roles of participants in a group. In a compartment with the eye-tracking method, the video recordings would help to analyze the group behavior in the decision-making process.

3.4.5. Questionnaire

In order to specify specific characteristics and background information of the participants that could be worth considering for the user test, participants will be asked to complete a questionnaire before starting the actual experiment. It would allow to choose the right prescription for the eye-tracking glasses and provided, user background information that could be used to interpret the results.

3.4.6. Interview

After completing all tasks, participants will be interviewed about their general satisfaction of the software and their execution of the tasks. The semi-structured group interview of participants will also help to evaluate the usability of the software. As it was mentioned at the beginning of the chapter, the usability measured through effectiveness, efficiency, and user satisfaction. Effectiveness and efficiency of the software tool would be mainly investigated through the methods applied during the workshop, whereas satisfaction would be measured through these interviews. Participants could discuss the strengths and weaknesses of the software and share ideas about future improvements.

3.5. Case study

The case selection for the workshop was based on real-world planning practice. The Kennispark Twente area was decided to be chosen for the case study. Kennispark Twente is a campus for innovative technology products and services, neighboring with the University of Twente (URL8). It is in the north-west part of Enschede, the Netherlands. Kennispark Twente was created in 1980 with an idea of a Business and Technology Center (URL9). Nowadays, it is aimed to support start-up companies and students and scientists interested in high-tech businesses, and it is hosting innovation centers, leading research institutes, and hundreds of high-tech companies (URL8, URL10).

The plan area (Figure 3.1) comprises all sub-areas of the Kennispark: The University of Twente (UT), the Business and Science Park (B&S Park) and Twente Village (an area from the stadium to the ice rink). The local government is working on a structural vision of the Kennispark Twente, with a focus on the Business and Science Park (URL11).

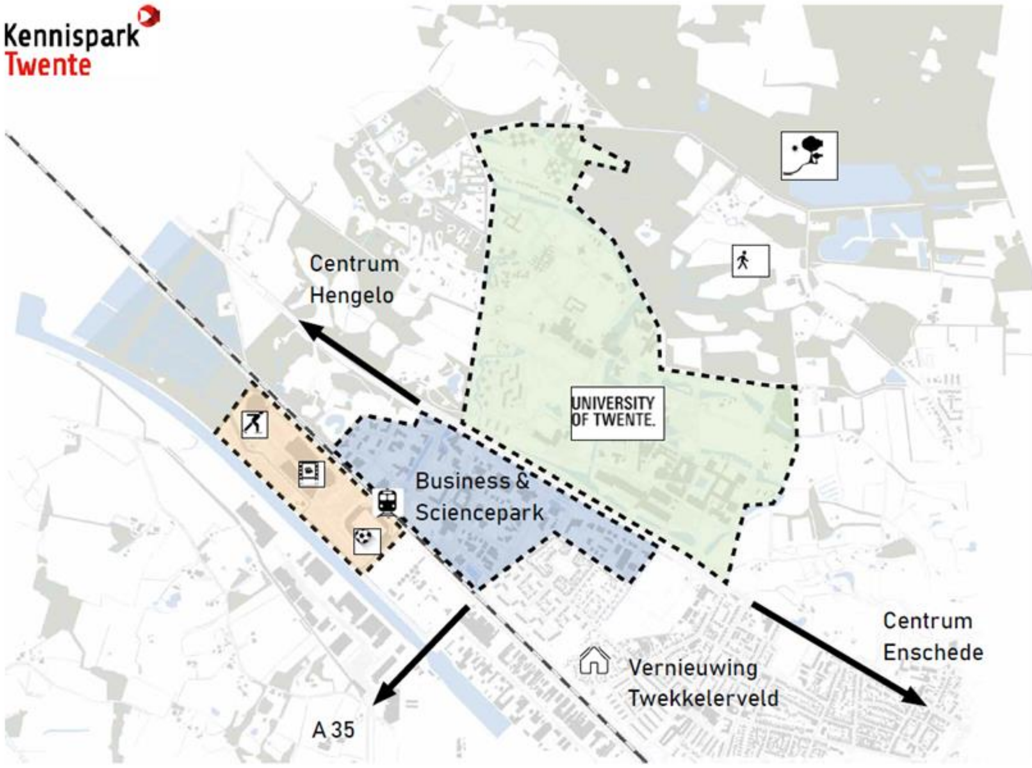


Figure 3.1 Plan of Kennispark Twente (Source: URL11)

The problem of this area is the clear divide between two parts of the Kennispark: the UT campus north of the Hengelosestraat, and the commercial and industrial area south of the Hengelosestraat. The municipality of Enschede is highly interested in revitalizing the industrial area (URL12), and the campus territory is lacking a lively atmosphere and is empty after 5 pm.

The context of the workshop sessions is the ongoing redevelopment and update of the land use plan for the Kennispark area. The goal of the workshop sessions was to get inputs from different groups of stakeholders on the development needs for the Kennispark area to better integrate the two parts of it and to create a lively urban atmosphere.

In the research of (Rzeszewski & Kotus, 2019) mentioned in Chapter 2, the tasks for the user tests were structured in the way of requiring an increasing level of attention at each stage, as well as to help users get familiarized with a map. The beginning stages were simple and not mentally challenging and forcing them to use the tools. The last stages were single tasks, asking the participants to execute more complicated tasks in terms of the spatial development of the neighborhood. The same principle was followed in this research too. The primary steps of the Kennispark workshop (using Phoenix) are given below:

- *Warm-up:* Asking users to indicate where they live in Enschede and how they get to the Kennispark area / UT campus. In this way, each participant, one by one, could learn how to use symbols and the drawing functionality in Phoenix.
- *Step 1: Sharing knowledge:* Identifying the facilities, that stakeholders know in the Kennispark area and that contribute to a lively urban living.
- *Step 2: Identifying development need*s: Pointing out which facilities or infrastructure are needed in their opinion in order to improve the living conditions and to make it a lively area ("Imagine, you live there, what do you need?"). A discussion together and come to a consensus.
- *Step 3: Designing a location for the new ITC Hotel:* Identifying which location is better for a new ITC Hotel in the Kennispark area and its implications. Discussion in a group.

3.6. Conclusion

In this chapter, all methods that are going to be implemented in the usability research have been discussed. The combination of eye-tracking, thinking aloud, observation and questionnaire, and interview techniques in a task-based experiment should provide a complete and wide range of observation data for qualitative analysis. By formulating the requirements for software through Focus Group interview with experts, the tasks were created for the user experiments/workshops to assess the usability of the maptable software tool Phoenix. The following chapter will cover the execution of the requirement analysis.

4. REQUIREMENT ANALYSIS

4.1. Introduction

As the first step in implementing the methodology, a requirement analysis has been executed in order to distinguish the functions and features of a maptable software that users might find needful. The requirements for the maptable software were developed based on the results of the Focus group interview with experts. This chapter presents the implementation of the requirement analysis in two steps: a functionality classification and a Focus Group interview, which are described in sections 4.2 and 4.3, respectively. The requirements for the maptable software are presented in section 4.4.

4.2. Functionality classification

The questions for the Focus group interview were prepared based on the review of two manuals of the maptable software. The manuals contain information that characterizes the functionality and capabilities of the existing software. The manuals used in this study were the Phoenix user manual (Phoenix 1.2.0, n.d.), as it is the software used in the user experiments, and CommunityVis guidebook (Walker & Daniels, 2011), as it is the one of the most used software in collaborative planning workshops. Based on the review, the functionality of a maptable software was classified into the following categories, which were used in preparing the interview questions:

- Navigation tools (pan, zoom, select, etc.)
- Drawing tools (sketch tool, etc.)
- Analytical tools (computations, data analysis, etc.)
- Visualization tools (3D visualization, graphs, etc.)
- Data management tools (import formats, export formats, etc.)

4.3. Interview with experts

The Focus group experts were invited to the interview via email. The sample of the invitation letter is presented in Appendix 1. The Focus Group interview (Figure 4.1) was held in the Group Decision Room at ITC and lasted 40 minutes. The interview started with a welcoming speech from the researcher. With the permission of the experts the whole discussion was recorded on a video camera (Handycam) and a voice

Figure 4.1 Interview with the Focus Group Experts

recorder on a smartphone with the free application called "Otter" (URL13) installed on it. This is a convenient tool for synchronous transcription of the conversation in a real-time, which allows exporting the recorded and transcript data in various formats.

4.3.1. Focus group participants

Three experts (ITC professors) were invited as the Focus Group, whose research interests represent urban and regional planning, and who had extensive experience in moderating collaborative mapping / participatory planning workshops that involved maptables. Two of the interviewed experts had experience in participating in from 20 to 30 workshops; the other one has been involved in 2 workshops only. During these workshops, they were generally moderating, organizing, navigating, coordinating, steering the discussion, and motivating participants to interact with the maptable interface, while acting as a technical facilitator or the chauffeur helping with the use of the tool. At these workshops, they have been working mostly with software such as CommunityVis (ArcGIS extension). Some had experience of using open-source software built by an angular framework in the project of one Ph.D. student, and one expert had experience working with Phoenix. In general, the workshops in which they took part were supposed to serve two primary goals. First, information sharing and awareness-raising with people through the maptables. The second goal is collecting information about preferences, how people make decisions, understanding how people interact with the maptable, etc. Summarizing, the focus of the workshops in which the experts participated was on capturing knowledge, understanding issues, raising awareness, as well as design of plans.

4.3.2. Interview results

The interview questions were divided into four parts: background information of the experts, the functionality of the software, software interface, and user interaction. Additionally, they were asked about their suggestions and important aspects not mentioned in the discussion. As it was written before, the categories of the required functionality of the maptable software were defined based on the software manuals. The description of the welcoming speech and the interview questions are given in Appendix 2.

For the *map navigation tools*, experts agreed that maptable software needs to have the same options as Google Maps because all stakeholders are familiar with that, such as finger pinch for zooming in and zooming out, panning and rotating the map. Additionally, they mentioned the return function to go back to the previous extent and the whole extent. Another suggestion was the search function that allows to type in a particular name of the place, and to be brought to that area. The experts also suggested having some querying tool for selecting the features on the map with a specific criterion, but that would be for more advanced users.

For the *drawing tools*, they suggested having freehand drawing, boxes and shapes, and the possibility to write annotations. One of the experts mentioned that moving the drawings to a different location would be more convenient rather than deleting and making new ones. Another expert noticed that having an option of showing the attributes (properties) of the selected features would be useful too. Also, one expert suggested having an option to copy and paste the features by selecting and grouping them.

For the *analytical tools*, the experts suggested having some querying tool for selecting the features on the map with a particular criterion, for instance, houses of a specific size. However, that option would be for more advanced users. Another suggestion was the information about the drawn features; for example, how many square meters is the circle, or what kind of land cover does it cover. Then that information could be analyzed, for instance, visualizing how many boxes are bigger than 100 m, or how many boxes cover mostly rural area versus urban area. Another crucial feature is to calculate the outcome indicators or to get the immediate feedback of the changes. For example, getting the immediate calculations of the drawn line, such as the length it covers, the cost of it, how quickly, etc. One expert also suggested having an option of editing the base map, because sometimes stakeholders would like to add something they know on a map, which contains information out of date. One more suggested function was to have two different designs or layouts next to each other or to be able to compare the outcomes in it. Because sometimes it is inconvenient for users going back and forth. For instance, they allocate the wind turbines, and that has a particular outcome. Also, then they want to check what it does for all solar panel and allocate all solar panels. However, then they have to remember what it was like when they had all wind turbines. So, having two "scenarios" on the screen would help them to see precisely the difference as a result.

For the *visualization tools*, the experts suggested having a 3D view, also changing the colors of the base map information. One expert mentioned that they had a tool, that allowed them to visualize the 3D content. They had two screens: a 2D screen, and the same scene in 3D on another screen. Once the user moved the map on one screen, the map on the other screen was moved as well, showing both perspectives. Another option is two different zoom levels. For instance, a user wants to zoom in to one particular area without losing the full extent, that can be compared to the zoomed-in part. That could be achieved with a magnifying glass or a fisheye effect. It would mainly be useful for people who are not familiar with navigating in maps, and they do not want to lose their location. That would also be convenient for those who want to check something on a map, without having to zoom in the whole map, and then zooming back out again. Concerning analytical functions, one expert suggested having graphs, that visualize the distribution of information that contains a secure layer. Also, they suggested a dashboard with different type of graphics: a pie chart, a bar chart, and even maybe some more advanced, but with an option of switching on and off the elements. Otherwise, seeing statistics of all layers included in the dashboard might be very convoluted.

As for the *data management tools*, the software needs to support basic functions, such as adding and removing the layer and changing the order of the layers. The experts consider that maptable software needs to support the import formats of shapefiles and excel tables. Additionally, PDF files, drawings, and photographs, in case if someone wants to include the picture of a map in visualization purposes. Also, the web services, to visualize web features, services, web coverage services, layers, because more data is available in that form. As for exporting files, the software needs to export images, geo-referenced images, regular snapshots of the screen for following the process.

The experts also mentioned one issue of simultaneous touching the screen. For instance, during the workshops, some people are actively talking, and once they get ideas, they immediately want to map something, but somebody else still has a finger on the screen. Alternatively, when ten people draw something, it is hard to recognize who created what. One expert suggested a solution to split the screen into smaller screens so that people can draw on their own. It would be four times the same screen where users can work individually on a copy of the original dataset at the same time.

Regarding the *interface*, the experts consider that the map should be the central element when a user looks at the software. However, they consider it to be user-dependent. If the users are experienced, they can see more, if the users are non-experts – as little buttons and functions as possible. Otherwise, they might get scared once they see lots of toolbars.

The *layout of the software*, according to the opinion of the experts, should contain navigation tools, a toolbar with main visible tools. They pointed out that the layers of features should be visualized, but also need to be able to be easily hidden, to avoid the long scrolling. So once the user does not need the table of contents, they can use the swiping gesture like in use of a mobile phone to hide it and bring it back to the interface. They also mentioned that the icons should be intuitive and straightforward so that people would be able to understand them. Probably they need to be designed as icons in Google because everybody is familiar with Google.

Regarding the *user interaction*, the experts agreed that the software should support two-finger gestures. The experts pointed out that Google Maps is a good example of user interaction gestures. However, it should be kept in mind that the user interaction with maptables is more complicated compared to Google maps because in the maptable software users change the map. As a result, experts agreed that the gestures should not differ from what people are used to. Another mentioned suggestion was the slider between two layers of the same "situation" to see the changes. The principle is moving the slider from left to right, overlaying the new situation with the old one. One expert suggested having the function of edit and non-edit mode. Since some of the users tend to switch between drawing something on a map and moving the map, defining the non-edit mode with grey color, would let users know that they are moving around; and when it is back in edit mode, users would know that they can do something on the map. However, it is important to distinguish the gestures or the function, so that people would see whether they are in the edit mode or not because it would require users to understand what the Edit Mode is. The last suggestion mentioned was the undo functions related to rescaling the map and one undo button related to interactions with the changes on the map.

To the question about the tasks that users find the most *challenging*, experts replied that it was editing. One expert explained that it depends on the shape, for instance, drawing freehand is easy for people, however, if they have to apply changes to the polygon, or any other feature it becomes complicated. She gave an example of the CommunityViz software, where it is complicated for users to select the features. That is why moderators do that for them using the keyboard. Another expert added that editing multiple features at the same time, adding a value changing attribute of many features is difficult.

The next question was about the *improvements* for the maptable software. Here one expert mentioned an issue of the data processing speed. The expert assumed that it is a matter of computing power and that it needs to be improved. One more suggestion from the experts was a sound-sensitive or a touch-based interface. Whenever somebody calls or touches the screen, the whole framework will rotate towards that user. They also suggested holograms and automatic 3D drawing.

At the end of the interview, the focus group experts gave last suggestions, such as screen recording. So far, they use separate systems for recording, and it does not work. The reason for having that option is when they want to look at the map afterward to know what people were talking about while drawing or rewind the whole mapping process. Another suggestion was the voice recognition to give the voice commands to the software, for instance, "go to the S marker." Another option was online access to remote participants so that different people in different actual locations could work on the map together or at different times. Because an issue that the experts encountered often, was getting everyone to come to one place at one time to the workshop.

4.4. Requirements for the maptable software

The information gathered from the interview results were structured into the requirements for the functionality of the software presented in Table 4.1 and the requirements for the usability of the software in Table 4.2.

Table 4.1 Requirements for the functionality of a maptable software

Navigation Tools	Drawing Tools	Analytical Tools	Visualization Tools	Data Management Tools
· Zoom in/out · Panning · Previous extent (back) · Rotating · The search function (by typing) · Showing attributes of selected items (by a simple touch)	· Freehand · Boxes, shapes · Adding annotation · Editing	· Spatial querying · Selecting/grouping · Showing features of freehand drawing · Feedback of changes · Calculations of outcome indicators · Editing base information (base map) · Two windows for two scenarios	· 3D · Changing the colors quickly · Additional Screen · Fish-eye zooming of the map · Nice dashboard · Graphs: pie charts, bar charts, etc. · Split interface for simultaneous drawing	· Adding/ removing/ changing order of layers **Import Files:** · Shapefiles · Excel files · Web features (services, web coverage services, layers) · PDF · Images **Export Files:** · Images · Georeferenced images · Snapshots of screen

Table 4.2 Requirements for the usability of a maptable software

Software Interface Visualization	User Interaction	Challenges	Further Recommendations
· Map as a central element · As fewer buttons, as possible · Toolbar with available tools · Main tools always visible · Navigations tools · Table of content (be able to be easily hidden) · Good icons	· Two-finger gestures (zoom in/out) · Map navigation as in Google Maps · Slider between the windows of two scenarios · Switching to Edit/ Non-Edit mode · Undo button · Undo for the extent of the map	· Editing of drawings · Selecting items · Editing by multiple users at the same time · Speed of data processing (software, internet)	· Voice control · Turning the interface towards editing person · Screen recording with sound · Online access for remote participation · Holograms

4.5. Conclusion

After studying the features and tools of the existing software Phoenix and CommunityViz, the Focus group interview with the experts helped to create a list of requirements for the ideal software for maptables. Based on this information, the tasks for the user tests will be developed in the next chapter, in order to investigate how the Phoenix software meets these requirements.

5. USER TEST

5.1. Introduction

This chapter describes the execution of the user experiment. The experiment aimed at testing and evaluating the usability of the Phoenix interactive maptable software. Section 5.2. gives an overview of the equipment used in the experiment, such as the eye-tracking glasses, maptable, video, and audio recording devices. Section 5.3 describes the groups and test participants involved in the user tests. Section 5.4. presents the implementation and the results of the pilot test which has been executed and the concurrent use of several eye-tracking glasses. An overview of the three user tests which were actually executed is presented in section 5.5. The outcomes of the experiments are listed in section 5.6.

5.2. Test Equipment

5.2.1. Eye-tracking glasses

The device used for eye-tracking during the experiments were called the Tobii 2 Pro eye-tracking glasses (Figure 5.1). This eye-tracking device consists of a head unit (the actual glasses), a recording unit and controller software. The recording unit is connected to the glasses via an HDMI cable. The recording unit holds a battery and an SD memory card for storing the recorded data. The recording unit is controlled by a tablet or computer with controller software. The recording unit can only be operated with a Windows 8 or later Pro tablet, or a computer with Windows 7 or later version installed. The software allows to control the glasses, view the gaze movements of the participants in real-time, and record the data. The tablet or computer and the recording unit are connected through a wireless or wired Ethernet connection (URL14). In our experiments, we used four pairs of glasses and one tablet with the controller software (see Section 5.4.1). Also, the glasses collected not only the eye-movements of participants but also recordings of the thinking aloud (through the microphone that is built into the glasses) and video recordings of where the participants look at (through the built-in camera).

Figure 5.1 Tobii 2 Pro Eye-Tracking Glasses: recoding unit and head unit (Source: URL15)

A separate set of optional prescription lenses for users with sight correction of short-sightedness or long-sightedness was also available. The prescription lenses can be fitted magnetically onto an adapter of the glasses, allowing participants to freely walk around with corrected sight (URL16). Before the test, study users were asked in the pre-test questionnaire, whether they had corrected vision. We had two pairs of adapters for the glasses per group, just in case if participants needed the sight correction lenses.

Before beginning every experiment with the eye-trackers, the researcher helped to fit the glasses onto the participants. Then, with the help of the controller software, the researcher started a new recording with a name or number of the participant concerned. Before beginning an actual recording, the glasses needed to be calibrated. Calibration is a process in which the geometric characteristics of a user's eyes are evaluated as the basis for precise gaze dot computation. To perform such a calibration, the participant was asked to focus at a specific calibration card or calibration sticker. During this process, the eye tracker measures features of the eyes and uses them with an anatomical 3D eye model to compute the gaze data (URL17). Once the calibration is verified, the recordings can be started. The live viewer in the software will continue showing the real-time eye-tracking on the tablet during the recording process.

5.2.2. Maptable

General characteristics of the maptables were discussed in chapter 2. The maptable used in the experiments was a PQ LABS touch overlay frame mounted on a regular Philips LCD screen with 42 inches (107 cm) diameter (Figure 5.2) and the resolution 1366x768 pixel. The technology of the touch is infrared. The maptable can be used by a group of up to six users. Research of Ryall, Forlines, Chia Shen, Morris, & Everitt (2006) revealed that small table sizes (such as 80 cm diagonal) may cause discomfort to participants, such as bumping elbows or arms while interacting with each other. Therefore, they recommend a minimum table size 107 cm in diagonal. During the test workshops, the maptable screen was recorded with "Techsmith Snagit" (URL18) screen recording software.

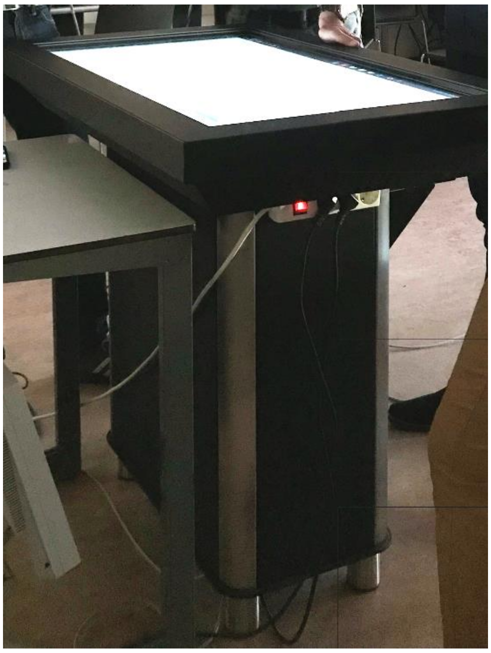


Figure 5.2 The maptable used in the experiments

5.2.2.1. Phoenix interface

The Phoenix software was installed on the desktop computer attached to the maptable. The information about the functionality of the Phoenix was retrieved from the User Manual of the software (Phoenix 1.2.0, n.d.). The software has the settings menu with basic options for setting up the software before starting the session, usually performed by the moderator. The menu has the following components:

- Tags – only apply to the SUR40 touchtable, to recognize the objects with a specific sticker ("tag").
- Fullscreen – defines the display of software in full-screen mode or window mode.
- Language – defines the language of the software display.
- Saving time interval - the software automatically creates a backup of the project every specific time interval. The time slot can be set between 5 to 30 minutes.
- Projection
- Logo – Geodan logo is displayed by default at the bottom of the screen, but it can be changed here by entering the path to another logo.
- Project Folder – defines the folder where saved export files can be stored.
- Extensions – allows to switch extensions (additional functionality to the software) on and off and customize them.
- Menu bar – the functionality of the software can be displayed via tags or menu bar on the right part of the screen. Unchecking the box here will hide the menu bar in case of using the tags.
- Log – the file that lists all actions carried out within the software.
- UV protection – enables the UV protection, in case if the maptable does not function properly under the direct sunlight or the lamps.
- Scale – allows to customize the Screen DPI and fixed scales for the Phoenix Scale tool (see Table 5.2).
- About – information about the number of the Phoenix installation and a license code.

The software uses map services to visualize different types of basemap, such as satellite imagery, topographic maps, etc. The boundaries of the Kennispark area were drawn for the workshop in a separate layer in advance. Figure 5.3 depicts the Phoenix software interface on the maptable when the Kennispark project is loaded. The layer management menu is displayed on the left part of the interface and shows the list of available layers. The menu with available tools (Table 5.1) is displayed on the right side of the screen and can be opened with a clicking arrow.

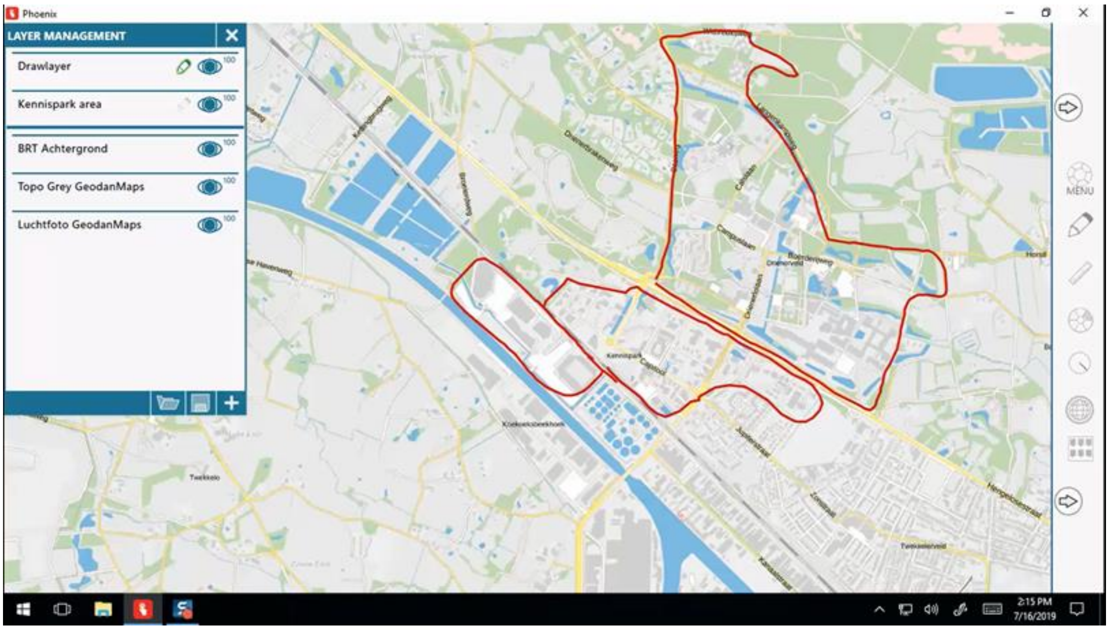


Figure 5.3 The Phoenix software interface on the maptable

The information below describes the capabilities and functionality of the Phoenix (Phoenix 1.2.0, n.d.):

1. *The map navigation* in Phoenix is touch-based. Here are the main touch gestures:
   - Panning – can be done using one finger to move the map;
   - Zoom in – is performed using two fingers by placing them on the map and moving them apart;
   - Zoom out – is performed using two fingers by placing them on the map and moving them closer.

2. *Layer management menu* (Figure 5.4) displays basemap layers on the bottom and drawing layers on top. In the experiments, the basemap layer included one grey topographic map, one more detailed topographic map, and the aerial photo map. The layer management window can be dragged by the blue bar. Clicking the eye icon makes the layer visible or invisible on the screen. An active green pencil icon means that the layer is active for editing, the grey icon implies the opposite. The cross icon on the top right part of the menu is for closing it. The + icon at the right bottom can be used for adding via the layers library and creating the new layers.

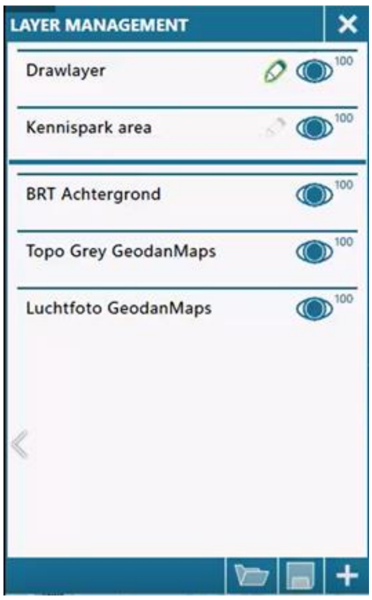


Figure 5.4 The layer management window

Pressing the layer name opens the additional options of the layer (Figure 5.5). The transparency of the layer can be adjusted by moving the slider to the left (1). The layer can be deleted by sliding the remove button to the left (2). The bottom buttons are used to change the name of the layer (3), to make the annotation one step bigger (4), to make the annotation one step smaller (5), to make the annotations visible or invisible (6).

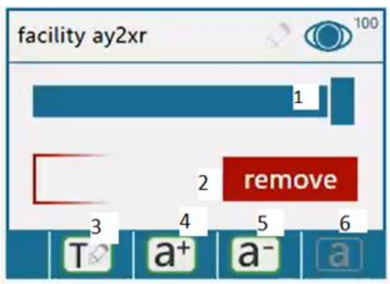


Figure 5.5 Additional options of the layers

3. *Loading local files* – different local format files can be loaded into Phoenix session. The menu can be opened with  button at the bottom of the layer management window (Figure 5.4).
    - PNG or JPEG files – the formats do not have coordinates but can be manually placed in a fixed location. Once an image is set, "fixate" button can be pressed. It will be fixed at that location and listed in the layer management window.
    - GeoTIFF files – the raster files need to correspond to the projection supported by Phoenix. Maximum size of the TIFF size should not exceed 50 MB.
    - KML files – small KML files created with Phoenix can be loaded.

4. *Save and export* – the software allows to export the drawings in different formats. The menu can be opened with  button at the bottom of the layer management window (Figure 5.4).
    - PHX - Phoenix project format – the project can be saved in .PHX format that can be reloaded to continue the session.
    - PDF - Portable Document Format – the drawn objects can be saved in PDF format and can be opened and edited in Adobe Illustrator software package.
    - SHP – Shapefile – can be exported in a widely used ESRI Shapefile format. If the drawings contain point, lines, and polygons, separate shapefiles will be created for each of them. The exported shapefile will not include the style of drawings; however, the styles will be stored as separate attributes.
    - KML - Keyhole Markup Language – various layers of drawings, including the style, can be exported in formatting language for geographic data used in Google Earth.
    - JPEG – screenshot of the current image.

5. *Phoenix Prepare Tool* – is an additional application for layer management that is included with Phoenix. The Phoenix Prepare Tool is operated with another non-touch device to prepare the layers to load into the Phoenix. It allows to create layers.xml file that contains a layer definition for the Phoenix library. The tool shows the library with available layers that are maintained and updated by Geodan over the internet. The Phoenix currently has two libraries: one for the Dutch Rijksdriehoekstelsel (EPSG code:28992) and one for Spherical Mercator (EPSG code:3857). The users can add their own library too. The Phoenix Prepare tool supports the following GIS formats: ArcGIS dynamic layer, ArcGIS tile layer, Tile Map Service, Web Map Service, ArcGIS Image Layer, Web Map Tile Service, GeoTIFF raster layer.

6. *The menu* with available tools of Phoenix are given in Table 5.1 and Table 5.2.

Table 5.1 The drawing and editing tools of the Phoenix

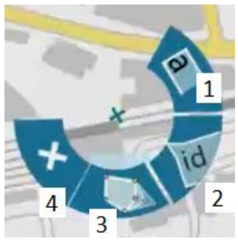
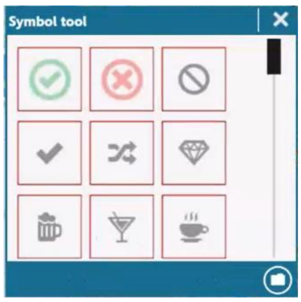
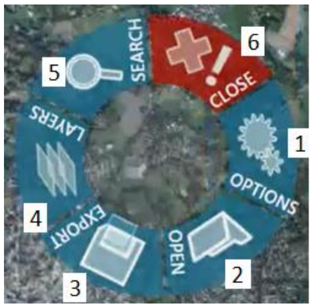
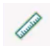
Tools and icons	Description	Screenshot
Sketch menu (Drawing tool) 	The sketch menu has the following options: • Color (1) • Line thickness (2) • Undo (3) The tool allows to draw: *Points* – by a single tap *Lines* – by moving a finger on the map *Polygons* – by drawing a line and closing it into a circle	
	Long press on the drawn feature will open the *context menu*. It shows three options: • Add notes (1) – allows adding an annotation • ID (2) – allows adding the identification • Edit (3) – allows applying changes to the feature • Close (4)	
	Editing window of the drawn feature from the context menu allows to: • change the description (1) • thickness (2) • color (3) • remove the feature (4) • close the window (5)	
Symbols tool 	The tool allows locating the symbols on a map Can be located by tapping on a symbol, then on a map	

Table 5.2 The tools of the Phoenix

Tools and icons	Description	Screenshot
Menu tool 	The menu tool has the following functions: • Settings menu (1) – to configure the settings of the application • Open (2) – to load files with different formats • Save (3) – to save the project • Layers (4) – to open the layer management window if it is closed • Search (5) – to search by location (streets, cities, etc.) • Shut down Phoenix (6) – to close the Phoenix	
Ruler tool 	A digital ruler to measure the distance The length be changed by pinching it	
Scale tool 	The tool allows working on a fixed scale. Zoom in or out is not possible if the scale is set	
Buffer 	Creates the buffer around a certain location Can be relocated by dragging with one finger and resized by placing two fingers on the buffer, and moving them close or apart	
Extent tool 	The tool allows to save (1) and load (2) the extend	

5.2.3. Video recording, voice recorder

The entire sessions of the experiments were recorded with an individual video camera (Handycam) as well. The post-test interviews were also recorded with this video camera and a voice recorder on a smartphone with the free application "Otter" (URL13) installed on it. This application, as well as the video camera, were previously used in the Focus Group Interview recording and mentioned in Chapter 4.

5.3. Test groups

The experiment involved three workshops with three groups of four participants, including a moderator. The moderator was the same person for all three groups and was giving instructions on how to use the maptable software tools in the beginning and running the test by giving the tasks to the participants. Before starting the execution of an actual experiment, the participants were asked to fill in a questionnaire to provide general background information about them. The background questionnaire used in the experiments is presented in Appendix (3). The answers were verbatim copied from the questionnaires to the tables below. Table 5.3 shows the division of the 9 participants (excluding the moderator) over the three groups. All participants were recruited at the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente. The first group (Table 5.4) consisted of three Ph.D. students with a geographical background. P3 in the question about the experience in collaborative mapping stated that he already participated in a workshop with a maptable, but in the question about the experience of working with a maptable, he marked "No," probably he made a mistake. The second group (Table 5.5) consisted of three Master students with mixed backgrounds. The last group (Table 5.6) consisted of staff from ITC holding Ph.D. degrees. The experts consulted during the Focus group interview for the requirement analysis did not participate in this experiment.

Table 5.3 General information about the test participants and allocation to three groups

Number of Participants	Group	Glasses	Physical Disabilities	Education Level
P1	1	Yes	No	MSc
P2	1	Yes	No	MSc
P3	1	No	No	MSc
P4	2	Yes	No	MSc
P5	2	Yes	No	BSc
P6	2	Yes	No	MSc
P7	3	Yes	No	PhD
P8	3	No	No	PhD
P9	3	Yes	No	PhD

Table 5.4 Test participants Group 1 (Ph.D. students)

Number of Participants	Experience in collaborative planning practice	Experience of working with maptable	Experience of working with Phoenix	Frequency of using maps	Experience with GIS
P1	Yes	Yes	No information	Very often (daily)	Yes (GIS specialist)
P2	Yes (attended in workshops on collaborative planning of energy using maptables; participated in course on using maptables and SMCE)	Yes	No	Rare (monthly)	Yes (used the SMCE (Spatial Multimedia Analysis/Evaluation) technique to analyze suitability of settlement sites)
P3	Yes (participated in a test session of the energy workshop in ITC using a maptable)	No	No	Rare (monthly)	Yes (worked for the government planning agency in home country and used GIS for displaying maps)

Table 5.5 Test participants Group 2 (Master students)

Number of Participants	Experience in collaborative planning practice	Experience of working with maptable	Experience of working with Phoenix	Frequency of using maps	Experience with GIS
P4	Yes (part of course curriculum in MSc at ITC)	Yes	No	Often (weekly)	Yes (as part of MSc course at ITC)
P5	No	Yes	No	Often (weekly)	Yes (a few Master and Bachelor level courses)
P6	Yes (in Urban Planning and Decision Public Spaces)	No	No	Very often (daily)	Yes (creation of maps that reflect urban problems in communities in Mexico)

Table 5.6 Test participants Group 3 (ITC staff members with a Ph.D. degree)

Number of Participants	Experience in collaborative planning practice	Experience of working with maptable	Experience of working with Phoenix	Frequency of using maps	Experience with GIS
P7	Yes (participatory GIS on paper-maps)	Yes	No	Very often (daily)	Yes (teaching, using for research)
P8	Yes	No	No	Very often (daily)	Yes
P9	Yes (Participatory planning workshops, hearings)	No	No	Very often (daily)	Yes (spatial analysis)

5.4. Pilot Test

Before starting with the workshops, it was important to examine different aspects of the experiment in advance. Therefore, a pilot test was considered to be necessary to prevent all flaws and technical difficulties that could appear during the test execution. Another reason for preliminary testing was to ensure that the task instructions were clear and that the implementation of the experiment did meet the timing frames.

5.4.1. Concurrent use of several eye-tracking glasses

The pilot test started with checking the concurrent use of several eye-tracking glasses by the participants of a workshop. After all, one of the research questions was whether several mobile eye-tracking devices can be used concurrently to investigate group decision processes in collaborative mapping.

Technically, the problem was to find a method to connect several eye-tracking glasses to one (tablet) computer with the controller software installed on it at the same time. Using more than one controlling tablet leads to problems with monitoring the experiment and synchronization of the recordings.

When the individual recording units are connected with one tablet via a wireless connection, it is impossible to connect more than two devices. The Tobii Pro Glasses 2 manual (URL16) indicates that the recording unit can act as a network access point so that several tablets with Tobii Glasses Controller Software can connect to it concurrently. However, one tablet connected with multiple glasses is bounded by the number of network hardware devices in the computer. Therefore, the manual recommends using Ethernet cables and the switch or router for connection so that the switch can act as an access point. No extra information on the maximum number of recording units nor other limitations are given in the manual.

Before executing the pilot test, we tried the method of using Ethernet cables to connect each pair of glasses to one tablet via a switch. We managed to connect more than two, and in our case, four pairs of glasses. Figure 5.6 shows the process of connecting the glasses to the tablet.

During the pilot test, it became clear that it was necessary to connect the glasses first and then turn on the software. Otherwise, we had to restart the tablet. Another challenge of this method, as we discovered in the

Figure 5.6 Connecting four eye-tracking glasses to one tablet

pilot test, was the length of the cables. During the session, participants had to be careful trying not to step on them (Figure 5.7), especially when they were changing their positions next to the maptable, trying to give each other a chance to draw and edit. Also, since the recording unit had to be attached to a piece of clothing, it was challenging for participants to carry it with two cables (HDMI and Ethernet) connected. But in terms of data recording, no other problems arose. The four views from the eye-tracking glasses were simultaneously displayed and controlled with the Tobii Glasses Controller Software on the tablet. The recordings were stored on four different SD cards.

Figure 5.7 Connecting eye-tracking glasses via cables to the tablet

5.4.2. Implementation of the Pilot test

The pilot testing of the experiment took place one week before the first actual test. The number of participants, tasks, and the conditions of the pilot testing were identical to the actual experiments. One participant is the professor from ITC, holding a Ph.D. degree, one participant was a Ph.D. candidate from the University of Twente, and one Master Student from the Technical University of Vienna. Recruited participants for the pilot test had mixed backgrounds.

Execution of the pilot test (Figure 5.8) showed the actual timing of the test, helped to improve the tasks and revealed challenges that researchers and participants may encounter. At the beginning of the pilot test, half an hour was spent on connecting the eye-tracking glasses to the tablet, helping users to fit them on, and finally, calibrating the glasses. It became clear that for further tests, it would be less time consuming if all technical set-ups of the glasses would be prepared in advance and only the calibration would be performed with the users. Initially the test was planned to be done within 1 hour and 30 minutes, including all preparations (filling in the questionnaires, putting the glasses on, calibration, etc.), explanations, execution of the test, and post-test interviews. However, in practice, we exceeded the time frame because of technical issues at the beginning and more extended execution of the tasks due to discussions and explanations. To prevent that in the future user tests, we increased the planned time.

Figure 5.8 Participants collaborating with the maptable during the pilot test

Test participants were informed that the experiment was a simulation of a real workshop. In such a workshop, the moderator usually helps stakeholders during the entire session, in trying to facilitate the process. In the pilot test, the moderator was guiding the users at the beginning of each task, showing and reminding them of how to use the tools. But after the pilot test, it was decided to adjust the moderator's role in the actual user tests, by only letting him explain all the tools in the beginning. This approach could reveal more user feedback on the usability of the software and its interface for executing the tasks.

According to the tasks, we also improved some points, to make them more logical and bring it to a real collaborative mapping scenario as close as possible. For instance, some details in the tasks were changed.

5.5. User tests

The three workshops/tests were executed on the 16th and 17th of July 2019. The first two test groups had their sessions on the first day, and the last group's experiment was conducted on the following day. Before starting the experiments, the researcher was prepared the test room following the checklist that is presented in Appendix 4 and turning on all equipment and connecting the glasses.

As it was mentioned in Chapter 3 the whole workshop session was divided into a warm-up session and three main steps. The tasks of the warm-up session and the steps were partly shaped based on the outcomes of the requirement analysis (see Chapter 4, Section 4.4). The tasks of the workshops are described in Table 5.7. The workshops started with a warm-up session, where participants worked individually one by one. In the remaining three steps the participants were stimulated to execute the tasks in a group decision-making process.

Table 5.7 Description of the tasks for the workshop

Steps	Tasks
Warm-up	To indicate on a map where the participants live, and to draw their route to the work/study To edit the drawn route to show an alternative way and add a name as annotation
Step 1 Sharing knowledge	To locate the existing facilities of the Kennispark area (the industrial area and the UT Campus) using the symbols tool
Step 2 Identifying development needs	Create a new drawing layer To add new facilities/infrastructure to improve the living conditions of the area To find a location for a new park and draw a 50x100m polygon in green color
Step 3 Designing a possible location for the new ITC Hotel	To find a location for a new ITC Hotel in the Kennispark area. To locate a cafeteria in walking distance to the gallery (the new location for ITC), not more than 100 m away from it (Euclidian distance).

Before starting each workshop, participants were filling in the pre-test background questionnaire, while the researcher was helping them to wear the glasses and calibrating them. After finishing all preparations and starting recordings, the researcher gave a short introduction to the research and experiment. Right after this general introduction, the moderator presented the case study and the Phoenix software. The introduction speech of the researcher, the case study description, as well as the description of the tasks, are presented in Appendix 5. During his speech, the moderator demonstrated all the tools, features and the interface layout of the software. The speech and introduction were the same for all three groups and lasted around 20 minutes. After that, the moderator conducted a warm-up session, in which the participants learned how to work with the software by executing a simple task and practicing thinking aloud. The warm-up step normally lasted for 10 minutes. In the first task the participants were asked to share their knowledge about existing facilities in the Kennispark area and identify them on a map displayed on the maptable. In the second step they were asked to suggest their own ideas to improve the living conditions of the area. The last task was about finding the most suitable space for building a new ITC hotel (providing accommodation for ITC students) and a cafeteria next to it. To complete all three steps each group spent approximately 20-30 minutes. Once all tasks were completed, the researcher stopped the recordings and collected the eye-tracking glasses, meanwhile letting the participants have some time for rest before conducting a post-test interview. These group interviews were recorded on a video and audio recorder and lasted around 10-12 minutes. The questions of the interview are presented in Appendix 6.

5.5.1. Groups

At the start of the first user test, we could not calibrate the glasses of two participants. This circumstance is extremely rare, but it still can happen. The causes may vary, but in this case, the exact reason remained unknown to us. For these two participants, we decided to start recording without calibration, accepting the recordings of the gaze movements would not be as accurate as recordings with calibration. Furthermore, during this first session we lost connection with the glasses of one participant. Consequently, we lost data of that one participant. The reason could be a disconnection between the cable and the recording unit. Also, the screen recording failed in the first experiment, due to some missing updates of the Techsmith Snagit recording software. As the user test began, participants were hesitating to think aloud and to play with the map and the tools. During the session, they were changing their positions instead of rotating the map, but in the end, they were all standing at one side of the maptable and were actively discussing their collaborative mapping. Figure 5.9 shows the process of mapping and discussion among the participants of Group 1.

Figure 5.9 Group 1 collaborating with the maptable

Group 2 (Figure 5.10) was actively using the thinking aloud method, and the participants were not hesitating to press different buttons, which led them either to results or accidental mistakes. During the collaborative tasks, participants were not discussing their ideas in detail, they directly started working with map, and talked while drawing or navigating. The group also ended standing at one side of the maptable after working with the map for some time. In technical terms, everything went well, and all data was successfully recorded.

Figure 5.10 Group 2 collaborating with the maptable

In the session of Group 3, the calibration of the glasses went well, but during the session, the connection with one pair of glasses was lost again. In trying not to disturb the participant in the discussion, the researcher resumed recording without calibration for the second time. Consequently, the recordings from this participant's glasses were done only for the last 20 minutes of the session. The group was actively participating in discussion and mapping, meanwhile making comments about the usability of the software (Figure 5.11).

Figure 5.11 Group 3 collaborating with the maptable

5.6. Outcomes of the experiments

The research data obtained from the experiments consisted of the following outcomes: pre-test background questionnaires, video recordings of the group decision-making processes, video and audio recordings retrieved from the eye-tracking glasses of the moderator and eight participants, two screen recordings of the maptable, and three audio and video recordings of the post-test interviews. All the resulting data was renamed according to the group numbers to be further processed and subsequently analyzed in the next chapter (Chapter 6). Examples of the screenshots of the screen and the participant's eye tracker recordings are presented in Figure 5.12.

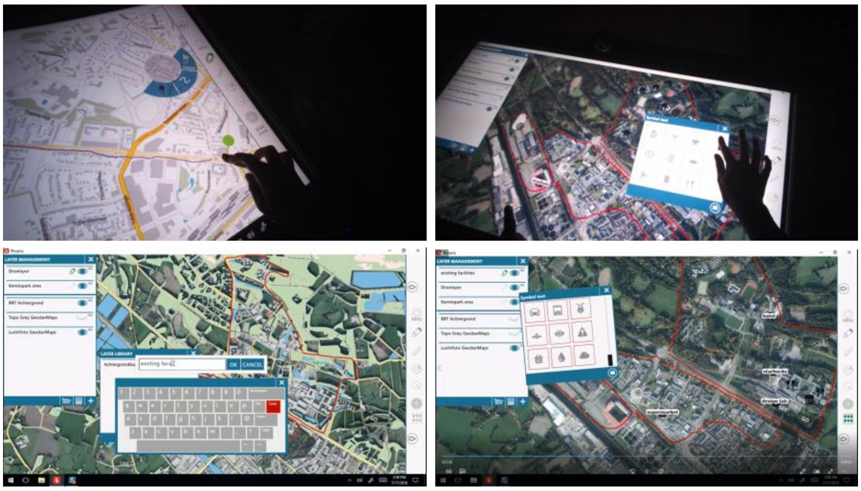


Figure 5.12 Examples of screenshots from the recordings

5.7. Conclusion

This chapter presented all technical setups, the pilot testing, and the actual user tests. In the pilot test, the connection of the glasses, data recording, and execution of the test went smoothly, and no data was lost. Findings of the pilot test helped to improve the user test preparations. In the actual user tests some technical issues caused the loss of part of the data, but, in general, the test groups executed their tasks very well. The participants were thinking aloud about all their actions and were giving meaningful comments. Post-test interviews summarized their opinions and suggestions towards the usability and functionality of the Phoenix software. The results obtained during the user test will be further analyzed in the next chapter.

6. DATA ANALYSIS

6.1. Introduction

This chapter describes the interpretation of the data retrieved from the user tests. Section 6.2 provides a detailed description of the entire experiment, including the actions, thinking aloud, errors, etc. The results of each of the three group user tests of three groups, the eye-tracking data, and the post-test interview answers are provided in respective subsections. Section 6.3 summarizes the results and concludes with the weak and the robust parts of the software. Section 6.4 suggests possible improvements for the Phoenix software.

6.2. Results of the experiments

6.2.1. User test results

Before starting with the warm-up step, the moderator introduced the participants to the Kennispark area on the map, the problems of that area, and the reason why they were invited to take part in the session. The moderator showed the basic navigation gestures to interact with the map, the various available layers and base maps, and the functions of the software. First, he introduced the drawing tool and showed how to pick the color and thickness, how to draw a line, polygons, dots, and the "undo" function. Then he demonstrated the ruler tool to measure a distance at any scale, and the use of it on the map. Afterwards, he showed the buffer tool for indicating the radius around any specific location. Then he showed the extent tool, which helps to zoom back to the extent of the case study area, in our case, the Kennispark area. The last tool he introduced was the symbols tool for mapping. During the introduction, the moderator showed how to turn on and off the layers and tools, how to drag the tools windows, and how to delete the items on the map.

Figure 6.1 presents the heatmap of the Phoenix software interface from the eye-tracking recordings of P4. The period depicted in this heatmap covers the introduction to the software functionality as presented by the moderator. The seven heatmaps created for the seven participants (Appendix 7), whose eye-tracking was working well, show similar results because they were watching the moderator's demonstration. As can be seen, they have covered all essential aspects of the tools and interface, and most of their attention was focused on the map.

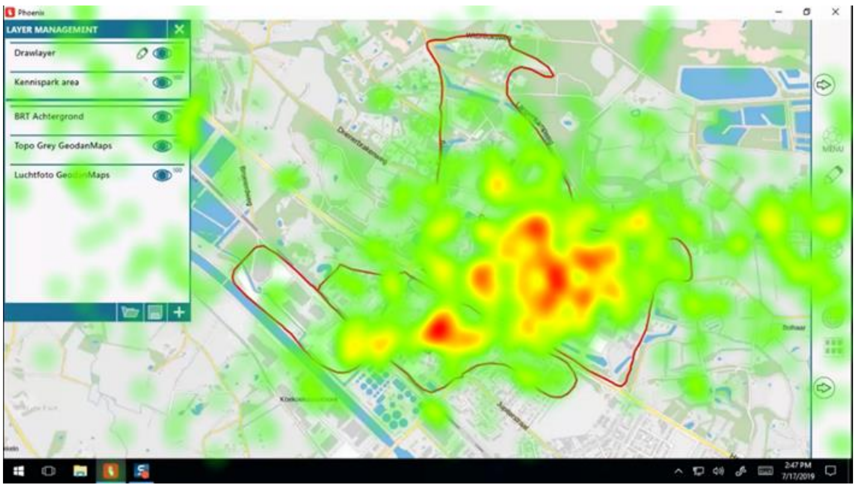


Figure 6.1 Heatmap of the software interface from the recordings of P4

6.2.1.1. Warm-up step

After the introduction, in the warm-up step, participants were asked to locate one by one their places of living by adding a symbol on the map and to draw their daily routes to work or study using the drawing tool. In the experiment of group 1, the moderator created a new drawing layer. All participants successfully found their locations and opened the symbols tool quite quickly. P2 made several mistakes when trying to pan the map because of the active drawing tool. She had to use the "undo" function several times and had to activate and deactivate the drawing tool in order to complete her turn. When P1 took over after her, she did not notice that the drawing tool was still active and drew an accidental line instead of dragging the map. After them, P3 performed the task quickly and had no errors. Group 2, in general, demonstrated excellent results in navigating the map and locating the symbols. Only a few confusing moments took place in the beginning when P5 wanted to drag the symbol from the symbols tool to the map, and when P4 opened the scale tool instead of the symbols tool. Most of the errors occurred with the drawing tool. The most common mistake was panning the map with the active drawing tool, which led to some accidental drawings on the map, as it happened with P4, and pressing the undo button too many times, as it happened to P6. In group 3, errors with dragging the map while drawing the line occurred to P8. When P7 was locating the facilities using the symbols tool, P9 unintentionally tapped the map and added a symbol. Another problem that P7 and P9 encountered was touching the screen with sleeves while drawing, which led to accidental actions with the map. P7 noticed that they had to do a lot of "undo" actions. During this task, participants had to be preconscious when the drawing tool was active. Because performing additional actions, such as panning, locating the symbols, etc. was impossible when the previous tool was active. This issue led to many mistakes and was distracting participants from mapping and discussing.

In the second task of the warm-up step, participants were asked to edit their route to show an alternative way. The moderator demonstrated how to switch to edit mode and usually asked the last drawing participant to perform the task. During the demonstration to group 1, the moderator added dots on the line with a long press, while he wanted to activate the edit mode. P3, who was editing the route, closed the editing window that was covering the mapping area. This action led him back to drawing mode, and he unwittingly drew a new line. After finishing the task, he pointed out that there were too many vertices. In group 2 and 3 P6 and P9 successfully edited the route, and during the process, P9 discovered a way to delete extra nodes. When participants completed the tasks, the moderator asked them to go back to the Kennispark area on the map, and participants used the extent tool for this action.

6.2.1.2. First step

In the first step of the experiment, participants were asked to map all the facilities and amenities in the Kennispark area that they were aware of using the symbols tool. Participants were supposed to work in a group decision-making process, starting from this task. At the beginning of the task, the moderator showed how to create a new drawing layer for existing facilities and asked participants to give the new drawing layer a name.

In the beginning, group 1 decided to work with a satellite image view in the background. Participants were discussing mostly looking at the maptable and were interacting with the map together depending on their position. For instance, the participant standing to the left of the maptable switched the layers, the person in the middle located the symbols, and the third one moved the map. P1 and P2 were adding the symbols on a map. When the participants were locating the facilities, they could not find the right symbol, and P3 suggested to have already grouped symbols for more straightforward navigation. Also, once P1 wanted to replace a just added icon by dragging, and then press long but did not succeed. Then she decided to delete the icon by the long press but could not find the right button in the toolbar that appeared. After one tap on the symbol, she finally found the delete button. P2 wanted to locate one symbol two times on a map, but could not do it, because the symbols tool allows locating a chosen symbol only once on a map.

Group 2 was managing the map navigation and location of the facilities pretty good; however, it had difficulties with some tools. When the moderator asked to type the name of the layer, the group encountered problems with the keyboard and layers. P4 made a typo and accidentally created three layers by confusing backspace with the enter button on the onscreen keyboard. The participants tried to remove the layers: P5 pressed the edit button on a layer, but it got activated to edit on the map. Thereafter, P5 clicked on a layer and opened a drag menu with a remove button. P4 repeatedly pressed the button with no result, until the moderator advised her to swipe the button. Finally, after several attempts to enter the correct name on the keyboard, P4 changed the name of the layer. When the moderator explained to them the task of the first step, P4 and P5 started a discussion whilst looking at the map. P5 opened the symbols tool and started locating while the discussion among the group members was going on. The moderator advised switching to satellite image to have a more unobstructed view, and P4 hesitantly switched the layer. P6 suggested that symbols had different colors because the icons were black, and on a satellite image, they had low contrast, so he tried to click to see whether it was possible to change the color. When P4 typed an annotation for the symbol, she pointed out that it covered the icon and suggested that it would be better if the text were placed next to the symbol, not on top. P6 noted that editing windows of the symbols overlap: "when you press each function, they maintain, so it will be nice if one appears, and you press another function, it will close, so you can see only one function." In handwritten annotations, P4 assumed that it would not be standardized since everyone has different handwriting. When P5 tried handwriting, a single click could lead to a big dot that covered part of the text, so she did not succeed.

Group 3 started the task implementation by typing the layer name. Participants had a discussion and were mostly looking at the map, and P8 was locating the symbols. When the moderator suggested adding the annotation to the symbols, the group had similar issues with the keyboard as the previous group. P7 commented on the keyboard "Having these labels instead of symbols that we are used to... Probably... Bit of an issue... At least for me. Because I am used to not having it [here] (pointing at the backspace button)". P7 also added, "It seems to be weird that you have to close the actual window where you type in and the keyboard as well. So, you have two windows, one with the name, or like the labels that appear, and the one where the keyboard is. And you close both". Regarding the comment about closing two windows while typing: the keyboard closes automatically when the typing menu is closed first. P8 was looking for the symbols in the keyboard (for instance, a dashed line), but there was no such. Both P7 and P8 were pressing the "Del" button for deleting the letters, but not the backspace. In the beginning, just like in group 2, P8, who started first, was dragging the symbol to the map. The group was locating the symbols and navigating the map, but again had problems with deleting and editing the symbols. For instance, P7 wanted to move the symbol after locating it on a map and intuitively pressed the symbol trying to drag it. However, this did not work, and she decided to remove the symbol and put a new one. When dragging and a tap method did not work, participants asked the moderator to help. During this task, the group 3 participants were hesitating to press the buttons and resorted to the help of the moderator. P8 also wanted to give an ID to the symbol by pressing it longer but did not succeed. P8 commented, that ID is not clear, and wondered what the difference between ID and annotation was. P9 was participating in the drawing process too but had some troubles in pressing the symbols to open the toolbar. During the task, the participants of group 3 were dragging the editing windows and the keyboard on the map towards themselves.

6.2.1.3. Second step

The second step was about adding the facilities that participants would like to have in the Kennispark area. The first task of the step was the same as the previous step in terms of implementation. Participants had to use the symbol tools again, but this time they had to discuss and come to a consensus within the group.

The group 1 members created a new drawing layer with a typo again and encountered problems with editing the layers. They solved the mistake after the second try with the help of the moderator. Typing was challenging because the maptable did not recognize the gestures of P1, as well as P2. Each letter had to be typed carefully one by one. Also, P1 was standing on the left side of the maptable, and she was not moving the keyboard towards her, so it was hard to type. P2 opened the symbols tool, added a symbol while the group was discussing, and kept adding symbols. P1 wanted to move on the symbol on the map, with a long press opened the edit toolbar, assumed that "x" symbol meant to delete, but it just closed the edit toolbar. The moderator asked to add the annotation, and P1 and P3 did that. When the moderator asked to annotate it in handwriting, participants opened the symbols tool and accidentally added a symbol to another place. P2 could not figure out how to delete it, so the moderator helped her, but he opened the edit menu after one wrong attempt. P2 could not find out how to press the remove button, though it was a swipe button. P3 told that "it's not easy [to understand]". The challenge of the handwriting annotation was to draw continuously; otherwise it became a huge dot or polygon. The second task of the second step asked participants to create a 50x100 m park. The group used the ruler tool to measure and find out the best location on the map and had no problems in drawing the polygon.

Group 2 created a new layer without any problems this time, but P4 made a typo and hesitated for a few seconds trying to figure out how to erase the typo (backspace). When the moderator asked to locate the possible facilities, P6 started wondering whether he could create a shape, as square, and was guessing whether the drawing tool would help him. Then he drew a polygon for a building with annotations. When the moderator asked whether he could change the color of the polygon, P6 commented: "Something interesting is that it looks for me... it indicates that this [pointing at color pallet] going to change the color of the outline, instead of the inside". Participants kept discussing and adding the symbols. P6 commented: "something will be interesting to see is that when you press the icon, it doesn't... some software just explains the definition of each symbol". However, the symbol tool defines the selected symbol, and the participant did not see it at first glance. P5 mentioned that the explanations are limited, for instance, when they picked the ball symbol, they meant sport, while the description said "games". "So, they would, maybe in a way be good, if it wouldn't be described, so you can just interpret the symbols," said P5. For the task of adding a 50x100 m park, P5 and P4 opened the ruler tool, adjusted the ruler, then zoomed to the area. When the participants found the perfect spot, P5 switched off the ruler, opened the drawing tool, and pressed "Undo". When the moderator commented that she could have deleted something, P5 answered: "when you just close it, it should't go back anymore. Then... no hidden thing will happen". P5 successfully created a polygon and annotated it. P6 suggested that it will be useful to be able to rotate the map, but P5 presumed that then it would be confusing, and P6 supposed that a north sign might have been useful in that case.

Group 3 also started their task by creating a new drawing layer. Then participants began the discussion, meanwhile adding the symbols. When suggested to add the hand-written annotation, P9 picked the drawing tool, thickness, and color, and tried to write, but accidentally added points. Participants decided that it did not work like that and added the usual annotation. The moderator opened the edit menu for the accidental dot so that users could delete it. P9 pressed the remove button, but it did not work until the moderator advised them to swipe the button. P9 commented that "it is not clear that you have to slide it" in the editing window. Participants resumed the discussion and concluded that the symbols were not good enough (because they could not find the proper train station symbol), so P9 added an annotation to a "train station" symbol. The moderator introduced the second task of the step and asked to draw a new 50x100 m park. Participants started over the discussion, picked the location, and P8 opened the ruler tool. P7 and P9 were resizing the ruler to adjust, and then the moderator suggested to zoom in to the map. P9 zoomed in to the map and fitted the ruler. P7 drew a polygon, slightly bigger than expected, so participants decided to cut the polygon. P7 noticed that "we cannot create a polygon and specify the size." Long press and the polygon switched to the editing mode, and P7 started editing the nodes. The moderator suggested them the simple solution to delete and draw it again, and P7 followed his advice. During the task execution, P9 commented that when they were working as a group, they could not work simultaneously.

6.2.1.4. Third step

In the third step, participants were asked to locate the new ITC hotel in the territory of the Kennispark. Group 1 started with a discussion and created a new drawing layer for that, following the moderator's advice. For the task of placing the cafeteria within 100 m from the ITC, participants used the buffer tool. P3 asked whether it is possible to assign an exact number to the buffer, or any other tool. Using the buffer tool was intuitive for all groups. However, group 1 discovered that it was impossible to add a symbol inside of the buffer, so they mentioned it as a weakness of the software.

Group 2 started the task with discussion as well. First, they decided to put the symbol, but then changed their mind to draw a polygon, and removed the symbol from the map. P6 commented that "there are no predefined symbols, like a triangle, squares." P4 created a polygon and gave an annotation. P5 pointed out that "it is bit slow, so you have to press multiple times "undo", which is bad." For the second task of the step, the group used the buffer tool as well. Participants were about to draw a polygon again, but following the advice of the moderator, located a symbol with annotation. P5 wanted to resize the icon (symbol) on the map. By the end of the session, the group became confident in using the software. However, they kept making the same mistake as in previous tasks, which was dragging the map while the drawing tool was active.

Group 3 fulfilled the request of the moderator to create a new drawing layer. By the last step of the experiment, the participants were confident with layer management, as P7 quickly created a new layer and switched between the layers. However, P7 hesitated with the button to press on the keyboard when she finished typing. After the discussion of where to locate the new hotel, P8 added a symbol on the map. While the moderator was explaining the following task of locating the cafeteria, P9 was playing with scale and checking the tool. Participants activated the buffer tool, and P7 pointed out that the buffer was around the point, not the whole building. During the discussion, P7 noticed that they never saved the session, and wondered if it was saved automatically. The moderator assured that it was. After the discussion, the group members agreed to locate the cafeteria inside of the ITC, so P9 added a symbol on top of the ITC building.

6.2.2. Post-Test Interviews

A semi-structured interview was conducted with the test groups to evaluate the usability and user satisfaction after completing the tasks. The findings of the interview helped to create an overview of the users' opinions regarding the functionality, user interaction, interface, and to outline the strong and weak parts of the software. It will help to develop the results of the usability testing and further recommendations based on that information. As indicated already in Chapter 5, the questions of the interview are presented in Appendix 6.

In *the first question*, test participants were asked about the tasks that were difficult to execute. While discussing the challenging issues they encountered, some of them already provided possible solutions, which can be considered as answers to *the second question*.

Participants were pointing out some difficulties in the use of drawing tools. For instance, P1, P5, and P8 found the handwriting with the drawing tool challenging. P5 pointed out two difficulties "which makes it impossible to just free handwriting": when the tool creates a polygon once the line closes, for instance, with the letter "e," and when it creates a big dot on top of "i".

More comments were made towards the symbols tool. P8 claimed they need more symbols, and P2 supported the suggestion of P3 to group the symbols by topics to make the selection easier, for example, restaurants, hotels, hospitals, etc. Another issue mentioned regarding the symbols by P4, is that text of the annotation of symbols was covering the symbol itself, so that "either you can see the symbols, or you can see the letters." P6 found confusing that the default color of the symbols was only black, especially when the base map was the satellite image. In those situations, there was low contrast between the symbols and the background at some dark areas of the image. P6 suggested having a chance to change the colors of the symbols. Another suggestion was the possibility of adding a new icon or image in cases when users can not find the right symbol. P4 noted that it would be better to have a set of shapes for drawing, such as rectangular or square shapes and circles, instead of drawing them by hand.

P2 and P3 encountered more difficulties in editing the drawn lines, such as editing the nodes, because there were too many vertices. The third group mentioned another issue users had to be careful with, which is re-scaling or panning the map while drawing. P8 stated that "you need to close the drawing section and then zoom in or zoom out or pan and start again. …you cannot zoom in and zoom out by dragging". P3 later added that it would be better to have an option to continue the drawing after zooming in or out without interrupting the line, like in ArcGIS. The undo function was quite challenging for groups 1 and 2 as well. In case of drawing a wrong line, participants had to "undo" the action, and redraw it several times. Thereby, the drawing process was time-consuming. P5 mentioned that "not accidentally making lines and not accidentally deleting lines was also very challenging." Because sometimes, during the discussion, one could draw something, while another person was trying to zoom in or out the map. Besides, the undo function was not taking place immediately, so participants could press the undo button for several times and that would lead to accidental removal of something that is drawn on the other side of the map, which is not shown on the screen.

Another issue of drawing was while using the buffer tool. P1, P2, and P3 could not draw within the buffer, because they had to switch off the buffer and "trust in their memory" to remember the selected area. P3 also suggested the function of assigning an exact number to the features, such as ruler and buffer. P2 supported: "In GIS there is an option, you click buffer, and you type 100, and then click, and it's done". P3 added, "Especially, if you are planning and then you want make a precise measurement". P7 wondered whether it was possible to make a buffer around the polygon: "100 meters around the building, that actually means you need the polygon of the building and not the point.\". Another issue of functionality of the software mentioned by P8 was selection because it was hard to select the items on the map.

In the interface of the software, the "remove" button confused the test participants. It was not clear enough for P7, P8, and P9 that the button should not be pressed, but swiped because the swipe line was not indicated by one homogeneous line. Another issue remarked by P8 is that the "remove" button "was moving from right to left. Usually, it moves from left to right. And so, and it wasn't so clear graphically.". P8 said: "I think the map should have the same language because only for removing there is a swipe. The others are just clicking. So that's why we tried to click. But if they want to use another language, like swiping, then it should be clear.". The appearance of different windows on the screen was also confusing for P6 because it was not clear which one is active, and which one is not.

Simultaneously drawing on the maptable was not possible for users because the software did not allow them to perform multiple tasks at the same time. P9 suggested to discuss and draw concurrently and then delete if it does not work, rather than doing it one by one, taking turns and asking each other what they want to do. P6 mentioned the sweaty hands problem that brought him some trouble in pressing the buttons on the touch screen.

Overall, P7 and P9 found the software quite intuitive, especially for the general public. P9 suggested integrating a small pop up tutorial at the beginning for introducing the functionality, particularly for users without a GIS background.

In *the third question*, participants were asked whether they felt comfortable while working with the maptable software. All three groups gave a positive response that it was "quite nice," "quite simple, and just have a few tools, but you can use them like in multiple ways to make other lines of areas," "easy to learn," "very innovative". Drawing, adding layers, a different source of data: the satellite image, the topography, and handy features were mentioned by P3 as well. Nice for a group discussion to see the entire picture, zoom in if needed. P9 noted the similarity with Google Maps in terms of interface and some functions. The third group discussed the need for a pen, that could have made the drawing, writing and selecting easier. However, they agreed that it is independent of the software and related more to the hardware.

The fourth question was whether it was easy for participants to use the software. P2 found Phoenix easier compared to other software (she did not specify which software she meant), and especially she liked that it has only a few functions. She noted that it was easy to master it even for the first time seeing. The second group already mentioned in an earlier answer that it was easy to learn. The third group, particularly P8 and P9, admitted that "it was not complicated" and "just needed an adjustment period.".

In *the fifth question*, test participants were asked to describe the strengths of the software. P1 stated that the software is intuitive, but not in the beginning. She also mentioned the clear interface and the option of dragging and rotating the windows. P3 mentioned that it was easy to maneuver into different layers: switch the layers on and off. P6 found the quality of the aerial image, easy drawing, pressing the buttons, and a variety of colors as the strengths of the software. He also mentioned the importance of the ruler and buffer tools, and P5 agreed. P4 pointed out the visualization. P6 also suggested to have the map navigation as in Google Earth, and the option of rotating the map, and P5 added that it was possible to move the editing tool windows and that it would make sense to be able to turn the whole map too. In the third group, P8 answered that the software is simple, and P7 mentioned that it has very easily accessible functions.

In the sixth question, participants were asked what improvements they could suggest for the maptable software. P1 suggested the drag and drop option, and also the redo function, which is "the undo of the undo," for cases when users accidentally delete something important. P6 found the software perfect because it is simple. In his opinion, if it will get complicated, users would get confused. P4 pointed out that adding more details and symbols could make it better. P7 found the software very appealing: the colors slide shows and how it looks. P8 noted that the colors are good, not disturbing.

6.2.3. Eye-tracking results

The analysis of the recordings from the eye-tracking glasses was performed with the Tobii Pro Lab software (Figure 6.2). This is a platform for interpretation, comparison, and presentation of the recordings of the eye gaze data (URL19). The recordings of each participant in the three groups were analyzed individually to the matter of defining the role of the maptable in the group decision-making process.

Figure 6.2 Tobii Pro Lab software (analytical) interface

The records from the eye-tracking glasses showed that Group 1 participants were mainly looking at the maptable during the session. They rarely looked at each other, usually only for 2-3 seconds when somebody was saying something, suggesting their ideas, or laughing. As it was mentioned before, the recording from the glasses of P3 was lost, but he was participating actively in the discussion, compared to others.

Group 2 participants were mostly discussing and drawing at the same time and had less time-consuming errors. All attention of the participants was on the maptable; they looked at each other in very rare cases, usually for 1-2 seconds. They only looked for 3-4 seconds at the moderator was when he was explaining the tasks. P5 was always actively involved in mapping, hardly looking at others, even when somebody was talking: she was pressing the buttons and mapping. Sometimes P5 and P8 were replying to each other's comments and looking at each other, probably because they were standing at two sides of the maptable. P6 was the person who was least active in mapping, but actively commenting and asking questions while others were drawing.

Group 3 participants were rarely looking at each other as well, mostly for a few seconds to seek for approval of their suggestions, or to have a look at a talking participant. They were looking at each other when they were laughing after finding a solution for an error or confusing action. Also, in this group, two participants tended to look at one particular person in the group and the moderator during the discussion. In this group, P8 was standing in the middle of the group and was starting the discussion and suggesting her ideas before the others did.

Some assumptions of why participants were looking at the maptable most of the time are that they were:

- exploring the map, even when the moderator was explaining the tasks;
- thinking about the tasks, where to locate, etc.;
- looking at where others were pointing at in the discussion;
- looking at how other participants were mapping;
- playing with the tools.

Figure 6.3 presents the time spent on the execution of the tasks, specifically on how much time participants spent on discussion and mapping in each step. Discussion in this context means a negotiation among participants that includes panning the map without changing it. Drawing includes the use of the drawing tool and symbol tool, dealing with errors, and discussion while mapping the facilities. The warm-up step was performed individually, so it was not considered as a group decision-making task. The first step of the test involved less discussion among all three groups because participants were mapping the facilities they knew, which are known facts. Group 2 even started locating them without a prior discussion after the explanation of the moderator. Steps 2 and 3 required participants to take collective decisions, as a result of which the discussion time increased.

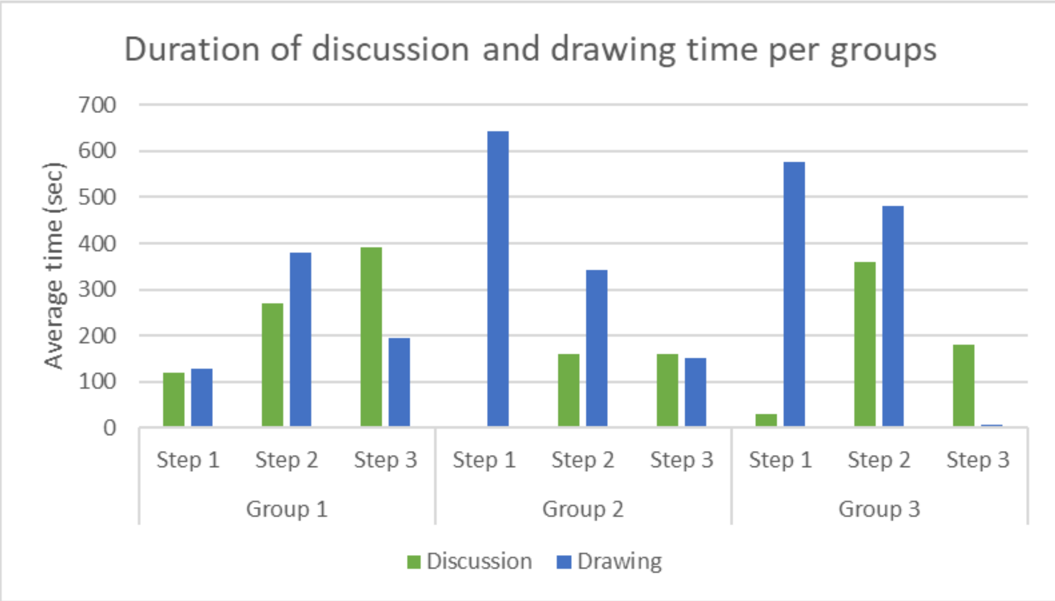


Figure 6.3 Duration of time spent on implementation of steps by the three groups

Figure 6.4 shows the total amount of time that the groups spent on drawing during the whole experiment. The duration of the error shows how much out of the drawing time the groups spent on struggling with them. Group 1 spent comparably more time on errors than others and spent more than half of their drawing time trying to fix them. Group 3 had comparably better results than other groups in terms of struggling with errors.

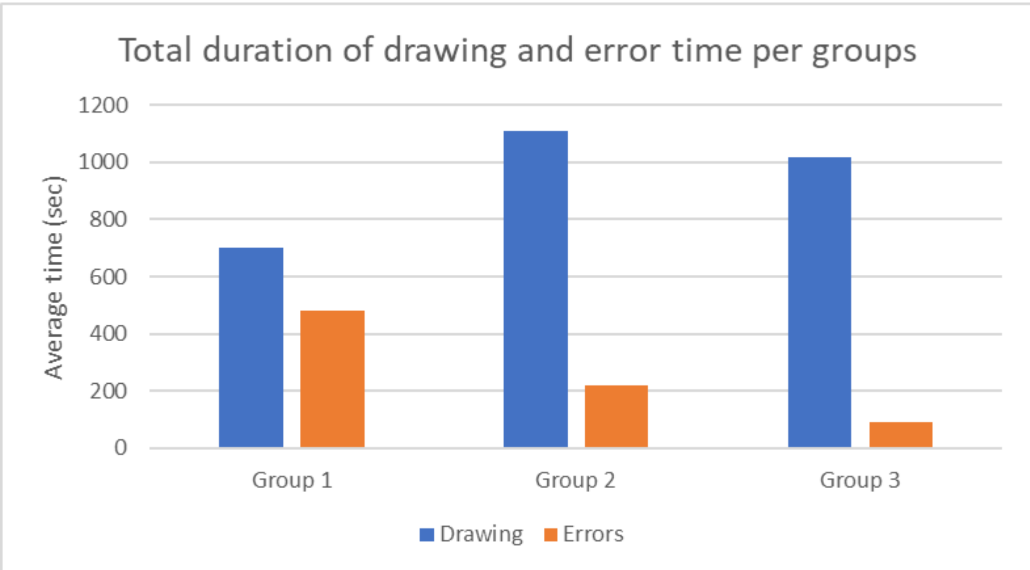


Figure 6.4 Duration of time spent on drawing and errors during the whole experiment by the three groups

As such, it was observed, that there were no explicit leaders since the groups were small (3 users and the moderator), and each participant had a chance to express his/her opinion without being interrupted. Everyone had space next to the maptable that allowed them to draw easily. The moderator also had an essential role in the group decision-making process, as he helped the participants during the deadlock cases, accelerated the mapping process, and gave floor to a less active participant. An interesting observation is that the most active participants were mostly standing in the middle or on the right side of the maptable.

6.3. Analysis of the results

The retrieved research material from the recordings amounted to a valuable source of qualitative information and was transcribed into tables (Appendix 8). In order to extract the needed information from all this data to answer the research questions, coding the different segments of the transcripts was found to be a convenient solution. Four main codes, each referring to a particular action of the participants, were defined based on the requirement analysis (see Chapter 4). Table 6.1 presents the list of codes used in the analysis with sample quotes from the transcripts of the recordings.

Table 6.1 The codes for the analysis of the transcripts

	Codes		**Sample quotes**
1	Functionality	Navigation	Participants used the extent tool to go back to Kennispark area
		Drawing	P3 about the symbols "sometimes it is not easy to find the right symbol because they are not grouped in one specific group."
		Visualization	P6 commented that editing windows of the symbols overlap "when you press each function, they maintain, so it will be nice if one appears, and you press another function, it will close, so you can see only one function."
		Analytical	P5 and P4 opened the ruler, adjusted the ruler, then zoomed in the area
		Data Management	P7 switched off the layers
2	Interface		P5 commented that she thought the "x" button in the edit menu of the line was for deleting it
3	User Interaction		P5 tried to drag and drop the symbol from the symbols tool
4	Challenges/Errors		P3 added a new layer, made a typo, accidentally pressed "Enter"

6.3.1. Functionality

Navigating the map was very intuitive and easy. Zooming in and out, panning and the extent tools were working fast and well. Some users were using both hands to pan and rescale the map while talking. However, it was impossible to rotate the map, and participants were suggesting to have that option in the future. That could make the planning and mapping process more manageable, especially when the group standing around the maptable consists of more than three people.

The drawing was easy and straightforward, since the tool allowed to draw the points, lines, and polygons at once. However, it was not possible to continue the previous line with snapping, especially when users had to pan the map. Because of that, the lines were not holistic. The absence of ready-made drawing shapes, such as rectangle, triangles, circles, etc. slowed down the drawing process and reduced the accuracy of drawing. The tool allows to create polygons in a very simple way but does not allow to specify their size.

In collaborative mapping, users need to write down some text on the map. The drawing tool does not allow that action, because it closes the polygon and creates a dot, which is not proportional to the thickness of the line. That is why none of the groups completed the handwriting task successfully. Figure 6.5 shows a sample of a handwritten annotation by P5 from Group 2.

Figure 6.5 Handwriting example

The symbol tool is a useful tool for collaborative mapping because of the variety of icons that makes it easier to define a particular facility and map it easily and quickly. The symbol tool was the most used in the experiment, mostly because of the specific tasks of our workshop. It makes the mapping process faster and creates a map with diverse outcomes. However, the scattered arrangement of symbols in the tool window made it difficult for users to find a particular one. Also, when they wanted to specify a specific symbol by giving it an annotation, the text was covering the symbol, making it impossible to recognize it. Another drawback of the tool is that except for two (green circle with a checkmark and red circle with a cross) all symbols were black, which made them less noticeable on the satellite image background.

The analytical tools, such as the ruler and buffer tools, were actively used by participants and they found them easy and helpful. Again, participants wanted to assign exact numbers to the tools to not adjust them manually. The software was also showing the length of the drawing line and the area of the drawn polygon, which is useful in was. In our experiment, users were not considering that information, and they were closing those windows once they finished drawing.

The visualization tools were simple and few in the software as well. The software shows one map that covers most of the screen. The only drawback noticed was that participants got confused when too many editing windows were open.

Data Management. The three layers of the base map that the software has (base map, topographic base map, and aerial base map) were beneficial for participants and they were switching the layers often and quickly. Additional manipulations with layers were not intuitive and not always understandable for participants, though they had different functions too, such as reducing the transparency of the layer, editing and removing. Participants rated well the quality and accuracy of the aerial image and maps. Each layer stored different types of information, such as all types of drawings, symbols, and annotations.

6.3.2. Interface

The interface was quite intuitive for users because of a few tools and a simple design. The blue color of the software was not distracting the users, and the icons of the tools were mostly talking for themselves. The tools presented in the right part of the screen were easy to work with, mainly because the moderator introduced them in the beginning. However, sometimes users were hesitating, accidentally opening other tools, perhaps because the icons were not self-explanatory.

However, the challenging part for the users was trying to find ways to delete the drawings. The reason for that was that the buttons are not intuitive. For instance, the "x" button in the examples below (Figure 6.6). One tap on the symbol opened the edit window with two buttons for deleting and closing the window (Figure 6.6a). One long press of the symbol opened the toolbar of the functions, where the "x" button was designed to close the menu (Figure 6.6b). This inconvenience led to confusion of users and hesitating to press the buttons.

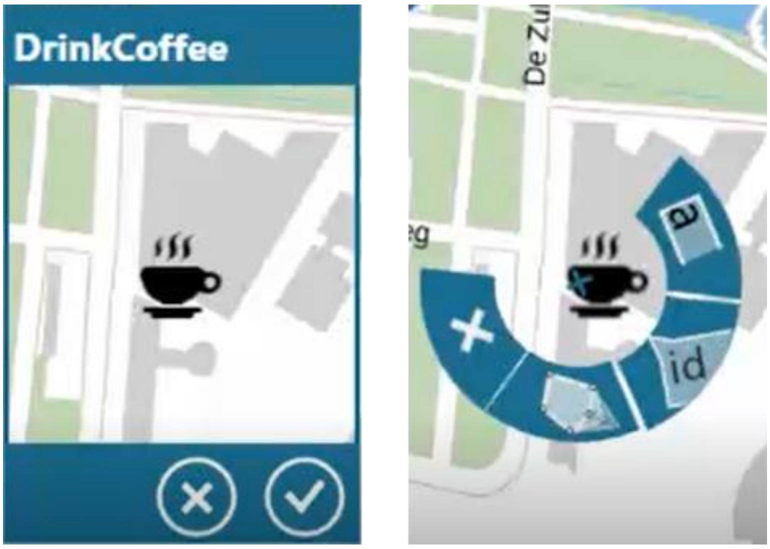


Figure 6.6 Editing menus of the symbol: a) one-tap menu of the symbol;
b) long-press menu of the symbol

As one participant has mentioned in the interview, the design of the buttons was not uniform. Only the "remove" button was designed as a swiping button, all other buttons of the software, including "delete" were clickable. The reason for the slide "remove" button was, I suppose, a try to avoid unintentional removal of features, for example when the sleeve of a user touches the screen. However, none of the users could find out how to interact with the remove button, once they saw it for the first time. Figure 6.7 depicts heatmaps of the layer management window and the editing window of the symbol. After several attempts of pressing the "remove" button, P4 (Figure 6.7a) and P8 (Figure 6.7b) were looking around the window to find alternative ways to do it.

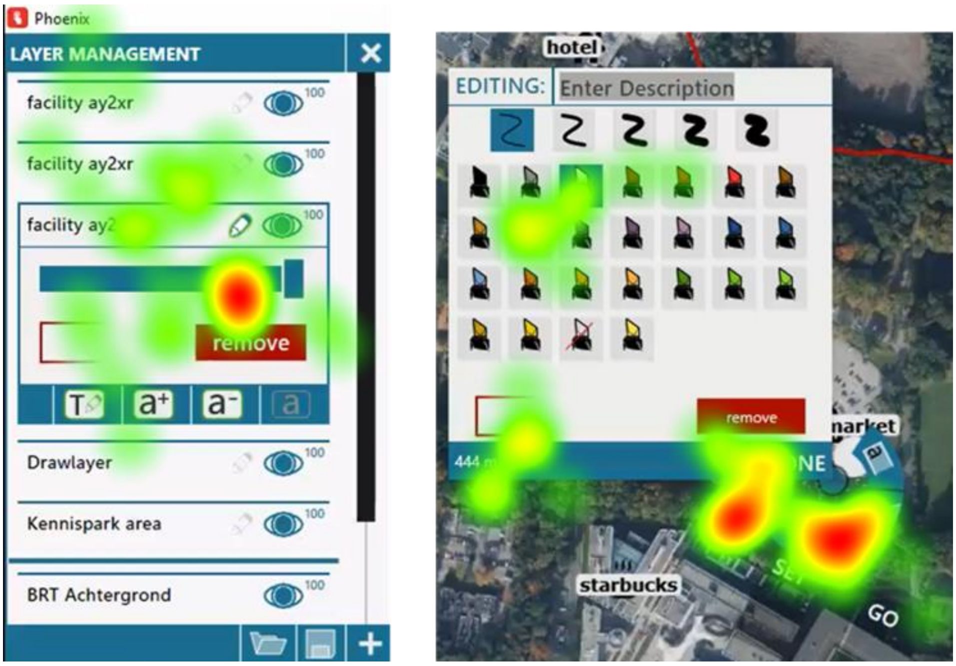


Figure 6.7 Heatmap of the layer management (a) and editing window of the symbol (b)

6.3.3. User interaction

The interaction with a map did not lead to any questions. One of the experts had commented in the requirement analysis focus group interview, that the interaction with the map should be the same as in Google Maps. The Phoenix software fulfilled this requirement and was recognizing all the gestures and, the way users were used to navigate the map. The option of dragging and shifting the windows was actively used by participants and was facilitating the drawing process. The users also mentioned that the layers window was easy to maneuver.

One drawback was the inability of moving the map while the drawing tool was active. Users were unintentionally dragging the map in some cases, and this sometimes led to mistakes. Also, users were not able to work on a map altogether, especially if someone was using it with some active drawing tool. Accidental tapping on a map of one user could ruin the drawing of another one, so this was considered to be a weakness of the software.

6.3.4. Errors and challenges

Errors and challenges were part of the experiment and helped to identify weak parts of the software. Table 6.2 describes the errors divided into groups depending on their categories and frequencies. Some of the mistakes were repeated quite often, while some were performed only once. Repeated errors may indicate tasks that were difficult to implement, while rare errors could happen because of human factors or bad design. However, most of the participants learned from the mistakes and did not reiterate them in subsequent actions.

Table 6.2 Error frequencies

Categories	Errors	Frequency
Symbols	Dragging the symbol from the symbol tool to the map	5
	Wanting to move the just located icon by dragging, and/then long-pressing	2
	Trying to add the same symbol twice on a map by selecting it once in the symbols tool	1
	Trying to annotate the symbol by one tap	1
	Opening another additional editing window (ID, annotation, edit) of a symbol	2
Drawing	In handwriting, the tool creates a polygon once the line closes, and dots	3
	Not being able to draw/add a symbol within the buffer	1
	Adding dots by long press, when he wanted to activate the editing mode of the line	1
	Wanting to add a symbol, but adding a dot, because the drawing tool was active	1
	Tapping the "Done" button of the edit menu to close the window, that was covering the map. while editing the vertices of the line, and stopped the editing	1
Navigation	Dragging the map while the drawing tool is active, and adding an accidental line	8
	Trying to rotate the map	1
Keyboard	Tapping the "Del" button instead of "Backspace"	3
	Tapping the "Enter" button instead of "Backspace"	3
	Low sensitivity of the keyboard while typing	7
Interface	Trying to edit the layer name, could not open the keyboard	1
	Could not switch off the layer	1
	Opening another tool	2
Deleting	Trying to delete a symbol with a long press	1
	In the layer management window clicking edit button to remove the layer	1
	Tapping the "Remove" button instead of sliding	3
	Sliding the "Remove" button in another direction	1
	Pressing the "X" (close) button to delete	3

The participants of all groups made most of the errors when they were trying to navigate the map while the drawing tool was active. This action, as was mentioned in previous sections, led to accidental lines on the map. However, when the symbol tool was active, the navigation of the map was fine. All actions made while the drawing tool was active led to accidental lines, so participants had to be extremely careful with that.

Another finding were the issues with the keyboard buttons. Most of the participants made typos and confused the "Del," "Backspace," and "Enter" buttons when they were looking for as erasing button. The number of assistant buttons and their placement (for instance, the "Del" button usually is placed above the "Backspace" button) confused some of the users. A screenshot of the keyboard and a gaze plot of P1 and a heat map of P8 are depicted as an example in Figure 6.8. Participants were looking at “Del” button most of the time when they needed to erase the letter. Another reason for that could be the lack of arrows corresponding to the buttons “Backspace” and “Enter,” as they appear in regular keyboards. As it is known, the “Backspace” button often has an arrow pointing left and “Enter” has an arrow pointing down and left.

Figure 6.8 Screenshots of the keyboard: a) Gaze Plot of P1; b) Heatmap of P8

Dragging the symbol from the symbols tool to the map was the third common mistake during the experiments. As mentioned before, the symbol tool was the most useful in the task executions, and one of the most accessible tools. The error of dragging the icons was performed mostly at the beginning of the work for each participant, and once a user understood that tapping the symbol is a correct way to add it on to the map, the problem was solved.

6.4. Suggested improvements for Phoenix

All these errors may seem insignificant, but in a group decision-making process, discussions usually take a long time. So, such small errors can be time-consuming for users because fixing a mistake or trying to redo it again distracts them from the initial goal of planning. Table 6.3 presents the possible improvements for the Phoenix software.

Table 6.3 Possible improvements for the Phoenix software

Issue	Improvements
Icons of the editing menu	Red “x” for “delete,” green checkpoint for “done,” pen for “edit,” arrow for drag menu, grey color for non-active sections.
Accidental actions	Redo and undo buttons in the toolbar.
Map navigation	Panning the map with two fingers at any active tool.
Drawing tool	A choice of point, line or polygon and colors in the menu. In case of choosing the polygon: square, circle, triangle, freehand.
	Option to continue drawing by snapping to vertices.
Keyboard	Keyboard with the following buttons: letters, arrow keys, caps lock, enter, backspace, and clear.
Buffer	An option of drawing within the buffer, assigning exact numbers.
Interaction	Clicking on one drawing tool deactivates the previous one.
Editing and removing the feature	Long press on a feature to open the context menu with options such as delete, annotation, color, edit (including change the position of a symbol), and done.

6.5. Conclusion

This chapter discussed and analyzed the results of the user experiments, specifically the eye-tracking recordings, interviews, and video recordings of the group decision-making processes. The outcomes of the experimental data were a fruitful source of information for the qualitative data analysis. The eye-tracking records helped to investigate the decision-making processes of the groups. The outcomes of the experiments were transcribed to tables using four main codes defined based on the requirement analysis. Each code referred to a particular action or comment of the participants. As a result of the investigation, the strong and weak parts of the Phoenix software were outlined and, that will be the base for the general recommendations for maptable software in the following chapter.

7. RECOMMENDATIONS AND CONCLUSIONS

7.1. Conclusions

This research aimed to investigate the usability of the Phoenix software and, based on the results obtained, to develop recommendations on design principles of GIS collaborative mapping software tools for maptables. The second objective focused on providing recommendations for the concurrent use of several mobile eye-tracking devices to investigate the usability of maptable software in collaborative mapping in group decision making processes.

Chapter 2 covers a literature review of the researches related to the topic that have been done before. It overviews the general characteristics of maptables, the most used software for maptables and applications of the maptables in workshops. The chapter also overviews the group decision-making processes related to spatial planning workshops and reviews the previous usability studies of maptables.

Chapter 3 describes the research methods selected for the experimental evaluation and justifies the reasons for choosing them. First, it provides general information about usability evaluations and qualitative analysis. Then it explains the requirement analysis through a Focus Group interview with experts. Following is a description of the mixed-method approach used in the workshop sessions: the eye-tracking method, thinking aloud, video observations, questionnaire, and the interview. The combination of these techniques in a task-based experiment provided a complete and wide range of data for further qualitative analysis. At the end of the chapter, the selected case study and the context of the workshops were discussed.

Chapter 4 covers the execution of the requirement analysis. The goal of the requirement analysis was to define the functions and features of the software that users would need. The requirements for the maptable software were developed based on the results of the Focus Group interview with experts. The interviewed experts were ITC professors, whose research interests represent urban and regional planning and who had experience with moderating workshops with maptables. The questions for the interview were prepared based on a review of two maptable software manuals.

Chapter 5 provides information on the execution of the user experiments aimed at testing and evaluating the usability of the Phoenix interactive maptable software. An overview of the equipment and software used in the experiments is given in this chapter as well. A pilot test was executed before the actual tests took place in order to examine different aspects of the experiment in advance. The concurrent use of several eye-tracking glasses, which is one of the research questions, was tested during the pilot test and described in this chapter as well. In the pilot test, the connection of the glasses, data recording, and the execution of the test went smoothly, and no data was lost. The results of the pilot test helped to improve preparations for the actual user tests.

The actual test involved three workshops with three groups of four participants, including a moderator. During the implementation of the experiments, the eye-tracking records of two participants were lost due to technical issues, but, in general, all test groups executed the tasks very well. The participants were thinking aloud about all their actions and were actively commenting on the software functionality. Post-test interviews helped to summarize their opinions and suggestions towards the usability of the Phoenix software. The results obtained from the experiments were fruitful data for further qualitative analysis.

Chapter 6 describes and analyses the results of the actual user tests, specifically eye-tracking recordings, interviews, and video recordings of the group decision-making processes. The records from the eye-tracking glasses of the participants helped to investigate the decision-making processes of the groups. The findings showed that the discussions among the participants happened while they were looking at the maptable, and there were no explicit leaders in the groups. The outcomes of the experiments were transcribed to tables using four main codes defined based on the requirement analysis: functionality of the software, interface, user interaction, and the errors and challenges. The codes were assigned to particular actions or comments of the participants. Based on the findings, the strong and weak parts of the Phoenix software were outlined. Additionally, possible improvements for the Phoenix software were suggested.

7.2. Answers to research questions

- *What is the usability of the Phoenix software?*
  - *Who are the users, and what are their characteristics?*

Users of maptables are typically a group of 4 to 10 people, involved in a group decision-making process. The users may vary by their background, depending on the goals and topic of the workshop, or age category. They can be citizens, city municipality workers, architects, etc.

  - *What are the specific requirements of the participatory use of the maptable software?*

The requirements for the functionality, including the navigation tools, drawing tools, analytical tools, visualization tools, and data management tools; software interface visualization, and user interaction were defined after the interview with the Focus Group experts. The full list of requirements is presented in Tables 4.1 and 4.2 in Chapter 4 – Requirement Analysis. In general, the maptable software should support basic map navigation gestures, as in Google Maps, such as zooming in/zooming out, panning, rotating the map and previous extent. Drawing tools need to contain freehand, boxes, shapes, adding annotation, editing tools. The functionality of the analytical tools depend on the user background, but in general tools for selecting, and calculations of outcome indicators. The visualization of the software needs to have a nice dashboard, with a 3D view, graphs, split interfaces, etc. Data management tools should support various formats of import and export files for mapping. The interface of the software needs to be as simple as possible, with a map as a central element. The user interaction needs to be intuitive, especially in switching between edit and non-edit mode.

  - *What are the effectiveness, efficiency, and user satisfaction of the Phoenix software for executing a collaborative mapping task?*

As it was mentioned in Chapter 3, the effectiveness of the software is measured in the success of task performances. All groups completed the tasks well, even though the collaborative planning workshops were not aimed at finding the right answers to the tasks. Participants are supposed to come to a specific decision through the discussions. All three groups came to a consensus in each task and used the software tools in their decision-making process successfully.

Efficiency can be measured in time and effort spent on task performance. In the group decision-making process, measuring the time spent on tasks cannot be an indicator of software efficiency. Because participants come to a decision through discussions, sometimes that can last long, the effort can also be measured through the challenges and errors, which are described in Chapter 6, Section 6.3. Based on the results of all groups, it can be concluded that a number of software tools need some improvements, such as design of the icons and the buttons need to be improved, the redo and undo actions need to be added, the navigation of map with any active tool, editing of the drawings need to be simplified. The possible improvements for the Phoenix software are presented in Chapter 6, Section 6.4.

The user satisfaction was determined by the answers given in the post-interviews held with participants. The interview results are given in Chapter 6, Section 6.2.2. In general, all participants responded positively. The common comments were that the software is easy to learn, helpful for group discussions, simple and nice. Some of them had troubles with some tools in the beginning, but by the end of the sessions, everything worked smoothly.

- *What recommendations could be given for the design of GIS collaborative mapping software for maptables?*

1. The software interface and the tools need to be as simple as possible, with intuitive icons and buttons.
2. The map should be the central element of the interface, with intuitively simple gesture navigation. The main difference of the maptable software from other touch-based map applications (such as Google Maps on tablets and smartphones), is that it should not only allow users to interact with a map but also to make changes on maps. Normally, during the interaction with a map, the users are not used to perceive the difference between non-edit and edit modes. For instance, they keep panning the map with the drawing tool being active. That is why it is important to design the navigation gestures in such a way that they will not conflict with other editing gestures. For example, to allow panning of a map with two fingers in any conditions.
3. Depending on the users, the maptable software needs to have simple functions for non-expert stakeholders and advanced tools for experts. Non-expert users, for instance, the local citizens of the neighborhood, would appreciate easy-to-use tools with basic analytical feedback, as presented in Phoenix. On the other hand, expert stakeholders, such as representatives of the urban planning sector, might need advanced tools to anticipate different scenarios of planning. The solution for that could be placing the most necessary and essential functions on the foreground of the interface and to only activate more advanced functions in case of need.
4. It should also be noted that the maptable software is intended for collaborative (group) mapping. Adding an option of simultaneous drawing for two users could be a good solution for supporting the collaborative mapping purpose.

- *Can several mobile eye-tracking devices be used concurrently to investigate group decision processes in collaborative mapping?*

Yes, they can. In this research, four eye-tracking glasses were used to investigate the group-decision making processes in collaborative mapping.

  - *How can data be collected? How can the collected data be synchronized and analyzed?*

In order to collect the data simultaneously from the glasses of four people in the group, the method of using Ethernet cables connected to each pair of glasses and one tablet via a switch was successfully applied. The details of the process are described in Chapter 5, Section 5.4.1. During the recording of the session, all views from the glasses of participants were simultaneously shown on the screen of the tablet. The recording data from the glasses of two participants were lost, probably due to a disconnection of the cable and the recording unit. Retrieved data was analyzed individually per participant in Tobii Pro Analyzer software, using the time marks of the tasks. However, in the future applications, it would be useful to sort out whether it would be possible to combine the recordings in one synchronous view so that they can be analyzed in conjunction.

This may lead to better insights into the group decision processes. The analysis of the eye-tracking records is described in Chapter 6, Section 6.2.3.

- *How are group decisions made?*

In the experiments, participants were discussing whilst looking at the map, navigating, and exploring the territory. The records from the eye-tracking glasses showed that they rarely looked at each other, usually only for 2-3 seconds when somebody was saying something, suggesting their ideas, or laughing. More details about each group and the analysis of eye-tracking data are described in Chapter 6, Section 6.2.3. It was also observed, that there were no explicit leaders, probably since the groups were small (3 users and the moderator), and each participant had a chance to express his/her opinion without being interrupted. However, it was observed that some participants were more active compared to other members of the group.

7.3. Further research recommendations

The outcomes of the experiments can provide support for the following recommendations for the further research:

- Since the case study chosen for the research was about the university campus, the participants invited to the experiments were people related to ITC and the University of Twente. Almost all the participants, except for one user in the actual user test and one participant in the pilot test, had a background related to the geographic field. The recommendation for further research would be to involve more participants with a non-geographical background.
- This research involved three participants and one moderator per group. For further research, more people can be involved in the experiments, so as to investigate the group-decision making processes of larger groups.

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APPENDIX 1

Invitation letter for the Focus Group Interview

Dear Sir/Madam,

Hello, my name is Altynay Kikkarina, I am a student of International Cartography Master Programme. Right now, I am doing my master thesis at ITC under the supervision of Dr. Corné van Elzakker and Dr. Johannes Flacke. The title of my research is "Recommendations for the design of collaborative mapping software tools for maptables".

The aim of the research is to test and evaluate the usability of existing interactive maptable GIS software, in particular, Phoenix. Based on results of the tests, recommendations on design principles of GIS software tools for maptables will be developed. We are planning to execute one pilot test and an actual experiment with 3 groups of users. The experiment will simulate a real workshop of urban planning to test the software. To perform the user test, we will use Tobii eye-tracking glasses.

But before testing, we need to do a requirement analysis of maptable software, based on the interview with experts. I would like to interview a focus group - three experts at the same time. Experience and recommendations of experts will be the basis for further user test.

I am writing to ask whether you would be willing to join our interview as one of the experts. I expect the interview to last from forty to fifty minutes. Please, let me know if you can join. If so, which time will be convenient for you the most.

I am looking forward to hearing from you soon. I do very much hope that you will be able to accept this invitation.

Thank you!

Best regards,
Altynay Kikkarina

APPENDIX 2

Interview with the Focus Group experts

My name is Altynay Kikkarina, I am a student of International Cartography Master Programme. Right now, I am doing my master thesis at ITC. The title of my research is "Recommendations for the design of collaborative mapping software tools for maptables".

The research aims to test and evaluate the usability of existing interactive maptable GIS software, in particular Phoenix. Based on the results of the tests, recommendations on design principles of GIS software tools for maptables will be developed. We are planning to execute one pilot test and an actual experiment with 3 groups of users. The experiment will simulate a real workshop of urban planning to test the software. To perform the user test, we will use Tobii eye-tracking glasses.

But before testing, we need to do a requirement analysis of tools, based on interviews with experts. Ideas and experience of experts will be the base for further user test.

- **Background**
  - How many planning workshops with maptables have you been involved in? What is your role within the projects?
  - Which GIS software for maptables do you usually use during the workshops? Why?
  - What were the goals of the workshops you participated in (increasing social awareness, planning, etc.)?

- **Functionality of software**
  - What kind of map navigation does the software need to have in your opinion? (pan, zoom, select, etc.)
  - What kind of drawing tools does the maptable software should contain? (Sketch tool, etc.)
  - What kind of analytical tools does it have to contain (computations, data analysis, etc.)?
  - What kind of visualization tools does it have to contain (3D visualization, graphs)?
  - What kind of data management tool does it have to contain (import formats, export formats, etc.)?

- **Software interface**
  - What do users need to see and access first when they look at the interface?
  - What do you think about the layout: what should be presented on the interface?

- **User interaction**
  - What gestures does the software have to recognize?
  - Which tasks on maptables are difficult to understand/perform to users?

- What improvements would you suggest for the software?
- Is there anything I have not mentioned that could be important for the requirements of the software?

APPENDIX 3

User background questionnaire

Dear participant, please provide information on the following:

- **Name** ____

- **Highest education level** ______________________________________

- **Do you wear glasses?**

  ☐ Yes ☐ No

  If yes, what is your glasses prescription?
  Left: ___________ Right: ___________

- **Do you have any physical disabilities that could affect your ability to work on a maptable?**
  ☐ Yes ☐ No

  If yes, please specify ____

- **Do you have experience in participating in collaborative planning practices (e.g. workshops, hearings)?**
  ☐ Yes ☐ No

  If yes, please specify ____
  ____

- **Have you ever worked with a maptable?**
  ☐ Yes ☐ No

- **Have you ever worked with the Phoenix software?**
  ☐ Yes ☐ No

- **How often do you use maps?**
  ☐ Very often (daily) ☐ Very rare (several times per year)
  ☐ Often (weekly) ☐ Never
  ☐ Rare (monthly)

- **Has GIS (Geographic Information Systems) ever been involved in your work or study?**

  ☐ Yes ☐ No

  If yes, how has it been involved? ______________________________________
  ____

APPENDIX 4

Researcher to-do list

Before the test:

- Check the state (battery, memory card, connection) of the following equipment: eye-tracking glasses, tablet, video camera, a maptable
- Prepare the project for the test on maptable
- Arrive one hour before the test to the Group Decision Room to:
    - turn on the maptable
    - connect eye-tracking glasses to the tablet
    - set up and turn on the camera
    - open the windows to air the room

Participants welcome and introduction

- Spread questionnaires to participants
- Help to wear the eye-tracking glasses to participants, perform the calibration of glasses and then start recording for each participant with glasses
- I will give an introduction to myself and my research
- Then I will turn on the camera and start screen recording on the maptable
- After that, I provide a short introduction to eye-tracking glasses and experiment
- If participants do not have any questions, we will start the session

During the test

- Dr. Johannes Flacke will introduce the case study and basic information about the maptable
- Then participants start executing the tasks under the supervision of Dr. Johannes Flacke
- Meanwhile, I will control the recording of camera and connection of eye-tracking glasses with the tablet
- Stop recording of eye-tracking glasses when the test is over

After the test

- Interview a focus group of participants to gather their opinion and impression about the session
- I will record the interview on audio and voice recorder
- Thank everyone for participation and finish the interview
- Collect all equipment

APPENDIX 5

User Test – Kennispark workshop

Dear participants, good morning and thanks for taking part in this experiment. My name is Altynay Kikkarina, and this experiment is part of my Master Thesis. The research aims to test and evaluate the usability of existing interactive maptable GIS software, in particular, Phoenix. Based on the results of the tests, I will develop recommendations on design principles of GIS software tools for maptables.

You will be recorded on a video camera to gather information about the group decision making the process. The video recordings will never be published without your explicit consent. The maptable screen will be recorded as well.

Tobii Glasses is the electronic equipment for tracking the movements of your eyes and verbalization. We ask you to wear the glasses during the experiment and speak out everything that comes to your mind. Glasses are connected to the tablet via cables, where the TobiiPro Glasses Controller software is running to control the experiment. Please be extremely careful with the glasses, and do not bend them after using. We also ask you to look down at the maptable with your neck, because if you look beneath your glasses, we lose the data.

After that, we will start the test. It consists of 4 steps. Johannes will be your moderator, who helps you to work on a maptable. You will get some time to get used to the glasses and practice thinking aloud your thoughts. It is a group process in which there are no right or wrong answers. Also, I would like to remind you that the research focus is on the use of the Phoenix tool and not on the planning outcomes.

Dr. Johannes Flacke:

Kennispark Twente is a campus for innovative technology products and services, linked with the University of Twente. It is aimed to support start-up companies, students, and scientists interested in the high-tech business, and it is hosting innovation centers, leading research institutes, and hundreds of high-tech companies.

The problem of this area is a split between the two parts of the Kennispark: the UT Campus north of the Hengelosestraat, and the commercial and industrial area south of the Hengelosestraat. The municipality of Enschede is highly interested in revitalizing the industrial area, because the territory is lacking a lively atmosphere and a 24/7 urban feeling, besides the territory is typically empty after 5 pm.

The goal of the session is to get inputs from different groups of stakeholders on development needs for the Kennispark area to better integrate the two parts of it (the UT Campus north of the Hengelosestraat, and the commercial and industrial area south of the Hengelosestraat) and to create a lively urban atmosphere.

Steps of the workshop (using Phoenix):

- **Warm-up (15 min).** Moderator briefly describes the problem and makes sure that participants got well introduced to the problem of the Kennispark. Then he gives an introduction to the maptable: how it works, what are the main tools, etc. At this step, each participant, one by one, learn how to use symbols and to draw in Phoenix. The tasks are:
    - Please indicate where do you live in Enschede and how do you get to the work or study
    - Please edit the route that you drew to show an alternative way that you could take and add your name as annotation

- **Step 1**: **Sharing knowledge (10 min)**.
    - What facilities of the Kennispark area (the industrial area and the UT Campus) that contribute to a lively urban living do you know?
        - Please locate and identify them (drawing all together using the symbols tool)

- **Step 2**: **Identifing development needs (10 min)**.
    - What other facilities/infrastructure are needed from your point of view in order to improve living conditions and to make it a lively area ("imagine you live there, what do you need?)?
        - Please discuss together and come to a consensus, and create a new drawing layer for that.
    - Which location would be the best for a park in Kennispark area?
        - Please draw a 50x100m polygon for a park location in a green color

- **Step 3**: **Designing a possible location for the new ITC Hotel (10min)**.
    - When ITC is moving to the campus, where do you think a good location for a new ITC Hotel would be in the Kennispark area? Please discuss in your group
    - Please locate a cafeteria in walking distance to the gallery (the new location for ITC), i.e., not more than 100 m away from it (Euclidian distance).

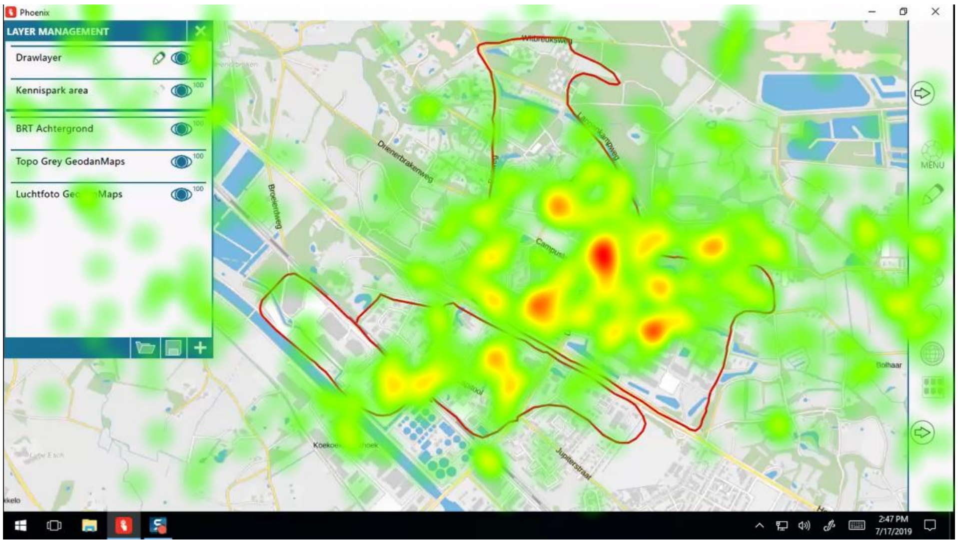
APPENDIX 6

Post-test interview questions

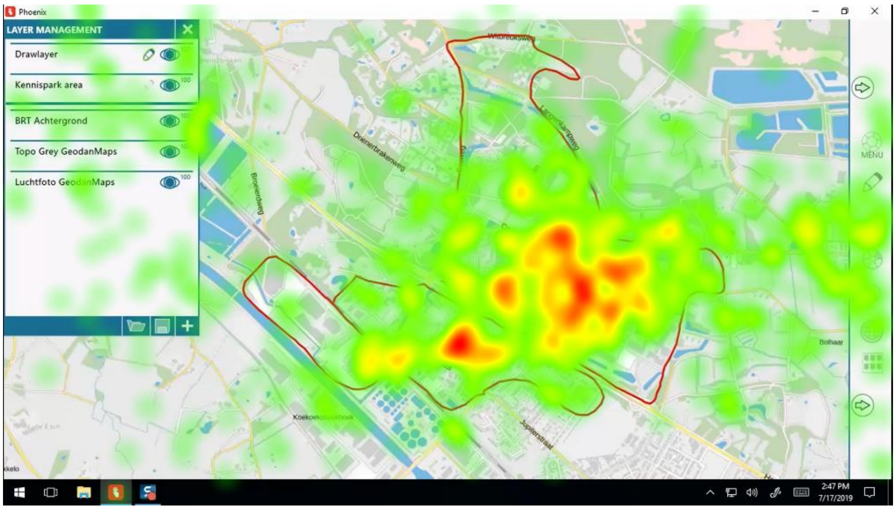
1. Which tasks were difficult to execute? Why?
2. How do you think this can be solved?
3. Did you feel comfortable when working with the maptable software?
4. Was it easy for you to use it?
5. What are the strengths of the software?
6. What improvements would you suggest for the maptable software?

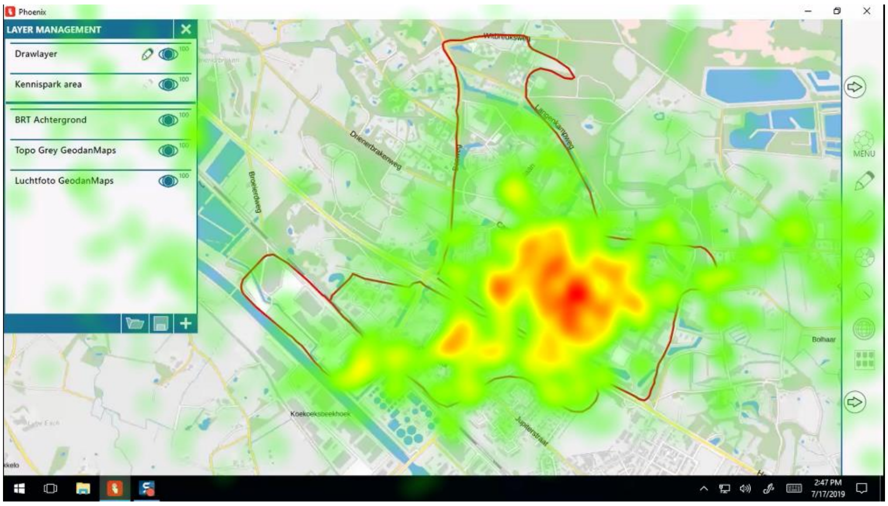
APPENDIX 7

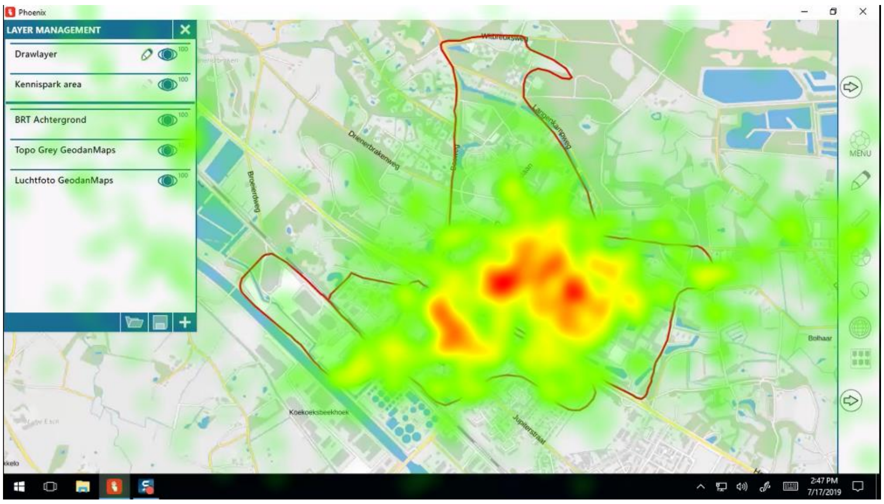
Heatmaps of the Phoenix Interface generated from the eye-tracking records of Group 1 (P1, P2)



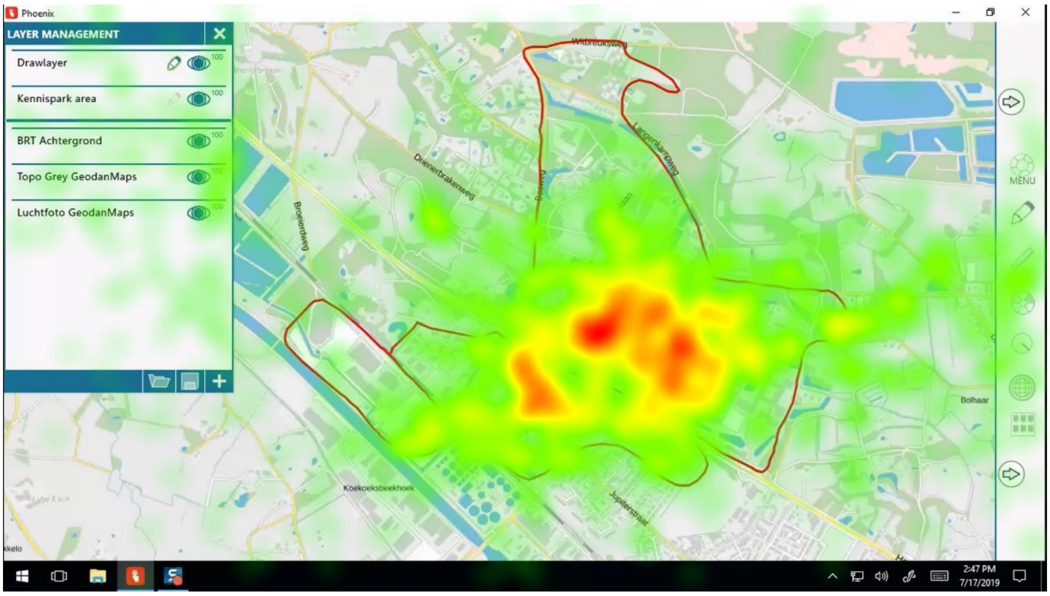
Heatmaps of the Phoenix Interface generated from the eye-tracking records of Group 2 (P4, P5, P6)

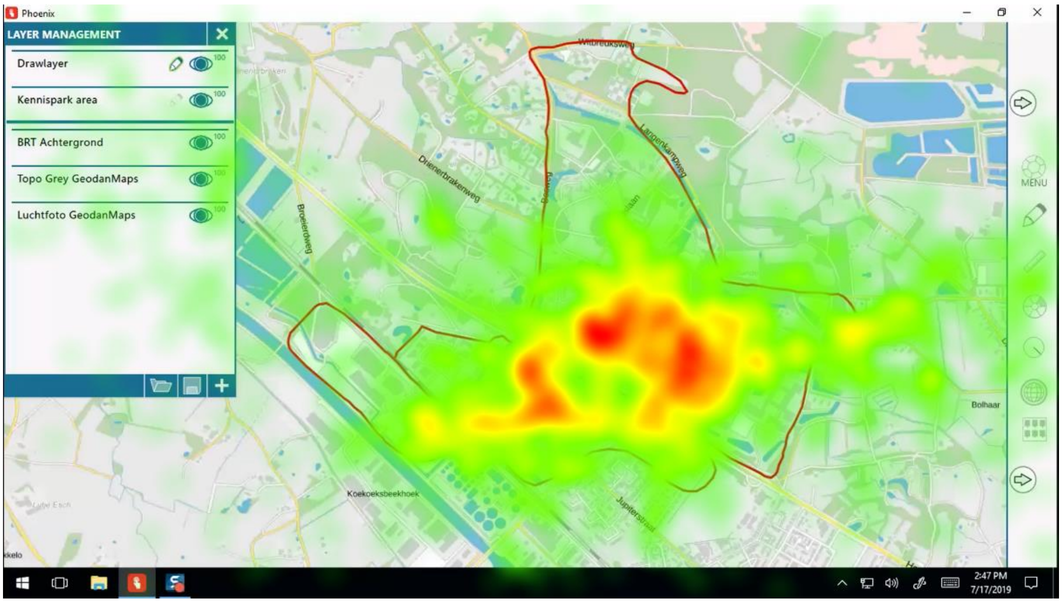






Heatmaps of the Phoenix Interface generated from the eye-tracking records of Group 3 (P7, P8)





APPENDIX 8

Table of the results of the Warm-up

Codes	Group 1	Group 2	Group 3
Navigation Tools	All participants were navigating the map; P2 started looking for home and ITC on a map	All participants were navigating the map; P4 found ITC on a map; P5 used the extent tool to go back to Kennispark area	All participants were navigating the map; Users were moving the map with two fingers (sometimes using both hands); Participants used extent tool to go back to Kennispark area; Participants used the extent tool to go back to Kennispark area
Drawing Tools	All participants used symbols and line drawing; P2 opened the symbols tool and placed one; P3 located a symbol and drew a line, quite quickly; P2 started drawing a line; P1 deleted the accident line and located a symbol for her house, and drew a line; P3 started editing the nodes; P3 kept editing, showed the rough way, and stopped editing, saying that there are too many vertices	All participants used symbols and line drawing; P5 located the symbol and drew a line to UT; P4 placed a house symbol; P4 opened the drawing function, started drawing, stopped, was hesitating in further actions; P6 drew a line, turned off the draw function, then added a symbol; P6 was editing the nodes of the line, and did not find it difficult; P4 drew her line again	All participants used symbols and line drawing; P8 added a symbol to her house; started drawing a line for a work; P7 picked the symbol; P7 deleted accident symbol; P7 located the symbol; P9 drew her line; P9 started editing the nodes (intuitively) and even deleted some of them
Analytical Tools	Not used	Not used	Not used
Visualization Tools	Not used	Not used	Not used
Data Management Tools	Not used	Not used	Not used
Interface	No comments	P4 opened the scale tool, instead of symbols tool; P5 commented that she thought the x of the edit menu of the line was for deleting	No comments
User Interaction	*Moderator shifted the keyboard	Participants were dragging the editing windows to see the map; P5 tried to drag and drop the symbol; P6 wondered if he can move the color pallet of drawing tool, and succeed	P7 moved the symbol tool window to see the map behind; P9 accidentally tapped the map and located the symbol, while P7 was going to press; P7 closed the symbol tool window in order to move the map; opened the symbol tool again; P7 commented "you have to do undo a lot"

Challenges/errors	P2 started drawing a line, made a mistake, pressed undo; started over again, while drawing wanted to move the map, accidentally drew another line; P2 did undo, turned off the drawing tool, moved the screen, activated the drawing function, choose the same color, continued drawing, had more accidents; P1 took over, wanted to move the map, but the drawing function was activated, so she drew a line; Moderator added dots by long press, when he wanted to activate the editing mode of the line; P3 started editing the nodes, but the edit window was covering the map, so he decided to close it, the edit mode turned off, and he accidentally drew a line	P5 tried to drag and drop the symbol; P5 wanted to put a bike symbol, choose it, when she tapped the map, the dot appeared, because two functions were open; then she turned off the drawing tool; P4 opened the scale tool, instead of symbols tool; P4 had problems with drawing the line and moving the map simultaneously; The undo function was challenging; P6 opened the drawing tool, picked the color, and accidentally deleted the line of P4 with "undo"	P8 while drawing wanted to pan the map with two fingers, but the drawing tool was on, and she accidentally drew a line. Had to turn off the line drawing function, to move the map; P9 accidentally tapped the map and located the symbol; While P7 was locating the icon, she touched the map with her sleeve; P7 while drawing the line, accidentally put a big dot, P7 closed the window again, moved the map; choose the drawing tool, accidentally touched the screen and big dot appeared, "undo" and she drew her line; P10 her sleeves were touching the screen too

Table of the results of the Step 1 – Locating existing facilities

Codes	Group 1	Group 2	Group 3
Navigation Tools	All participants were navigating the map	All participants were navigating the map	All participants were navigating the map
Drawing Tools	P1 used symbols tool to allocate the facilities; P2 located the symbols P2 added symbols; the group was working with a map together; P1 could not find the right symbol in the symbols tool for some time, P3 suggested to have already grouped symbols	P5 opened the symbols tool and started locating the symbols; P4 mentioned that annotation of the symbol covers the symbol, and suggested that it could be placed somewhere next to it, not on the top; P6 suggested that symbols had different colors (because symbols are black on the satellite image, and low contrast), he tried to click to see whether it was possible to change the color	P8 started locating the symbols; P8 started typing the annotation; P7 located the symbol, wanted to edit the position (drag), participants started trying to move it; P8 pointed out that ID is not clear: "what's the difference between id and annotation?"; P8 added the last symbol and annotated
Analytical Tools	Not used	Not used	Not used
Visualization Tools	Not used	Not used	P7 commented: "It seems to be weird that you have to close the actual window where you type in and the keyboard as well. So, you have two windows, one with the name, or like the labels that appear, and the one where the keyboard is. And you close both"
Data Management Tools	P1 switched to satellite image layer (by switching off other layers); P1 switched to topographic map layer	Participants tried to remove the layers, after several attempts, they succeed; P4 edited the name of the layer, after several attempts; P4 switched off the layer (not confidently)	P8 was playing turning on and off the layers; P8 typed the layer name
Interface	No comments	P6 commented that editing windows of the symbol overlap "when you press each function, they maintain, so it will be nice if one appears, and you press another function, it will close, so you can see only one function."; In changing the name of the layer, there are three buttons at the bottom, which are not intuitive	P8 was looking for the symbols in the keyboard (for instance, dash line), but there are no such in the keyboard; P7 about the keyboard "Having these labels instead of symbols that we are used to… Probably... Bit of an issue… At least for me. Because I am used to not having it [pointing at the backspace button]"

User Interaction	P1 shifted the Symbol Tools window to draw on a map (P2 too) Note. Participants work with the map altogether, click/drag/switch the buttons depending on their position, for instance, one standing left from the maptable switches the layer, while person in the middle locates the symbols, third moves the map	Moving the map was fine (all participants)	It was easy for participants to open the Symbol tools P8 shifted the Symbols tool window to draw on a map Participants were shifting the keyboard, symbol tools towards themselves
Challenges/errors	P1 Wanted to move the just located symbol by dragging, and then long-pressing, but did not succeed; then decided to delete the symbol by long press, could not; after one tap, deleted it; P2 wanted to locate the same symbol twice, but could not, so had to select the icon one more time; P2 could not find the right symbol, and put something else	P4 started typing, made a typo, wanted to press backspace, accidentally pressed enter (slightly longer), and the new 3 layers were created with a typo in the names; P5 wanted to remove the layer, clicked the edit button on a layer, it got activated, but no window opened (3 times); Then P5 tapped on a layer and opened a drag menu with a remove button; P4 tapped remove button; nothing happened (several times), then with the advice she slid the button to remove; P4 tried to edit the typo in the layer name, clicked on a layer, click on the edit button, then found the right button in a drag list of the layer; P4 while typing wanted to press backspace, but pressed enter again, the layer got saved with a typo; P4 tried to edit the layer name, could not open the keyboard ; P4 made a typo again; P5 used handwriting, in a single press it became a dot "if I do it this way it becomes a dot... Oh.. no that doesn't work"	P8 started locating symbols: she was dragging the symbol to the map; P8 started typing the annotation but did not find the symbols; Both P7 and P8 were pressing DEL button for deleting the letters, not the backspace; Participants tried to delete the symbol by long press, by clicking the symbol, did not succeed, asked the moderator to show it; P8 wanted to give an ID to the symbol with a long press, did not succeed; P8 added the symbol, but could not open the menu for annotation, P7 helped; P8 wanted to switch off the layer, but could not; P8 wanted to annotate the symbol and opened the ID window accidentally. Note. Participants were hesitating to press the buttons confidently, that is why the functionality did not work well; Regarding the comment about closing two windows after typing: in case of closing the typing window, the keyboard closes as well; P9 was participating in the drawing process too and had some troubles in pressing the symbols to open the menu bar too

Table of the results of the Step 2 – Locating new facilities

Codes	Group 1	Group 2	Group 3
Navigation Tools	All participants were navigating the map	All participants were navigating the map; P6 commented that it would be good to be able to rotate the map; P5 replied that then it would be confusing; P6 told the north sign might have been useful	All participants were navigating the map
Drawing Tools	P2 opened the symbol tool, added a symbol; Discussion in the group, meanwhile adding symbols; P1 started typing an attribute (annotation), P3 helped her; P3 about the symbols "sometimes it is not easy to find the right symbol because they are not grouped in one specific group"; P2 suggested to have already pre-cooked words for annotation; P1 added a symbol, P2 started handwriting; P2 drew a polygon for a park Note. No participants were using the information about the features of free hand drawing	P6 drew a polygon and added annotation; P6 changed the color of the polygon; P4 added a symbol; Participants were adding the symbols; P6 was wondering before drawing a polygon "it is possible to... create like a … shape, I mean... like a square right, I can use it... it's only drawing function, right? I can't make a polygon? Or I can do it as well?" then he drew a polygon: "and if I press on top, can I add like a…title? I think so, yes?"; P6 could change the color of the polygon, and noted "something interesting is that it looks for me… it indicates that this (pointing at color pallet) going to change the color of the outline, instead of the inside"; P6 could change the color of the polygon easily; P5 drew a polygon for a park; P3 added an annotation for the park	P9 added symbols while the group was discussing; P9 picked the drawing tool, thickness, and color; Participants decided that handwriting does not work, and added the usual annotation; P9 deleted the points; Participants agreed that the symbols are not good enough (they could not find the proper train station symbol); P9 added an annotation to a "train station" symbol; P7 noted "we can not create a polygon and specify the size"; P7 drew a polygon for a park, slightly bigger than expected; participants decided to cut the polygon; Long press and the polygon appeared in editing mood, and P7 started editing the nodes; *Moderator suggested them simple solution to delete, and draw it again; P7 followed his advice
Analytical Tools	P3 opened the ruler tool, and measured the area; First, he adjusted the ruler, then zoomed in the area	P5 and P4 opened the ruler, adjusted the ruler, then zoomed in the area	P8 opened the ruler tool for drawing the park; P7 wanted to resize the ruler, make it smaller, but could not; P9 resized the ruler ; *Moderator suggested zooming in the map ; P9 zoomed in the map, and it fit the ruler
Visualisation Tools	Not used	Not used	Not used

Data Management Tools	P3 added a new layer (with accidents); P1 and P2 renamed the layer; P3 added a new layer (quickly); P1 tried to edit the name of the layer. To open the features of the layer pressed long instead of one tap; P1 switched the layers	P4 created a new layer (quickly)	P7 created a new draw layer (quickly); P7 switched off the layers
Interface	P3 commented about the sliding remove button "it's not easy [to understand]"	P4 while typing hesitated for a few seconds trying to figure out how to delete the typo (backspace); P6 commented: "something will be interesting to see is that when you press the icon, it doesn't… some software just explains the definition of each symbol". However, the symbol tool defines the selected symbol, and the participant did not see it; P5 noted that the explanations are limited, for instance they picked the ball symbol, and decided it means sport, while the explanation says "games", in a different meaning. "So, they would, maybe in a way be good, if it would not be described, so you can just interpret the symbols"	No comments
User Interaction	P2 could not find out how to press the remove button (slide); P1's sleeve was interfering with moving the map; P1 was standing on the left side of the maptable, and she was not moving the keyboard towards her, so it was hard to type	P6 while typing "when I just write something, the letters, it didn't match with... When I'm just pressing the... [letters]"; P5 switched off the ruler, opened the drawing tool, pressed Undo. Moderator commented that she could have deleted something, P5 answered: "when you just close it, it shouldn't go back anymore. Then... no hidden thing will happen"	P9 deleted the points, after the demonstration of the Moderator; P9 noted that "it is not clear that you have to slide it [delete button]" in the editing window; P9 noted that when they are working as a group, they can not work simultaneously

Challenge s/errors	P3 added a new layer, made a typo, accidentally pressed enter; P1 wanted to edit the name of the layer, could not do it, moderator demonstrated; P1 wanted to move on the symbol on a map, long-press opened the edit toolbar, assumed that "x" symbol means delete, but it just closed the edit toolbar; Participants opened the symbols tool, and accidentally added a symbol to another place; P2 had a challenge in deleting the symbol; *Moderator showed how to do it, but also pressed ID, annotation before finding the edit option to remove button (symbols); P2 could not find out how to press the remove button (slide); Typing was challenging; P1 could not type correctly, the screen did not feel the touches; P2 also had issues. Each letter had to be typed carefully one by one; P2 opened the extend tool instead of symbols tool Challenge in handwriting, participants had to draw continuously; otherwise it becomes a big dot or polygon	Sometimes when users want to move the map, they forget that drawing tool is active, and they accidentally draw on a map; It was challenging to delete the symbol, it was not intuitive, one press opens the delete function, and long press opens the editing functions ; At the end of the step, P4 added annotation and closed the editing menu with x button	P9 wanted to add handwritten annotation, picked the drawing tool, thickness, and color. She tried a couple of times, but accidentally added points; All participants could not find out how to press the delete button in an editing window of points; P7 even suggested swiping the remove button in other direction

Table of the results of the Step 3 – Locating a new ITC hotel

Codes	Group 1	Group 2	Group 3
Navigation Tools	All participants were navigating the map	All participants were navigating the map	All participants were navigating the map
Drawing Tools	P2 added a symbol with the symbols tool	P4 opened the symbols tool, then decided to make a polygon, and deleted the symbol; P6 commented "so there are no predefined symbols, like a triangle, squares"; P5 wanted to resize the symbol; Participants wanted to draw a polygon; the moderator suggested putting a symbol; P4 created a polygon, added annotation	P8 added a symbol from the symbols tool; P9 added a symbol on ITC building (inside)
Analytical Tools	P3 opened the ruler tool, then buffer, placed the buffer; P3 asked whether it was possible to assign an exact number to a buffer; Using the buffer tool was intuitive ; Participants discovered that they could not add a symbol inside of buffer, they mentioned it as a weakness of the software	P5 opened the buffer tool; Using the buffer tool was intuitive	Participants activated the buffer tool; Using the buffer tool was intuitive; P7 commented that the buffer was around the point, not the whole building
Visualisation Tools	Not used	Not used	Not used
Data Management Tools	P1 created a new drawing layer	Not used	P7 created a new layer; P7 switched the layers quickly; P7 wondered, "we never saved this, or is it saved automatically?"
Interface	No comments	No comments	P7 hesitated in typing: where to press done (enter)
User Interaction	P1 had problems with typing (pressing the letters); Using the buffer tool was intuitive;	P4 opened the drawing tool, decided to zoom in, P5 closed the drawing tool; P5 noted that "it is a bit slow, so you have to press	P9 was playing with scale and checking the tools; Using the buffer tool was intuitive

		multiple times "undo", which is really bad"; Using the buffer tool was intuitive	
Challenges/errors	P1 had problems with typing (pressing the letters); Could not place a symbol inside the buffer	P4 forgot to close the drawing tool, before starting to move the map (2 times)	No comments