Technische Universität München
Department of Civil, Geo and Environmental Engineering
Chair of Cartography
Prof. Dr.-Ing. Liqiu Meng

Usability of an adjusted IndoorTubes map design for indoor wayfinding on mobile devices

Vasileios Toutziaris

Master's Thesis

Submission: 19.05.2017

Study Course: Cartography M.Sc.

Supervisors: Dr. C.P.J.M. Corné van Elzakker
M.Sc. Juliane Cron

2017

Declaration of authorship

I hereby declare that the submitted master thesis entitled **Usability of an adjusted IndoorTubes map design for indoor wayfinding on mobile devices** is my own work and that, to the best of my knowledge, it contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution, except where acknowledgement is made in the text.

Munich, 19th of May 2017 Vasileios Toutziaris

Signature

Acknowledgements

I would like to thank my family and especially my beloved grandmother for supporting my studies during this master program both financially and emotionally. It would not be possible without them. I also want to thank the good friends I made these last three years, in the three different countries and five cities I lived before completing this program. My interest for indoor cartography and different design approaches for indoor maps started with the course “Mapping Project” taught in TU München, on which I worked with my colleague and friend Abdalla Musab. I thank him for his ideas and support. I am also grateful to everyone in Dresden who supported me in completing this research. The faculty members who provided data and advice, the students of the fifth intake of the International Master in Cartography who took part in the user study and all my other friends who provided accommodation and nice home cooked meals. Finally, I would like to thank my supervisors, Juliane Cron and Corné van Elzakker for their continuous support, constructive feedback and academic guidance.

Abstract

Indoor cartography has yet to gather the attention and popularity of its outdoors counterpart both by the industry and academia. Two major reasons for that are the accuracy of indoor positioning technologies and the lack of standardization on architectural blueprints that prevent the automated creation of indoor maps. In this thesis, it is hypothesized how these indoor maps should be in terms of design when the technical issues mentioned will be resolved. The current trends in indoor cartography are presented and a new solution for simplified indoor maps is proposed that focuses on the corridors and discards other unnecessary for wayfinding building-elements, primarily inspired by the IndoorTubes concept first developed by A.S. Nossum. A user study is then conducted in one of TU Dresden's campus buildings comparing the new design with an existing one and two online surveys are distributed for additional feedback. The research shows that the new solution performs better in terms of usability than the existing one. Based on the results of the research some guidelines are proposed for the creation of indoor maps, suggesting elements that future cartographers should focus on when creating them, like using a small color palette, focus on corridors, include important indoor landmarks (floor connections, WCs etc.), preserve geometry and relative distances, exclude rooms and building outline, use simple but self-explanatory symbols.

Keywords: indoor maps, indoor cartography, indoor landmarks, floor connections, corridors, IndoorTubes

Table of contents

Declaration of authorship 2
Acknowledgements 3
Abstract 4
List of tables 7
List of figures 8

1 Introduction 9
1.1 Background and motivation 9
1.2 Hypothesis and scope 9
1.3 Research objectives and questions 10
1.4 Outline 11

2 Literature review 12
2.1 Current indoor map design approaches for wayfinding 12
2.1.1 Raw blueprints 12
2.1.2 Simplified blueprints 14
2.1.3 IndoorTubes 20
2.2 State of indoor mapping related technologies 21
2.2.1 Indoor positioning systems 21
2.2.2 Building Information Modelling 22
2.3 Summary 22

3 Methodology and implementation 23
3.1 Original idea 23
3.2 Basic research structure 23
3.3 Building and time-slot selection 24
3.4 Proposed map design – draft 1 24
3.4.1 Theoretical background 24
3.4.2 First draft 26
3.5 Online surveys 28
3.6 Experts' evaluation survey 28
3.7 User study preparation 29
3.7.1 Basic structure of the user study 29
3.7.2 Composition of the user group 29
3.7.3 Pre-study survey 30
3.7.4 Exact time selection 31
3.7.5 Mobile websites 31
3.8 User study 33
3.8.1 Execution of the user study 33
3.8.2 After-study survey 34
3.9 Summary 34

4 Results and discussion 35
4.1 Proposed map design – draft 2 35
4.2 User study results 37
4.3 User surveys' results 40
4.3.1 Feedback on the three designs 40
4.3.2 Average importance of building elements 47

4.3.3 Opinion on symbols 49
4.3.4 User survey results conclusion 49
4.4 Additional observations 50
4.4.1 User study 50
4.4.2 Pre-questionnaire 52
4.4.3 After-study questionnaire 53
4.5 Summary 54

5 Conclusions and future suggestions 55
5.1 Shortcomings 55
5.2 Conclusions and indoor map design guidelines 56
5.3 Future suggestions 56

6 References 58

Appendix 1 60

Appendix 2 64

Appendix 3 75

Appendix 4 81

Appendix 5 94

Appendix 6 95

Appendix 7 97

List of tables

Table 1: Composition of the two groups of participants 31
Table 2: Participants who took part in the user study and completed the task 38
Table 3: User study results per group and per gender in each group 39
Table 4: Performance based on gender 40
Table 5: Responses to the two main surveys 41
Table 6: Indoor map design preference for route planning and navigation 42
Table 7: Opinion on amount of information in the Campus Navigator design 43
Table 8: Opinion on amount of information in the proposed design 44
Table 9: Opinion on amount of information in the IndoorTubes design 45
Table 10: Opinion on the usefulness of depicting multiple floors in the same view 46
Table 11: Average importance of building elements 47
Table 12: Opinion on how intuitive are the symbols of the three indoor map designs 49
Table 13: Additional observations during the user study 50
Table 14: Additional replies on the pre-questionnaire 52
Table 15: Additional replies on the after-study questionnaire 53

List of figures

Figure 1: IndoorTubes map example 1 (Nossum, 2011) 9
Figure 2: TU Dresden Campus Navigator app 12
Figure 3: Example of emergency YAH map (Klippel, Freksa, & Winter, 2006) 13
Figure 4: 2D indoor map design (Lorenz, Thierbach, Baur, & Kolbe, 2013) 14
Figure 5: Kamppi mobile map (Puikkonen, Sarjanoja, Haveri, Huhtala, & Häkkilä, 2009) 16
Figure 6: Google Maps indoor map example (Google Maps, 2017) 17
Figure 7: HERE WeGo indoor map example (HERE WeGo, 2017) 17
Figure 8: Cartogram indoor map example (Cartogram, 2017) 18
Figure 9: Mapwize indoor map example (Mapwize, 2017) 18
Figure 10: MazeMap indoor map example (MazeMap, 2017) 19
Figure 11: Micello indoor map example (micello, 2017) 19
Figure 12: IndoorTubes example 2 with legend (Nossum & Nguyen) 20
Figure 13: Placement of indoor map designs based on complexity of information 25
Figure 14: TU Campus Navigator indoor map (Chemie/Hydrowissenschaften-Bau, ground floor) 26
Figure 15: Proposed design – draft 1 (Chemie/Hydrowissenschaften-Bau, ground floor) 26
Figure 16: Introduction and Group A maps 32
Figure 17: Group B maps 32
Figure 18: Proposed design – draft 2 (Chemie/Hydrowissenschaften-Bau, ground floor) 35
Figure 19: Proposed design – draft 2 (Chemie/Hydrowissenschaften-Bau, first floor) 36
Figure 20: TU Campus Navigator indoor map (Chemie/Hydrowissenschaften-Bau, first floor) 37
Figure 21: Importance of indoor design elements according to the Cartography Experts 48
Figure 22: Importance of indoor design elements according to the Study Participants 48
Figure 23: User study additional observations 51

1 Introduction

1.1 Background and motivation

Unlike outdoor cartography, indoor cartography has gathered much less attention both by the industry and academia. Although there are several indoor navigation solutions in the market, none of them has yet to reach a big user-base and have a financial and cultural impact like outdoor navigation has had. There are two technical reasons for that. Firstly, there is not yet an accurate, standardized, affordable and widely implemented indoor positioning technology (some high accuracy solutions exist, but they are expensive and demand from the owner of the building to install proprietary hardware) (Fallah, et al., 2013) and secondly, indoor maps suitable for navigation and way-finding are based on architectural floor plans that also suffer from a lack of standardization, making automation very difficult or almost impossible (Sánchez Ortega, 2016). Having said that, there is widespread hope that the above mentioned technical difficulties will soon be resolved, creating the opportunity for experimentation with new indoor cartographic designs and demanding research that will explore their usefulness. This master thesis will focus on the design of indoor maps and how they can affect the user experience.

Currently, most indoor solutions use either architectural plans or simplified versions of these plans. The problem with these architectural plans, or so-called blueprints, is that they include too much unnecessary information that confuses and overloads the user without assisting in way-finding. Therefore, most commercial solutions are based on simplified architectural representations. Although they are an improvement compared to raw blue-prints, it is believed that they could be even simpler and only focus on building elements that assist way-finding. Nossum (Nossum, 2011) tried to tackle some of the above-mentioned issues in an interesting and innovative way with the IndoorTubes concept he developed, although user response was mediocre (Nossum, et al., 2012). For this master thesis, an alternative design is created, inspired by the IndoorTubes concept but preserving some elements found in more traditional floor plans and will be tested with a user study.

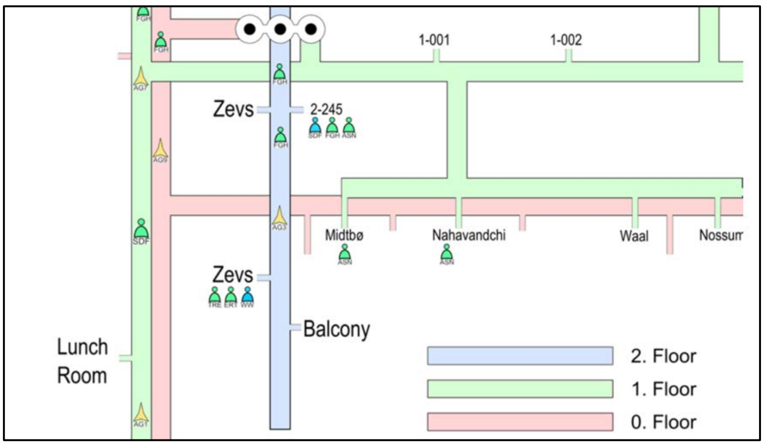


Figure 1: IndoorTubes map example 1 (Nossum, 2011)

1.2 Hypothesis and scope

The basic assumption of this Master thesis is that all a user needs to help him/herself navigate, are the corridors, some general shapes for things like big waiting rooms, atriums, mezzanines and basic indoor landmarks (staircases, elevator and WC positions etc.). All else that is included in a more traditional indoor map / floor plan is a distraction, at least for orientation and wayfinding purposes and can be removed. On the other hand, it is believed that Nossum's approach (Figure 1), although innovative and in the right direction, was a bit too minimalistic and the decision to include multiple floors in the same view can confuse the average user. The hypothesis is that a new proposed design that strikes a balance between simplicity and features will better assist users in indoor wayfinding.

Especially in a mobile, digital and interactive environment there is no need to combine different floors together, since you can very easily switch between them. The new design that is proposed, and is believed will better assist the user to navigate in indoor spaces, will focus on basic building elements (as mentioned above), and will preserve some, but not all, geometric accuracy. Only one map per floor will be shown and more traditional symbology will be used for connections between floors, instead of transit map inspired little circles that are traditionally associated with stations in a public transportation map and not as connections between different floors of a building. In general, the minimalistic design and simplicity of the IndoorTubes concept will be kept, but transit references will be excluded since it is believed that they do not translate well in a pedestrian environment and enrich the design with helpful symbols and shapes for waiting areas etc. In this way, the user will only focus on what is necessary and nothing else. A user study will reveal the validity of this hypothesis.

In this thesis, the researcher will not bother with different indoor positioning technologies, instead solely focus on the cartographic aspect, particularly on 2D maps. 3D alternatives will not be explored, due to time constraints and the fact that for 3D it makes more sense than 2D if you can manipulate it with your fingers on the touch screen (thus creating the need for a more complicated interactive solution to be developed). Additionally, the new design will be created with mobile screens in mind and the user testing will be conducted using mobile devices and not paper handouts.

After the end of this project someone could use some of the design ideas of the improved IndoorTubes maps created for this thesis, further work on them, add interactive elements that may assist wayfinding or incorporate them in a mobile app and assess the overall user experience of such a product. The insights learned by the end of this thesis could perhaps help to develop better indoor maps, useful to any user of mobile devices visiting big indoor spaces like: shopping malls, hospitals, university or company campuses, transportation hubs etc.

1.3 Research objectives and questions

This Master thesis has two main research objectives:

1. Develop an alternative design of the IndoorTubes concept for display on small screens of mobile devices. I plan to test a design that mainly focuses on corridors, being flexible with - but not completely disregarding - shapes, sizes and distances and only depicting one floor at a time.
2. Conduct a user study to determine the usability of the new adjusted design. Users will use the new map in a real-life situation, feedback will be collected and conclusions on the new approach's effectiveness will be drawn.

To fulfill the objectives the following research questions and sub-questions will be answered:

1. How can the IndoorTubes design be improved (for display on mobile device screens)?
    a. What are the current solutions for indoor maps for wayfinding?
    b. How can the IndoorTubes design be improved?
    c. What are the indoor map design requirements for display on small mobile screens?

2. What is the usability of the adjusted IndoorTubes map design for indoor wayfinding on mobile devices?
    a. What is the effectiveness of the new design?
    b. What is the efficiency of the new design?
    c. What is the user satisfaction of the new design?

1.4 Outline

The **Introduction** presented here in **Chapter 1**, explores the possibility for a new approach based on the original IndoorTubes concept and sets the research objectives and questions that this thesis will try to answer.

Chapter 2: Literature review describes in more detail the current state of indoor maps in both the industry and academia and discusses other research relevant to this thesis.

Chapter 3: Methodology and implementation, offers a description of the methods used to choose the right building for the user study, designing the new proposed map, seeking the opinion of cartography experts, assessing the study participants, planning and conducting the user study and collecting feedback.

Chapter 4: Results and discussion, presents the results of the user study and of the online questionnaires, interprets the results and reflects upon the validity of the hypothesis by answering the research questions.

Chapter 5: Conclusions and future suggestions, gives a general overview of the thesis and presents the basic conclusions that were produced by it. It reflects upon the contributions this research has added to the field of indoor mapping, but also discusses its limitations and suggests topics and guidelines for future research.

2 Literature review

Cartographic representation is all about abstraction. Different levels of abstraction define different types of maps. In this chapter, the current state of indoor map design in academic research and the design trends in the most popular (indoor) mapping applications are partially presented. The different types of indoor maps are categorized based on their abstraction level from reality. In the end of the chapter, a brief mention on other aspects of indoor wayfinding related technologies is made, so the reader can form a more holistic view of indoor wayfinding that will help him/her better grasp the proposals for further research in chapter 5.

2.1 Current indoor map design approaches for wayfinding

2.1.1 Raw blueprints

For indoor maps, the primary raw materials that are already widely available are the architectural blueprints. The problem with these is that they are not created with indoor wayfinding (route planning and navigation) in mind and it is believed that they include too much unnecessary information that overloads the user. Despite these issues, they are often used in wayfinding products, for example in TU Dresden’s Campus Navigator, which is both a website and a mobile application (Figure 2).

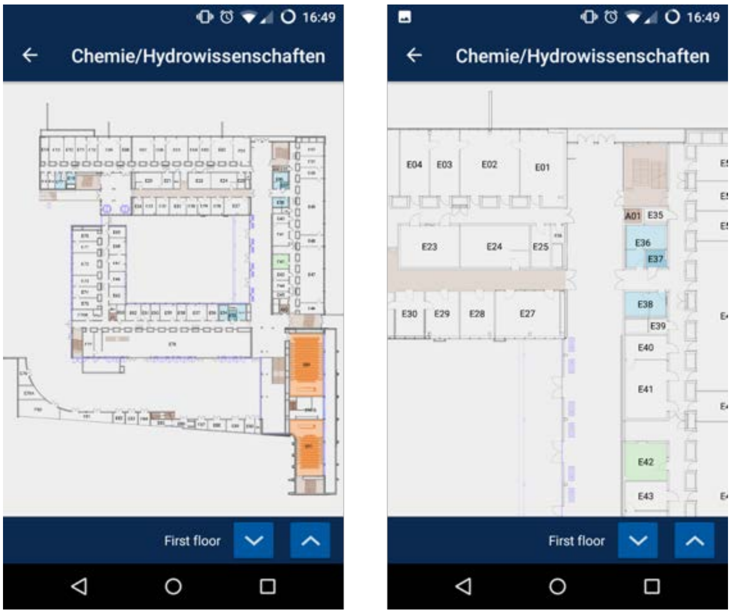


Figure 2: TU Dresden Campus Navigator app

Another usage of traditional blueprint style maps for indoor wayfinding are the so-called You-Are-Here (YAH) maps (Figure 3). As (Klippel, et al., 2006) indicate, these maps are mostly annotated floor plans placed in various locations inside buildings and they complement emergency signage and evacuation training of the users of the building. They usually follow guidelines by local or other authorities, like OSHA (Occupational Safety and Health Administration) in the US (OSHA, 2017), insurance companies etc. Thus, their design tends to be conservative.

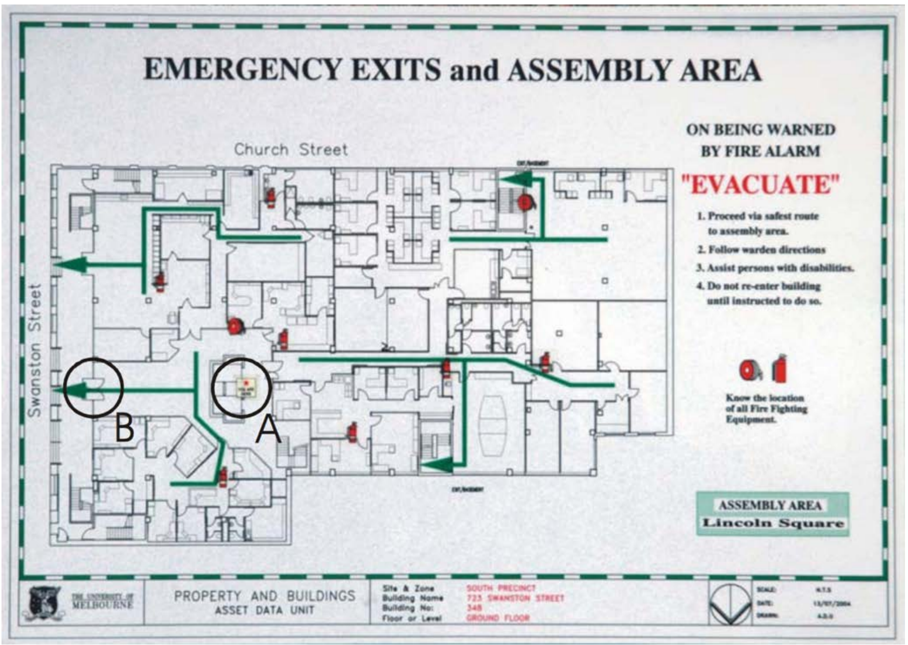


Figure 3: Example of emergency YAH map (Klippel, et al., 2006)

2.1.2 Simplified blueprints

In this paragraph, examples of simplified blueprints are presented. Their major characteristic is that they preserve the shapes, sizes and geometry of the rooms and usually the general outline of the building but with less detail than traditional blueprints. Wall thickness, exact position of windows, direction in which doors open (and whether they are single or double doors), exact design of staircases etc. are all discarded as being irrelevant for wayfinding in indoor spaces. Almost all the popular commercial applications that could be found by the researcher use this style of indoor map for their product.

2.1.2.1 Academic research

In their research with one of TU Berlin's buildings as a case-study, (Lorenz, et al., 2013a, 2013b) have created a few indoor maps in 2D and 3D. The 2D design is a simplified version of a blueprint. It accurately preserves shapes, sizes and geometry (Figure 4).

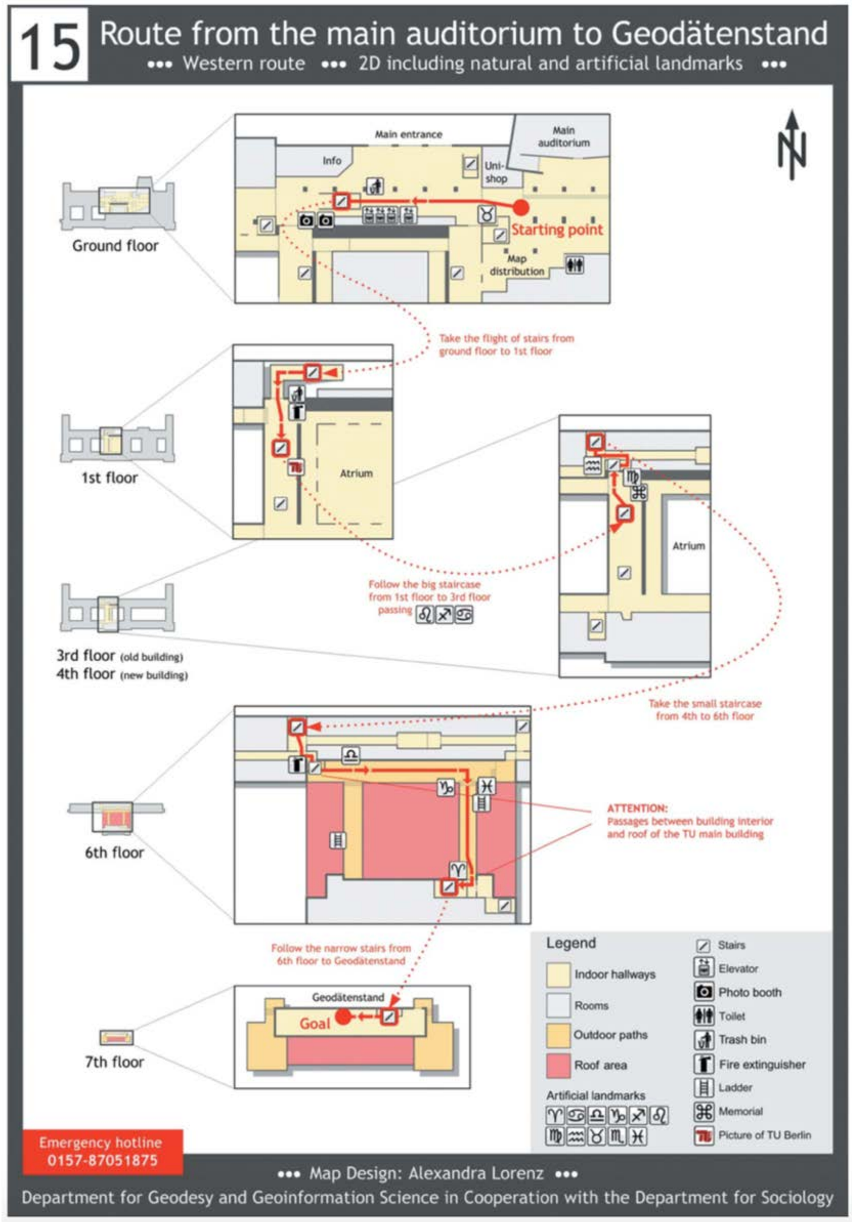


Figure 4: 2D indoor map design (Lorenz, et al., 2013)

Their research primarily focused on a comparison between 2D and 3D maps and their user study was executed with paper hand-outs. They hypothesized that 2D is better because it is more suitable for the presentation of horizontal structures although it was proven by their user study that if 3D has good written explanations it can achieve similar user satisfaction. A potential drawback of 2D depiction is that floors need to be segmented, unlike 3D where they can be shown with one unified graphic. The IndoorTubes concept (Nossum, 2011) (chapter 2.1.3) tried to solve this by depicting multiple floors in a 2D design. The 2D maps they used in their research are based on existing floor plans, but generalized. They only kept relevant for orientation purposes architectural structures like stairs, big pillars and other connecting elements. They also chose to focus on the corridors, rooms, outdoor paths and roof areas (relevant because of the design of the test building) for navigation purposes. A major focus of their research (Lorenz, et al., 2013) were indoor landmarks. They used both natural (part of the building) and artificial (additional signs) landmarks.

They organized and conducted a big user study and took advantage of the "Long Nights of Science", an event held by TU Berlin annually and open to the public. They managed to recruit a very big and diverse group of participants (1140 people), of different ages (4-78) and equally distributed among sexes. This way they avoided the common reality with many academic user studies (like this master thesis) of only managing to attract students of a very uniform age and social background. Their study was also a collaboration between geoinformation scientists and sociologists. They used a mixed method of research design, including both qualitative and quantitative elements. At first, they distributed an a-priori questionnaire to check familiarity with the location, orientation skills and the background of the participants. Then they split the participants in two competing groups with different routes, assigned them with maps and asked them to complete the wayfinding task. The participants were only allowed to use staircases as connections between the different floors. After they completed the task, an a-posteriori survey was distributed to assess their navigational approach and experience with the maps and the overall process. During the study, members of the research team followed and observed how the participants oriented themselves and used the maps.

The basic conclusions of their research when it comes to 2D indoor map design are mostly focused on landmarks and their importance. They concluded that they are useful if the connection between landmark and route is obvious and their research showed that their inclusion is strongly correlated with user satisfaction. Additionally, according to them:

> *"Users find landmarks very helpful, depending on perspective and route complexity, but regardless of the amount and type of landmark." (Lorenz, et al., 2013b)*

In another study, (Puikkonen, et al., 2009) also used a simplified blueprint for the indoor map they created for their user study in a shopping mall (Figure 5). They recruited 23 participants, split in two groups. One made of regular visitors of the mall and the other of students. Each participant filled in a background questionnaire, completed a few wayfinding tasks using a mobile device, and then replied to some more questions providing their feedback for the map they used and the overall wayfinding experience.

Figure 5: Kamppi mobile map (Puikkonen, et al., 2009)

Their goal was to help users find POIs (Points of Interest) in the building. To achieve that, they created a simplified indoor map based on a blue print and included landmarks such as escalators, elevators and WCs. They did not show all indoor landmarks by default - in some cases the users had to choose to show them in the UI of their application - and for the ones they showed by default, they used abstract icons, causing confusion to some users.

In their recommendations for future indoor map designs, they suggest that all visible and important landmarks on an indoor space should be included by default, with clear and unambiguous symbology and that using a map with fewer details, which only focuses on indoor “eye-catchers” such as pillars, strange corners, large windows, shops’ signs etc. should be preferred. Additionally, they make the case that unlike the outdoors where a uniform graphic style works almost universally (gray for streets, brown or green for soil etc.), indoor spaces have a much larger variety of materials, colors and shapes. Thus, they suggest that designing and testing an indoor map on site should be considered.

2.1.2.2 Commercial applications

As mentioned before, most of the current commercial indoor wayfinding applications are using a simplified variation of the blue print approach for depicting indoor spaces. There are no major differences between the most popular offerings from the main providers of indoor maps concerning their approach to indoor map design. They preserve the shape of the building, of the corridors and the rooms, while using a simple color pallet.

Two of the most popular applications are Google maps and HERE WeGo. As can be seen in Figures 6 and 7 they have an almost identical cartographic design. They preserve the outline of the building, the corridors and the shape of the rooms.

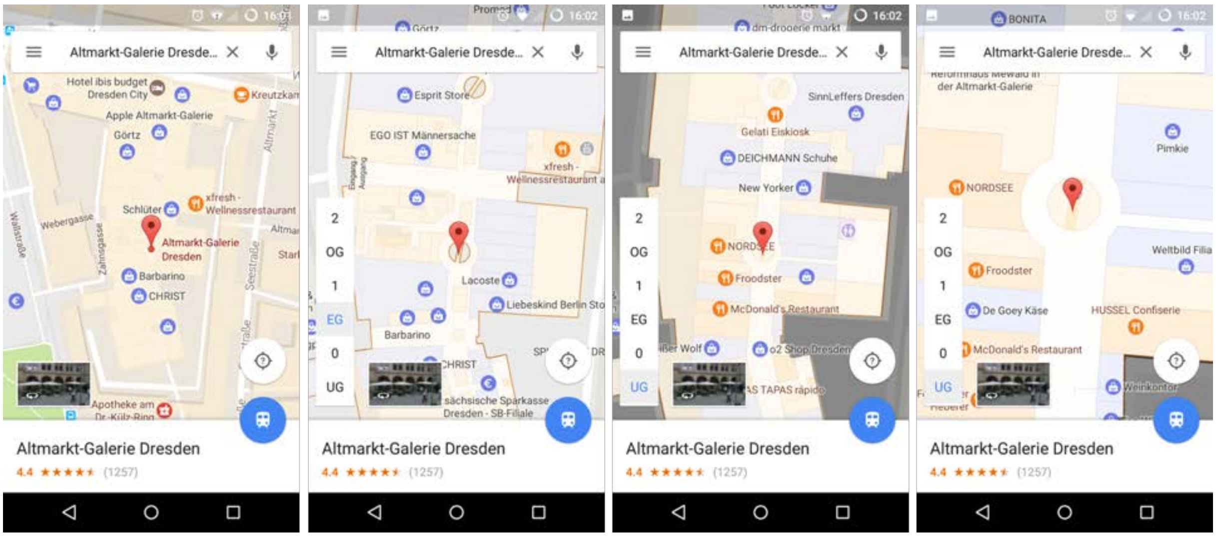


Figure 6: Google Maps indoor map example (Google Maps, 2017)

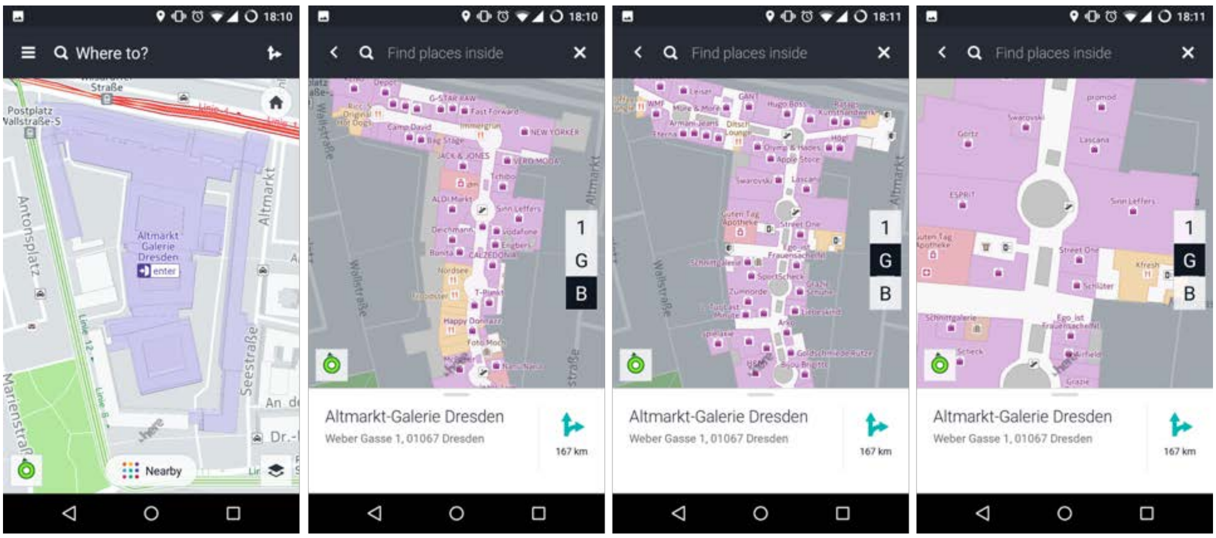


Figure 7: HERE WeGo indoor map example (HERE WeGo, 2017)

Other popular examples can be seen below, in Figures 8 and 9. Cartogram and Mapwize also chose the simplified blueprint approach for their indoor maps.

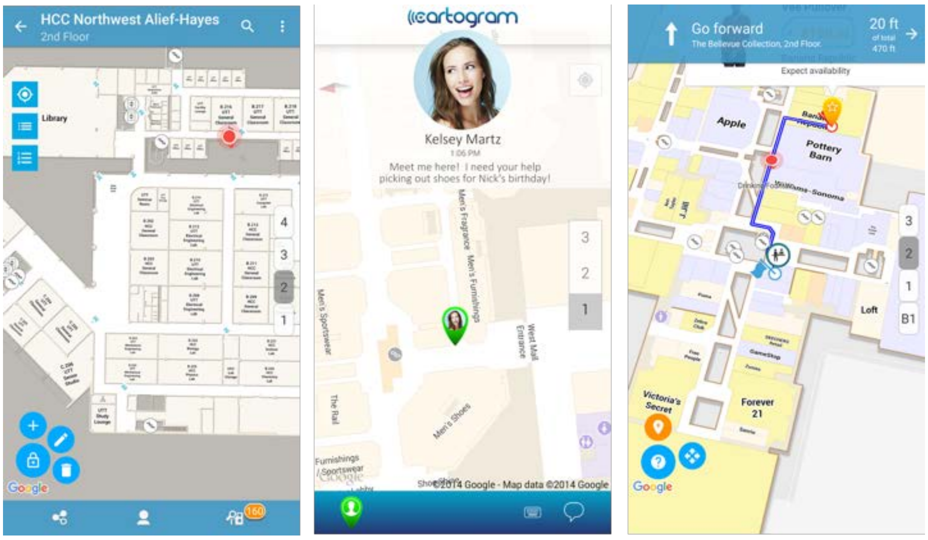


Figure 8: Cartogram indoor map example (Cartogram, 2017)

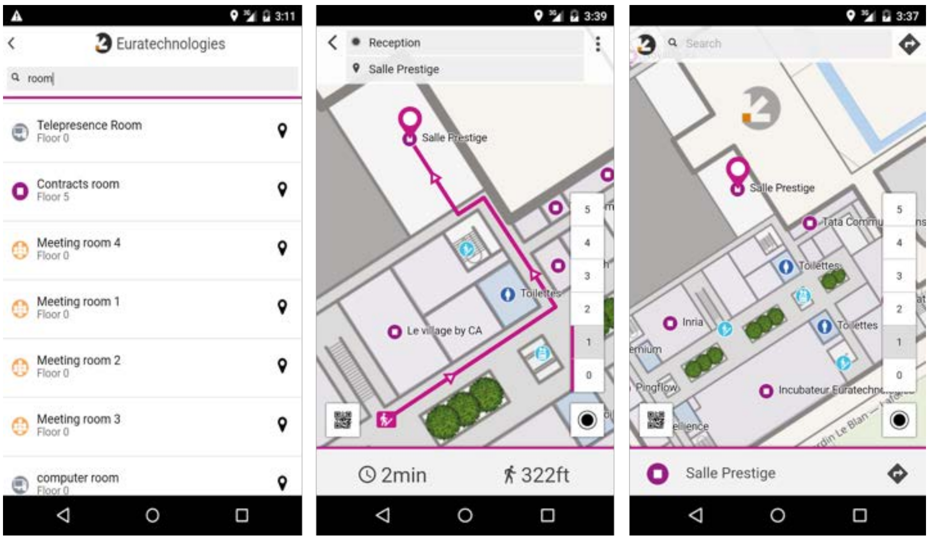


Figure 9: Mapwize indoor map example (Mapwize, 2017)

A few more examples can be seen below as well, in Figures 10 and 11. The design approach of MazeMap and Micello seems to be very similar with the previous examples.

Figure 10: MazeMap indoor map example (MazeMap, 2017)

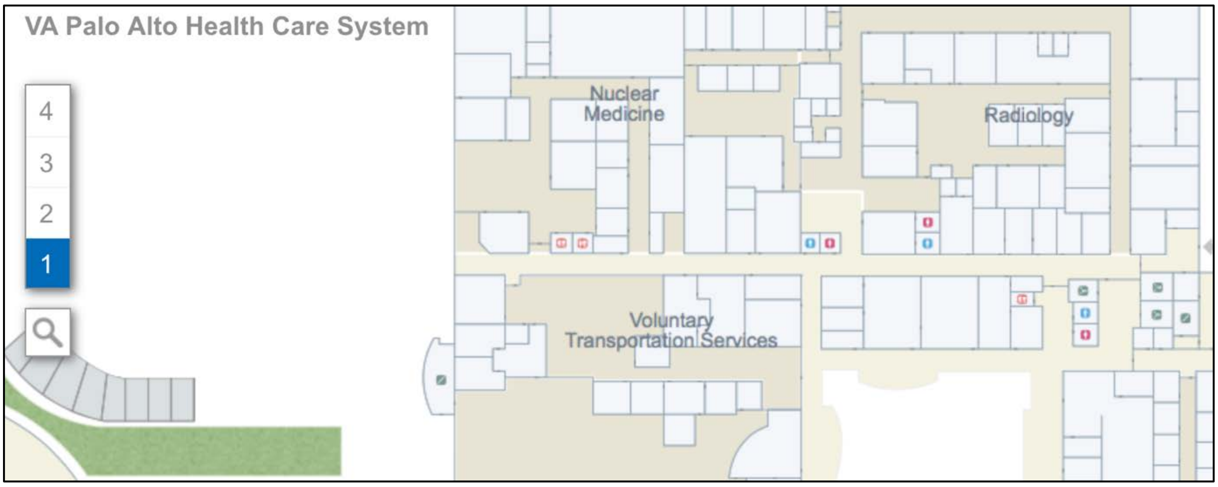


Figure 11: Micello indoor map example (Micello, 2017)

Like in the academic examples seen in chapter 2.1.2.1, most commercial applications preserve the shapes, sizes and geometry of the rooms but with less detail than traditional blueprints. Wall thickness, exact position of windows, direction in which doors open (and whether they are single or double doors), exact design of staircases etc. are all discarded as being irrelevant to wayfinding in indoor spaces. The question arises if even more information could be excluded.

2.1.3 IndoorTubes

A different, more minimalistic approach was taken by (Nossum, 2011) and his IndoorTubes concept which is inspired by Harry Beck's London Underground Tube map (Vertesi, 2008). As in this famous map, Nossum hypothesizes that topology is more important in indoor environments that geometry. Connections between floors are depicted as "stations" with little circles and corridors as simple lines. Geometry, shapes, sizes and distances are discarded as not very important for wayfinding. Multiple floors are depicted simultaneously in the same view (Figure 12).

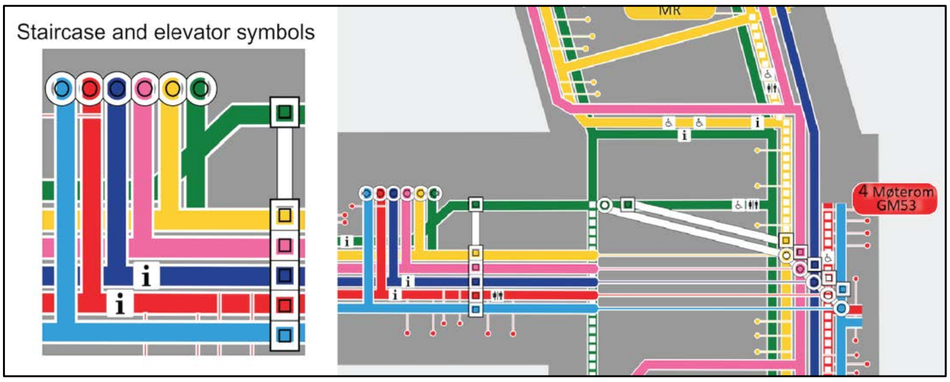


Figure 12: IndoorTubes example 2 with legend (Nossum, et al.)

In follow-up papers, (Nossum, et al., 2012) and (Nossum, et al.) have conducted a user study in a hospital in Norway to check the validity on the IndoorTubes design concept. They recruited 30 participants with no prior familiarity with the building, mostly students, balanced between genders and their self-reported familiarity with maps. They split them in three groups. The first group was given a traditional floor plan based map already used by the hospital, the second an IndoorTubes inspired map and the last group no map. The maps were distributed as paper hand-outs. The participants were asked to reach a few locations in the building in a certain order. A researcher followed them, recording the time they needed to finish the task and observing their wayfinding behavior. After they completed the task they answered a few questions and filled in the Santa Barbara Sense of direction scale (SBSD) (Hegarty, et al., 2002).

The results of the study showed that most users preferred the traditional floor plans, with only a minority of them opting for the IndoorTubes design. The participants who chose the floor plan cited familiarity with the concept and a preference for geometrical accuracy which they said gives them a sense of distance and helps them navigate in an unknown indoor environment. On the other hand, users complained about the luck of geometrical accuracy in the IndoorTubes concept and thought they had insufficient time to familiarize themselves with the new and unusual design. Despite that, many felt more comfortable with the design after some time and expressed the opinion that it might work better in familiar buildings, or in a digital and interactive form. Many also liked the feature of depicting multiple floors in the same view. The average time of task completion was almost identical between the two groups that used the maps, with the IndoorTubes group performing a bit better. Both groups though performed significantly better than the group with no map. The researchers suggested that the efficiency of the participant's navigation and consequently the accuracy of the results, might have been affected by conducting the experiment in a crowded, public building and by varying waiting times for the elevators to arrive.

Nossum and Nguyen (Nossum, et al., 2012) concluded, based on the statistical results, the interviews with the participants and their observations, that the IndoorTubes concept has potential for certain user cases, especially when users are already familiar with a building and want multiple floors depicted simultaneously.

2.2 State of indoor mapping related technologies

An indoor map by itself, especially one created for mobile devices, is only part of an indoor wayfinding solution. Another part is the indoor positioning technology that will make such an experience possible and on par with outdoor solutions. Although not directly related with this thesis's scope, a brief introduction to the state of indoor positioning systems and additionally the situation surrounding building information modelling (BIM) solutions will be given. The latter, is important because if indoor positioning ever takes off and reaches the popularity of its outdoors counterpart, a fast, effective and efficient way will be needed to convert raw blueprints into user friendly, easy to use maps. As mentioned in the beginning of this chapter, this paragraph, along with the results of the research, will help the reader form a more holistic view of indoor wayfinding in general and better understand the conclusions and proposals for future research in chapter 5.

2.2.1 Indoor positioning systems

Currently there are many competing indoor positioning systems but none of them fulfills all the necessary requirements for a good implementation. According to (Gotlib, et al., 2012), since the GNSS (GPS, GLONASS etc.) signal is too weak in indoor spaces, other technologies and techniques must be used. The most popular ones according to (Fallah, et al., 2013) are:

1. **Dead reckoning.** This technique uses the mobile device's sensors and a previously estimated or known position to calculate the current one. It is not very accurate.
2. **Direct sensing.** This method identifies the user's position by sensing beacons that have been previously installed in the environment. This can be done using a variety of technologies like: RFID tags, ultrasound identification and more often Wi-Fi and Bluetooth. The biggest drawback is that it requires from the owner of the building to invest in expensive infrastructure.
3. **Pattern recognition.** This technique uses data from the mobile device's sensors and tries to match them with data collected in a previous instance from the same location. The most popular implementation of this technology is signal fingerprinting (usually Wi-Fi or Bluetooth). The drawback is that the location must be surveyed beforehand and the process needs to be repeated whenever there is a change to the space, thus making it costly.

These are some of the most popular technologies for indoor positioning, but not the only ones. There are plenty more at different stages of experimentation and development and in many cases various vendors try to combine a few different techniques in the same solution to achieve an improved result. None of them is ready for wide market acceptance due to accuracy problems or high cost.

2.2.2 Building Information Modelling

The US National Building Information Model Standard Project Committee has the following definition:

> *"Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition." (National BIM Standard USA, 2017)*

This is important for this thesis because BIM could help drastically automate the creation of indoor maps. As (Grilo, et al., 2010) wrote, a standardized version would benefit many industries (construction, engineering, architecture, building management etc.). Unfortunately, there are many incompatible BIM implementations mostly due to competition between vendors who sell the software used to create them (Sánchez Ortega, 2016) and the different specifications for building blueprints that several countries and territories demand from architects to submit.

2.3 Summary

In this chapter, a brief overview of the current state of indoor cartography was presented, based on how abstracted indoor maps are from reality. Three basic categories were identified. Raw architectural blue prints, simplified blueprints and the innovative minimalistic approach of the IndoorTubes. Examples of academic research from all three categories were presented. It is common consensus that the raw blue prints are not the optimal solution for indoor wayfinding, not surprisingly since they are created for a completely different purpose. There has been some research on the simplified blue prints approach and many commercial applications seem to have adapted it. Finally, research on the IndoorTubes has shown that user response to the new design compared to a traditional floor plan was mediocre but with potential. The question arises if there is room for a forth category that lies in complexity between the simplified blue prints and the IndoorTubes concept. In the next chapter the new proposed design will be presented as well as the methods used to test its usability.

3 Methodology and implementation

In this chapter, all the different steps necessary for completing this research will be discussed. The original idea's conception will be explained, the basic research structure will be described, the new proposed design will be presented, the choice of the online surveying and thinking aloud (recording) research and data collection methods will be explained, how the right building in TU Dresden's campus was selected and how the participants were assessed and split in two groups. The steps will be described in chronological order.

3.1 Original idea

The biggest source of inspiration for this research was, as mentioned in chapter 2.1.3, Nossum's IndoorTubes concept. Based on an adjusted version of his original idea, it has been decided to test a similar approach by conducting a user study in the Chemie/Hydrowissenschaften-Bau of TU Dresden to compare the new proposed design with an indoor map already in use by the website and mobile application: "TU Dresden Campus Navigator". The new design was not compared with Nossum's original, because this would require the creation and adaption of an additional design and there were time constrains preventing that from happening. Additionally, it is believed that the nature of the IndoorTubes concept makes them difficult to implement on a building whose floor plans are almost identical, thus most rooms are overlapping, plus the fact that the Chemie/Hydrowissenschaften-Bau has a very large number of rooms and that would complicate the design even more. Finally, if three different designs would have been compared, it would have been necessary to recruit even more study participants, which is a particularly challenging task. For these reasons, the decision was made to only compare the new proposed design with the existing one.

3.2 Basic research structure

This paragraph is meant to give a small description and to clarify the basic research structure. All the aspects of the implementation of the research will be then explained in more detail in the following paragraphs of this chapter.

A user study was conducted in which the new adjusted IndoorTubes map design was compared with the official indoor map solution currently used in TU Dresden, the Campus Navigator (Figure 2). That design was selected because it is familiar to the users. Most people know what architectural blueprints are and they often experience a variation of them as emergency maps in most public buildings. Additionally, they are accustomed to the simplified blueprints used in many commercial applications and these share many similarities with raw blueprints, like preservation of shapes, sizes and geometry of the rooms, outline of the building etc. For these reasons and the practical ones explained in chapter 3.1 the decision was made to compare the new proposed design with the Campus Navigator in a real-life wayfinding situation. Additionally, some user feedback that would also include Nossum's original IndoorTubes approach was desired, so two online questionnaires were sent to two different groups of users. Thus, the research had two main parts.

The **first** is the two main online surveys comparing all three designs. One was send to a group of cartography experts (chapter 3.6) (Appendix 2) and collected feedback that was used for improving the new proposed design and the other was distributed to the user study participants after they completed the wayfinding task in the Chemie/Hydrowissenschaften-Bau (Appendix 4). The surveys were identical and asked the same questions. They also compared the same maps except for the new design, which in the after-study questionnaire (Appendix 4) was in the improved second version (more in chapter 3.4.2 and chapter 3.8.2)

The **second** part of this research was the actual real-life user study (chapter 3.8), were the participants had to find their way in a building that was new to them by only using the two maps provided. The Campus Navigator blueprint based design and the new proposed design.

3.3 Building and time-slot selection

The first step was to choose the right building. TU Dresden has a big campus with a diverse selection of buildings and other facilities. After considering the different options, the choice was narrowed down to 5 possible selections. The buildings had to fulfill some basic criteria. They had to be reasonably big and complicated enough, so that it is not too easy to navigate in them and creating an indoor map would make sense and cover a real need. The researcher wanted to make sure that the participants had no or very limited prior experience with the chosen building, so that they would not use memories from a previous visit for wayfinding and primarily depend on the maps provided to them. To make sure that this was the case, an online survey (Appendix 1), not to be confused with the surveys in chapter 3.2 (Appendices 2 & 4), was send to the users asking them if they had visited the candidate buildings before. The same survey asked the users to choose from a selection of three possible timeslots for the user study to take place. The goal was to accommodate and attract as many participants as possible.

The five proposed buildings were: Georg-Schumann-Bau, Barkhausen-Bau, Zeuner-Bau, Mollier-Bau, Chemie/Hydrowissenschaften-Bau. In terms of floor plan suitability Georg-Schumann-Bau was the best candidate, with its complicated floor plan, unconventional room numbering and reputation among the TU Dresden students of being particularly challenging for new visitors to find their way. Unfortunately, the clear majority of the participants had experience with the building since they took some classes there, so it had to be ruled out. The Barkhausen-Bau was under renovation and so the best available option left was the Chemie/Hydrowissenschaften-Bau. The building is big, with multiple corridors and many different possible ways for participants to reach their target. Thus, this building was chosen for the user study.

Additionally, most of the participants responded that Thursday 16 and Friday 17 of February 2017 was their preferred time-slot for the study to take place, so these dates were chosen as well.

3.4 Proposed map design – draft 1

3.4.1 Theoretical background

As described in more detail in chapter 2, the researcher initially looked and found examples of indoor maps in the industry and academic publications. One approach that has a lot of potential and discards many unnecessary elements found in most traditional indoor maps was the IndoorTubes (Nossum, 2011), although it is believed that this approach gets a bit too minimalistic and research (Nossum, et al., 2012) has showed that user response to this design has been mediocre.

As mentioned in the hypothesis (chapter 1.2) a new design is proposed in which elements like: wall thickness, exact position of windows, direction in which doors open, exact design of staircases etc. are discarded. On the other hand, corridors, some general shapes for things like big waiting rooms, atriums and basic indoor landmarks, like staircases, elevators and WCs and their positions are preserved.

Unlike the IndoorTubes concept though, the researcher planned to preserve some, but not all, geometric accuracy and to only focus on one floor per view to avoid user confusion and get rid of transit references that is believed do not translate well in a product for pedestrians.

The diagram bellow categorizes the different design approaches for indoor maps based on their complexity and indicates where the new proposed design fits.

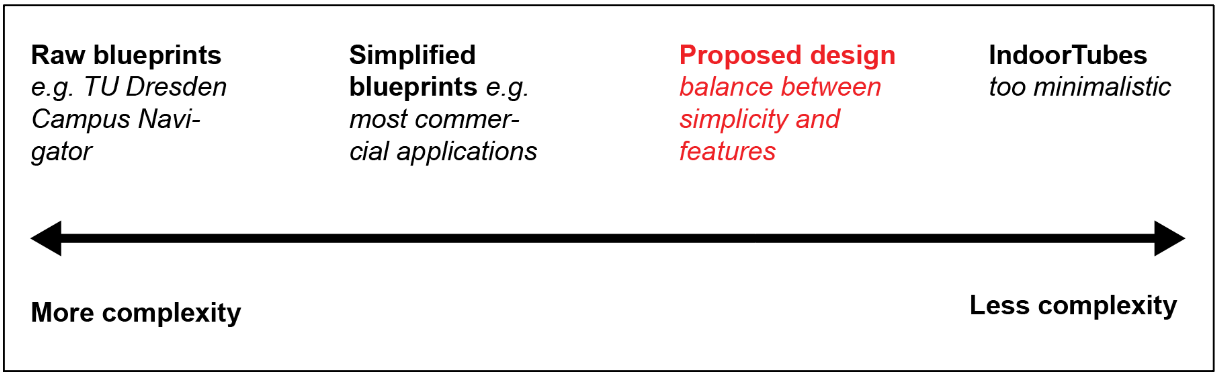


Figure 13: Placement of indoor map designs based on complexity of information

3.4.2 First draft

Based on the considerations discussed in the previous paragraph and using the existing TUD Campus navigator indoor map (Figure 14) as a base, the first draft of the proposed design was created (Figure 15).

Figure 14: TU Campus Navigator indoor map (Chemie/Hydrowissenschaften-Bau, ground floor)

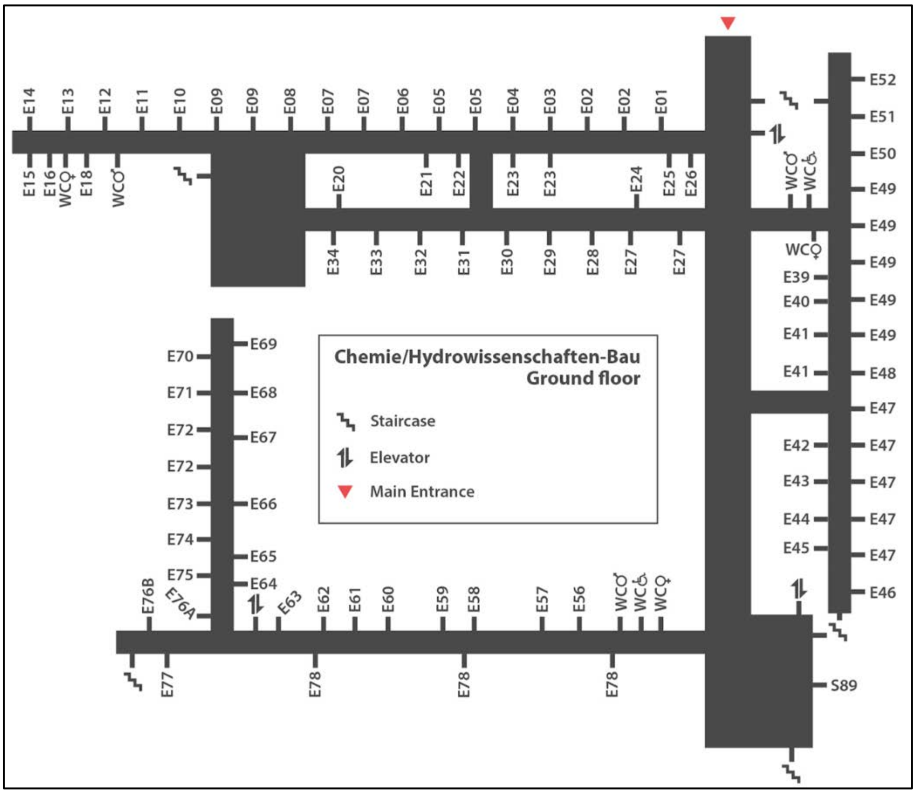


Figure 15: Proposed design – draft 1 (Chemie/Hydrowissenschaften-Bau, ground floor)

Like in the IndoorTubes concept, the new design mainly focused on the corridors, since they are believed to be the single most important building element for wayfinding since this is what an actual person walking in an unfamiliar indoor space initially encounters and will eventually lead him/her to his/her destination, most likely a room. On the other hand, the researcher believes that the exact shape and size of the rooms is irrelevant and if included in the map will only result in visual clutter that will unnecessarily burden the user cognitively. So, it was decided to depict rooms the way Nossum did, with simple lines and their number/name.

Unlike the IndoorTubes concept though, the researcher chose to preserve the shape, geometry and size of the corridor, believing that these attributes assist navigation, especially in a newly visited building. The user can judge relative distances and get a better sense of his/her position. The main corridor was drawn with double width to distinguish it from the other, less wide corridors. If not, some users would probably get confused when walking in corridors of different widths looking at a map that makes no clear distinction between them. The exact room positions were mostly preserved, but not very strictly. Some of them were moved a bit to achieve a more balanced and pleasant visual end-result. Only one floor per view was kept, since otherwise it is believed users would be confused, especially in a building like this with a big number of rooms and with almost identical floor plans on most floors. Finally, transit inspired symbols for connections between floors (staircases and elevators), were replaced by more traditional ones for important indoor landmarks like the ones mentioned and for WCs.

Concerning the adaptation of the design for mobile devices, the researcher wanted to make sure that the new proposal was as clean and uncluttered as possible. As already mentioned in the hypothesis (chapter 1.2), it is believed that the raw blueprint approach creates a visually cluttered result and unnecessarily distracts the users from wayfinding. This effect is multiplied on a small screen and makes simplicity more desirable. For that reason, a sans serif typeface for room labelling and only two colors, red for the entrance/start point and dark-gray for everything else were chosen. The researcher also created simple and self-explanatory symbols for the floor connections (staircases and elevators) and used the universally recognizable male, female and wheelchair symbols for the WCs. A few iterations of this design were tested on a Motorola Moto G (3rd generation) with the Android mobile operating system version 6.0. This device has a 5-inch display with a resolution of 720x1280 pixels. The maps were distributed as JPEGs on a mobile website and it was made sure they were of high resolution so zooming would not create blurry artifacts. This way, users could focus at any specific part of the map they wanted at the zoom level of their choice.

In the user study (chapter 3.7 and 3.8), the participants were asked to bring their own devices. This decision was taken for practical reasons. The researcher could not give them his device since he was using it to record the process. Since his device has average screen specifications, any substantial difference in their experience with the map were not expected. Additionally, modern day mobile devices and browsers behave very similarly.

The result can be seen in the proposed draft 1 (Figure 15). Then, the draft was sent to people knowledgeable in cartography to help find problems with the new design and further improve it. Their feedback and the improved version will be discussed in chapter 4.1.

3.5 Online surveys

The **first method** that was used to collect data for this research were the online surveys that were sent to two groups of users. In total four surveys were sent out, using the free Google Forms tool. Three of them were send to the participants of the real-life user study conducted in the Chemie/Hydrowissenschaften-Bau in TU Dresden and one was send to a group of cartography experts (more in chapter 3.6). For clarification purposes, they will briefly be presented here, in the chronological order they were sent and some explanations concerning their purpose will be given, with more details following in the paragraphs and subparagraphs below.

1. **Building and time selection survey** (Appendix 1). This survey was sent to the students who participated in the user study and helped identify which buildings have not been visited by them and which dates better suited them.
2. **Experts' evaluation survey** (Appendix 2). This survey asked questions about the three designs to a group of cartography experts. It also provided feedback on the first draft of the proposed design (Figure 15) and helped to improve it.
3. **Pre-study questionnaire** (Appendix 3). This survey was sent to the students and helped collect information about their background, their prior map usage experience and included the Santa Barbara Sense of Direction Scale questionnaire that was used to assess their spatial abilities.
4. **After-study questionnaire** (Appendix 4). This survey was sent to the students after they completed the wayfinding task of the real-life user study and asked them to compare and give feedback on the three designs. It asked exactly the same questions as the experts' evaluation survey and had the same maps with the exception of the new proposed design. This survey included the improved second draft (Figures 21 and 22). It also asked some additional questions (chapter 3.8.2)

This research method (online surveying) was chosen to collect data and compare the three indoor map designs. As explained in chapter 3.2, for practical reasons and time constraints the user study in the Chemie/Hydrowissenschaften-Bau only compared two of the designs (Campus Navigator and the new one), but some feedback on the IndoorTubes concept was still desired. The advantages of online surveying are that it is easy and practical to organize and has a higher likelihood of participation, since it is not inconveniencing users too much. Additionally, because of its digital nature, it provides an easy and fast way for the researcher to analyze the results.

3.6 Experts' evaluation survey

For this step of the research, an online survey (Appendix 2) was created and sent to faculty members of the participating universities of the International Master Program in Cartography. The supervisors of this thesis were excluded, since they were too involved with the project and the feedback had to be as objective as possible. In total eighteen people from TU München, TU Wien, TU Dresden and the University of Twente / ITC were invited. Fourteen replied.

In the questionnaire, the participants were presented with three different indoor maps. The first was the blueprint currently used in the Campus Navigator product (Figure 14), the second was the new proposed design – draft 1 (Figure 15) and the third an IndoorTubes example (Figure 1). The first two designs depict the ground floor of the Chemie/Hydrowissenschaften-Bau. The third is simply an example from another building and was presented to the participants to give them an overview of that concept. As explained in chapter 3.1, an IndoorTubes mock-up of the test building was not created because of time constraints and practical reasons.

The same questions were asked twice, one time concerning indoor route planning and the second for indoor navigation. The rationale behind this decision is that planning and navigation are two different cognitive functions of wayfinding and different users may react differently when commenting on the suitability of the same map for both purposes. A detailed analysis of the results will be presented in Chapter 4: Results and discussion, where they will be compared with the results from the online survey (Appendix 4) answered by the participants of the actual user study. They replied to the same questions concerning route planning and navigation of the three designs (as can be seen in Appendices 2 & 4) with only the new proposed design slightly changed between the two online surveys, since it was improved based on the feedback given by the cartography experts, which helped discover weaknesses in the first draft (Figure 15) and create a second, final draft (Figures 21 and 22) (that second draft was also used in the real life user study in which the participants were asked to find points in the Chemie/Hydrowissenschaften-Bau).

3.7 User study preparation

In this paragraph, all the preparations that were made to conduct the actual user study in the Chemie/Hydrowissenschaften-Bau will be explained. These include a questionnaire sent to the participants before the study to collect necessary information (Appendix 1), some planning and scheduling for the two days that the study lasted and the tools needed to execute it.

3.7.1 Basic structure of the user study

In this sub-paragraph, a brief overview of the structure of the user study will be given. More details will follow in the sub-paragraphs below.

The basic purpose of the user study was to compare the new adjusted IndoorTubes map design with the TU Dresden Campus Navigator one. To achieve that the participants were split in two groups. Group A would use the old, blueprint based design and group B the new design. To get a fair and balanced result the two groups should be comparable in terms of the characteristics of the participants. Therefore, the users' spatial and orientation abilities had to be evaluated and their age and gender considered. For the first the Santa Barbara Sense of Direction Scale (SBSD) (Hegarty, et al., 2002) was used, for the other two the researcher asked in the pre-study questionnaire (Appendix 3) (chapter 3.7.3).

3.7.2 Composition of the user group

Most participants were recruited from the fifth intake of the International Master of Science in Cartography program, jointly taught by TUM, TUW, TUD and UT/ITC. An effort was done to recruit more students from TUD. In total I invited 32 participants, 22 replied positively and eventually 19 showed up.

From the 19 participants who showed up 16 were Cartography students, two were Architecture students and one is studying Energy Engineering. It was obvious that almost all the participants were accustomed to some level with maps and floorplans due to their academic background. It would have been interesting to conduct such a study with people unrelated with these disciplines so that the result would be closer to the average potential user of indoor maps and wayfinding products, like (Lorenz, et al., 2013) did in their research, but it was logistically not possible.

3.7.3 Pre-study survey

This survey (Appendix 3) was sent to the 22 students who replied to the invitation for participation and indicated that they will take part in the study. The survey has two parts. In the first some simple questions are asked, like age, gender, education level and a few questions related to map usage and experience with indoor wayfinding products. The information about age and gender along with the SBSD results (more below) was used to split the users in two groups. This decision was taken because the user group was of a relatively small size and the researcher decided that this was sufficient. Since the rest of the results were not used, they are presented as additional observations in chapter 4.4.

This survey also included the Santa Barbara Sense of Direction Scale (SBSD). The SBSD was developed by (Hegarty, et al., 2002) at the University of California-Santa Barbara and the researcher used it to assess the spatial abilities of the participants of the user study. As seen in Appendix 3, there are 15 questions that according to the Scale's website (2002) it can be used as a self-report measure of a user's environmental spatial ability. According to the same website:

> *"The recommended scoring procedure for the scale is to first reverse score the positively phrased items. This ensures that all items are coded such that a high number indicates more ability and a low number indicates less ability. The items that should be reverse scored are items 1, 3, 4, 5, 7, 9, and 14. After reverse scoring, then sum the scores for all the items together, and then divide the total by the number of items (15) to compute the overall score for the scale (average score across items). Using this technique, the score will be a number between 1 and 7 where the higher the score, the better the perceived sense of direction."*

After using this technique, the following results shown in Table 1 were produced:

Group A				**Group B**			
Participant ID	***Gender***	***Age***	***Santa Barbara score***	***Participant ID***	***Gender***	***Age***	***Santa Barbara score***
21	female	21-25	5,27	3	female	21-25	5,07
16	female	21-25	4,93	8	female	21-25	6,07
11	female	21-25	5,27	1	female	21-25	4,93
13	female	26-30	3,20	14	female	26-30	4,60
2	female	21-25	4,87	10	female	21-25	4,47
15	male	31-35	4,13	12	female	21-25	2,47
18	male	21-25	5,07	19	male	21-25	5,80
9	male	21-25	5,27	20	male	21-25	4,93
22	male	26-30	4,33	7	male	21-25	2,53
6	male	31-35	4,20	4	male	26-30	4,93
5	male	21-25	6,13	17	male	31-35	5,33

Santa Barbara score averages			
Group A		**Group B**	
Males:	4,86	Males:	4,71
Females:	4,71	Females:	4,60
Total:	**4,79**	**Total:**	**4,65**

Distribution per age group			
Group A		Group B	
21-25	7	21-25	8
26-30	2	26-30	2
31-35	2	31-35	1

Table 1: Composition of the two groups of participants

The table includes the 22 participants who replied to the pre-study questionnaire, including the Santa Barbara sense of direction scale. Based on the data, these participants were split in two groups. Each group has 11 students. There are in total 11 males and 11 female students. Due to these numbers, it was not possible to have exact number of males and females in each group. So, group A has five female and six male students and group B vice versa, six females and five males.

An effort was made to distribute the students as evenly as possible based on their Santa Barbara scale of orientation results. As can be seen on the second part of Table 1, the average results for males, females and total, for both groups are very similar. There is only a difference of about 0,1 on a scale of 1 to 7, so I believe the distribution was quite balanced.

Finally, when it comes to age and as can be seen in the third part of Table 1, the participants were distributed as equally as possible to the two groups.

3.7.4 Exact time selection

The user study took place on two consecutive days (Thursday 16 and Friday 17 of February 2017) and the whole process took about 20-25 minutes per user. Doodle, the free online scheduling tool was used to organize when the participants would come. As explained in chapter 3.8, each participant came by him/herself and completed the task alone. It was necessary for them to come individually and give enough time between each appointment so they would not collide. A new participant arrived every 30 minutes.

3.7.5 Mobile websites

As explained in chapter 3.7.1 the idea was to compare how the two design approaches assist in way-finding and see if there is a significant difference in their usability. For that purpose, new maps for the ground and first floors of the Chemie/Hydrowissenschaften-Bau (Figures 21 & 22) were created. As explained in chapter 3.7.3, the users were split in two subgroups of equal composition (age, sex, spatial abilities based on SBDS). The first group (A) used the old, Campus Navigator design. The second (B) the new proposed one.

Each user, based on which of the two groups he/she belonged to, was given one of two available URLs linking to websites with a simple explanation of the task to be performed and the maps so they could use them on their mobile phones (see Figures 19 and 20). The websites included an introductory text with detailed explanations on the task they had to perform and things they should take care of, to avoid disturbing the people working in the building (Appendix 7). As explained in that text, the users first had to reach a point in the ground floor and then go to the first floor and reach a second point there. Each user reached the targets by him/herself, one at a time, without any help from other people in the building or other media/apps etc. By measuring the time they needed to complete the task, the researcher could check the effectiveness and efficiency of the two competing designs (more in chapter 3.8.1). Additionally, they were urged to vocalize (think aloud) their thoughts concerning the whole experience and express opinions on the map design during the process to get insights on the user satisfaction (more in chapter 3.8.1). Since the groups were of equal composition, the two groups' results were comparable. Feedback was also collected on the after-study survey (Appendix 4) to assess usability (effectiveness, efficiency and user satisfaction)

The websites were created by the researcher, based on a freely available template which was adapted for the specific needs of this master thesis.

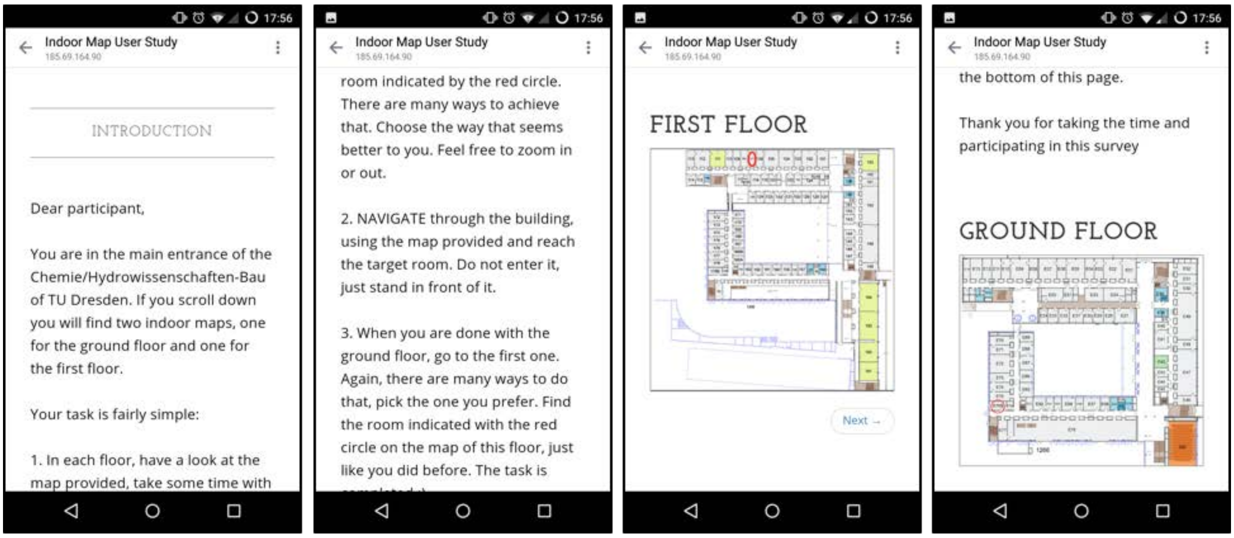


Figure 16: Introduction and Group A maps

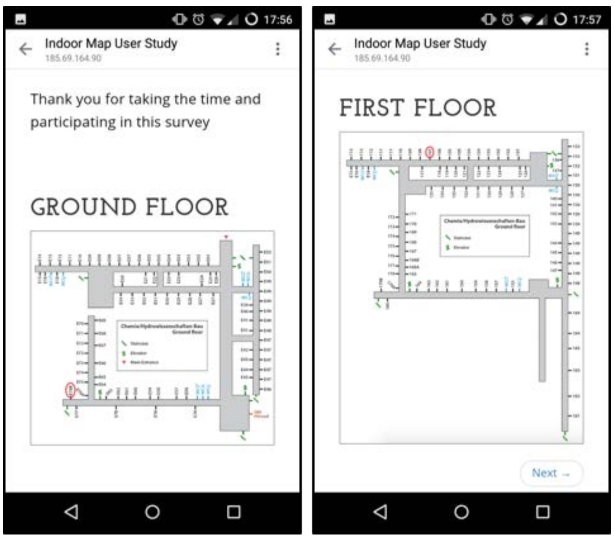


Figure 17: Group B maps

3.8 User study

After creating the new maps for both floors of the selected building, splitting the participants in two groups of equal compositions, scheduling the appointments on the selected dates with each participant and creating the websites for them to use for completing the task that was asked of them, the study was ready to be conducted.

3.8.1 Execution of the user study

On the days of the user study, the researcher arrived at the building half an hour before the first participant. He walked around the ground and first floors to make sure there were no changes or obstacles that could cause any kind of problems. These two floors of the Chemie/Hydrowissenschaften-Bau have mostly administrative and faculty offices. Additionally, February is the exam period for most universities in Germany, so not many students were around, since there were not any classes taught. The building was quiet and with relatively low traffic and the study was conducted with no issues. The building also had wireless internet connectivity, necessary for the users to load the websites on their phones. The researcher also had printed a script (Appendix 5) to help him remember all the necessary steps and make sure the experience was the same for all participants, a list of all the students with the time of their appointment and the group they belonged to and the links of the two websites for them to load. Finally, a handout was printed (Appendix 6) with the three designs for the participants to conveniently look at when replying to the final questionnaire (Appendix 4) after the completion of the task.

When the first student arrived, she was welcomed and given the link to the website of the group in which she belonged. The top part of the website included a detailed explanation of the task (see Appendix 7) and the maps of the two floors (the design of which differed between groups A and B). Then the students could ask any questions or clarifications they might need and the process began. The students first had to navigate on the first floor and find the first point indicated on the map. Then they could choose any of the staircases or elevators available to go to the next floor and find the second point.

The researcher decided to follow and record the users on video, using his personal mobile device. This was the **second method** by which data for this research was collected. The inspiration to use recordings was taken from previous research and a discussion with the supervisors of this thesis. Both (Lorenz, et al., 2013) and (Nossum, et al., 2012) used recordings to collect data and feedback, indicating that it is a proven and tested method for this kind of usability studies, similar to the one conducted for this research. One of the benefits is that not only one can accurately measure how long it takes each participant to find the target points on each floor, but also as explained to them on the task description (Appendix 7), urge them to vocalize any thoughts (think aloud) and comments they have about the maps, the building and the wayfinding experience in general. It also proved a useful way to collect additional interesting information, not directly related to the scope of this thesis, but still of some value which I were not anticipated during the planning of the study (more in chapter 4.4).

The potential benefits of the “think aloud” method for feedback collection from the users are that their replies will most likely be more spontaneous and natural and by recording them the researcher can take his time to interpret them later. A possible downside is that since speaking one’s thoughts is not something that people usually do, at least in public, and the fact that the participants will be cognitively occupied with finding their way in an unknown indoor environment, there is the possibility that by asking them to multitask, their focus and consequently how fast they will reach the target points will be negatively affected and they will not cooperate. Because of that possibility and the fact that the researcher did not want the users to be exposed to the map designs before the execution of the user study, it was planned for them to reply on the online survey (Appendix 4) right after they completed the wayfinding task in the Chemie/Hydrowissenschaften-Bau. The websites with the maps they used, contained a link to that survey (that survey also asked them about the IndoorTubes design).

Concerning the data collected from the recordings, the researcher plans to compare the task completion times for both floors based on the gender, group and combination of gender and group in which the participants belong to. This way the effectiveness and efficiency of the two designs can be compared. The user satisfaction will be assessed by any comments the users might express during the process and from the feedback they will give in the after-study questionnaire (Appendix 4).

3.8.2 After-study survey

After the completion of the task the users were asked to fill in the last online survey (Appendix 4). To do so, they had to click the “next” button on the bottom of the website they used during the wayfinding task. It was linked to the Google Forms survey. For their convenience and to avoid constantly scrolling up and down to look at the designs on their mobile devices, they were given a print out with the three designs (Appendix 6) which they could more easily look at if they wanted.

This survey had exactly the same questions as the Experts’ evaluation survey (Appendix 2). As mentioned in chapter 3.6, the same questions were asked twice, one time concerning indoor route planning and the second for indoor navigation. The maps that the users had to compare where the same with the exception of the new design, which in the after-study survey was in the improved second version (Figures 21 and 22).

3.9 Summary

In this chapter, the choices that were made while creating the first draft of the new proposed design were explained. The research methods used and their selection were discussed. The necessary steps to collect data that would help evaluate the hypothesis were shown in chronological order and the building selection and participants’ assessment processes were described. In the next chapter the results of the research will be presented.

4 Results and discussion

In this chapter, the creation of the second version of the new proposed design will be explained. The results from all the online surveys that were sent out and the user study that was conducted will be discussed. Additional observations made during the research process will also be presented.

4.1 Proposed map design – draft 2

Coming back to the expert's evaluation online survey (Appendix 2) and their feedback on the first draft of the new proposed design, one of the participants found it difficult to initially grasp that the dark grey area in the first draft (Figure 15) is walkable (corridor), since darker colors are usually used for walls etc. Another participant complained that it was a bit monotonous and perhaps using a variety of colors, especially for the symbols and some special rooms would be a good idea. Based on the feedback from the experts' evaluation survey a final version of the new proposed design was created.

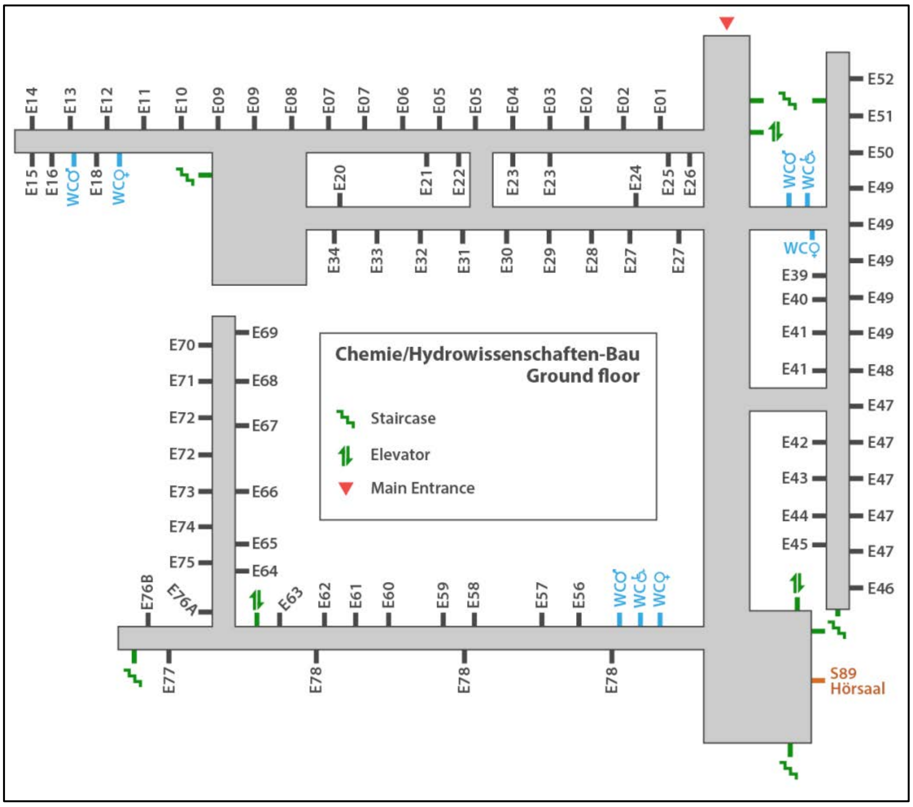


Figure 18: Proposed design – draft 2 (Chemie/Hydrowissenschaften-Bau, ground floor)

For this **second draft** the overall design of the first one was preserved, but it got improved with the use of more colors. Unlike the first one (Figure 15) that only used one single shade of gray, it now has six different colors. The corridor is colored with a lighter gray but the outline and room extensions keep original darker gray. The other difference is the four different colors chosen for the symbols and for the Hörsaal (big lecture room).

The researcher chose to mostly use basic colors, that are quite different from each other. Red for the entrance because it is an intense color and quickly gets noticed, blue for the WCs, since this color is internationally associated with WCs and water, green for the connections between the floors (staircases and elevators) and orange for the Hörsaal. Although the building has a variety of rooms, others used for education and others for administrative purposes, they all share a similar relatively small footprint. The only difference was the Hörsaal due to its big size and the fact that it is architecturally different and used by way more people than the average room in the building. This difference in functionality makes it more probable that new visitors would look for it in their first visit, thus it was decided to present it in a different color.

Since with this second draft the researcher settled on the exact design language that would be used for the new proposal, a version for the first floor of the building was also created. Maps for both floors were necessary for the user study as explained in chapter 3.8.

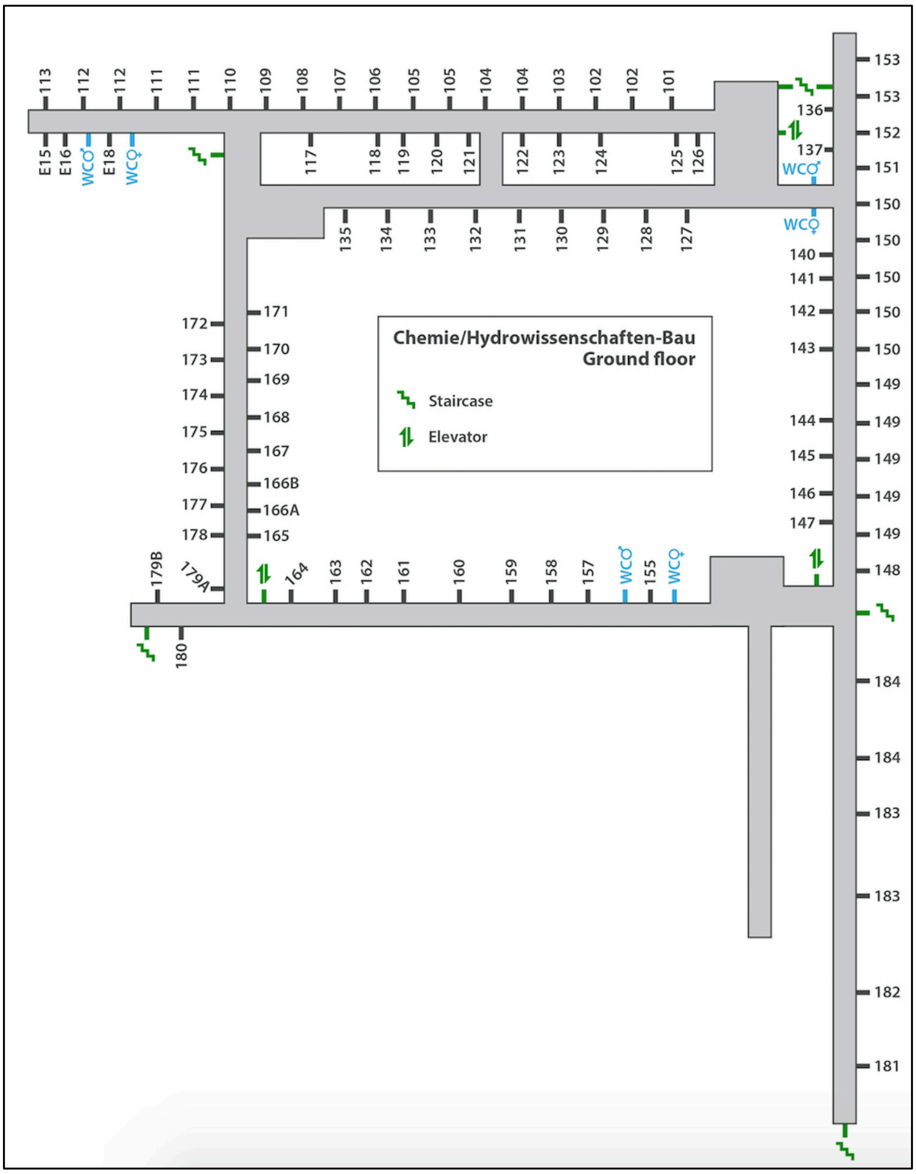


Figure 19: Proposed design – draft 2 (Chemie/Hydrowissenschaften-Bau, first floor)

The draft for the first floor of the building was based on the map of the same floor of the Campus Navigator (Figure 20). It is presented here since for the first draft of the new proposed design a first floor version was not created because the researcher still had not settled on the final design language that would be used.

Figure 20: TU Campus Navigator indoor map (Chemie/Hydrowissenschaften-Bau, first floor)

4.2 User study results

In this paragraph, the results from the user study conducted on Thursday 16 and Friday 17 of February 2017 in the Chemie/Hydrowissenschaften-Bau of TU Dresden will be presented. As shown in Table 1, 22 participants replied to the invitation, but eventually only 19 showed up. Participants 17, 11 and 15 could not eventually make it and the results of participant 21 were excluded because the participant could not finish the task due to technical issues as the mobile device could not reload the website with the explanation of the task and the maps due to connectivity issues. The participant managed to find the target point on the first floor by memory but it was not possible to load the second map. By the time it took to solve the issue the next participant had arrived. Therefore the results were incomplete.. In the end, 18 valid results were collected. The distribution of the participants can be seen in Table 2.

Group A				Group B			
Participant ID	***Gender***	***Age***	***Comment***	***Participant ID***	***Gender***	***Age***	***Comment***
21	female	21-25	Invalid result	3	female	21-25	✓

16	female	21-25	✓	8	female	21-25	✓
11	female	21-25	Did not come	1	female	21-25	✓
13	female	26-30	✓	14	female	26-30	✓
2	female	21-25	✓	10	female	21-25	✓
15	male	31-35	Did not come	12	female	21-25	✓
18	male	21-25	✓	19	male	21-25	✓
9	male	21-25	✓	20	male	21-25	✓
22	male	26-30	✓	7	male	21-25	✓
6	male	31-35	✓	4	male	26-30	✓
5	male	21-25	✓	17	male	31-35	Did not come
Final number of User Study Participants who successfully participated							
Group A				**Group B**			
Males:	5			Males:	4		
Females:	3			Females:	6		
Total:	**8**			**Total:**	**10**		

Table 2: Participants who took part in the user study and completed the task

Despite of Participant 21 (of Group A) not being able to complete the user study, the participant filled in the last survey (Appendix 4) that asked from the users to compare the three different designs and give their opinion on how they perform concerning indoor route planning and indoor navigation (the same questions were asked to the cartography experts, for a reminder look at chapter 3.6 and Appendix 2)

As can be seen in Table 2, the final distribution was not ideal because Group B ended up having twice the number of female participants compared to Group A, but there was no way to predict that out of the three participants who did not show up, two would be from Group A. Since the participants were assessed (chapter 3.7.3) and split in the two groups beforehand it was not possible to re-arrange them at that point. Additionally, technical issues invalidated the results of one more Group A participant.

In Table 3 below, the results of the participants' time measurements (in minutes) for each of the two floors and in total are displayed. For the ground floor, the researcher started measuring when the users started walking from the entrance of the building after they read the task description and any questions they had were answered. For the first floor, the time measurement started right after they had found the target point on the ground floor. This included the time they needed to move one floor up. They were given the choice to use any type of floor connection they wanted (elevator or stairs) so that the experience was closer to a real-life situation. In retrospect, this was perhaps a mistake because elevator waiting times varied and might have affected the results. A similar problem was faced by (Nossum, et al., 2012).

Group A					**Group B**				
ID	***Gender***	***Ground floor***	***First floor***	***Both floors***	***ID***	***Gender***	***Ground floor***	***First floor***	***Both floors***
2	Female	3:34	2:21	5:55	1	Female	1:40	3:27	5:07
5	Male	1:16	1:35	2:51	3	Female	2:17	2:14	4:31
6	Male	1:16	3:05	4:21	4	Male	1:40	2:03	3:43
9	Male	1:26	2:04	3:30	7	Male	2:59	2:33	5:32
13	Female	3:36	5:18	8:54	8	Female	1:49	2:57	4:46

16	Female	3:11	3:05	6:16	10	Female	1:17	1:31	2:48
18	Male	2:09	1:58	4:07	12	Female	1:50	2:58	4:48
22	Male	1:34	3:20	4:54	14	Female	1:32	6:58	8:30
					19	Male	1:42	2:08	3:50
					20	Male	1:31	1:49	3:20
Total:		**2:15**	**2:51**	**5:06**			**1:50**	**2:52**	**4:42**
Results per group for females									
2	Female	3:34	2:21	5:55	1	Female	1:40	3:27	5:07
13	Female	3:36	5:18	8:54	3	Female	2:17	2:14	4:31
16	Female	3:11	3:05	6:16	8	Female	1:49	2:57	4:46
					10	Female	1:17	1:31	2:48
					12	Female	1:50	2:58	4:48
					14	Female	1:32	6:58	8:30
Total:		**3:27**	**3:35**	**7:02**			**1:44**	**3:21**	**5:05**
Results per group for males									
5	Male	1:16	1:35	2:51	4	Male	1:40	2:03	3:43
6	Male	1:16	3:05	4:21	7	Male	2:59	2:33	5:32
9	Male	1:26	2:04	3:30	19	Male	1:42	2:08	3:50
18	Male	2:09	1:58	4:07	20	Male	1:31	1:49	3:20
22	Male	1:34	3:20	4:54					
Total:		**1:32**	**2:24**	**3:57**			**1:58**	**2:08**	**4:06**

Table 3: User study results per group and per gender in each group

Based on the first part of Table 3 it can be concluded that the participants of Group B completed the task faster (ground floor, total) or at almost the same time (first floor) as participants of Group A. Group B used the new proposed design. A potential reason for the results of the two groups being so similar for the first floor can be explained by the fact that the ground floor was the first contact the users had with the maps and they needed some time to adjust to the design, grasp the general shape and size of the building and orient themselves. As will be discussed in more detail in chapter 4.3 the users seemed to prefer the new proposed design and believe that it can better assist in route planning and navigation, thus Group B adapted faster and performed better on the ground floor. By the time they had reached the first floor they already had some experience with the task and the whole process was more fluid for both groups. This might be a reason that performance seems so similar for the first floor. Additionally, the measurements for the first floor include the time it took users to move one floor up and as mentioned previously these times were affected by varying elevator waiting times that could also have altered the first-floor measurements.

In general, some participants performed better than others and there were a few cases that some of them got really confused, were slow, got lost or chose a longer route. The most extreme cases were participants 13 and 14, but since they were in different groups their results cancelled each other out when it comes to comparing time performance based on which indoor map design was used.

In general the results indicate that the effectiveness and efficiency of the new design surpass the ones from the old, blueprint based design, keeping in mind the issues just mentioned.

Similar conclusions can be drawn by studying the results per gender per group. In most cases Group B had shorter or similar times except for males in the ground floor. This can be partially explained by the fact that participant 7 got lost in the building and needed almost twice the time to find the target point of that floor. One of the problems of having a small user group is that extreme results can significantly alter the outcome.

It can also be seen that males outperformed females in completing the task (except in Group B ground floor as just mentioned). The reasons for such a difference between genders are out of scope and will not be discussed in this master thesis. Related literature exists (Lawton, et al., 1996) and (Lawton, 1994), discussing differences in wayfinding and orientation skills between genders. In Table 4 one can also see the overall time for males and females irrespectively of which group they belonged to.

Females					Males				
ID	*Group*	*Ground floor*	*First floor*	*Both floors*	*ID*	*Group*	*Ground floor*	*First floor*	*Both floors*
1	B	1:40	3:27	5:07	4	B	1:40	2:03	3:43
2	A	3:34	2:21	5:55	5	A	1:16	1:35	2:51
3	B	2:17	2:14	4:31	6	A	1:16	3:05	4:21
8	B	1:49	2:57	4:46	7	B	2:59	2:33	5:32
10	B	1:17	1:31	2:48	9	A	1:26	2:04	3:30
12	B	1:50	2:58	4:48	18	A	2:09	1:58	4:07
13	A	3:36	5:18	8:54	19	B	1:42	2:08	3:50
14	B	1:32	6:58	8:30	20	B	1:31	1:49	3:20
16	A	3:11	3:05	6:16	22	A	1:34	3:20	4:54
Total:		**2:18**	**3:25**	**5:44**			**1:44**	**2:17**	**4:01**

Table 4: Performance based on gender

Apart from measuring task completion times, the recordings were used to collect "think aloud" feedback from the participants. This method was unsuccessful. Users in general did not talk much and the researcher chose not to pressure them because it was more important for them to focus on the wayfinding task. Since relevant feedback was collected on the after-study survey (chapter 3.8.2. and Appendix 4) this was not such a big problem. The issue will be further discussed in chapter 5.

4.3 User surveys' results

In this part, the results of the two user surveys in which the two groups of users were asked to compare the three indoor map designs (Appendixes 2 and 4) will be presented.

4.3.1 Feedback on the three designs

The questions asked to the cartography experts and the user study participants were the same (Appendices 2 and 4). The goal was to collect feedback on the route planning and route navigation potential of the three maps. The first map was the map of the ground floor of the test building and was the same in both surveys. The second map was of the new proposed design. This map differed between the two surveys. The first draft was in the expert's survey (Figure 15) and the second improved one, in the final after-study survey (Figures 18 and 19). Since only the colors where changed on the second final version, it is believed that the two maps are very similar and the results can be compared. The third map was an original IndoorTubes example

(Nossum, 2011). In the final survey (Appendix 4) an arrow and some text clarifying that the transit map inspired symbols represent the connections between different floors were added.

In the Tables 5-10 below, the results of the two surveys are presented. Table 5 includes the responses to all the questions asked in the surveys. In Tables 6-10 the replies to each question are visualized, both for the cartography experts and the student participants of the user study so the reader can compare the results between the two groups.

	Cartography Experts				**Study Participants**			
	Route planning		***Route navigation***		***Route planning***		***Route navigation***	
In your opinion, which map design is better for route planning and navigation?								
	Replies	%	Replies	%	Replies	%	Replies	%
Campus Navigator	4	28,6	6	42,9	5	26,3	8	42,1
Proposed design	8	57,1	7	50,0	13	68,4	11	57,9
IndoorTubes	2	14,3	1	7,1	1	5,3	0	0,0
Do you think the amount of information in the Campus Navigator design for route planning and route navigation purposes is:								
Not enough	1	7,1	1	7,1	0	0,0	0	0,0
Just right	1	7,1	4	28,6	5	26,3	9	47,4
Too much	12	85,7	9	64,3	14	73,7	10	52,6
Do you think the amount of information in the Proposed design for route planning and route navigation purposes is:								
Not enough	5	35,7	6	42,9	4	21,1	5	26,3
Just right	9	64,3	8	57,1	15	78,9	14	73,7
Too much	0	0,0	0	0,0	0	0,0	0	0,0
Do you think the amount of information in the IndoorTubes design for route planning and route navigation purposes is:								
Not enough	4	28,6	5	35,7	11	57,9	13	68,4
Just right	8	57,1	5	35,7	4	21,1	2	10,5
Too much	2	14,3	4	28,6	4	21,1	4	21,1
In your opinion, depicting multiple floors in the same view of an indoor map assists or complicates route planning and route navigation?								
Assists	7	50,0	5	35,7	6	31,6	4	21,1
Complicates	7	50,0	9	64,3	13	68,4	15	78,9

Table 5: Responses to the two main surveys

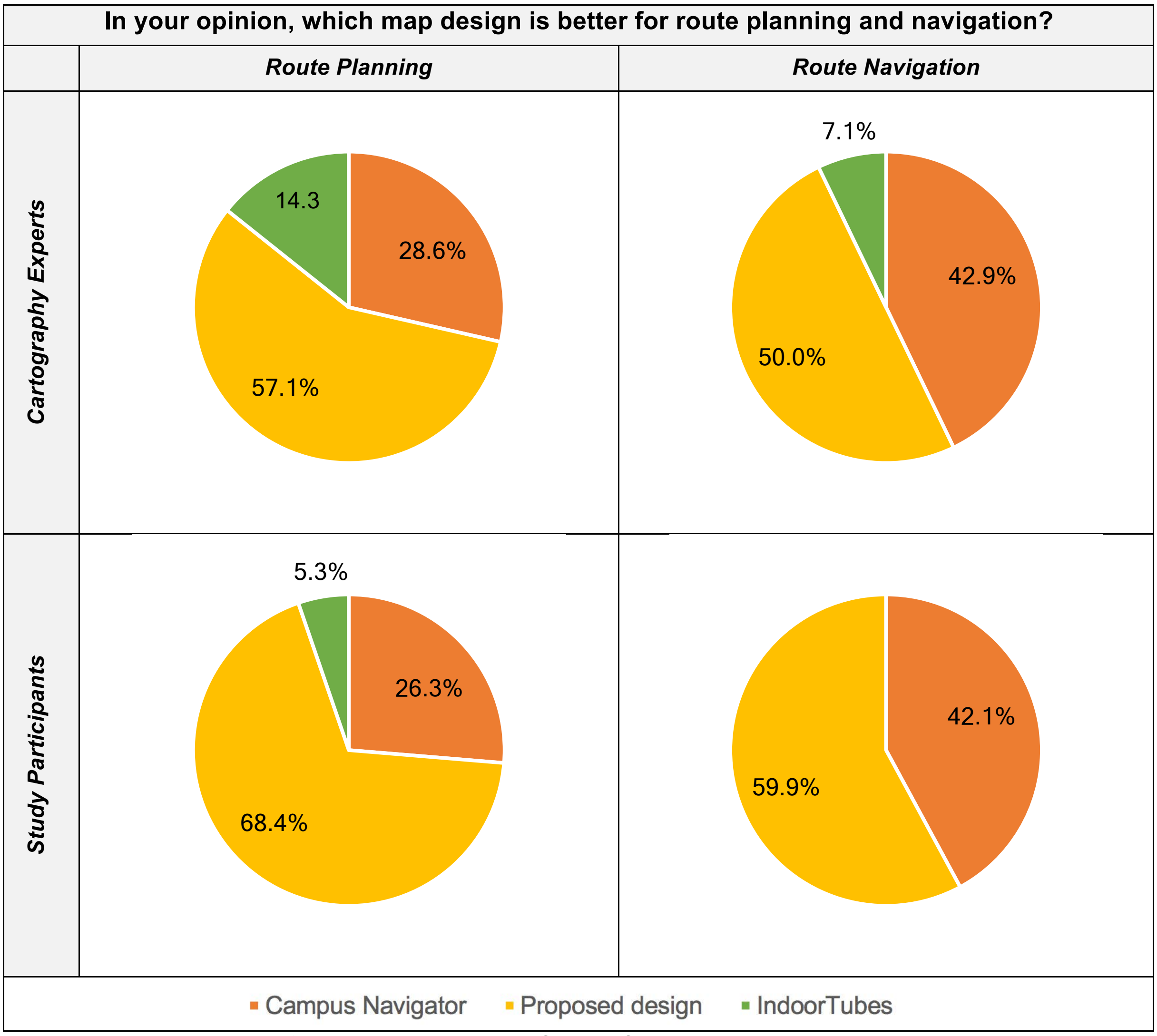


Table 6: Indoor map design preference for route planning and navigation

The proposed design was preferred by most of the participants, especially for route planning. Most of them believe that the amount of information it includes is enough to help someone visiting an indoor space for the first time to find his/her way. It was commented by one participant that it focuses on relevant information such as the corridors and basic indoor landmarks.

A minority of users preferred the Campus Navigator's more traditional approach. They believe that it can better assist in route planning and navigation since it is closer to reality. Most of the users though, expressed the belief that this blueprint based approach is including too much information that is not necessary.

Concerning the IndoorTubes concept, although many participants found it innovative and interesting they were concerned that the average user would find it too exotic, that it is unsuitable for navigation since the corridor design and room placement are too abstract and its depiction of multiple floors at the same time could potentially create many problems in complicated floor plans with a big number of rooms. On the positive side a participant commented that it would have potential in cases where the user needs to switch many floors and the floorplan is relatively simple.

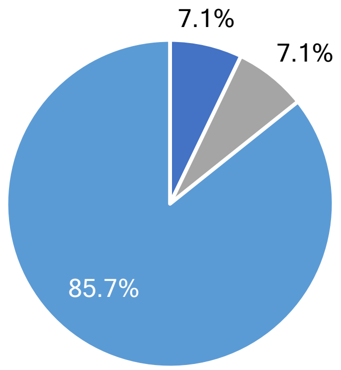
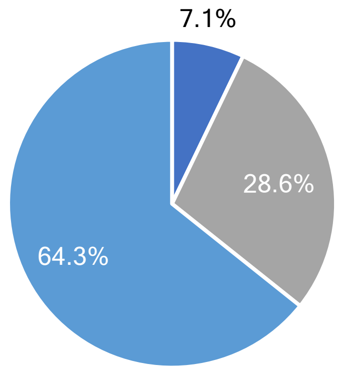
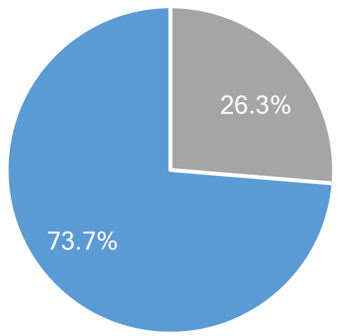
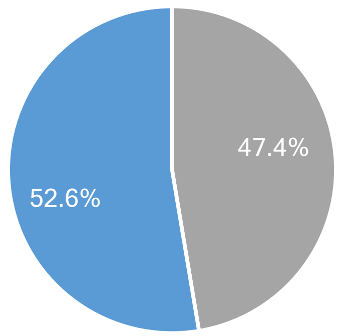
<table>
<tr><th colspan="3">Do you think the amount of information in the Campus Navigator design, for route planning and route navigation purposes is:</th></tr>
<tr><th></th><th>Route Planning</th><th>Route Navigation</th></tr>
<tr><td>Cartography Experts</td><td>
</td><td>
</td></tr>
<tr><td>Study Participants</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">■ Not enough ■ Just right ■ Too much</td></tr>
</table>

Table 7: Opinion on amount of information in the Campus Navigator design

Most participants agreed with the hypothesis that the blueprint based Campus Navigator design includes too much information for planning purposes. Some participants said that the depiction of private rooms and inner connections between them serves no purpose and just clutters the map. Another participant commented that this design works, but it is not very user friendly, because it contains too much visual information.

On the other hand, one of the participants said that although the new proposed design seems to be a better solution for planning, the Campus Navigator design should be preferred for navigation since it depicts details such as size of doors and classrooms that he thinks are important when you are looking for a destination in a new building.

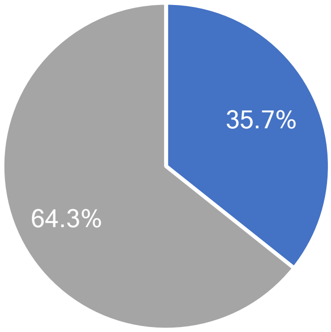
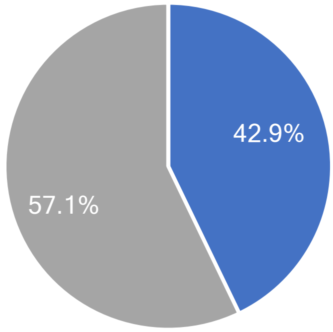
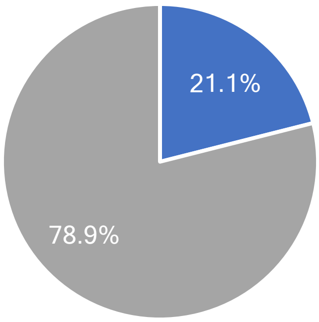
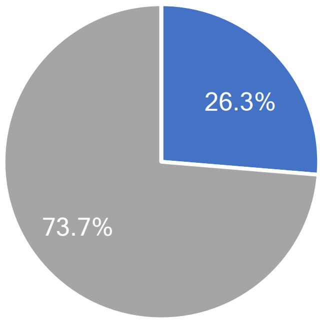
Do you think the amount of information in the proposed design, for route planning and route navigation purposes is:		
	Route Planning	***Route Navigation***
Cartography Experts		
Study Participants		
■ Not enough ■ Just right ■ Too much		

Table 8: Opinion on amount of information in the proposed design

Most participants thought that this design depicts the right amount of information, especially for route planning. Some of them liked the simple design and most of them agreed that preserving corridor shape and relative distances was helpful. A user commented positively on the fact that the overall design language was minimalistic and only a few colors where used.

Some users expressed the opinion that more details could be useful for navigation purposes. Interestingly, none of the participants in either group (cartography experts or students) found the amount of information in this design to be “too much”.

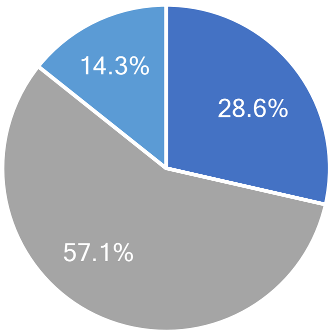
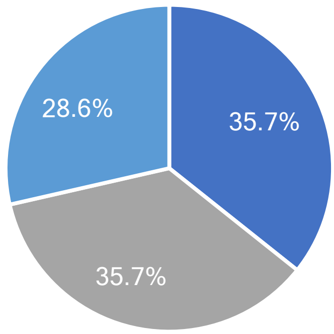
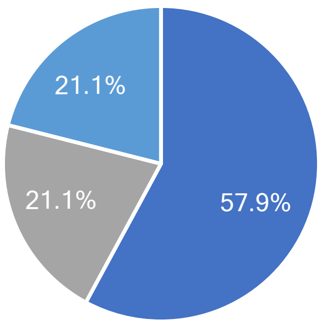
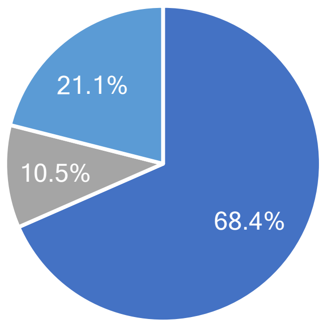
<table>
<tr><th colspan="3">Do you think the amount of information in the IndoorTubes design, for route planning and route navigation purposes is:</th></tr>
<tr><td></td><td>Route Planning</td><td>Route Navigation</td></tr>
<tr><td>Cartography Experts</td><td>
</td><td>
</td></tr>
<tr><td>Study Participants</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">■ Not enough ■ Just right ■ Too much</td></tr>
</table>

Table 9: Opinion on amount of information in the IndoorTubes design

This was the only case that the cartography experts and the user study participants had quite different opinions. But there is a clear trend in that the respondents of the questionnaire thought that this design is more suitable for planning rather than for navigation.

Most participants disliked the fact that relative distances and corridor geometry where not preserved, since they think these are very important elements that assist wayfinding.

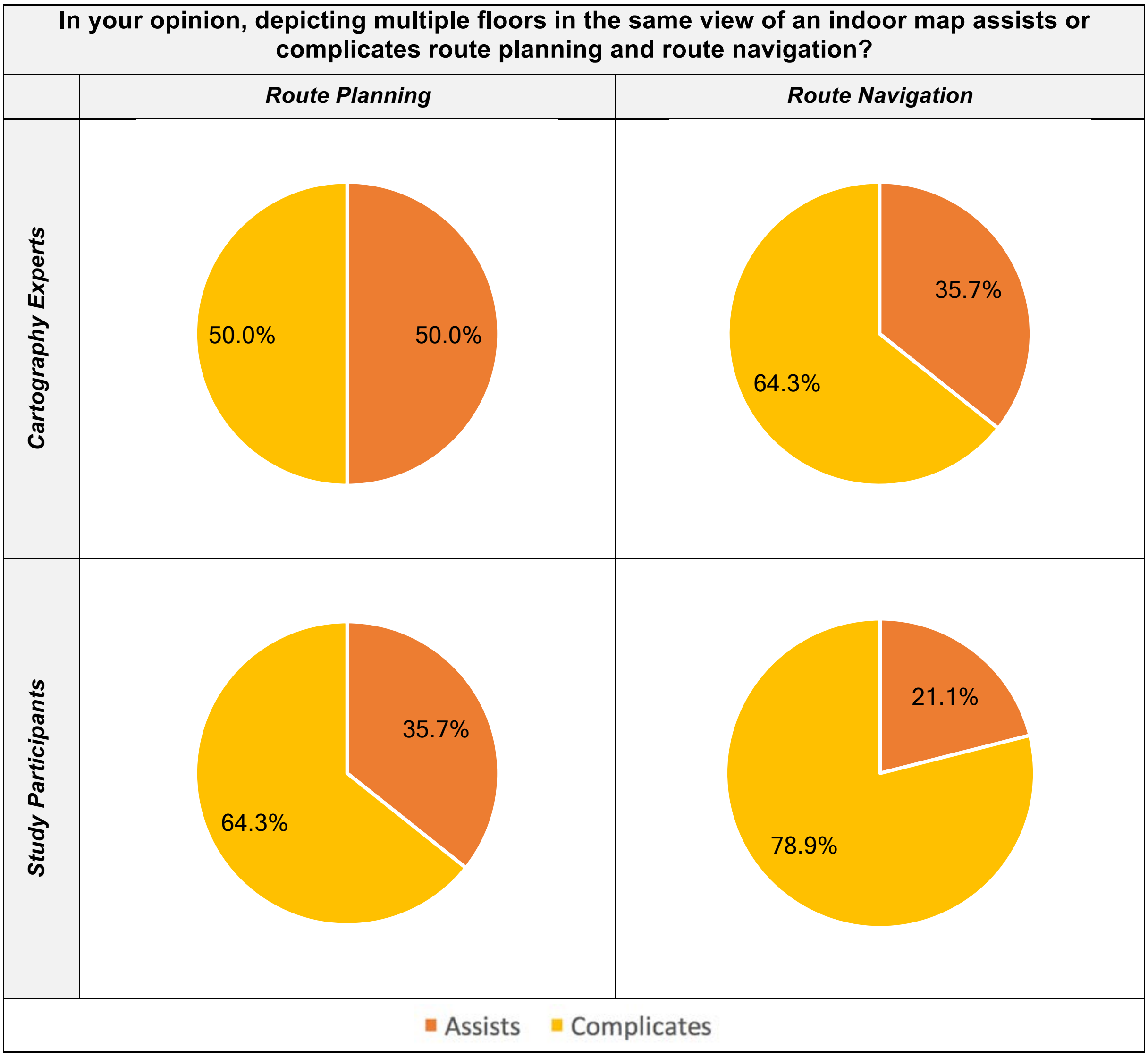


Table 10: Opinion on the usefulness of depicting multiple floors in the same view

Most participants believe that depicting multiple floors in the same view, although having some potential for route planning, has the danger to confuse the average user, especially when navigating. It also depends on the complexity and floor configuration. One participant said she would like to have a multi-floor overview for planning and then switch to a one-floor map for navigation. Another believes that the inclusion of multiple floors is completely unnecessary since reaching the desired floor is usually easy and uncomplicated. As the participant said, one simply takes the elevator or climbs the stairs to the desired floor. The challenging part, that could use the help and guidance of an indoor map, starts when you must navigate through the corridors of the floor on which you want to reach a certain point.

4.3.2 Average importance of building elements

Both the cartography experts and the user study participants were asked to assess the importance of eight basic building elements usually included in indoor maps (see table 11 below). The results are also visualized in Figures 21 and 22.

Average importance of building elements				
On a scale of 1 (very important) to 5 (not important)	***Cartography Experts***		***Study Participants***	
	Planning	***Navigation***	***Planning***	***Navigation***
1. Corridors	1,00	1,21	1,16	1,11
2. Corridors' width	2,86	3,00	3,53	3,37
3. Exact position of rooms	2,86	2,50	2,05	1,95
4. Accurate preservation of distances	2,86	2,71	2,79	2,58
5. Big indoor navigable areas (waiting areas, atriums etc.)	1,79	1,64	1,74	1,95
6. Strict preservation of indoor geometry	3,21	2,79	2,79	2,79
7. Indoor landmarks (like staircases, elevators and WCs)	1,14	1,29	1,37	1,32
8. Outline of the building	2,86	3,29	3,11	3,05

Table 11: Average importance of building elements

The results in both cases are almost the same except for the “Exact position of rooms”. The students who participated in the user study think that this element is more important. They replied to this questionnaire after completing the wayfinding task assigned to them, so perhaps their experience with a real wayfinding situation influenced their answer.

Overall, the corridors, the depiction of big navigable indoor areas and inclusion of landmarks like staircases, elevators and WCs is considered important. On the other hand, corridors' width, strict preservation of distances and/or geometry and the building outline, where not considered to be as important.

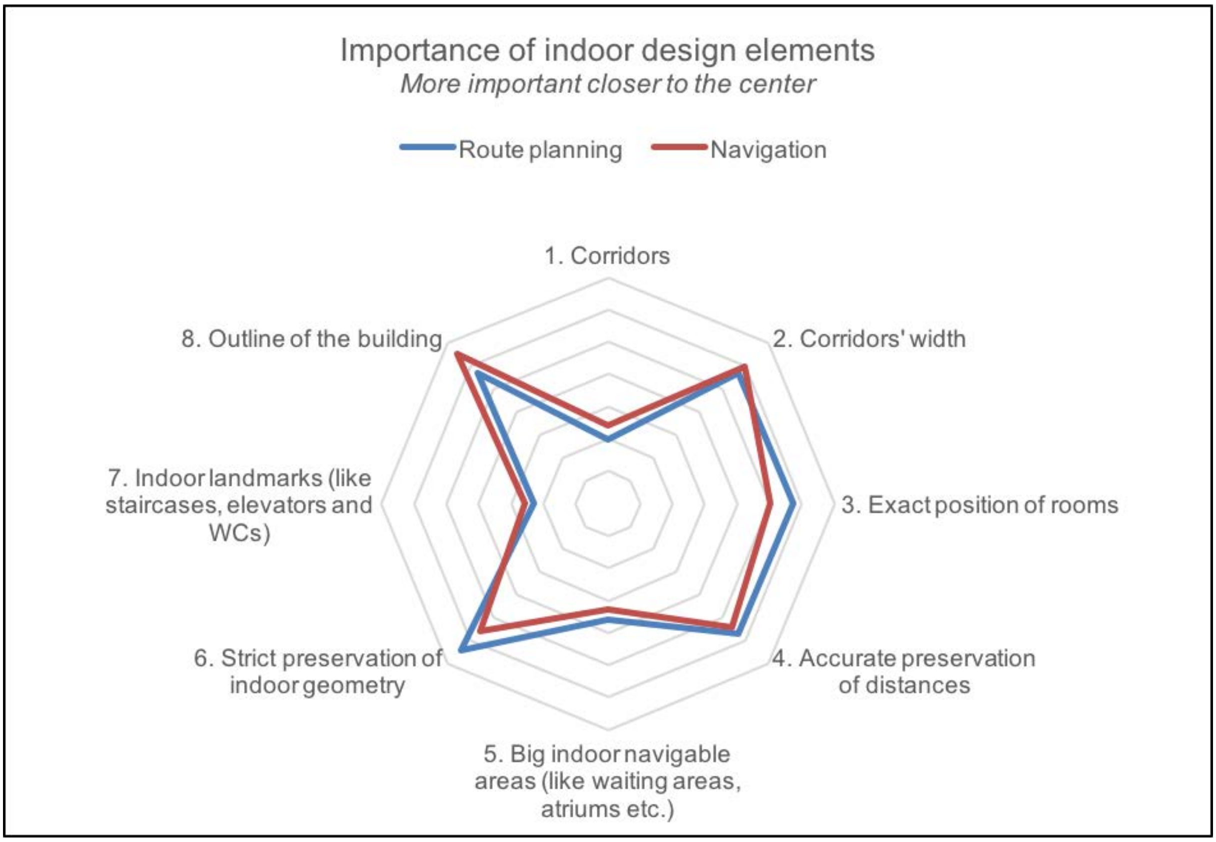


Figure 21: Importance of indoor design elements according to the cartography experts

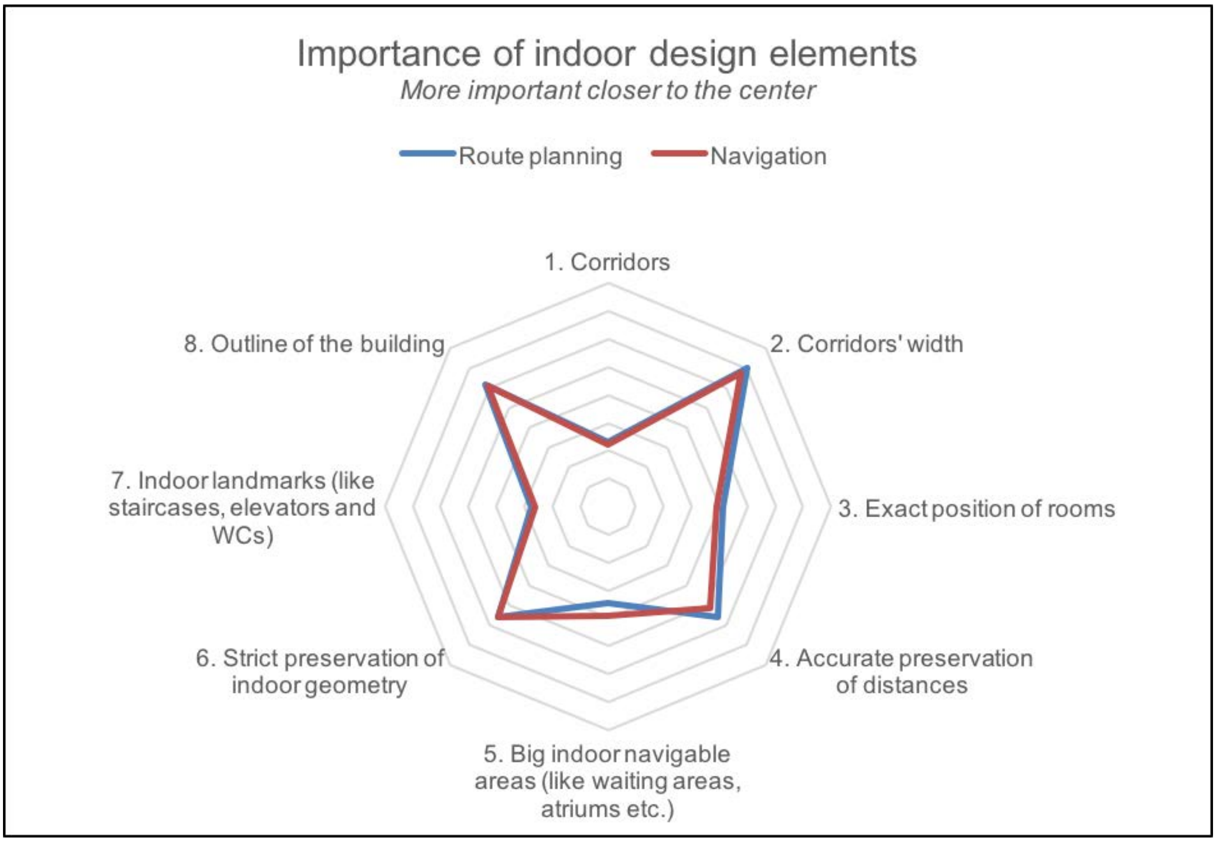


Figure 22: Importance of indoor design elements according to the study participants

4.3.3 Opinion on symbols

The user study participants were asked in the last survey (Appendix 4) to assess the symbols in the three indoor map designs as well. The results can be seen below, in Table 12.

Which design do you think has the most intuitive symbols?		
	Replies	%
Campus Navigator	8	42,1
Proposed design	11	57,9
IndoorTubes	0	0

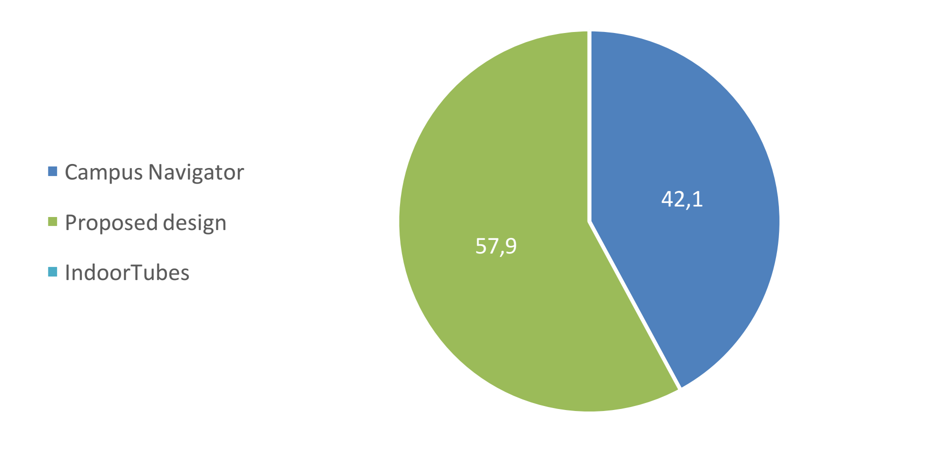


Table 12: Opinion on how intuitive are the symbols of the three indoor map designs

About 42% of the respondents preferred the Campus Navigator symbols. A participant replied that she prefers this approach because she is already used to the standard way the staircases are depicted. Another one liked that some areas of the building are color coded.

About 58% of the participants preferred the symbols in the new proposed design. A respondent said that he liked that they are simple and uncomplicated. Another one believes they are a good compromise between the Campus Navigator and IndoorTubes approaches, striking a balance by being informative without becoming overcomplicated.

None of the users preferred the transit map inspired IndoorTubes design approach, verifying the hypothesis that these symbols do not translate well in a pedestrian, indoor environment. Perhaps because this solution is highly associated with public transportation maps and feels unfamiliar when applied to a different product.

4.3.4 User survey results conclusion

Based on the results of the two online surveys and as can be seen in Tables 5-10, the user preference/satisfaction of the new proposed design is higher than the two alternatives presented to the participants. Additionally, as explained in chapter 4.2 it is also more effective and efficient than the Campus Navigator's design, since in most cases users completed the wayfinding tasks faster. Based on these results it can be conclude that the overall usability of the new proposed design (effectiveness, efficiency and user satisfaction) is superior and its approach, philosophy and design language help with the creation of an indoor map that can potentially better assist a new user of an unknown building reach his/her target.

4.4 Additional observations

In this paragraph, additional findings extracted from the user study and the online surveys will be presented. In each step of the research, information was collected that although could not directly answer the research questions, it was still relevant and interesting.

4.4.1 User study

While conducting the user study certain patterns on the behavior of the participants were noticed. As can be seen in Table 13, some of them rotated their mobile device so the map always pointed to the direction they were walking to, while others did not do that. Other participants preferred to use the elevator to go to the next floor, while others chose to use the staircase. As can be seen in Figures 16 and 17 the point the students had to reach in the ground floor (marked by red circle on the maps they used in the user study on the mobile websites) was equally close to an elevator and a staircase. This was by no mistake since the researcher wanted to give the users the freedom to choose their preferred floor connection and the choice between the two would not be influenced by distance. This has no direct implication with the design of an indoor map, but is still interesting since it gives some insights in the general user behavior in indoor spaces. Therefore, it is presented in this paragraph.

ID	*Group*	*Gender*	*Turning of map*	*Floor connection*	*Phone Brand*	*Mobile OS*
1	B	Female	Yes	Elevator	Samsung	Android
2	A	Female	No	Stairs	Apple	iOS
3	B	Female	Yes	Stairs	Huawei	Android
8	B	Female	Yes	Elevator	Sony	Android
10	B	Female	No	Stairs	Apple	iOS
12	B	Female	No	Elevator	Apple	iOS
13	A	Female	No	Elevator	Apple	iOS
14	B	Female	Yes	Stairs	Apple	iOS
16	A	Female	Yes	Stairs	Apple	iOS
4	B	Male	Yes	Stairs	Honor	Android
5	A	Male	No	Stairs	Apple	iOS
6	A	Male	No	Stairs	Sony	Android
7	B	Male	No	Elevator	Apple	iOS
9	A	Male	No	Stairs	Sony	Android
18	A	Male	Yes	Elevator	Samsung	Android
19	B	Male	No	Elevator	Apple	iOS
20	B	Male	No	Stairs	Nokia	Windows mobile
22	A	Male	No	Elevator	Samsung	Android

Table 13: Additional observations during the user study

Table 13 also includes the device brands and mobile operating systems the participants used. As mentioned in chapter 3.4.2, they were asked to bring their own phones in the study. In theory, this creates a situation where each user had a slightly different experience since they used different devices, but it is believed that this is not really the case since the participants used a very basic HTML5 website with only some text and two images (Figures 16 and 17). Modern browsers have virtually no differences in rendering such basic content that includes no JavaScript or interactivity.

The devices had various screen sizes. This was not a big issue, since they were not that different from each other (1-1.5 inch) and the users could zoom in and out as they saw fit, so each one could adapt the map scale to his/her preference. The results presented in Table 13 are also visualized in Figure 23 so the reader can have a quicker look at them.

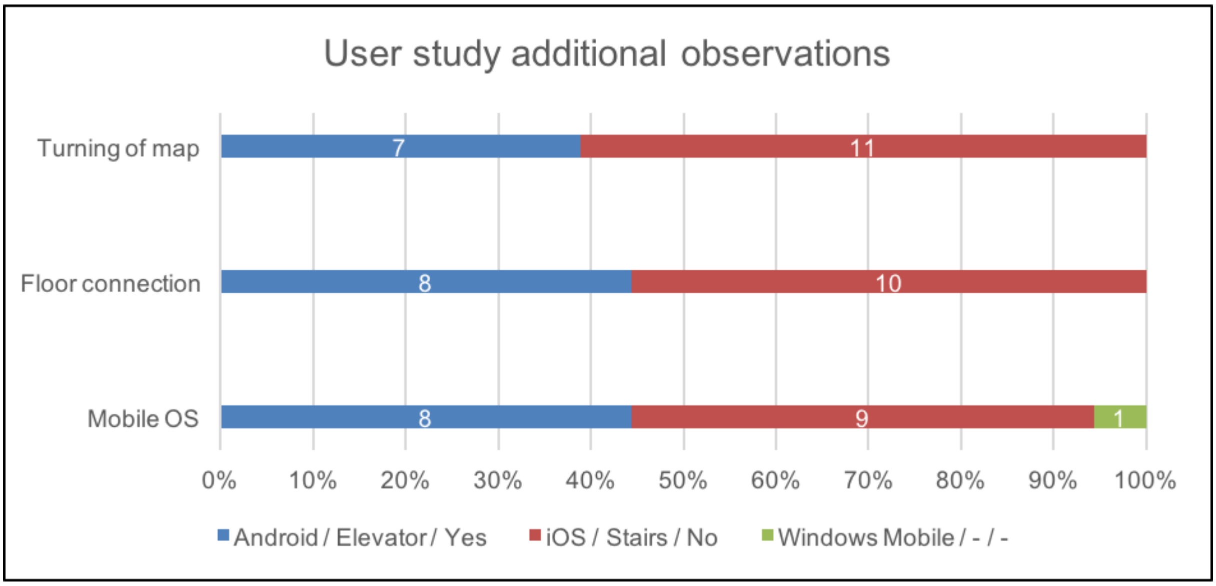


Figure 23: User study additional observations

4.4.2 Pre-questionnaire

Apart from the Santa Barbara Sense of Direction scale, the 22 participants of this survey replied to some other questions. The results can be seen bellow.

<table>
<tr><th colspan="6">Self-assessment questions (average of all replies)</th></tr>
<tr><td>How often do you visit big indoor spaces (shopping malls, transportation hubs, hospitals, campuses etc.)</td><td>2,3</td><td colspan="4" rowspan="3">On a scale of 1 (very often) to 5 (never)</td></tr>
<tr><td>When you visit big indoor spaces, how confident are you that you will find your way on your own?</td><td>2,5</td></tr>
<tr><td>When you visit big indoor spaces, how often do you get confused/lost?</td><td>3,1</td></tr>
<tr><th colspan="6">When you visit an unfamiliar big indoor space, how do you find your way (you can choose more than one)?</th></tr>
<tr><td></td><th colspan="2">Replies</th><th colspan="3">%</th></tr>
<tr><td>Use big, wall-mounted indoor maps</td><td colspan="2">19</td><td colspan="3">86,4</td></tr>
<tr><td>Use signs and number plates on doors</td><td colspan="2">17</td><td colspan="3">77,3</td></tr>
<tr><td>Use mobile phone applications</td><td colspan="2">3</td><td colspan="3">13,6</td></tr>
<tr><td>Other (e.g. asking people)</td><td colspan="2">5</td><td colspan="3">22,7</td></tr>
<tr><th colspan="6">Usage frequency per map type</th></tr>
<tr><td></td><th>Daily</th><th>Weekly</th><th>Monthly</th><th>Yearly</th><th>Never</th></tr>
<tr><td>How often do you use maps (of any kind)?</td><td>15 (68,2%)</td><td>7 (31,8%)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>How often do you use Indoor maps?</td><td>1 (4,5%)</td><td>4 (18,2%)</td><td>10 (45,5%)</td><td>5 (22,7%)</td><td>2 (9,1%)</td></tr>
<tr><th colspan="6">User experience with current commercial solutions</th></tr>
<tr><td rowspan="2"></td><th colspan="2">Yes</th><th colspan="3">No</th></tr>
<tr><th>Replies</th><th>%</th><th>Replies</th><th colspan="2">%</th></tr>
<tr><td>Do you have experience using popular mobile map applications like: Google Maps, Here WeGo, Apple Maps etc.</td><td>22</td><td>100,0</td><td>0</td><td colspan="2">0</td></tr>
<tr><td>Do you know that the above-mentioned commercial applications include indoor maps for select buildings?</td><td>9</td><td>40,9</td><td>13</td><td colspan="2">59,1</td></tr>
<tr><td>If yes, have you ever used the indoor functionality of these commercial applications?</td><td>3</td><td>33,3</td><td>6</td><td colspan="2">66,6</td></tr>
<tr><th colspan="6">Which mobile map application do you most often use?</th></tr>
<tr><td></td><th colspan="2">Replies</th><th colspan="3">%</th></tr>
<tr><td>Google Maps</td><td colspan="2">19</td><td colspan="3">86,4</td></tr>
<tr><td>Other</td><td colspan="2">3</td><td colspan="3">13,6</td></tr>
</table>

Table 14: Additional replies on the pre-questionnaire

The first three questions were asked to assess the participants' confidence in their orientation and wayfinding skills. In retrospect, these questions were unnecessary since the Santa Barbara Sense of Direction Scale was used (chapter 3.7.3).

The fourth question asked the users which methods they usually use for wayfinding in unknown indoor spaces. They could choose more than one option, since in real life the average person uses a combination of techniques to reach a goal. The clear majority of participants prefer to use big wall mounted indoor maps (usually in the entrances) and signs placed around the building. A smaller percentage of them ask other people for help and only a small fraction uses mobile applications. The reason for the latter is probably the fact that indoor navigation unlike its outdoors counterpart (as explained in chapter 1.1) has not reached a sufficient market penetration yet. The underwhelming popularity of indoor wayfinding solutions can also be seen in the replies to the next two questions asking how often the participants use outdoor and indoor maps and applications. Although outdoor maps are clearly a daily part of life for most, usage of indoor products is way more sporadic.

The next three questions were asked to check the participants' familiarization with commonly used map and wayfinding mobile apps. As can be seen by the replies in the fourth part of Table 14, virtually all the respondents are users of mobile outdoor maps. Most major commercial applications include indoor maps of important indoor venues, but the replies reveal a clear trend. Almost 60% of the participants do not even know that such functionality exists. Even from the people who are aware of this feature, only one third have ever used it. Keeping in mind that the user group for this study mostly consists of cartography students, one could conclude that the statistics in the general public will probably be even worse. Most people have no idea that indoor maps exist on the map applications they already use daily and from the minority who knows about them, most people do not even bother using them.

The last question asked which commercial application users prefer. Most of them (more than 85%) prefer Google Maps.

4.4.3 After-study questionnaire

The participants, who showed up for the study, replied to some questions after they completed the task. The results can be seen below, in Table 15. They include the answers of 19 participants in total. Participant 21 could not complete the task due to technical problems (chapter 4.1) but filled in the last survey.

User familiarization with TU Dresden Campus Navigator				
	Yes		**No**	
	Replies	**%**	**Replies**	**%**
Do you know that TU Dresden has a website and smartphone application for its campus (TU Dresden Campus Navigator)?	16	84,2	3	15,8
Have you ever used it?	12	63,2	7	36,8
Do you know that it includes indoor maps (TU Dresden Campus Navigator)?	14	73,7	5	26,3
Have you ever used the indoor map functionality?	14	73,7	5	26,3

Table 15: Additional replies on the after-study questionnaire

Most of the participants have used Campus Navigator. The number of users who used its indoor functionality are more than those who used the outdoor one. This makes sense because if a student wants to find a building he/she can also use any other commercial solution, but for finding a certain room in one of the buildings they must use TU Dresden's product since it is the only one with that content.

4.5 Summary

In this chapter, the results of the research have been discussed. The researcher explained how based on the feedback he got from the cartography experts he improved the proposed design and created the second and final version of it. The results of the two research methods that were used to collect data were presented. The user survey conducted in the Chemie/ Hydrowissenschaften-Bau helped compare the new design with the blueprint based Campus Navigator one from TU Dresden and the feedback that was collected from the two online surveys was used to compare the above-mentioned designs with the IndoorTubes concept. Additionally, the results of which indoor building elements users think are important and need to be included in indoor maps for route planning and navigation purposes and on the design of symbols used for indoor landmarks were discussed. It can be concluded that the new proposed design can better assist users to find a location they want in an unknown indoor environment.

5 Conclusions and future suggestions

In this chapter, the major shortcomings of the research are summarized. Finally, ideas for future research concerning indoor maps and indoor wayfinding in general are proposed.

5.1 Shortcomings

In this paragraph, the shortcomings of this research will be presented. Some of them were anticipated but some were unexpected.

As in most academic user studies, a big challenge was to successfully attract a satisfying number of participants. As mentioned in chapter 3.7.2, 32 participants were invited, 22 replied and eventually 19 showed up. The results of one participant had to be excluded because of technical problems. Because of that incident the number of actual participants in the user study was lowered at 18 and as explained in chapter 4.2 the distribution of participants in the two user groups became a bit unbalanced.

Even before the problems that lowered the expected participation from 22 to 18 students, it was clear that there were not enough volunteers to compare three designs. Because of that and time constrains, it was decided to compare the proposed design with an existing design (TU Dresden Campus Navigator) in the user study. To partially compensate for that it was asked in the two user surveys (Appendices 2 and 4) from the respondents to also compare the two above mentioned designs with the IndoorTubes concept of Nossum (Nossum, 2011). Due to the size and complexity of the Chemie/Hydrowissenschaften-Bau and time constraints, the participants of the two surveys were presented with a concept of the IndoorTubes design and not an actual rendering for the selected building. This was rightfully mentioned by some of them as a disadvantage and they wished they could have compared all three designs applied to the same floor plan in both the user study and the online surveys. Additionally, the participants were of a very specific social and academic background. It would have been interesting if the user group was both bigger and more diverse. Unfortunately, this was not logistically possible.

An issue that was noticed while conducting the user study concerned the participants who chose to use the elevator (Table 13, Figure 23). The waiting times for the elevator to arrive varied. This affected the results, but on the other hand, the researcher wanted to give them the freedom to choose which type of floor connection they preferred to use.

Another issue was that the participants did not “think aloud”. This was partially expected, but not to that extent. As explained in chapter 3.8.1 the researcher did not want to push them too much since he believed that allowing them to focus on the wayfinding task was far more important. Additionally, many users pointed out that they had to reply to too many questionnaires and that they included too many questions, some of them repetitive. A potential way for tackling both issues would have been if instead of asking them to “think aloud” during the study and then fill in a long questionnaire, to conduct a short, recorded interview with prepared in advance questions right after the task completion. This way spontaneous replies could be collected while the experience was still “fresh” in their minds, without them having to fill in text one more time or lose focus when they were trying to find their way in the building. Concerning the online surveys, they could have been briefer and the participants’ fatigue could have been taken more into account.

5.2 Conclusions and indoor map design guidelines

This research indicates that the proposed design that tried to strike a balance between the minimalistic simplicity of the IndoorTubes and the features of the raw blueprint based Campus Navigator performed better in both indoor route planning and indoor navigation and can be suggested as a better solution for indoor maps.

As a result, the following design guidelines for future indoor mapmakers are proposed:

1. Use colors to distinguish the corridors from the rest of the design and to highlight rooms of different functionality and floor connections.
2. The total number of colors should be relatively small.
3. Focus primarily on the corridors and try to preserve most of their geometry since they are the single most important element of a building when it comes to wayfinding.
4. Include big indoor areas (like atriums etc.) since they function as a kind of indoor landmark and help users orient themselves and check where they are on the map.
5. Include other important indoor landmarks like elevators, staircases and WCs. Apart from being useful, their location assists users in wayfinding and orientation.
6. Preserve the overall geometry and relative distances between the different building elements as much as possible.
7. Do not include rooms and the building's outline.
8. Use self-explanatory symbols and make sure their design fits the overall design language you are using. Make them as simple as possible, but avoid abstract ones.

5.3 Future suggestions

Although this thesis proved that simple indoor maps that focus on corridors are preferred towards blueprints for indoor route planning and navigation, it only scratched the surface. A future study could be conducted to compare a design like the one proposed in this thesis and a simplified blueprint-based one, since this seems to be the favored type of indoor maps among the most popular indoor applications.

It would also be very interesting to research how interactivity can affect or improve the indoor wayfinding experience. For example, the user can turn on or off different map elements on will or some automatic function can be developed. This way it will not be necessary to depict multiple floors on the same view as in the IndoorTubes concept and avoid confusing the users.

Another possibility is to create and test a digital solution that includes dynamic maps that change in style and abstraction level based on zoom level or building type. For example, airports or shopping malls could be depicted using a variation of the simplified blueprint, as in most popular applications nowadays, since the "rooms" in these maps are usually stores with glass windows and generally open to customers, but switch to a more minimalistic design that only focuses on the corridors and discards room geometry when depicting hospitals and university or company campuses for simplicity, efficiency and privacy.

If and when indoor wayfinding technology reaches an acceptable balance between performance and cost, it will be necessary to automate the process of transforming architectural plans into proper indoor maps. This is an area that faces many challenges and research needs to be conducted.

Finally, it would be scientifically interesting for all future research to be conducted with a large and diverse user group, closer to the potential real users of indoor maps and not just university students.

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Appendix 1

Prior experience with suggested buildings and time availability

Dear students of the fifth intake,

My name is Vasileios Toutziaris and I am a student of the fourth intake. I am currently writing my master thesis with the title: "Usability of an improved IndoorTubes map design for indoor wayfinding on mobile devices" and I need your help to conduct a user study in one of TU Dresden's buildings. Please take a couple of minutes and reply to the questions below.

Your feedback will help me better plan and execute the study. On a later date I will ask you to participate in it and I would be really grateful if you did :)

I understand that February is the month that you have most of your exams and deadlines, so I want to accommodate as many of you as possible.

The study will take place on two consecutive days. Each participant will pick a day that better suits him/her and will come on his/her own. The whole process will take 15-20 minutes. The last question will try to determine which 2-day time slot is more convenient for you. The survey will be conducted on the time slot that better suits the majority of you :)

Thank you in advance for your time and help :)

* Required

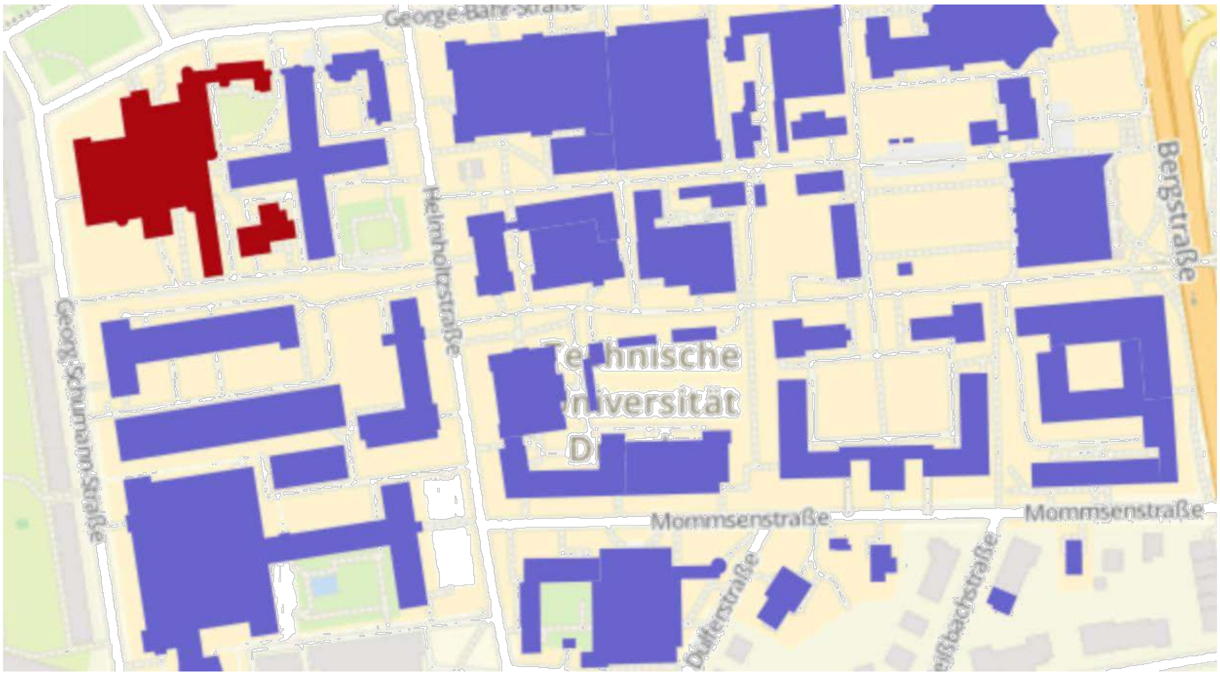
1. **First name & family name** *

2. **Email** *

3. **Have you ever visited the Georg-Schumann-Bau in TU Dresden's campus?** *
   Mark only one oval.

   ◯ Yes
   ◯ No

Georg-Schumann-Bau

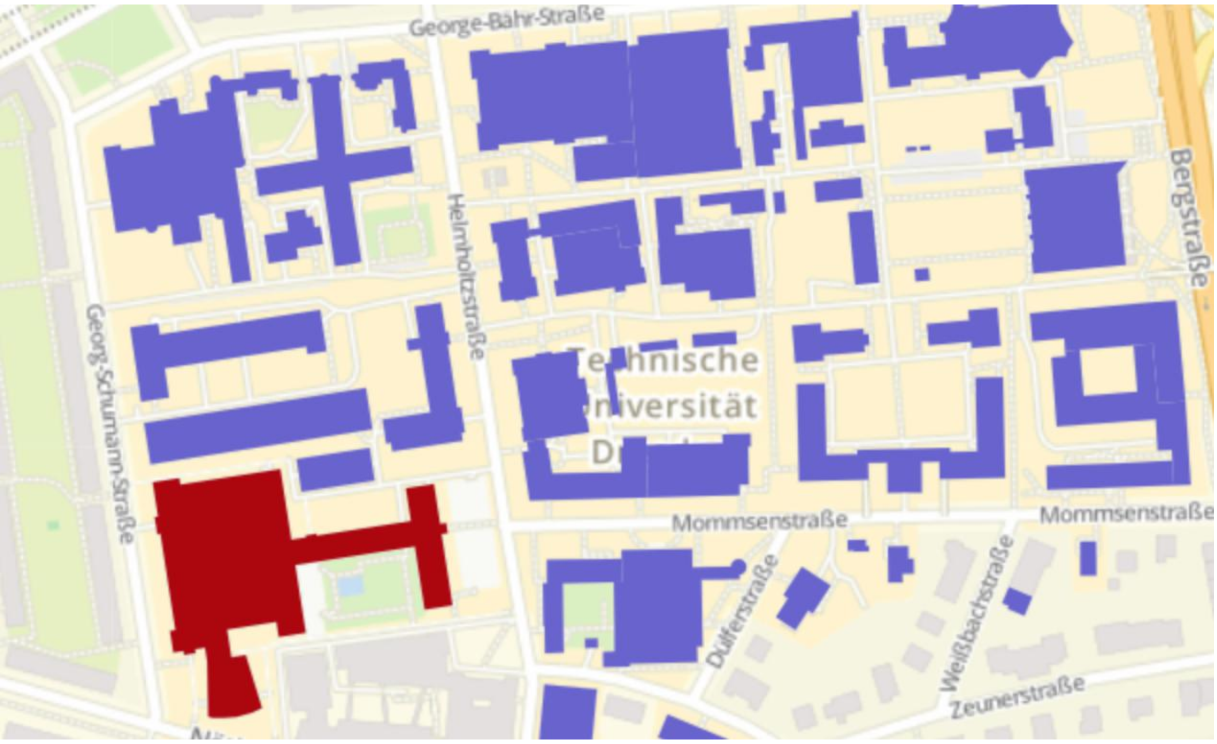


4. **Have you ever visited the Barkhausen-Bau in TU Dresden's campus?** *

Mark only one oval.

- Yes
- No

Barkhausen-Bau

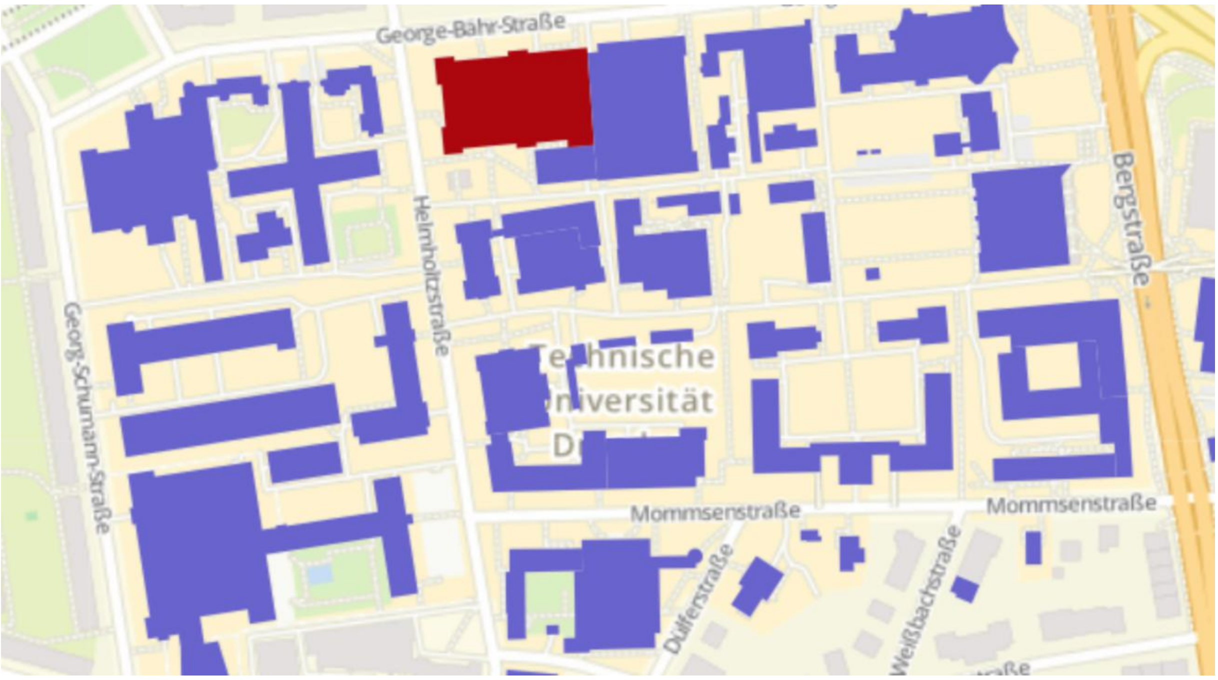


5. **Have you ever visited the Zeuner-Bau in TU Dresden's campus?** *

Mark only one oval.

- Yes
- No

Zeuner-Bau

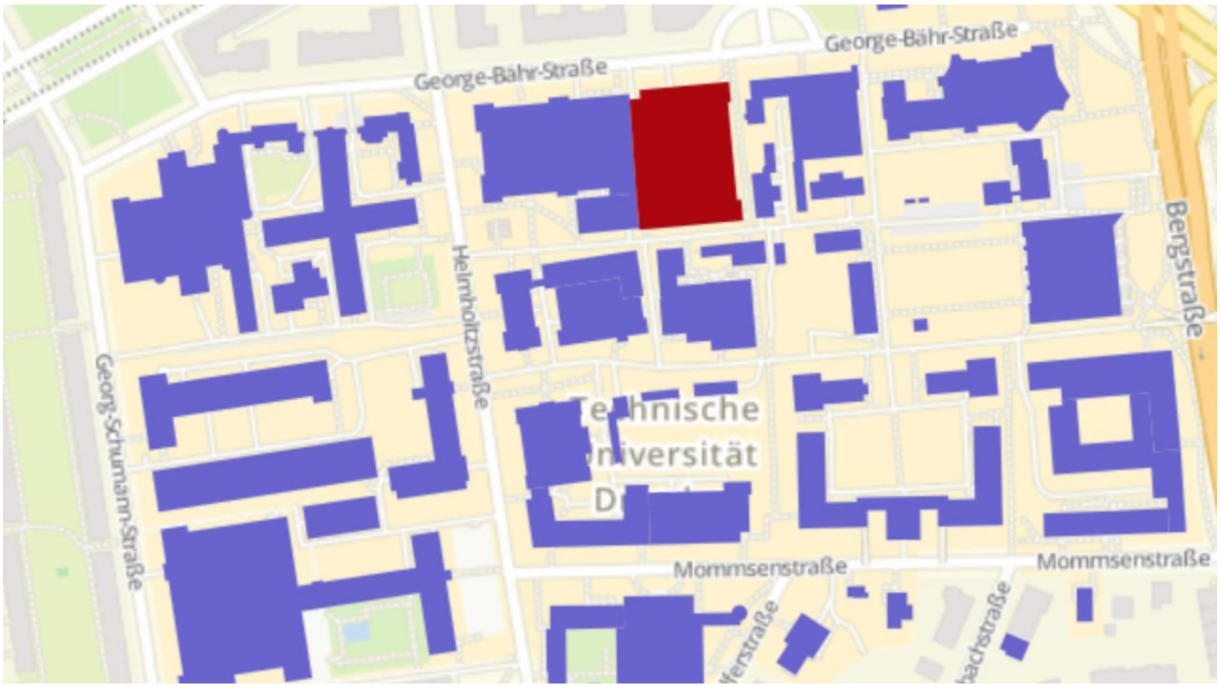


6. **Have you ever visited the Mollier-Bau in TU Dresden's campus?** *

Mark only one oval.

- Yes
- No

Mollier-Bau

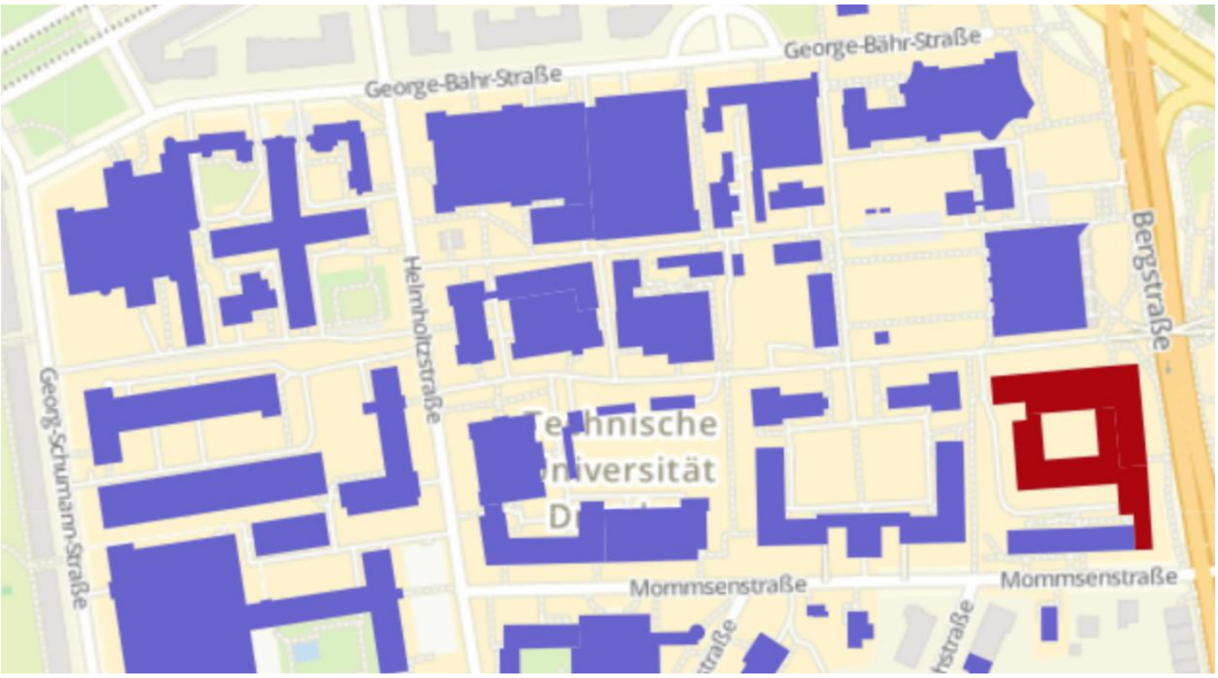


7. **Have you ever visited the Chemie/Hydrowissenschaften-Bau in TU Dresden's campus?** *

Mark only one oval.

- ( ) Yes
- ( ) No

Chemie/Hydrowissenschaften-Bau



8. **Which time slot for conducting the user study better suits you?** *

Mark only one oval.

- ( ) Thursday 16 & Friday 17 of February
- ( ) Thursday 23 & Friday 24 of February
- ( ) Thursday 02 & Friday 03 of March

Appendix 2

Expert evaluation of proposed indoor map design

Dear Sir or Madam,

My name is Vasileios Toutziaris and I am a student of the International MSc in Cartography jointly taught by TUM, TUW, TUD and UT/ITC. I am currently writing my master thesis with the title: "Usability of an improved IndoorTubes map design for indoor way-finding on mobile devices" and I need your help and feedback. I plan to conduct a user study in the Chemie/Hydrowissenschaften-Bau in TUD in mid-February comparing different types of indoor maps.

Below you can see and compare the three approaches. Please take a few minutes, have a look at the different indoor map designs and answer the questions. Your feedback will help me further develop my approach and create a final iteration that will be tested by users in a real-life situation.

I want to thank you in advance for your time and contribution.

Best regards,
Vasileios Toutziaris

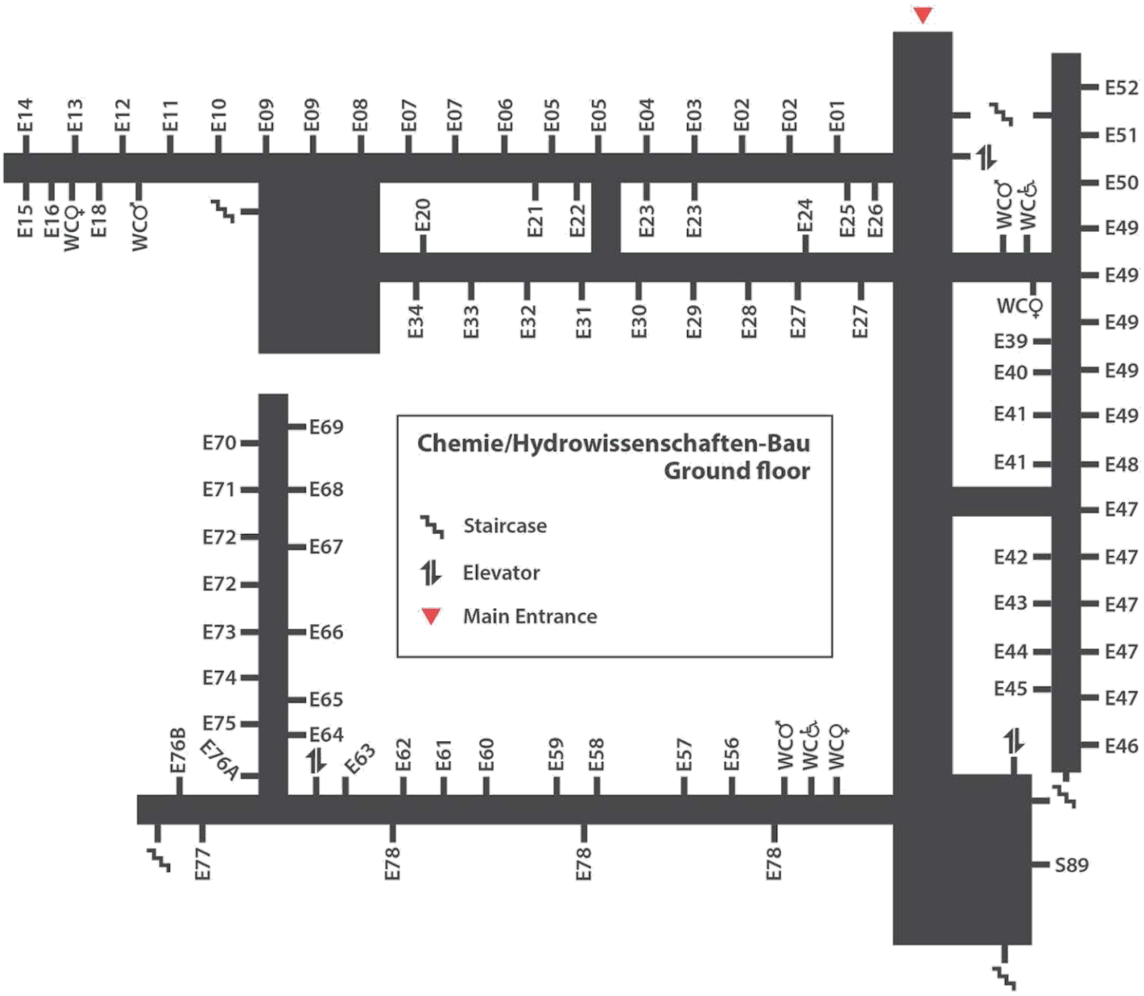
* Required

Design A (Chemie/Hydrowissenschaften-Bau in TUD)

This is the official solution currently used in TUD for new visitors to the campus. It is based on raw blueprints. Similar solutions (usually a bit more generalized) can be found around the industry and implemented in commercial products (like indoor Google Maps etc.). Their basic characteristic is that they depict the whole floor plan. Only one floor is depicted per view.

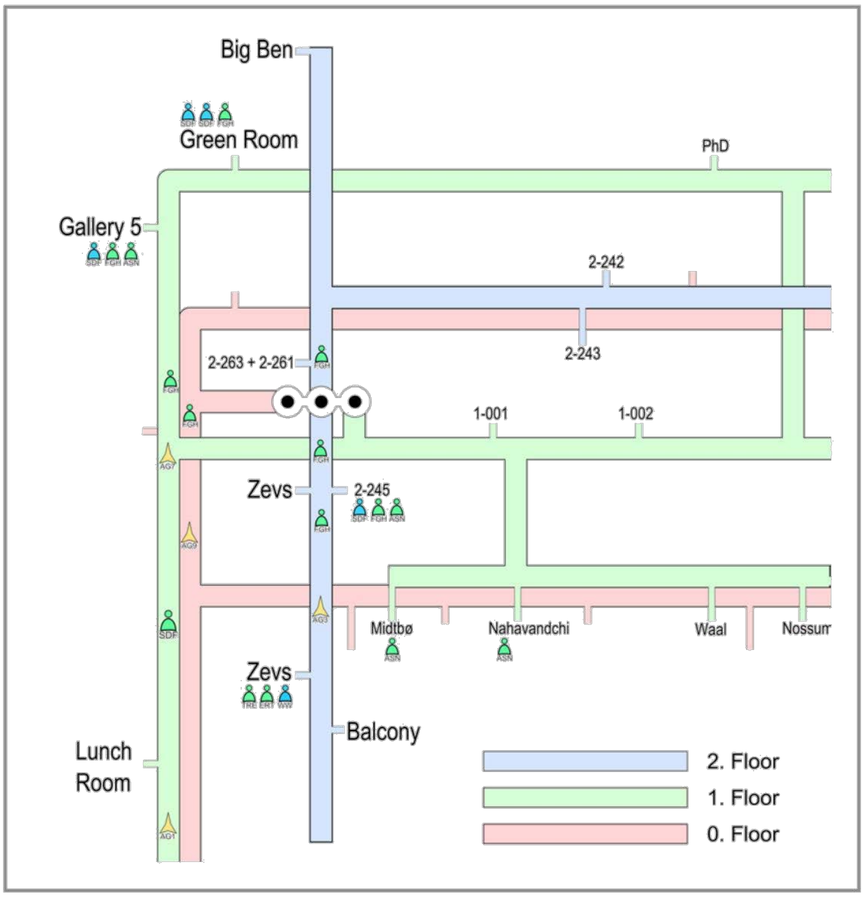
Design B (Chemie/Hydrowissenschaften-Bau in TUD)

In this design the focus is on basic building elements like: corridors, some general shapes for things like big waiting areas, atriums and basic indoor landmarks (staircases, elevator and WC positions etc.). All else that is included in a more traditional indoor map / floor plan is removed. Only one floor is depicted per view.



Design C

This is the IndoorTubes design concept (A.S. Nossum). This is an example from another building (not the Chemie/Hydrowissenschaften) so you can see the design philosophy behind it. All corridors are represented by simple lines, leading to rooms (lines perpendicular to the corridors) and the connections between floors use transit-map inspired symbols. Multiple floors are depicted per view.



1. **First name & family name** *

Route planning

2. **In your opinion, which map is better for route planning?** *

   Mark only one oval.

   - Design A
   - Design B
   - Design C

3. **Please explain your decision**

4. **Do you think the amount of information in Design A, for route planning purposes is:** *
Mark only one oval.
- Too much
- Just right
- Not enough

5. **Please explain your decision**

6. **Do you think the amount of information in Design B, for route planning purposes is:** *
Mark only one oval.
- Too much
- Just right
- Not enough

7. **Please explain your decision**

8. **Do you think the amount of information in Design C, for route planning purposes is:** *
Mark only one oval.
- Too much
- Just right
- Not enough

9. **Please explain your decision**

10. **In your opinion, depicting multiple floors in the same view of an indoor map:** *
Mark only one oval.

- ( ) assists route planning
- ( ) complicates route planning

11. **Please explain your decision**

____

____

____

In your opinion, how important are the elements below in assisting a user with route planning, thus should be included in an indoor map

12. **1. Corridors** *
Mark only one oval.

	1	2	3	4	5	
Very important	( )	( )	( )	( )	( )	Not important

13. **2. Corridors' width** *
Mark only one oval.

	1	2	3	4	5	
Very important	( )	( )	( )	( )	( )	Not important

14. **3. Exact position of rooms** *
Mark only one oval.

	1	2	3	4	5	
Very important	( )	( )	( )	( )	( )	Not important

15. **4. Accurate preservation of distances** *
Mark only one oval.

	1	2	3	4	5	
Very important	( )	( )	( )	( )	( )	Not important

16. **5. Big indoor navigable areas (like waiting areas, atriums etc.)** *
Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

17. **6. Strict preservation of indoor geometry** *
Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

18. **7. Indoor landmarks (like staircases, elevators and WCs)** *
Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

19. **8. Outline of the building** *
Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

20. **Any other elements not mentioned above that you think help with route planning and should be included?**

21. **Any other comments?**

Route navigation

22. **In your opinion, which map is better for route navigation?** *
Mark only one oval.

- Design A
- Design B
- Design C

23. **Please explain your decision**

24. **Do you think the amount of information in Design A, for route navigation purposes is:** *
Mark only one oval.

- Too much
- Just right
- Not enough

25. **Please explain your decision**

26. **Do you think the amount of information in Design B, for route navigation purposes is:** *
Mark only one oval.

- Too much
- Just right
- Not enough

27. **Please explain your decision**

28. **Do you think the amount of information in Design C, for route navigation purposes is:** *
Mark only one oval.

- Too much
- Just right
- Not enough

29. **Please explain your decision**

30. **In your opinion, depicting multiple floors in the same view of an indoor map:** *
Mark only one oval.

- assists route navigation
- complicates route navigation

31. **Please explain your decision**

In your opinion, how important are the elements below in assisting a user with route navigation, thus should be included in an indoor map

32. **1. Corridors** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

33. **2. Corridors' width** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

34. **3. Exact position of rooms** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

35. **4. Accurate preservation of distances** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

36. **5. Big indoor navigable areas (like waiting areas, atriums etc.)** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

37. **6. Strict preservation of indoor geometry** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

38. **7. Indoor landmarks (like staircases, elevators and WCs)** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

39. **8. Outline of the building** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

40. **Any other elements not mentioned above that you think help with route navigation and should be included?**

41. **Any other comments?**

Appendix 3

Pre-survey for user study

Dear participant,

This survey is part of my Master thesis which aims to compare different types of indoor maps. The questions bellow will provide some background information and help assess your spatial abilities. All personal information will be kept strictly confidential and individual details will not be disclosed or identifiable from this survey. You will be assigned a participant ID number so that you will remain anonymous.

Thank you for participating in this survey

* Required

Background information

3. **First name & family name** *

4. **Age** *

Mark only one oval.

- 18-20
- 21-25
- 26-30
- 31-35
- 36-40
- 41-45

5. **Gender** *

Mark only one oval.

- Female
- Male

4. **Country of origin** *

5. **Current occupation** *

6. **Highest completed education level** *

Mark only one oval.

- Bachelor
-

Master

PhD

Other:

9. **Field of completed degree** *

10. **If your current occupation is student, in which field do you currently study?** *

11. **How often do you visit big indoor spaces (like: shopping malls, transportation hubs, hospitals, campuses etc.)** *

Mark only one oval.

	1	2	3	4	5	
Very often						Never

11. **When you visit big indoor spaces, how confident are you that you will find your way on your own?** *

Mark only one oval.

	1	2	3	4	5	
Very confident						Not confident at all

13. **When you visit big indoor spaces, how often do you get confused/lost?** *

Mark only one oval.

	1	2	3	4	5	
Very often						Never

14. **When you visit an unfamiliar big indoor space, how do you find your way (you can choose more than one)** *

Check all that apply.

- Use big, wall-mounted indoor maps
- Use signs and number plates on doors
- Use mobile phone applications
- Other:

15. **How often do you use maps (of any kind)? ***
Mark only one oval.

- Daily
- Weekly
- Monthly
- Yearly
- Never

16. **How often do you use Indoor maps? ***
Mark only one oval.

- Daily
- Weekly
- Monthly
- Yearly
- Never

17. **Do you have experience using popular mobile map applications like: Google Maps, Here WeGo, Apple Maps etc. ***
Mark only one oval.

- Yes
- No

18. **If yes, which is the application you most often use?**

19. **Do you know that the above-mentioned commercial applications include indoor maps for select buildings? ***
Mark only one oval.

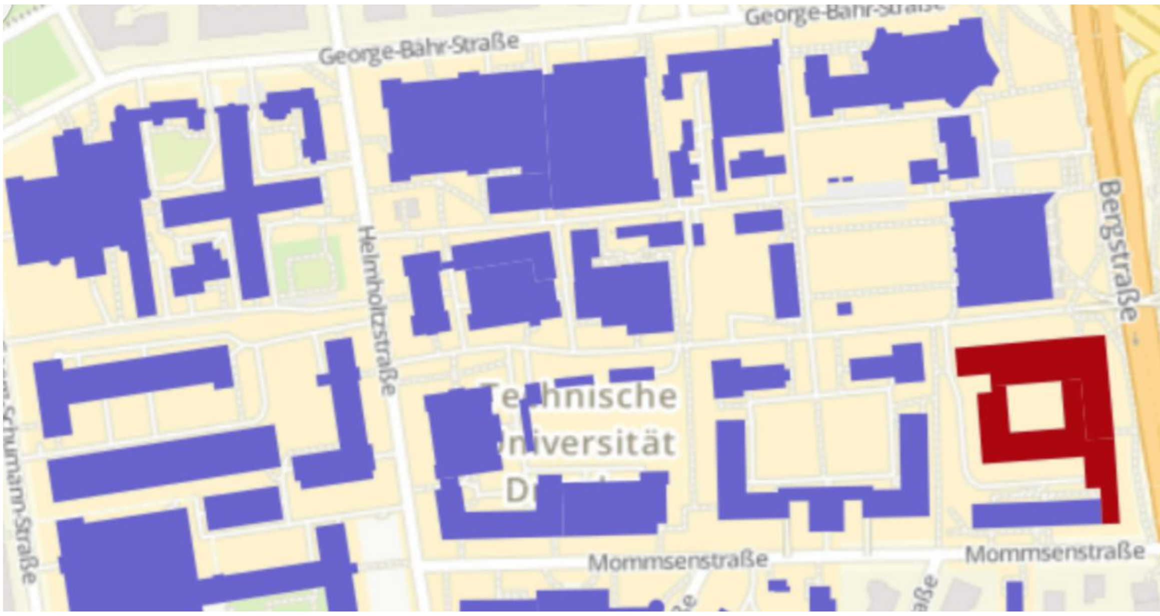
- Yes
- No

19. **If yes, have you ever used the indoor functionality of these commercial applications? ***
Mark only one oval.

- Yes
- No

19. **If not, why?**

20. **Have you ever visited the Chemie/Hydrowissenschaften-Bau in TU Dresden's campus?** *



Mark only one oval.

- No
- Yes, 1-2 times
- Yes, more than 2 times

Santa Barbara Sense of Direction Scale

This is a standardized test that will help assess your spatial abilities.

21. **1. I am very good at giving directions** *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

23. **2. I have a poor memory for where I left things.** *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

25. **3. I am very good at judging distances.** *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

27. **4. My "sense of direction" is very good.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

29. **5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

31. **6. I very easily get lost in a new city.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

33. **7. I enjoy reading maps.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

34. **8. I have trouble understanding directions.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

35. **9. I am very good at reading maps.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

36. **10. I don't remember routes very well while riding as a passenger in a car.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

37. **11. I don't enjoy giving directions.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

38. **12. It's not important to me to know where I am.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

39. **13. I usually let someone else do the navigational planning for long trips.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

40. **14. I can usually remember a new route after I have traveled it only once.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

41. **15. I don't have a very good "mental map" of my environment.** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

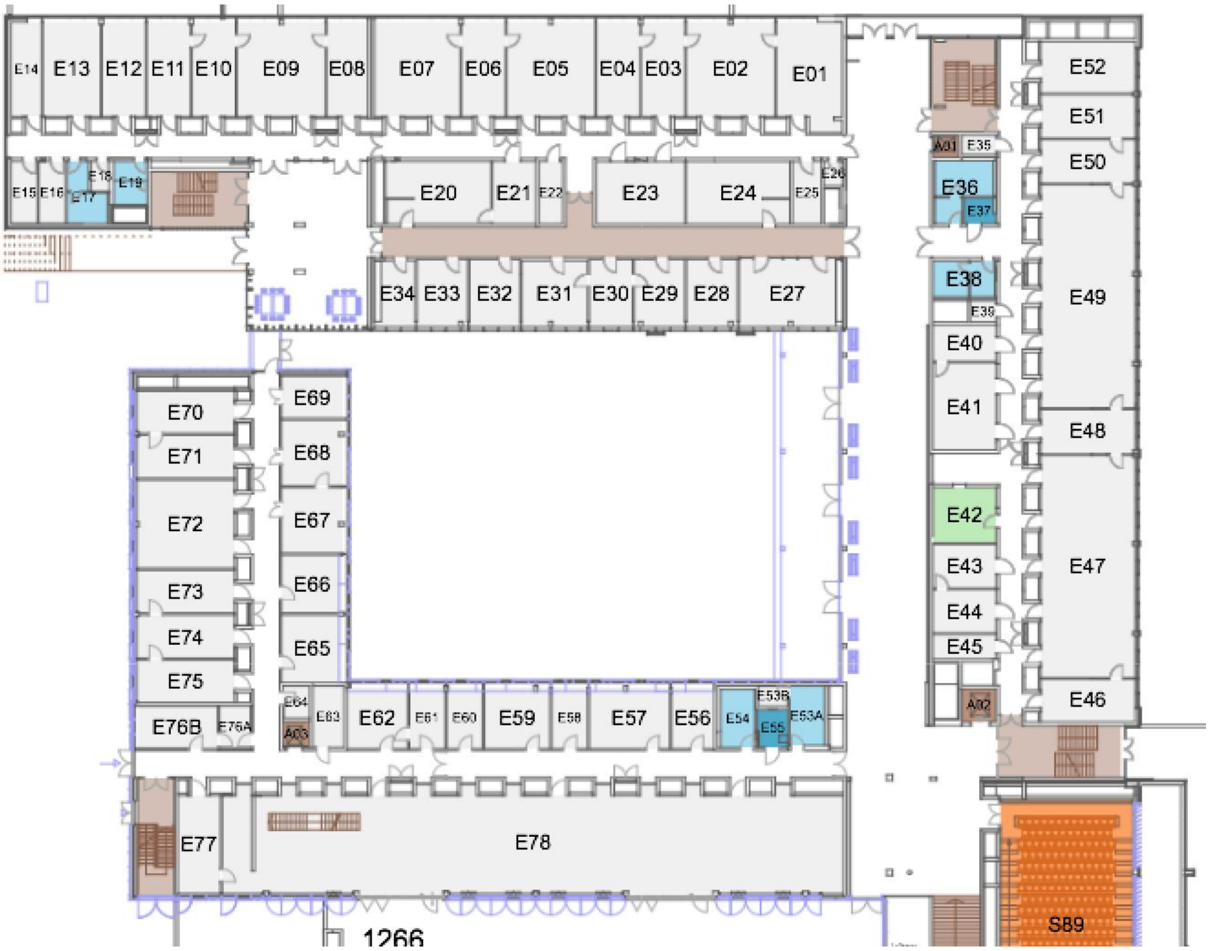
Appendix 4

A few final questions

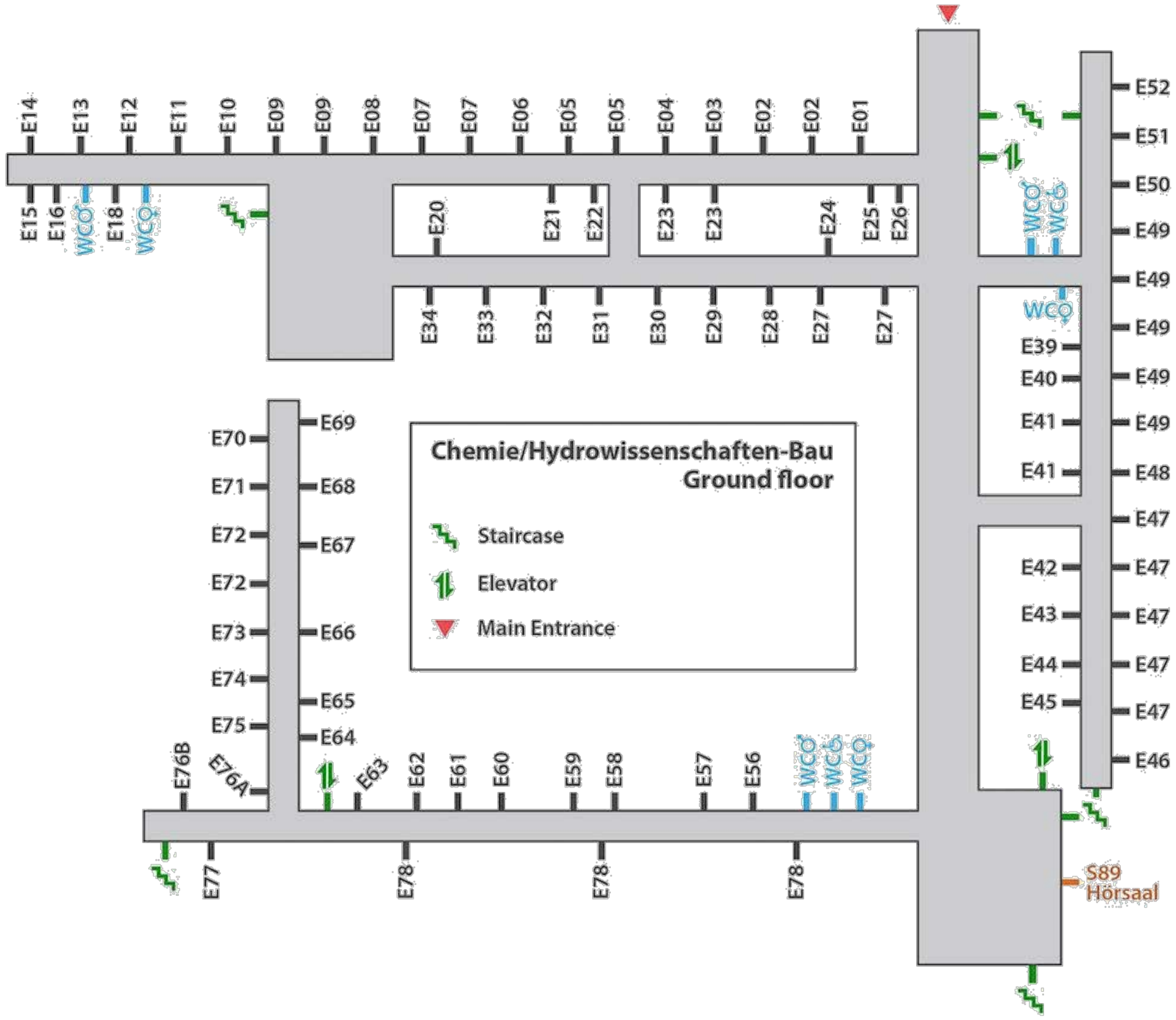
Please have a look at three different designs for indoor maps and take a couple of minutes to reply to the following questions regarding route PLANNING and route NAVIGATION

* Required

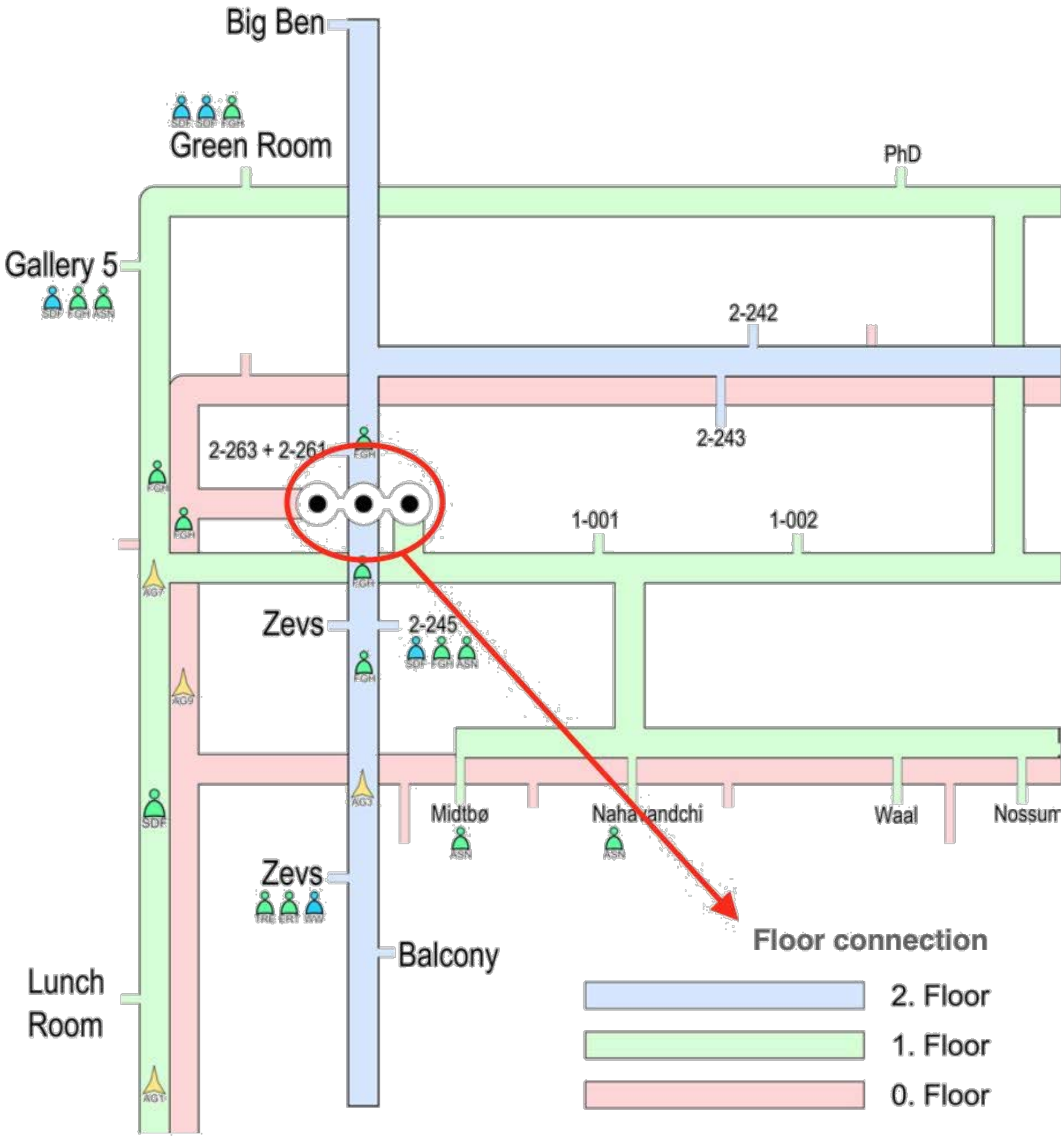
Design A



Design B



Design C (IndoorTubes -- CONCEPT)



6. **First name & family name** *

7. **Model of your phone (example: Samsung Galaxy 7 + Android, or iPhone 6S + iOS, etc.)** *

Route PLANNING

Please answer this first set of questions about the different map designs with the route PLANNING function in mind. Image you are at a particular location and before you start moving you use the map to plan a route to a certain destination

7. **Which map do you think is better for route PLANNING?** *

Mark only one oval.

- Design A
- Design B
- Design C (IndoorTubes concept)

4. **Please explain your decision**

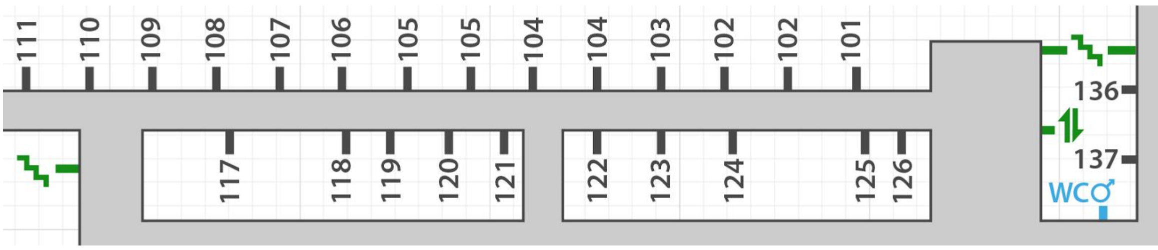
5. **Do you think the amount of information in Design A, for route PLANNING purposes is:** *

Mark only one oval.

- Too much
- Just right
- Not enough

6. **Please explain your decision**

7. **Do you think the amount of information in Design B, for route PLANNING purposes is:** *

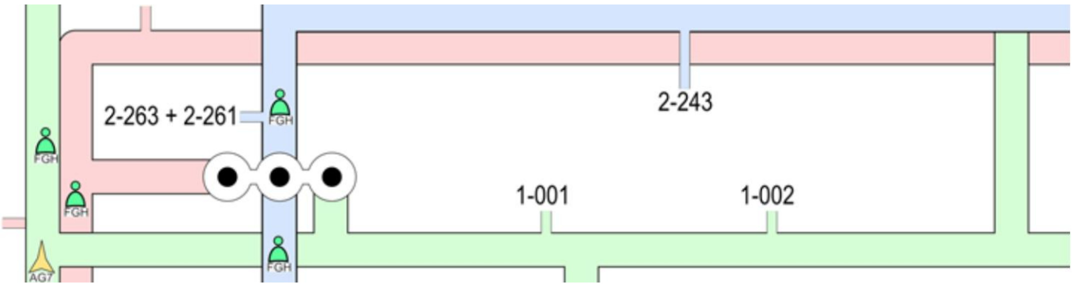


Mark only one oval.

- Too much
- Just right
- Not enough

8. **Please explain your decision**

9. **Do you think the amount of information in Design C, for route PLANNING purposes is:** *



Mark only one oval.

- Too much
- Just right
- Not enough

10. **Please explain your decision**

12. **In your opinion, depicting multiple floors in the same view of an indoor map:** *

Mark only one oval.

- assists route PLANNING
- complicates route PLANNING

12. **Please explain your decision**

In your opinion, how important are the elements below in assisting a user with route PLANNING, thus should be

included in an indoor map

12. **1. Corridors** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

14. **2. Corridors' width** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

15. **3. Exact position of rooms** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

16. **4. Accurate preservation of distances** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

17. **5. Big indoor navigable areas (like waiting areas, atriums etc.)** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

18. **6. Strict preservation of indoor geometry** *
Mark only one oval.

	1	2	3	4	5	
Very important						Not important

20. **7. Indoor landmarks (like staircases, elevators and WCs)** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

20. **8. Outline of the building** *
Mark only one oval.

	1	2	3	4	5	
Very important	◯	◯	◯	◯	◯	Not important

21. **Any other elements not mentioned above that you think should be included?**

Route NAVIGATION

Please answer this second set of questions about the different map designs with the route NAVIGATION function in mind. Imagine following the route that you have just planned in your mind.

21. **Which map do you think is better for route NAVIGATION?** *
Mark only one oval.

◯ Design A
◯ Design B
◯ Design C (IndoorTubes concept)

23. **Please explain your decision**

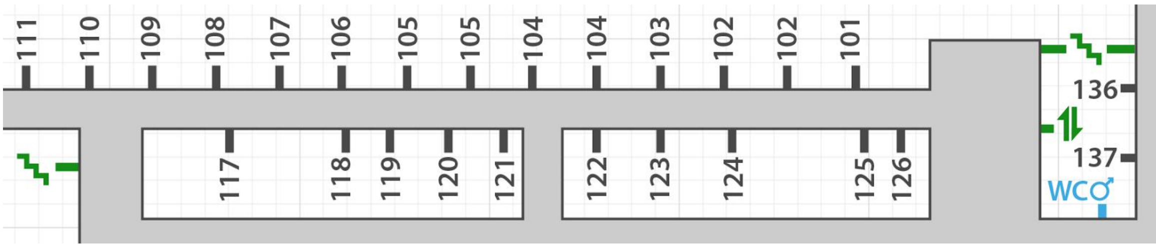
22. **Do you think the amount of information in Design A, for route NAVIGATION purposes is:** *

Mark only one oval.

- Too much
- Just right
- Not enough

25. **Please explain your decision**

24. **Do you think the amount of information in Design B, for route NAVIGATION purposes is:** *

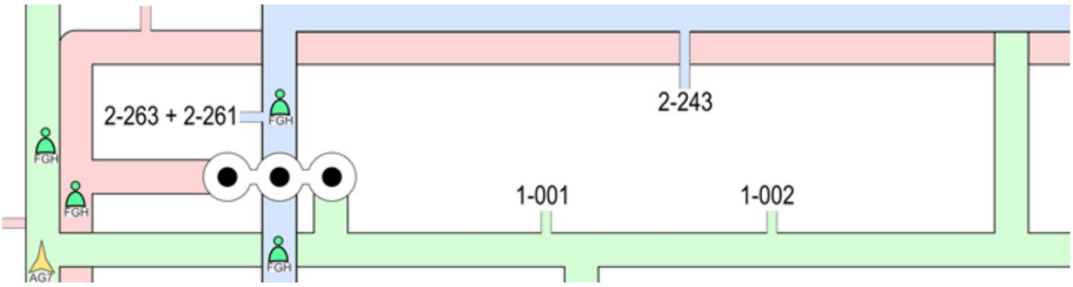


Mark only one oval.

- Too much
- Just right
- Not enough

27. **Please explain your decision**

26. **Do you think the amount of information in Design C, for route NAVIGATION purposes is:** *



Mark only one oval.

- ( ) Too much
- ( ) Just right
- ( ) Not enough

29. **Please explain your decision**

28. **In your opinion, depicting multiple floors in the same view of an indoor map:** *

Mark only one oval.

- ( ) assists route NAVIGATION
- ( ) complicates route NAVIGATION

31. **Please explain your decision**

In your opinion, how important are the elements below in assisting a user with route NAVIGATION, thus should be included in an indoor map

30. **1. Corridors** *

Mark only one oval.

	1	2	3	4	5	
Very important	( )	( )	( )	( )	( )	Not important

32. **2. Corridors' width** *

Mark only only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

34. **3. Exact position of rooms** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

35. **4. Accurate preservation of distances** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

36. **5. Big indoor navigable areas (like waiting areas, atriums etc.)** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

37. **6. Strict preservation of indoor geometry** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

38. **7. Indoor landmarks (like staircases, elevators and WCs)** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

39. **8. Outline of the building** *

Mark only one oval.

	1	2	3	4	5	
Very important	⬭	⬭	⬭	⬭	⬭	Not important

40. **Any other elements not mentioned above that you think should be included?**

General questions

40. **Which design do you think has the most intuitive symbols (building elements, floor connections etc.)** *

Mark only one oval.

- Design A
- Design B
- Design C (IndoorTubes concept)

42. **Please explain your decision**

41. **Do you know that TU Dresden has a website and smartphone application for its campus (TU Dresden Campus Navigator)?** *

Mark only one oval.

- Yes
- No

42. **Have you ever used it?** *

Mark only one oval.

- Yes
- No

45. **If not why?**

46. **Do you know that it includes indoor maps (TU Dresden Campus Navigator)?** *

Mark only one oval.

- Yes
- No

47. **Have you ever used the indoor map functionality?** *

Mark only one oval.

- Yes
- No

48. **If not why?**

49. **Any final comments on Design A?**

50. **Any final comments on Design B?**

51. **Any final comments on Design C (IndoorTubes design concept)?**

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Google Forms

Appendix 5

User study script (final version)

1. Before test starts

I am already familiarized with the two floors of the test building and there are no preparations necessary for the user study area. It is an openly accessible public space. I plan to be there half an hour before the first participant.

Make sure the two test websites function and have the two different URLs printed.

Have a list of participants (including the time-slot they are booked for) printed, split in two groups (based on age, sex and Santa Barbara results).

2. Test person welcome and introduction

Meet the participants in the main entrance of the Chemie/Hydrowissenschaften-Bau.

Welcome them and thank them for showing up.

Give them one of the links (depending on which group they belong, no reason for them to know any of that) and ask them to load it on their mobile phone's web browser.

Ask them to read the detailed introduction on the website, ask if they have any questions. Answer possible questions.

Although everything is written in the introduction, repeat and stress the following two facts:

Do not enter any rooms and disturb people who work and study in the building

Since this is a chemistry building, there are secure rooms and restricted areas. Keep away from them

3. During the test

Film the participants and politely keep reminding them to vocalize any thoughts, comments, opinions they have for the maps and the whole process.

After they finish the task, remind them to answer the final questionnaire (digitally, on their phones – link will be included in the website they will use for the task completion

4. After the test

Make sure they filled in the online questionnaire

Thank them for their participation

Give them chocolate

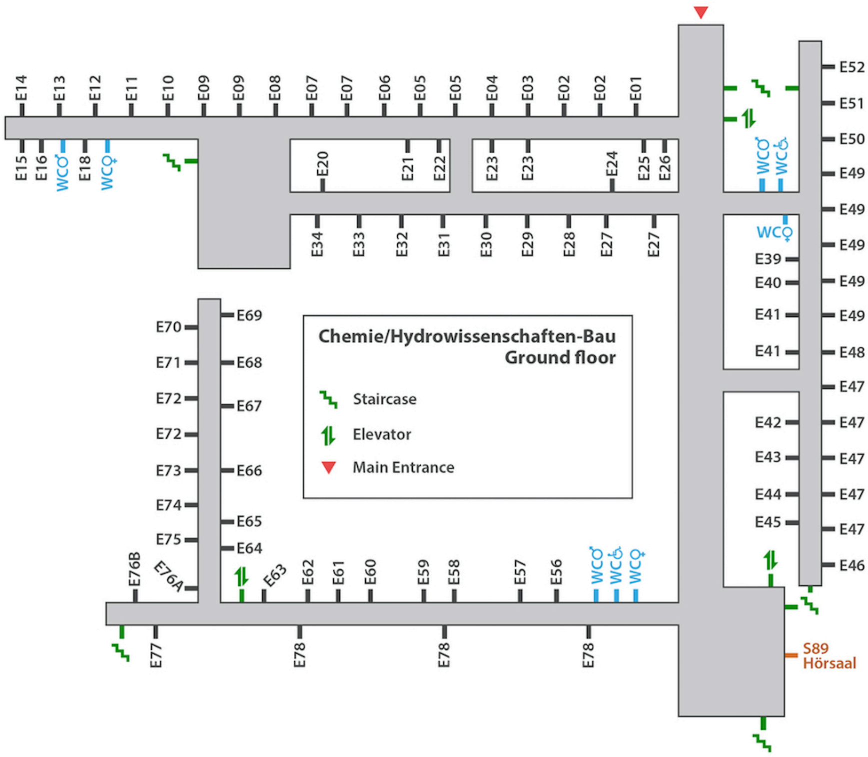
Go back to the entrance and wait for the next participant.

Appendix 6

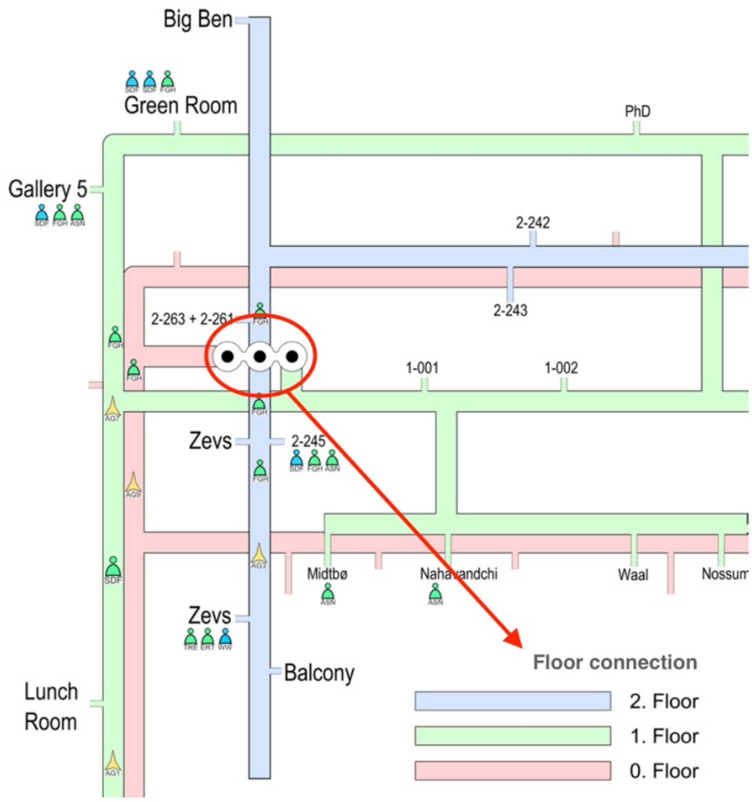
Handout with the 3 different indoor map designs

Design A

Design B



Design C (IndoorTubes CONCEPT)



Appendix 7

Task description as given to the participants before they started the wayfinding task in the Chemie/Hydrowissenschaften-Bau

Dear participant,

You are in the main entrance of the Chemie/Hydrowissenschaften-Bau of TU Dresden. If you scroll down you will find two indoor maps, one for the ground floor and one for the first floor.

Your task is fairly simple:

1. In each floor, have a look at the map provided, take some time with it and try to PLAN your way to the room indicated by the red circle. There are many ways to achieve that. Choose the way that seems better to you. Feel free to zoom in or out.

2. NAVIGATE through the building, using the map provided and reach the target room. Do not enter it, just stand in front of it.

3. When you are done with the ground floor, go to the first one. Again, there are many ways to do that, pick the one you prefer. Find the room indicated with the red circle on the map of this floor, just like you did before. The task is completed :)

Do not enter any of the rooms! The task only requires you to go through the public areas of the building. Please try not to disturb the people working in the building or enter restricted areas.

Try to vocalize your thoughts and decisions regarding the task you were asked to complete. Feel free to express any opinions on the design of the two maps. I will follow you, recording the whole process on video. Keep in mind that all personal information will be kept strictly confidential and individual details will not be disclosed. You will be assigned a participant ID number so that you will remain anonymous.

After completing the task, please take a few minutes and reply to a few questions by clicking "next" on the bottom of this page.

Thank you for taking the time and participating in this survey