Campus Data

How to help students find a workplace?

Creative Technology
Graduation Project
Marloes ten Hage

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Supervisor: Angelika Mader / Critical Observer: Wouter Eggink

ABSTRACT

The University of Twente has access to a large number of different kinds of sensors around the campus, allowing them to collect a lot of useful data. A prototype application that uses this data to help students find a workplace in the university library was developed. In order to create this application, it was needed to narrow down what was achievable with this data. To narrow things down, different conversations with students and the staff of the library where held. During and after creating a working prototype, the students were asked for feedback to tweak the prototype into a user-friendly prototype. The application consists of multiple components that process a data API and store and transform data in a database. A website finally gives students real-time insight into the number of free workspaces available with an accuracy down to individual areas within the library.

CONTENTS

1. INTRODUCTION

1.1 THE PROBLEM:

The assignment for this graduation project was to do something with the data that was available on the campus of the University of Twente. The first couple of weeks of this graduation project was spent on figuring out what was possible with the available data. A starting point was to do something with the data that the students could use. Most of the available data is generated by students, by them being on the campus. With this in mind, different brainstorms and conversations with different people were held, and out of these brainstorms and conversations, it became clear that the library had a problem that could be helped with the available data.

Because the University of Twente is growing, the study space that the University provides is shared by more students. During the exam weeks, it especially becomes busy in the study areas. The library of the University of Twente is used as study area by many students. During exam weeks, the library has longer opening hours, but finding a good workplace stays a challenge. When it is busy, the students need to be lucky to have a spot, and not every part of the library is a good study place for every student. It is not possible for the students to know if they're a good study place for them available in the library, that they can be as productive as they can be.

1.2 THE RESEARCH QUESTIONS:

In this bachelor project an application will be made to help students find a better workspace in the library. This application will indicate how busy it is in the library and will show a history on how busy it was. The application should also be able to show different indicators of the air quality in certain projects rooms. These indicators are the temperature, the CO_2 level, the humidity and if someone is present in the room. They main research question for this bachelor project can be defined as:

> How to design an application that helps students find a workplace in the library?

To answer this question two other important questions needs to be answered. The first question is:

> How to design an application in a user-friendly way?

Because this application is going to be used by students and the system that they use now works (in the end they often find a workplace). The system should be user-friendly otherwise they will not use the application. The other question that needs to be asked is:

> How to use the data provided for the intended application?

There is data provided for this application but how should this data be transformed and used to be able to say something useful, how to get the correct information out of the data.

1.3 THE OUTLINE:

This report consists of 9 chapters. In chapter 1, an introduction about this project is given. In chapter 2, there will be information on what a smart place is, how Wi-Fi triangulation works, and there will be examples of current workspace management systems. In chapter 3, the results of the stakeholder's interviews will be discussed. In chapter 4, there will be more information about the data and the technology that are going to be used in this project. In chapter 5, the ideation phase is described, personas and scenarios are created, a check is done to see if the data is accurate enough, and the first quick sketches are drawn. In chapter 6, a description of the specification phase will be given. The first visualizations are made and evaluated with a user test. Out of the results of these user test is a set of requirements that the application should follow. In chapter 7, a description of the realization process is given. There are explanations on what materials are used to create the application and why. The prototype is tested, and a final version is made. In chapter 8, an evaluation over this project is given and as last in chapter 9, acknowledgments are given to everyone who contributed to this project.

2. BACKGROUND

In this chapter, the necessary background information needed to understand the scope of this graduation project is explained. This chapter is divided into two sections. The first section is related work, which consists of a literature review on smart spaces, an explanation on smart workplaces management systems and an explanation on indoor crowd sensing. In the second section is explained what already has been done in smart workplace find systems and what could be used in this graduation project.

2.1 RELATED WORK:

2.1.1 Literature review:

2.1.1.1 Smart Spaces

There are many types of smart spaces. Nonetheless, all the different types of smart spaces have one thing in common: they are made smart. It is hard to define "smart" because there are many different definitions in the literature. Nonetheless, most definitions are similar to each other. Gračanin et al. [1] define a smart space as an environment that uses sensors and actuators that are built into said space to enhance the functionalities of the space or to provide new functionalities. Additionally, Marikyan et al. [2] require that artificial intelligence (or something close to artificial intelligence) is combined with the available technology to make a space smart. On the other hand, Dalton et al. [3] define that a space is smart simply when the space is improved by smart technologies that make life easier.

However, more detailed definitions are also provided in the literature; such definition is provided by Nigon et al. [4]. Features of smart space share one trait and that is they all depend on context. Context may seem trivial but extracting the relevant information is the key to a space being smart. An even more detailed definition that also incorporates the definition of Nigon et al. [4] is given by Versteavel et al. [5]. They state that there are four fundamental aspects: The first aspect is the ICT is used to improve and manage the services offered; the second aspect is that the quality of life is improved in the space; the third aspect is that the users should play a central role in building a smart space; and finally the fourth aspect is that there is an interdisciplinary aspect in making a space smart, it is not just technology. All these different aspects are incorporated in the definition of Versteavel et al. [5]. In this review the definition of Versteavel et al. [5] is used to define what makes a smart space smart.

With this definition of smart, it makes it easier to look at all the different types of smart spaces that exist. There are three well-known types of smart spaces. The first type of a smart space is a smart city. The goal of a smart city is to provide a higher quality of life for the people living and visiting the city [6]. The second type of a smart space is a smart building. In a smart building, the goal is often to monitor, manage and reduce the energy consumption [7]. The third type of a smart space is a smart home. In a smart home, appliances that are used in homes that are connected with the internet so that the life of the person living there is more comfortable [2]. Other than these three types of smart spaces there are other types of spaces becoming smart. In healthcare, for example, smart systems are used to make hospital rooms, ambulances, and pharmacies smart. In these systems devices measure body position, weight, sleep quality,

blood pressure, body temperature, heart rate, et cetera [8]. Most authors reach similar conclusions despite writing about different types of smart spaces. This suggests that research on one type of smart spaces can be used in the context of another type of smart spaces.

2.1.1.2 Technology

Many different technologies can be used to make a space smart. All these technologies can be divided into four categories. The first category is the sensors. Balandin and Waris [9] describe sensors as the main technology that are used in a smart space because they continuously observe the characteristics of that space. For a sensor to be useful, there needs to be a connection between it and the system. Balandin and Waris [9] note that this connection can be through the World Wide Web (or internet) or the Semantic Web. Nonetheless, with the introduction of Internet of Things (IoT) technologies, the connection between sensors and the system does not need to be made through the World Wide Web or the Semantic Web anymore. Sensors can communicate using technologies such as the Wireless Sensor Network (WSN), Machine-to-Machine (M2M) communications, Low Power Wireless Personal Area Networks (LoWPAN) or Radio-Frequency Identification (RFID) [10].

The second category is middleware. When a connection is made between the sensor and the rest of the system, the middleware takes over. Middleware is a piece of software that processes the information from the sensors and send commands to the actuators. Shih [11] describes middleware as an essential part of the technology. The middleware is needed because systems use different sensors and actuators, and these sensors and actuators might be made and sold by different companies and thus could communicate using different protocols. Middleware can be used to communicate with all the sensors and actuators. Middleware also makes it easier the reconfigure the system should that be needed. Balandin and Waris [9] argue that the success of a smart space depends on reliable communication between sensors and the processing device, something that could be accomplished with middleware. The third category is actuators; they are used to control some external factor that needs to be changed according to the output of the sensors data [12]. For example, when a temperature sensor senses that is getting too cold in a room, an actuator turns the heating on.

Finally, the fourth category is the user interface that allows the user to control the smart space. For this to work, the interface should be easy to use and recognizable for the user. The user interface should ideally work from a mobile device since most users already have these, and modern mobile devices come with enough processing power and data storage capacity for this to work [9]. There are many different technologies available that can make a space smart. As long as technologies from all of these four categories are present in the smart space, it does not matter which specific technology is used.

2.1.1.3 Impact and challenges

There is not much literature describing the impact of smart spaces; there are four different challenges described in the literature. The first challenge is the only aspect of smart spaces on which also the impact is described, and that challenge is the privacy aspect. Röcker and Feith [13] argue that if an environment has been enhanced with technology the social behavior will play a more important role in that environment than the technology. They introduce the "if you can see me, I can see you" -principle[13, p. 5]. This principle is often used when discussing

a feeling of safety. However, this principle does not apply to smart spaces; sensors can see (or sense) the users while the user does not always know about the sensors or how they react because of this could make users of smart space feel uneasy and introduces privacy and safety concerns. Loukil et al. [14] add to this that the increasing rate of data collection in a smart space increases the worries of the data owner about for what the collected data is being used. These privacy concerns should be considered when designing a smart space. Research into the impact of a smart space on users should be done before building a smart space.

Besides privacy, the most significant and second challenge to building a smart space is the complexity of the "smart" ICT system. Verstaevel et al. [5] describe that due to the number of sensors, and because of the scale and the dimensionality of the data, the ICT behind the sensors reaches an unprecedented scale. The data also needs to be stored and manipulated, but because of the amount of data, this becomes a challenge. Shih et al. [11] agree that the complexity of the system is a challenge. They divide this challenge into three subcategories: manageability, connectivity, and programmability. With manageability Shih et al. [11] refers to managing the services that are provided on a large number of devices remotely. With programmability, Shih et al. [11] refer to the composing services onto IoT devices and last, with connectivity Shih et al. [11] refer to the ability to exchange data between the sensors and the system. An aspect described by Nigon et al. [4] that adds to the complexity of a smart space is that the system is not linear. In other words: one small change in the input could lead to significant changes in the output. This makes controlling such a system difficult.

The third challenge is the openness of the system. In smart spaces sensors, devices or sources of data are added while others are taken offline. The system should be able to handle all these different outputs [4]. The infrastructure of the building should also be taken into account; adding a sensor should not require the building to be entirely rebuilt [5]. The fourth challenge is taking the user into account, as described by Gračanin et al. [1] and Versteavel et al. [5]. Gračanin et al. [1] note, for example, that without a correct user interface, the interaction in a smart space becomes complicated. Taking the user into account should help to reduce the privacy and security challenges laid out above. Although there is enough discussion in the literature about the challenges of designing a smart space, all these challenges when they are taken into account, they should not form an insurmountable problem.

2.1.1.4 Conclusion and discussion

This literature review aimed to give insight into what makes a space smart. There are different requirements for a space to be smart. The first requirement is that creating a smart space should be an interdisciplinary project that does take not only technology but also the user into account so that a smart space makes the life of the user more comfortable. The second requirement is with the technology used. The technology used can differ wildly between each smart space, but there are four categories of technologies that each smart space should have. These four categories are sensors, middleware, actuators, and a user interface. When building a smart space, three challenges need to be taken into consideration: the complexity of the system, the openness of the system and the user of the system.

Since the literature used in this literature review is about all different types of smart spaces and not just one specific type of smart space. When designing a smart space, there should be

more research done the specific type of smart space. The research that is available and thus used in this review focusses a lot on smart cities, homes, and buildings. There are more types of smart spaces or spaces that could be made smart. Research into how to make a space smart without defining what a space is, is not that often done, and when literature was found, this literature was old (from the 1990's – 2000). Since how fast technology is changing there should be more research done on this. Another area which this literature review tried but failed to explain is the impact a smart space has on people. It was hard to find research that was done in this field, and before building a smart space, it would be important to know the impacts of making a smart space has. Therefore, this would be an excellent area for future work.

2.1.2 Indoor crowd sensing:

Different technologies can be used to sense and track people indoor. How people are tracked indoor can be divided into two categories. The first category is sensing with human interaction. In this category fall sensors like an RFID reader that senses if someone is there by the user holding an RFID card in front of the RFID reader.

The second category is automatic sensing without user interaction. For this, different techniques can be used. In the past, videos, and surveys were used to monitor people. These techniques are costly and give different problems. For the video, the lighting needs to be good and how good the footage can be analyzed depends on the density of the crowd. For surveys, this does only give a sample in time and thus may not represent the reality; however, with the increase of smartphones and laptops. Crowds can be analyzed through Bluetooth and Wi-Fi. Each device has a MAC address which can be used to track people simultaneously, unannounced and non-participatory [15].

The first step in tracking a crowd through Wi-Fi is scanning the available devices. The scanning can be done through an Access Point (AP), an AP is used by devices to connect to the Wi-Fi. At the AP it is than know which devices is connected to that AP. This data could be used to see how someone moves through a space since their devices connect to different AP as they walk through a space. With the AP it is even possible to measure the distance of a device. This can be done because of the signal strength of the device. The further away the device is the weaker the signal strength. This can be used to decide where people are more accurately. However indoor some factors influence the signal strength and thus the accuracy of the data coming from an AP.

Table 1 Effects of obstruction on Wi-Fi signal [15]

Obstruction	Obstacle Severity
Wood	Low
Drywall	Low
Furniture	Low
Clear glass	Low
Tinted glass	Medium
People	Medium
Ceramic tie	Medium
Concrete blocks	Medium/High
Mirrors	High
Metals	High
Water	High

The number of devices that uses Radio Frequency (for example microwaves and phones use this) and the number of Electronic Device (such as computers, fans, lighting fixtures) influences the signal strength. In the table above can be seen, what for the effect the different obstruction has on the signal strength [15].

To help decide where a person is, multiple scanners can be used to see in which zone the person is. For this often three scanners are used that have overlapping scanning zone. So that when a MAC address is detected by two scanners than when the data is analyzed, it is known that the person is in between these two scanners. Because the signal strength can also be measured if the signal is stronger at one scanner than that person must be closer to one scanner than the other one [15].

2.2 State of the art:

2.2.1 IotSpot:

IotSpot is an app that helps companies to work more agile. With the IotSpot app employees can find a workspace that fits the task they want to do that day, reserve a workspace in advance and if needed reserve a workspace on the go and make it easier for meetups with colleagues for collaboration. The app has an indoor map, on which the different workspaces can be seen. If a workspace is free, there is a green dot, when a workspace is not free there is a red dot, when the workspace is partly available there is a blue dot. They use three types of sensors, there is an occupancy sensor, a Co2 sensor, and a temperature & dB sensor. These sensors are placed in meeting rooms, next to doors, and each workplace has a sensor.

Figure 2.1 Workplace sensor and application interface [17]

The sensor that is placed on each workplace has a Beacon, NFC, IoT-hub and availability indicator which shows the colors that are also used in the app. The app also has a function that lets the user create a colleague list so that if a colleague is visible, the user can see where the colleague is working [16], [17].

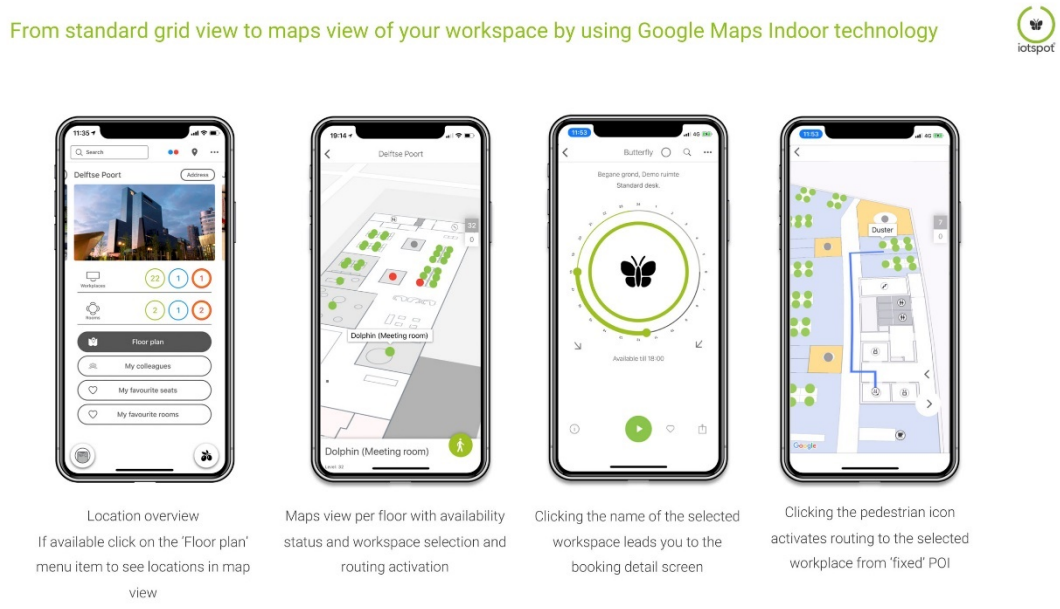

Figure 2.2 User interface of Iotspot [17]

2.2.2 Smartsigns:

Smartsigns is a company that focusses on the new way of working. They want to improve efficiency and make the working environment more pleasant. They have built a system that is called smart workplace; this system helps employees to find a better workplace for them. Sensors are placed on different parts of the building, and with these sensors, it is possible to monitor the workplaces. With this system, it is more comfortable for the employees to find a better workspace. The employees can access online a system that shows a map of the building and where a workplace is still available[18].

Figure 2.3 Interface of Smartsigns [18]

2.2.3 WRLD smart workplace management:

They have created a system that shows 3d maps of the office building; these maps are used in combination of IoT technologies to give a better understanding and monitor the workplace, to improve workplace productivity. In the WRLD system, it is essential that all the operations are unified in one system. They have four core values that the system should do, that is to find colleagues, equipment and workplaces in real time. The user should be able to interact with

the system, reserve meeting rooms with a click of a button. There should be visualization, because this helps monitor the workplace and encourage proactive maintenance [19].

2.2.4 Planon:

With the planon space & workplace management solution, the software they want to create is one system that can be used for space management but also personal management. In their space & workplace system the registration of the workplace, the asset data and the central space in one database. For them, it is vital that all this data is standardized so that the space can be more easily categorized in their divined categories. Their system works with a self-service portal, kiosk, touch screen devices, and their system has a smartphone app; this makes reserving meeting rooms or a flexible workplace. They use sensors to know the real occupancy [20].

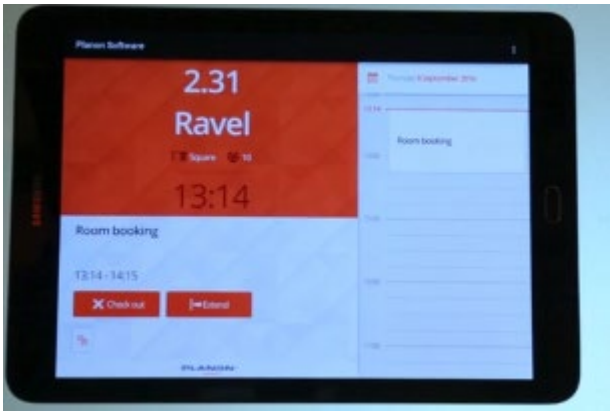

Figure 2.4 Interface of Planon system by a room [20]

Figure 2.5 Interface of the Planon that can be accessed everywhere [20]

2.2.5 Spacefinder:

This is a system that matches the study preferences of students across different study areas across Cambridge. A website was created that showed different study areas that student can select on their preferences. When a student selects different preferences study areas that match those preferences are shown on a map. With a list next to it which shows some information about the study areas. When someone selects a place more information is shown about the place [21].

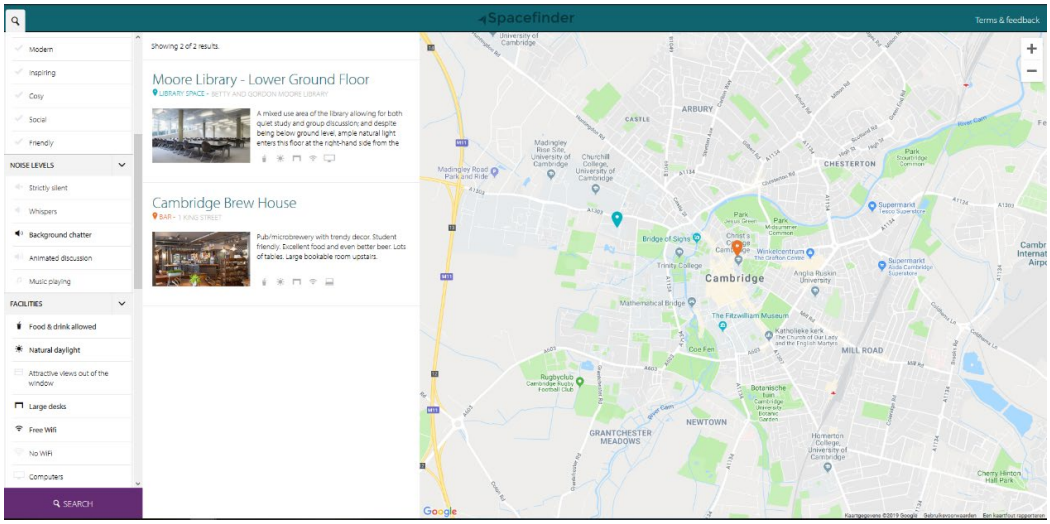

Figure 2.6 Interface of the Spacefinder system [21]

2.2.6 DTU smart library:

At the technical university of Denmark, a new library was built, and this library was built as a study area for the students. When designing this library, they wanted it to be an indoor living lab so that it was not just only a study area but the data from the system could also be used by the students. In the library different sensors where build into the space to measure, count and monitor the library. There where temperature sensors, humidity sensors, particle sensors, CO_2 sensors, sound sensors [22].

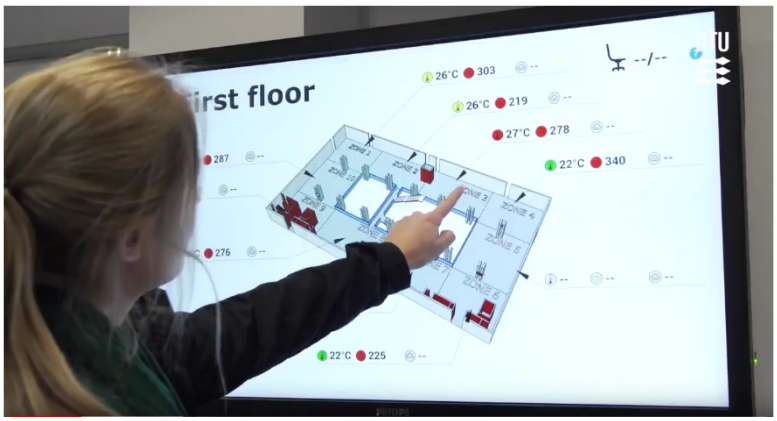

Figure 2.7 Interface that is in the DTU smart library [22]

2.2.7 Conclusion:

The most significant difference that is between IotSpot, Smartsings, WRLD smart workplace management, Planon, and this Graduation Project is to track people; they rely on people placing a card on the table to show they are working there. This gives a more detailed and more accurate picture of what places are available. However, it does not work autonomously. The user of the system needs to influence the system actively.

Another difference between these four systems and this graduation project is the angle. These four systems all have the same angle, and that is that they want to save space. With their system, other companies can save on workstation since nobody has a permanent desk. Whereas, this graduation project wants to help students guide to a study place.

With Spacefinder, it is a similar project. The students can give their preferences to a study place and then the perfect study location is shown, which is also something that could be added to this graduation project. However, Spacefinder does not indicate how busy it is, and it is over the whole city, not just the library.

The DTU smart library is the closest to the system in this graduation project. However, the DTU smart library is more extensive than the proposed system. Their whole library was rebuilt to make the library smart. So, there are elements that could be used in this graduation project.

3. STAKEHOLDERS

With this project there are different stakeholders; different people have an opinion on what should work and what does not work. The first stakeholder is the student.; they are the primary users of the application. For the application to be useful, input from the students is needed. The second stakeholder is the Liberians; they can give more insight into what the problems are, what areas the application could help. The third stakeholder is an expert on privacy and security because, in this project, data is collected it is important to talk with an expert on what is allowed by law and the security problems that should be considered.

3.1 STUDENTS:

Since the students are the primary users of the system, conversations with students on what they want in such a system is essential. To get a better idea of the problems that a student has in the library, an interview with a student was held. After this interview, it became clear that there was more information needed and a focus group was organized to have a brainstorm on what the best system would be.

There are a couple of different problems identified that the library has during the interview and the focus group. Three main conclusions were drawn from the interview and the focus group. The first conclusion was that the students would like to see a system that could tell them before going to the library if there was space.

The second main conclusion was that this system should not be an app but a website that could be accessed on a mobile phone as well. That this system should be easy to access and that they would like if there would also be a screen in the library which they could use to find a workplace.

The third conclusion was that they would like to have more information about the project rooms. Now it is not easy for students to see if a project room is free, and thus they do not go and sit in a project room if they did not reserve a project room beforehand. This leads according to the students to, inefficient use of these rooms and that if they knew when a project room is reserved the project rooms would be used more efficiently. A more detailed description of the interview and the focus group can be found in Appendix A.1.

3.2 LIBRARY STAFF:

To get a better idea of what problems the library experiences and which areas they would like help with an interview was held with the head of the library. During this interview, a couple of different areas where identified that could be improved with this application.

The first area was in the project rooms. The library would like to have more information about the project rooms. When are they reserved? How often do no-shows happen? How often do students leave early? How often do students show up late? How many people are at ones in a project room? The library would like to get answers to these questions.

The second area was in the open space. Especially during exam weeks, it is busy in the library, and thus people walk around often to find a workplace. By walking around the other students that are working, there are taken out of their concentration, which is not optimal. So, the library would like a system that could decrease the number of people that are walking around in the library. For a more detailed explanation on this interview can be found in Appendix A.2

3.3 SECURITY AND PRIVACY:

The data that is used in this project is collected automatically and the GDPR. An interview with someone who knows a lot about security and privacy was held. During the talk to the security and privacy expert, it became clear that this project does not infringe on any rules laid by the government but that there should be questions if the goal of the project and the use of the data to accomplish this goal is the correct method. It would, for example, be better to place a sensor under each table that measures if someone is present because with that data it is not possible to learn anything more. With the data from the Access Points, it is possible to measure a lot more, and that data could be used in a maleficent way. The data that is used in this project is entirely anonymized, in the sense that the data should not be able to lead back to one specific person. However, in the academic world, there is not yet a clear consensus on when data is completely anonymized, and thus this could mean that the data is not entirely anonymized. For the security of the data, because the data is as anonymized as possible, the data should not necessarily be extra secured, and all the information that can be extracted from the should be oke to show. A more detailed description of this interview can be found in Appendix A.3

4. TECHNOLOGY

In this chapter, the different technologies that are going to be used in this graduation project are explained. First, the available data is explained; in the second part of this chapter, guidelines are given for different part of the application. There are guidelines for how to design a user interface for a web application, there are some problems defined that comes with big data, and there will be an explanation on the technology that can be used for building the web application.

4.1 SENSOR DATA:

There are three different ways the data is gathered in this project. The first is a CO2 sensor; this sensor is placed in different project rooms in the library. This sensor is placed in the following project rooms: 193A, 193D, 193G, and 193K.

The second sensor called a space sensor. This sensor measures a couple of different things, it measures movement (through passive infrared), it measures the temperature, and it measures the humidity in the project room. This sensor is placed in the following project rooms: 193A, 193B, 193D, 193E, 193F, 193G, 193I, 193J, 193K, 193L, 193N.

Table 2 The different project rooms in the library and what sensors that are placed in which project rooms

Project rooms	CO2 sensor	Space sensor
193A	X	X
193B		X
193C		
193D	X	X
193E		X
193F		X
193G	X	X
193H		
193I		X
193J		X
193K	X	X
193L		X
193N		X

The last way the data is gathered is not through a sensor but an access point. Throughout the whole campus of the University of Twente, there are access points placed so that students and staff members have access to Wi-Fi. Each access point can count the number of devices is connected to a specific access point. Usually, this would not give accurate enough data since nowadays everyone also carries at least a smartphone that is connected to the Wi-Fi. However, to be able to connect to the Wi-Fi the student/staff member uses an account. These accounts can be counted and thus give a more accurate representation of the number of people in a place. With these access points, the application could be scaled so that it could work with all the self-study area's that the University of Twente has. The only requirement is that there are

multiple access points in that area so that it is a bit clearer in which part of the study are the students are studying.

4.2 APP TECHNOLOGY:

4.2.1 User interface:

During the stakeholder interviews, it became clear that this application should be accessible through a website, but that is very important for the application to be accessible through a mobile phone. Since the application should be as easy to access as possible. This makes the user interface more complicated since it should work on a standard size computer screen and a phone screen. A problem that arises when designing a user interface for both web applications and website is that the user interface should work in portrait mode (web application) and landscape mode (website).

Since the invention of the graphical user interface, there are guidelines made for how to design such an interface. However, when web application became popular, the guidelines of the website where copied but the interface of a web application differs from a website so there should be new guidelines on how to design such an interface. Wroblewski and Rantanen [20] developed 19 guidelines that a designer should take into account. Below are the most important guidelines.

- The number of windows should be minimized. This reduces the mental load of the user.
- The layout should be consistent; there should be a constant value for fonts, tables, and visual elements.
- Avoid double clicks, on a website the user is already not used to double-clicking on a mobile phone a user does not double click.
- There should be pull-down menus, checkboxes, the users are familiar with these elements on a website, and they save screen space because they allow more possible options.
- The application should use the standard functionalities of a web application and a website. This helps the user transform the knowledge for the website to the web application.
- The application should manage time and workflow within the application. When the flow of the application is correct, it will guide the users through the application and thus help them find what they need.
- When designing the interface, the aesthetic integrity of the interface should be considered. When the aesthetic of the application matches the applications get a bit of a personality, and this helps the user enjoyment, however by placing too much emphasis on the aesthetics the usability could suffer.

4.2.2 Big data:

What classifies as big data depends on what application the data is used for. For one application 1GB can be big data but for another application 1TB or bigger can be big data. Since the world has become more digital the increase in which data is created has increased a lot [23]. This is

because of the use of sensors, the internet, smartphones et cetera. For smart spaces that are IoT enabled there are a couple of problems that arise when speaking about big data.

The first problem is that when an IoT enabled space is built, there is no historical data. However, when in an application historical data is used, it often used to predict certain things in the IoT enabled space. To process all the data often a lot of processing power is used. When the system also needs to deal with historical data, there is even more processing data needed which is often forgotten to think about.

The second problem is that the data that is used in the application is not perfect. The data is noisy, the data is biased, and there will be multiple data streams that all have a different interval on when the data is updated. There should be thought about how to deal with this data and how to transform this data, to help improve the quality of the data real time. What should be done to unify the data and how would that work if new data sources are added [24].

These problems should be kept in mind when setting up the infrastructure of saving and using the data. The historical data should not form a big problem in this application since from the start historical data is used to create this application. The second problem does affect the accuracy of the data, and there should be thought about how to handle data imperfections.

5. IDEATION

In this chapter the ideation process that was done for this graduation project is explained. To begin with the ideation personas were created to help understand the users of the product better. These personas are placed in a scenario in which they are going to use the application. There was research on if the data that is available would be good enough to be used in this graduation project and finally early sketches are made.

5.1 PERSONAS:

In the study that the library did [25], there are four different categories in which students can fall, regarding what they want to do in the library. The first is the category in which students want to work alone and want to focus on study/work. This category could be called efficient. The second category is where the students want to work in a group and want to focus on study/work. The library names this group competence. The third category is where students want to work alone and want to work on other activities than study. The category is called distraction. The fourth and final category is where students want to work in a group and work on other activities than their study. This category is called homeliness. In figure 5.1, a picture on how these categories relate can be seen.

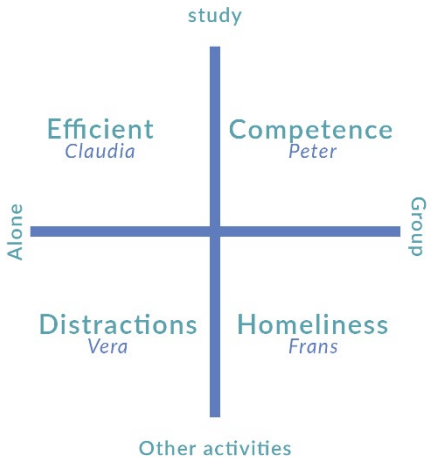

Figure 5.1 Diagram on how the different personas relate to each other

To understand the different ways the students could use the intended application, it is important to have a persona for each category and see in which way they match or differ.

Efficient:

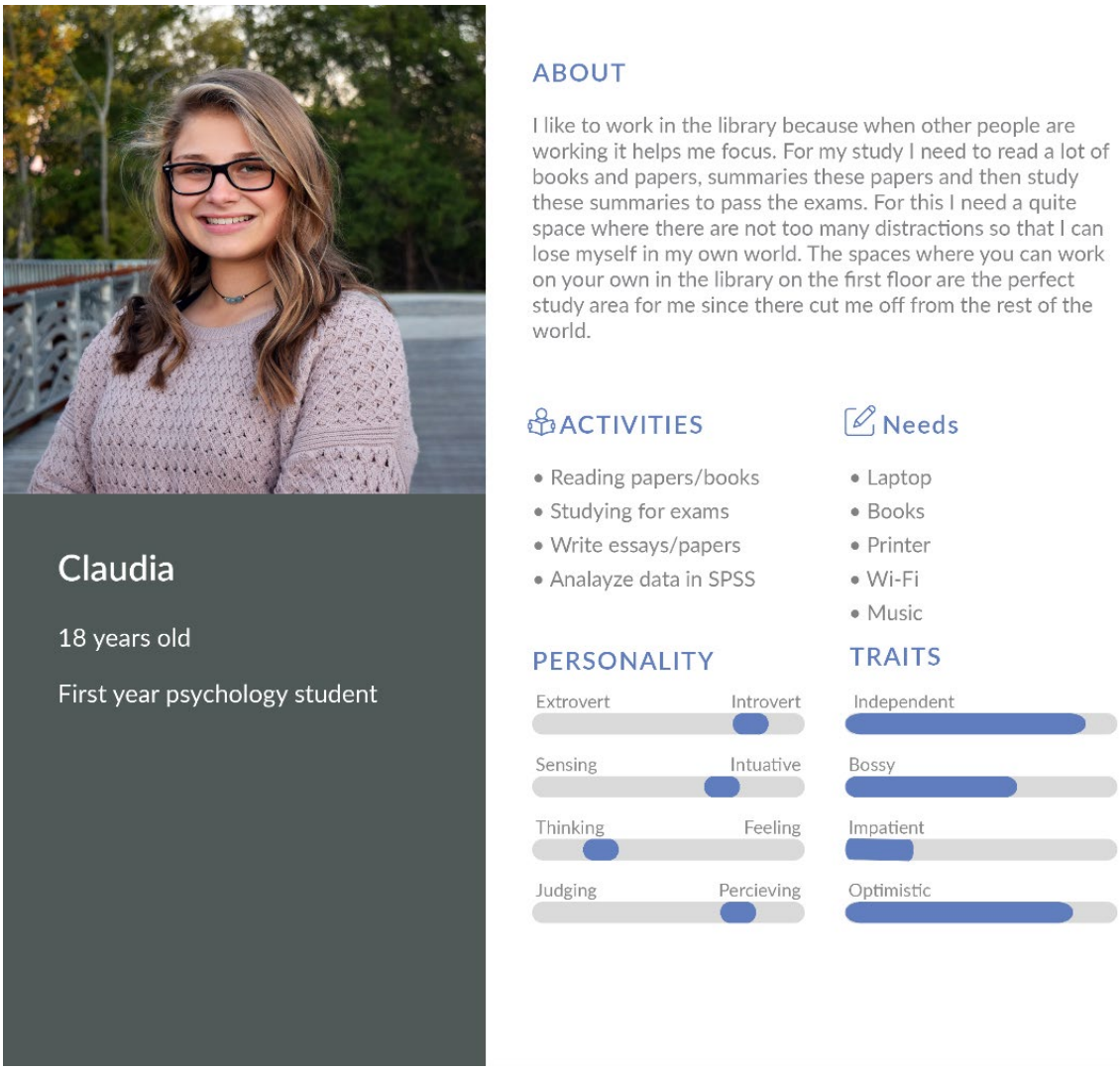

Figure 5.2 Persona efficient. Image source: [25]

Competence:

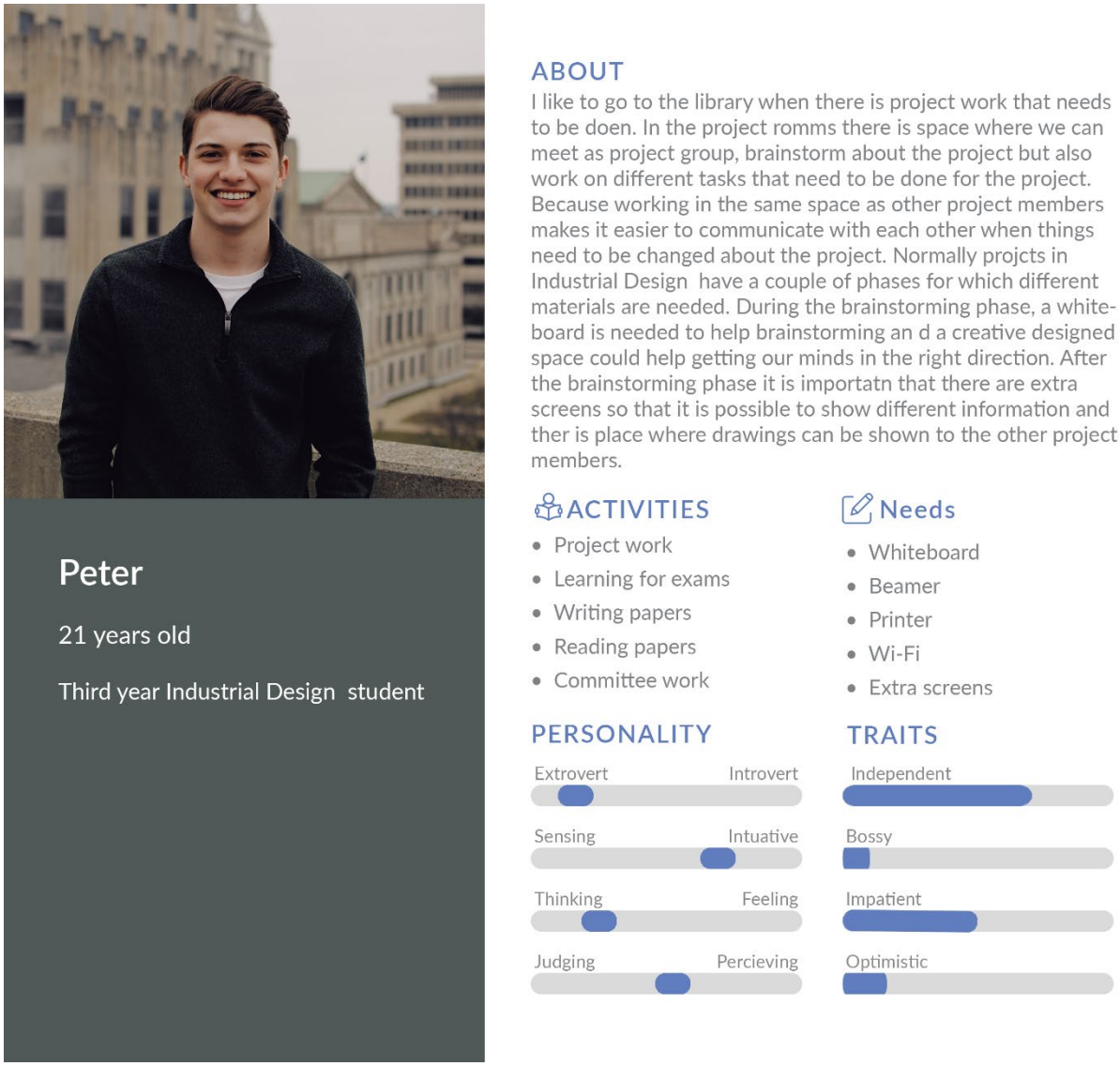

Figure 5.3 Persona competence. Image source: [26]

Distractions:

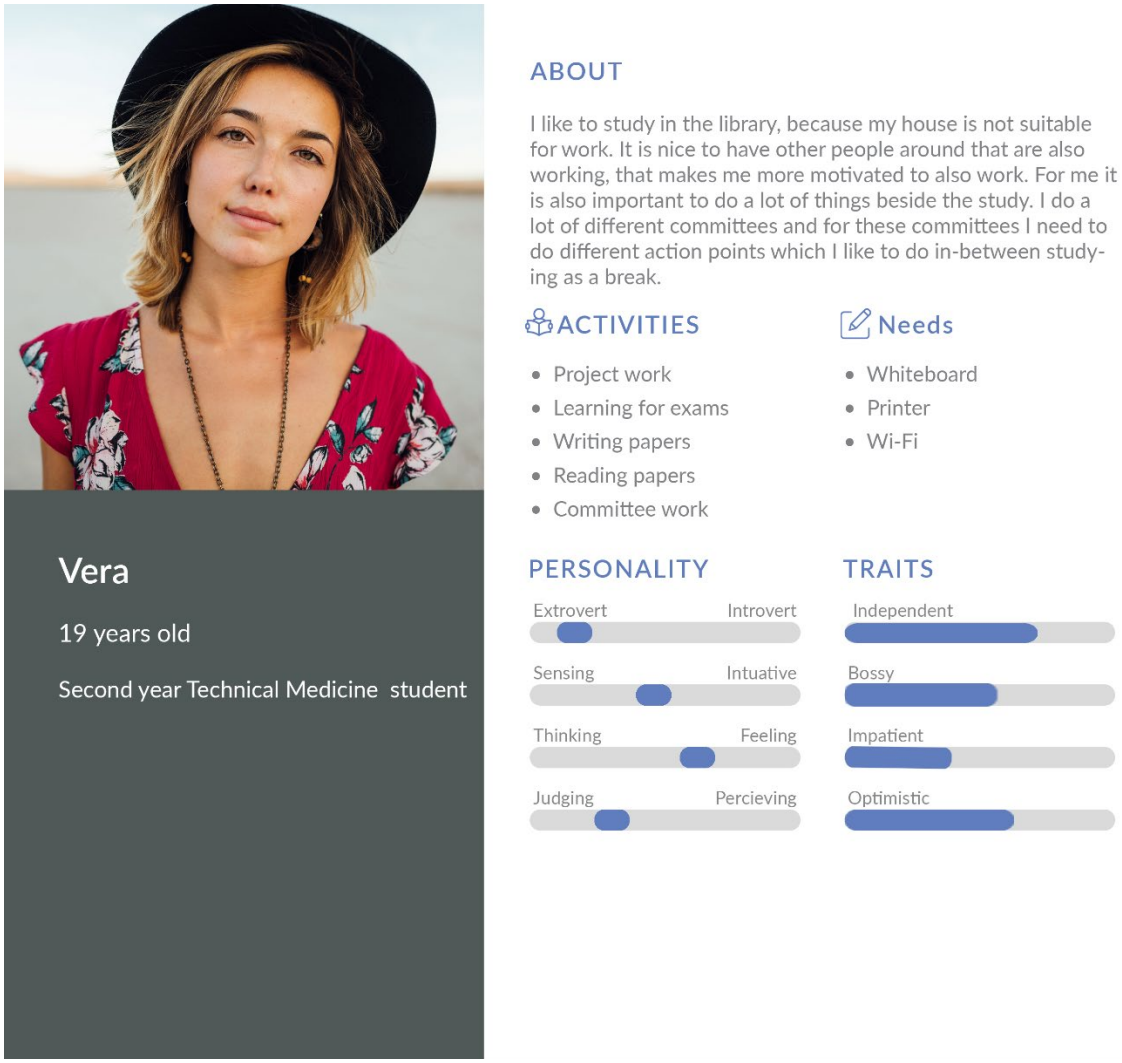

Figure 5.4 Persona distractions. image source [26]

Homeliness:

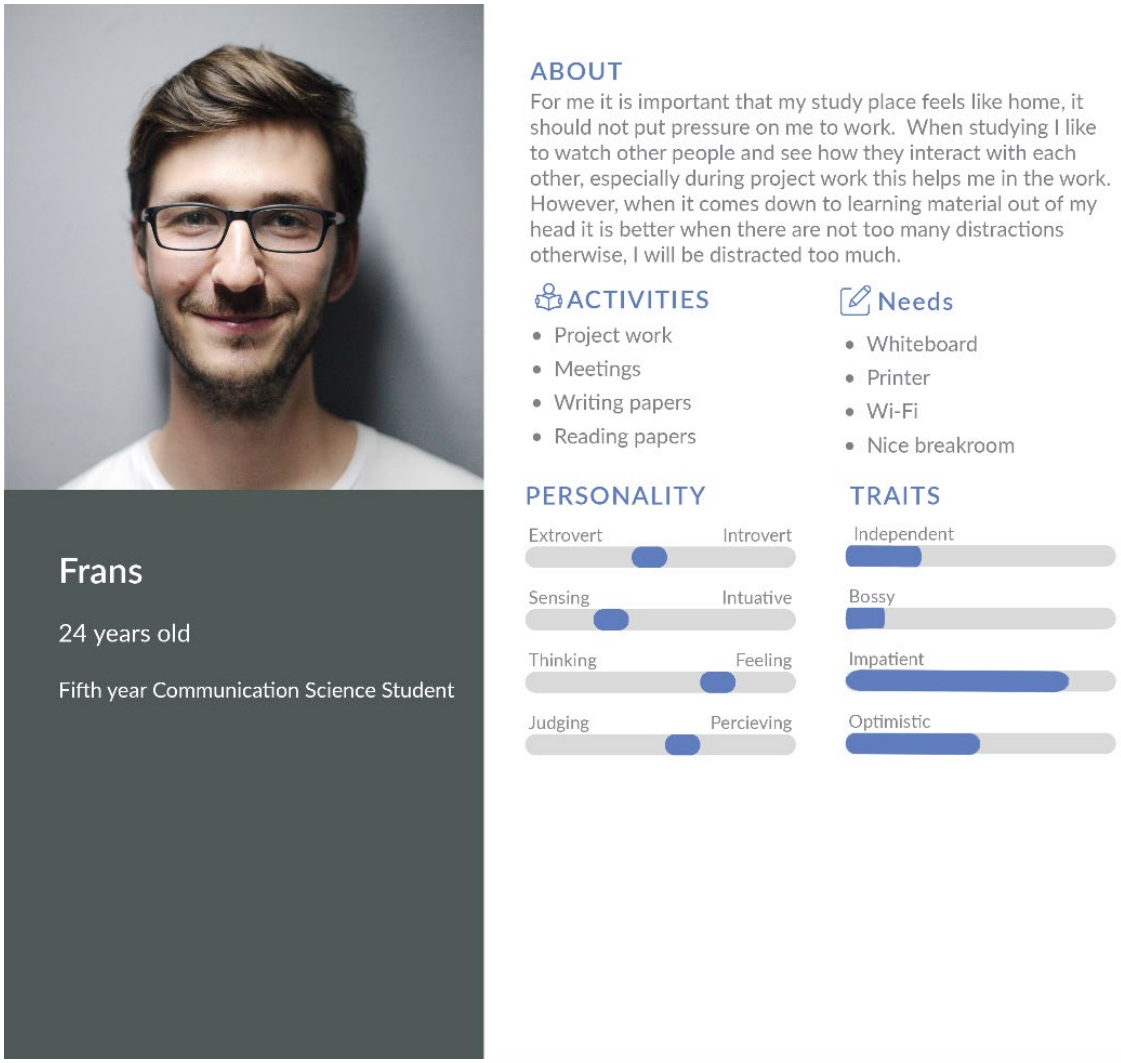

Figure 5.5 Homeliness persona. Image source: [25]

5.2 Scenario:

How a student uses the application depends on what the student does in the library. The four different categories defined in section 5.1 can also be applied by how the students use the application. For that reason, it is important that each persona has his/her own scenario to understand the difference in how they interact with the application.

Claudia (efficient):

For my study, I need to read a lot of study materials and summarize these materials. When I was in high school, I always studied in the public library so when I heard that the University had a library that was designed as a study place, I knew that that was my study place. In the library, there are these small rooms where you can work on your own. These rooms can be reserved. The only downside to these rooms is that you can only book them twice a week, which is understandable since many people use them, but it is not possible to see if the rooms are reserved. Which means that they are times that they are not in use. There is this website that I can go to and see if it is busy in the library, I like to go the site the night before I want to study

in the library and see how busy it was that day. I check at what time it becomes busy. Then I change the date to a week earlier to see how busy it was and at what time it became busy. With this in mind, I plan at what time I want to be in the library. The next morning when I wake up, I recheck the website to see how busy it is. When it is already busy when I wake up, I go a little earlier to the library than planned to make sure there is a place for me to study. Once at the library, I check the map to see which part of the library has the least amount of people, and I go and work there for the day. The one functionality that I hope is added soon to the website is that it is possible to see when the project rooms are reserved and when they are not reserved so that I work more often in one of those rooms.

Peter (competence):

For my studies, I work mostly in the library when I am working on a project. The project rooms in the library are an excellent place to have project meetings but also work on the project in the same place as the other project members. The good thing about being in a project is that each member of the project can reserve the project room twice a week, so we do not have the problem that we cannot book a project room. The website that shows how busy the library is is something that I do not often use. Since most of the time that I work in the library, there is a project room that I need to go to, and thus I already know that there is a place for me to work. There are times when I have a lot of deadlines that I do go to the library to work on my deadlines. However, I always forget that the website exists until I am there. Once I am in the library and see that it is busy, and I remember that there is a website. Sometimes I go the site when I remembered that it exist and see what part of the library is not busy, but most of the times I completely forget that I can do that with a website and just walk around to see where I can work.

Vera (Distractions):

My favorite place to study is in the library, I do not only study, but I also do a lot of work for the different committees I am in. I like to switch between studying and doing other things since I find it boring, just doing one thing. Because of lectures, tutorials, and committee meetings, I often work in the library for about an hour or 2 and then maybe come back later in the day and work for another 2 hours. Since the launch of the new website where I can see how busy it is, I can plan my time even better. Before going to the library, I like to go the site and see how busy it is, if it is really busy then I will try and find a different place to work and not waste time going to the library and figuring out that there is not a suitable workplace for me.

Frans (Homeliness):

As a fifth-year student, it does become time for me to finish my studies. It is, however, hard for me to keep focused. During the first three years of my studies, I would study at home because I like to be comfortable when I study. The problem was that my room was not the most optimal study place since I would need to clean my desk first before studying. Combining this with the fact that if I studied at home, I could sleep in, it was not the perfect study place. At home, it was also not possible to watch other people when studying, which is something I like to do when I need a little break from studying. In my fourth year, a friend of mine suggested that I should work in the non-silence part of the library, that this could help me study better. I

tried it out, and indeed, since I regularly study in the library, my grades are getting better, and I am even in the last part of my study. For the last year, it is possible to see on a website how busy it is the library. For the first couple of months, I tried using the application, before going to the library, I would look and see if there was a place for me to work. I thought that the website was a good idea and that it could help not spend 10 minutes looking for a workplace in the library during the exam weeks when the library is almost full. However, the problem was that when I saw that the library was busy, I would not go the library thinking I could better study at home but as I tried out in the first three years, I am not someone who can study at home. So, what I do now is that go to the library, and if I see that the library is busy. When it is busy, I go the website and look at the map which area of the non-silence part is the least busy and walk over there and find a workplace. Since starting to use the website this way, I did decrease the time I spend on finding a workplace, but I do still go to the library to study.

5.3 DATA CHECK:

During a conversation with Maarten van Steen, scientific director of the digitalization research institute of the University Twente, it became clear that the data from the access points may not be accurate enough to be used in this application. Maarten van Steen said that for the Wi-Fi data to be accurate enough 3 access points are needed to give a more exact location of where a person is. However, when three access points are used the data becomes more privacy invasive and that is something that is not desired in this application. Before going forward, it was important to research how accurate the data is and if it could be used in the indented way.

To investigate how accurate the data was, the number of people in the library needed to be counted, then there should be looked at the data from the access points and see if this matched with the number that was counted. The counting was done over several days, and the counting took place on different times so that the data was tested with the different occupancies levels the library has. The results can be found in appendix B.

For the first try, a map was drawn by hand and the access points where placed in the map. This drawing can be found in figure 5.6. A bigger picture can be found in appendix B. Then everyone was counted. This however proved to have some problems since the map that was drawn was not accurate enough and it was hard to recognize which access point belonged to which dot on the map.

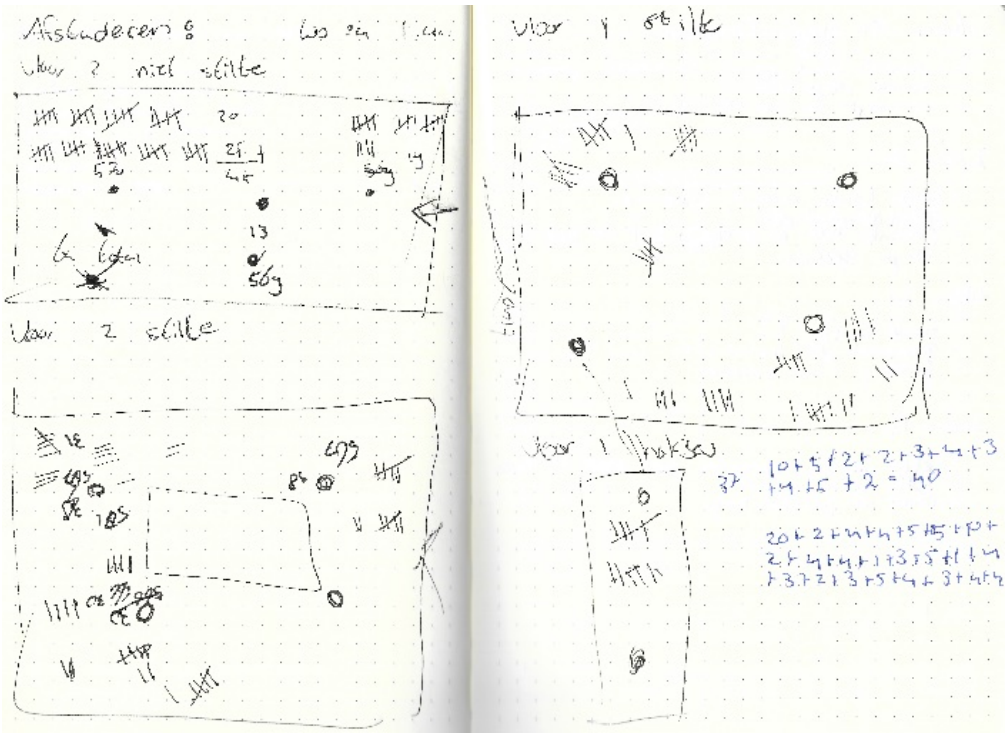

Figure 5.6 The first counting try. Map drawn by hand

After that this method was shown to be not exact enough. The access points where added to google maps to create a map that way. This gave a better picture on where people where in the library. However, this time the data did not seem to match with the amount of people in the library. To make sure that the correct access points where used, the next time the counting happened the access points names where written down and it became clear that some access points where missed in the previous counting. When these access points where considered the data seemed to match a little better.

Figure 5.7 Second counting try of the first floor. First time map by google maps.

For the final counting all access points where considered. With this counting most access points seemed give the same number of estimated people and the number of people in reality. In one part of the library the access points where a little off. When the counting was done it was noticed that there were a couple of high school students studying for their exams. These high school students do not have access to Wi-Fi network of the library and thus are not counted by the access points.

Through this process, since most access points do count the correct amount of people and in this application, an estimation on how many people there are is good enough. The data could be used to give an indication on how busy the library is. There are also enough access points in the library, to divide the library into subsections and give an indication of these subsections on how busy it is.

5.4 Early Sketches:

After it was concluded that the data was accurate enough. A brainstorm was held about what of visualizations where needed. During the brainstorm, the personas and the scenarios were kept in mind.

5.4.1 Visualizations:

During the data visualization course given by Andreas Kamilaris at the University of Twente, it was taught that there are different types of data and that data can be visualized in different ways. The data that is collected in this project is quantitative data. This type of data can be visualized in different ways. The following attributes can be used to visualize the data [27].

- The position
- The size
- The brightness
- The color

There are five qualities that a visualization needs to have to be a good visualization of the data [27].

- Needs to be truthful
- Needs to be functional
- Needs to be beautiful
- Needs to be insightful
- Needs to be enlightening

There are different types of visualizations for different messages [27].

- To visualize who or what a portrait is needed
- To visualize how much a chart is needed
- To visualize where a map is needed
- To visualize when a timeline is needed
- To visualize how a flowchart is needed
- To visualize why a multiple variable is needed.

With this project the goal is to help students find a workplace in the library. This goal cannot be accomplished with one type of visualizations. For this project, there is a map needed to show that it is busy in certain parts of the library. A timeline is required to show how busy it has been throughout the day, and a chart is needed to show busy it is at that exact moment. With all of this in mind the following early sketches were made to see what type of visualizations where needed.

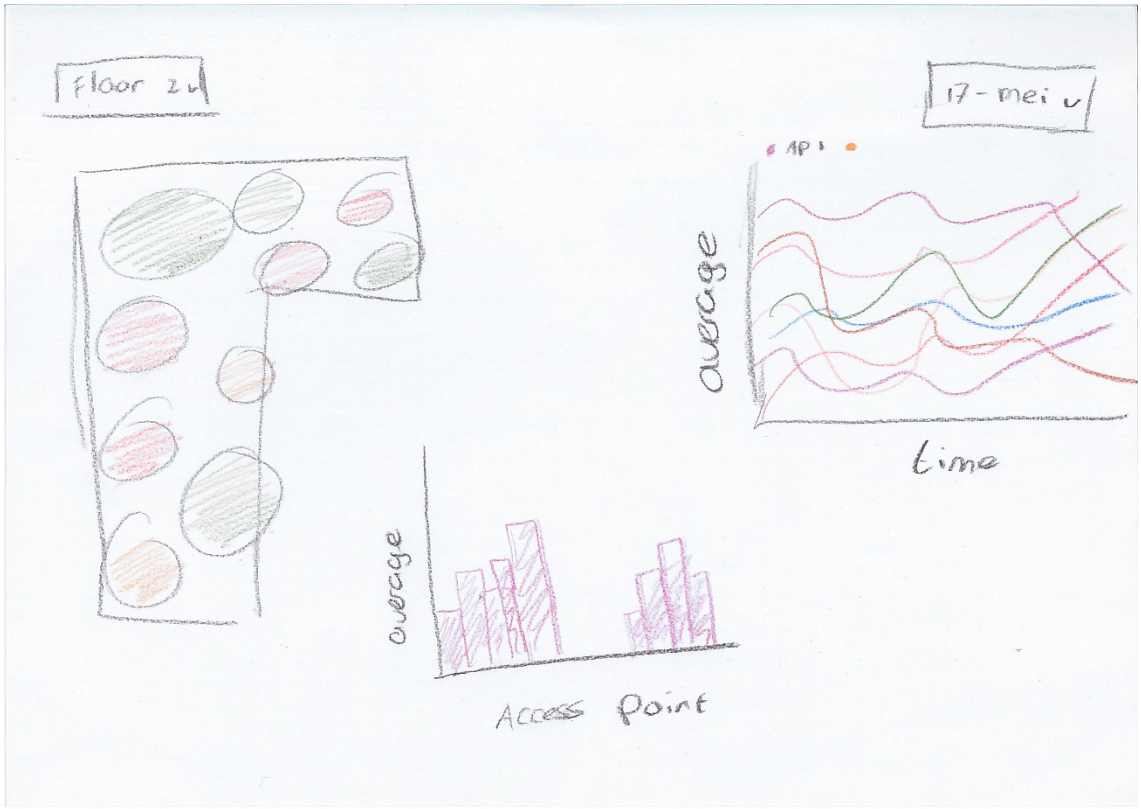

Figure 5.8 first sketches of the different visualizations

6. SPECIFICATION

In this chapter, the process of going from some early sketches to a set of requirements that the application should have. It starts with creating the visualizations, playing with the data, and seeing what is possible. After that, these visualizations were made it these visualizations were tested and out of the answers of the users, the requirements where made.

6.1 VISUALIZATIONS:

For the visualizations, it is important that everyone understands the visualizations. For that reason, a couple of visualizations were made and then these visualizations where evaluated. To evaluate the visualizations, people that were coming out of the library were asked if they wanted to give their opinion on the visualization, out of the responses that were collected, requirements where concluded.

6.1.1 The visualizations:

The first visualization that was made was the bar chart that shows the number of people in the library per access point. This visualization can be seen in figure 6.1 The second visualization that was made shows the average amount of people throughout an hour per access point. This visualization can be seen in figure 6.2 The same line chart is also made to show the average amount of people throughout the day per access point, which can be seen in figure 6.3

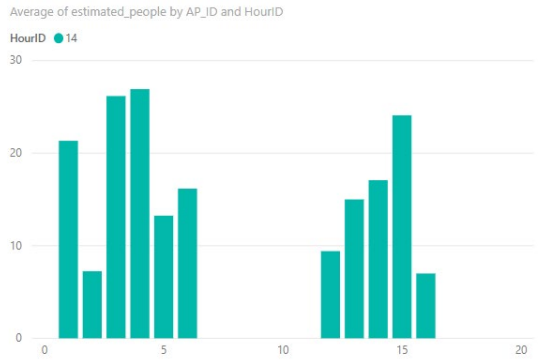

Figure 6.1 Amount of people in the library on the second floor. On 17th of May at 2 o'clock

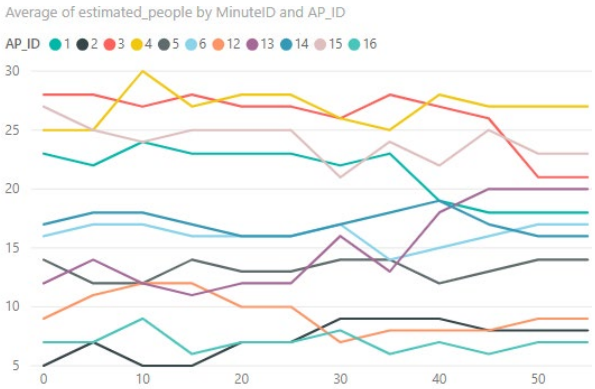

Figure 6.2 Average amount of people in the library throughout one hour on the 17th of May

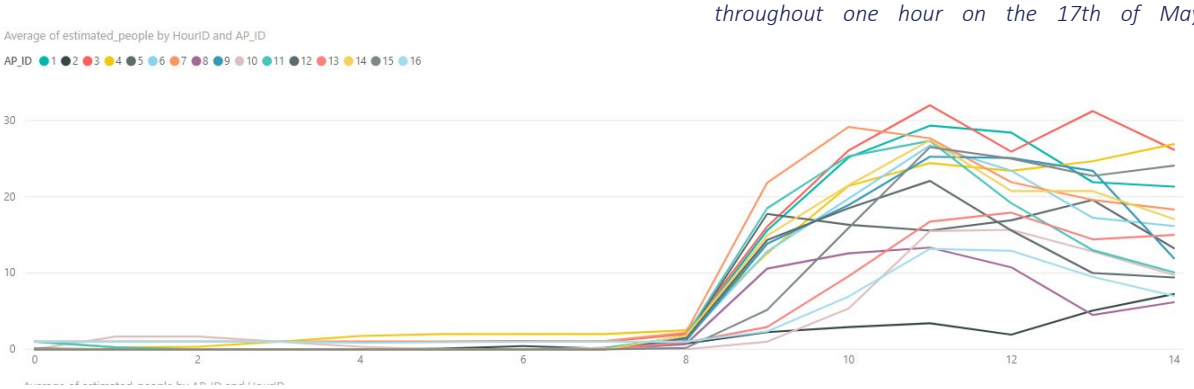

Figure 6.3 Average amount of people in the library on the 17th of May.

The last visualization that needed to be made is the map that could show how busy it is at a specific part of the library. First circles were used to indicate the range the access points covered, figure 6.5 However, during the creation of this visualization a different idea came to mind, and that was not to use circles but to trace the areas which were covert by different access points, figure 6.5.

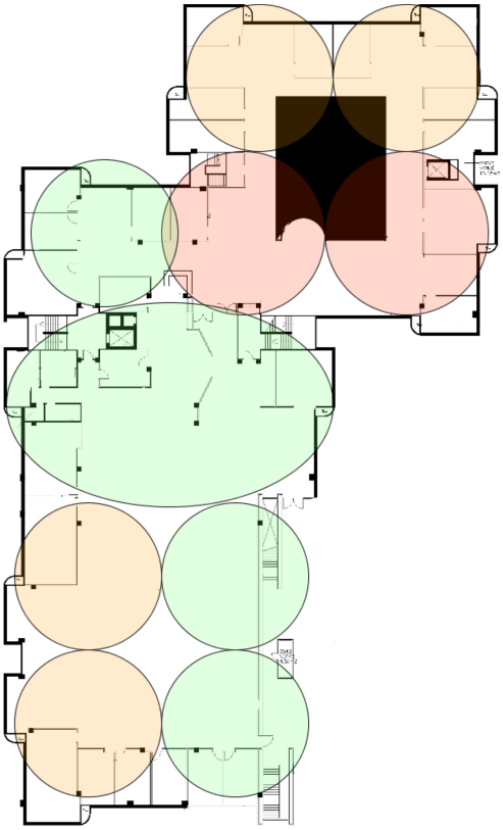

Figure 6.5 Floor layout of the library that shows how busy it is in the library using circles

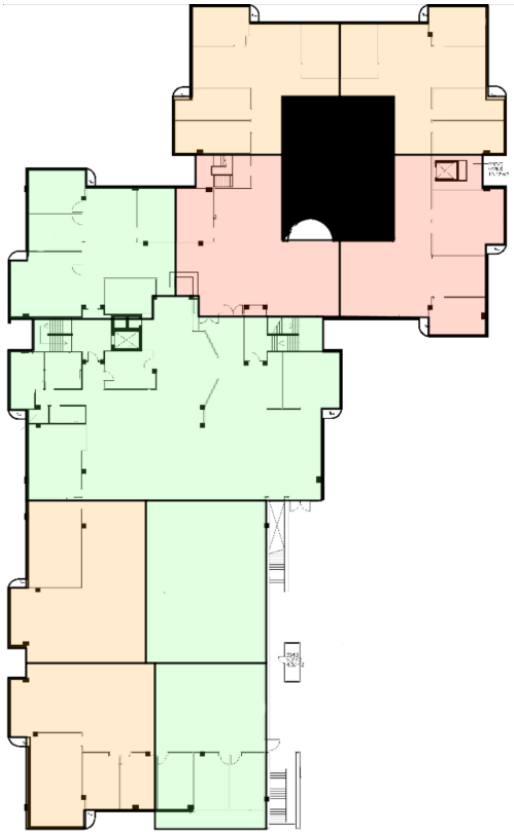

Figure 6.4 Floor layout of the library that shows how busy it is in the library, when the areas are traced

6.1.2 The user testing protocol:

For the user testing, there was a poster made with the different visualizations on there. Then people that walked from the library were asked to give comments on these visualizations. When they were willing to participate, an explanation will be given on what the project is about, and they will be asked to answer a few questions. These questions will be along the following lines:

- What do you think about these visualizations?
- What would you change?
- What information do you miss in these visualizations?

The answer that they give will be written down and ordered into categories. These categories are the comments per visualizations and the general comments. Out of these opinions, the requirements that these visualizations have are then concluded.

For this user test ethical approval was requested, to get this ethical approval the procedure stipulated by ethical committee of EEMC at University of Twente was followed. The documents can be found in appendix C

6.1.3 The results:

In total, 17 people gave their opinion on the visualizations. During the testing, it became clear that there are a couple of things not clear of the visualizations. The main things that were said over and over again was that figure 6.1 and figure 6.2 did not add any extra value, that the same information was in figure 6.3, 6.4, 6.5. That figure 6.1 and 6.2 do not add additional information, this is also supported by the fact that only people gave an opinion about the visualizations when they were explicitly asked about the visualization in figure 6.1 and 6.2. Out of all of this, it can be concluded that the visualizations about figure 6.1 and 6.2 are not needed. Another problem that was indicated was that there is now not a clear connection between access points and the AP id's that are used to show the lines in figure 6.3. A couple of solutions where mentioned:

- one was to make small texts boxes that in figure 6.3 by each line that describes the area.
- Another one to number the area's in figure 6.4 or 6.5, with a big number in the middle of the area and let these numbers correspond with the ID of the lines in figure 6.3.
- Another idea was to give the areas in figure 6.4 or 6.5 logical names, use the same names in figure 6.3 to make a more explicit connection. These names could even be hung in the library so that it also easier to find the areas once in the library.
- The last idea was to make the visualizations interactive so that one area was selected in figure 6.4 or 6.5 that than the line that corresponds to that area in figure 6.3 is highlighted and vice versa.

When asked about figure 6.4 and figure 6.5, almost everyone preferred figure 6.4. One-person preferred figure 6.5 because figure 6.5 showed that the data in the application is not exact and thus helps people understand that it may not be 100% accurate. There are a couple of problems with figure 6.4 that should be looked at. The first and most crucial problem is that it is now not clear to people what they are looking at when they are first looking at figure 6.4. When people look at it a bit longer, it becomes clear but does take too long. This could be solved in a couple of ways:

- Above the picture, it should be clearly stated which floor of the library it is.
- The elements of the room structure that were still left in the visualization should be taken out of the visualization.
- Add a clear red dot where the entrance of the library is.
- A person suggested making the visualization in 3D in the same way as can be seen in figure 6.6.

- It was also suggested that if a person hovered over an area in figure 6.4 that a tooltip is shown with a picture of the area and some statics of the area such as the number of chairs and at what time it usually is the busiest.

Figure 6.6 An example for how to visualize an office area in 3d [31]

Another problem that was noticed when people were asked was that people thought that the areas where rooms with actual walls instead of the open space that the library is. This problem could be solved by not using a solid line to show the different areas but use a dotted line. A dotted line gives less the idea that it is a wall.

There were some general remarks about the visualizations that could be taken into account when building this application. These where:

- That there were no scales on the graphs, so it was hard to read what the information on in the visualization said.
- That it would be a good idea to show different parts of the university to steer people to less busy places
- It would be a good idea to show the project rooms and if they are busy
- The average should be shown in percentages instead of number since chairs differ in each area.

The last question people were asked was what information they would like to have if they went to such a website and is not in these visualizations. Everyone gave the same answer, and that was that they would like to have a number of how many seats there are available in the library, in the same way as parking garage show the number of empty parking spots.

6.2 Requirements:

The requirements for this application can be divided into four different categories. The first category is Functions and Events; this category has all the requirements for the functionality of the application. The second category is interactions and usability issues in this category; all the requirements are given that have something to do with how the user interacts with the application. The third category is content and structure, this category is about what information should be in the application, and the fourth category is style and aesthetics which has all the requirements about how the application should look.

6.2.1 Functions and Events:

ID: **F1**

Requirement:	The website must be accessible on a mobile device.
Source:	Stakeholder interview
Rationale:	Students will not always have their laptop to check the website, but a mobile device they almost always have.
Priority:	Must

ID: **F2**

Requirement:	The averages must be shown in percentages.
Source:	User test
Rationale:	A user may not know how many tables there are in a zone and thus cannot conclude if a place is busy by just an average.
Priority:	Must

ID: **F3**

Requirement:	The user must be able to select different floors.
Source:	Stakeholder interview
Rationale:	To see the different maps in figure 6.4, the user needs to select which floor they want to see.
Priority:	Must

ID: **F4**

Requirement:	There must be scales on all the graphs in the application.
Source:	User test
Rationale:	When there are no scales, the user does not understand what they are looking at, it takes than too much time to read the graph.
Priority:	Must

ID: F5

Requirement:	The user should be able to change the date.
Source:	User test
Rationale:	So that the user can see the historic data and see when it is busy in the library.
Priority:	Should

6.2.2 Interactions and usability issues:

ID: I1

Requirement:	There must be a connection between the different zones showed in figure 6.4 and the other visualizations.
Source:	User test
Rationale:	So that the user understands which line in figure 6.3 is which zone in figure 6.4
Priority:	Must

ID: I2

Requirement:	When an area is selected the corresponding data in the other visualizations must be highlighted.
Source:	User test
Rationale:	This helps by making the connection between a zone and the other graphs.
Priority:	Must

ID: I3

Requirement:	There should be a clear indication in figure 6.4 on where the entrance of the library is.
Source:	User test
Rationale:	It is for the user not clear where the entrance is for the library when this is not clearly indicated on the map
Priority:	Should

ID: **I4**

Requirement:	To show figure 6.3 on a mobile device the graph should be scrollable
Source:	User test
Rationale:	On a mobile device the x axis of the line graph can become too big to show clearly.
Priority:	Should

ID: **I5**

Requirement:	There could be a tool tip when a user hovers over an area in figure 6.4 that shows a picture of the area and the number of chairs in that area.
Source:	User test
Rationale:	This could make it clearer where which area of the library is.
Priority:	Could

6.2.3 Content and structure:

ID: **C1**

Requirement:	There must be an estimation on the number of empty chairs left
Source:	User test
Rationale:	It is possible to see by one number if there is enough space in the library for the user to work.
Priority:	Must

ID: **C2**

Requirement:	The data showed in figure 6.3 must only be from the times that the library is open.
Source:	User test
Rationale:	To decrease the size of the x axis and thus make the graph better readable.
Priority:	Must

ID: C3

Requirement:	There could be an indication on if the project rooms are in use
Source:	User test
Rationale:	Students can then also use the project rooms even if they did not reserve a project room.
Priority:	Could

ID: C4

Requirement:	The user could be able to give their time frame they want to see and the graph in figure 6.3 should update
Source:	User test
Rationale:	The users can decide on the length of the x axis themselves
Priority:	Could

ID: C5

Requirement:	There could be a prediction on how busy the library is going to be
Source:	User test/stakeholder interview
Rationale:	The user does not have to think for themselves on how busy it is.
Priority:	Could

6.2.4 Style and Aesthetics:

ID: S1

Requirement:	In figure 6.4, the zone areas must be indicated with a dotted line
Source:	User test
Rationale:	By using a dotted line, it is clearer that this a zone and not a wall
Priority:	Must

ID: S2

Requirement:	The map in figure 6.4 could be made in 3D
Source:	User test
Rationale:	This could help the students figure out how the map of the library works
Priority:	Could

ID: S3

Requirement:	The image for the map used should not contain anything more than just the walls
Source:	User test
Rationale:	All the other things in the image are distracting and do not help by understanding where someone is in the library.
Priority:	Should

7. REALIZATION

With the set of requirements, the realization phase was started. In this phase, the actual application is built, and, in this chapter, it is described what was used to create this application and what choices were made. When the first prototype is finished, some users will be asked to provide some feedback, and their feedback is used to better the first prototype into a second and final prototype.

7.1 TECHNOLOGIES:

7.1.1 Application:

7.1.1.1 MySQL database

The first step that was taken to create the application was to create a database where the data could be saved. This was the first step because then the data could already be collected, and when it was time to create the first visualizations, more data would be available to create the first graphs.

The database contains two tables, the first table is called access_points, and this table contains all the information that is available for the access points in the library. This includes an id, the name of the access point, the latitude and longitude, the floor the access point is on, the map vertices (these are the coordinates to help create the map visualization) and the number of chairs.

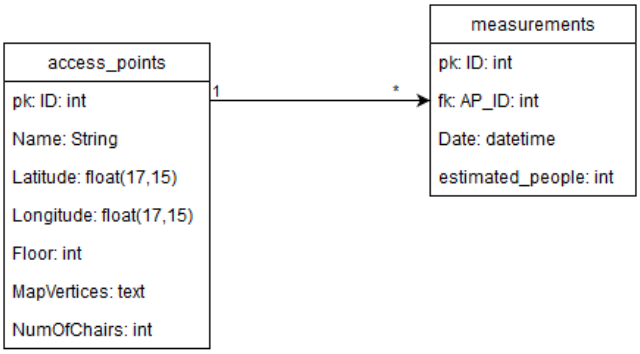

Figure 7.1 UML diagram of the database

The second table is called measurements, and this table contains all the information for each "measurement." Each measurement has an ID, an access point ID, the date and time the measurement was taken and the number of estimated people.

7.1.1.2 Bootstrap

For the website, it was chosen to use bootstrap as a framework since bootstrap makes a webpage responsive to the size of the screen. Bootstrap uses something that is called a grid system [28] . The width of each column in the grid depends on the size of the screen. When a display is bigger, more columns can be next to each other, when the display becomes smaller columns that were next to each other are moved below each other not to make each column to small. Because one of the most important requirements of this website was that it should work on your computer but also on your phone a good framework was needed that made layout of the site responsive to the size of the screen of the device.

7.1.2 Visualizations:

For the visualizations, it was decided to make them in JavaScript. This was done because JavaScript has a lot of libraries that can be used to make interactive visualizations. In this project, different libraries are used to create the visualizations.

7.1.2.1 P5.js

P5.js was chosen because it was created by the same foundation as processing. The map visualization was already made in processing, so changing the code to p5.js would be easier than reprogram the visualization into a different language. P5.js has a goal to make it easier for artist, educators, and beginners to start programming [29]. The library has a lot of different drawing functions that made drawing the map easier compared to other JavaScript libraries that do not have those drawing functionalities.

The code that makes the map visualization works as follows. To get the data from the database, two PHP scripts are used (one for the access points and one for the measurements). To show the data of the correct floor first a list of all the access points id's is made. The data for the measurements is all the data for that day, so when the data is loaded it the last measurements are taken and with the list of access points id's only the relevant measurements are used. With the number of chairs and the number of estimated people, a percentage is calculated to see how full that part of the library is. With this percentage, it is decided if the color needs to be green, orange, or red. When this is all decided the map vertices are used to create the shape of each area in the library and fill it with the correct color. To make the map resizable, the width of the screen is taken and used to calculate the height of the image. With the width and the height two (one for the width and one for the height), scaling factors are calculated. These scaling factors are used when creating the shapes of each area in the library, to position the shapes in the correct place.

7.1.2.2 Chart.js

Chart.js is one of the many libraries that can be used to create charts. The reason for using chart.js instead of one of the other libraries like d3.js or recharts is that chart.js has a relatively easy learning curve with good beginner tutorials online and a proper documentation, which is something that d3.js does not have, d3.js has a steep learning curve, and it is hard to figure out what part of the code does what. Chart.js was chosen instead of p5.js to make the line chart visualization because the library has already code to draw the line chart only some customization code was needed to create the line chart.

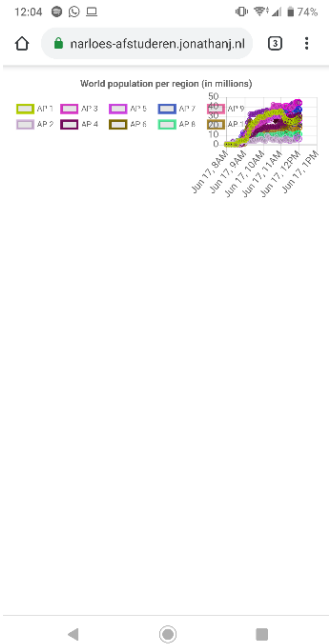

Figure 7.2 line graph with chart.js on a mobile phone

However, when trying to make the chart mobile-friendly, there were some problems. Since the x-axis of the line chart can become quite long, it can be problematic to show the graph on a mobile device. When the graph was opened on a mobile device, the graph was not readable anymore as can be seen in figure 7.2. It was not possible with chart.js to change the scaling in such a way that it

would be readable, so it was decided to make a new line graph with a different JavaScript library.

7.1.2.3 Highchart.js

Highchart.js is just like chart.js a library that can be used to create graphs. The reason that this library was chosen is that there were examples of making the chart scrollable, which was one of the solutions thought of to make the line chart readable on a mobile device.

The line chart is made as follows; the data is loaded in through a PHP script. Before the graph is made, the data needs to transform into the correct format. For the graph, the data that belongs to one access point should be in one array, and the date at which the measurement is done needs to be changed into the correct format. The format from the database is dd/mm/yy hh:mm:ss, which contains a lot more information than is needed for the graph. For the x-axis of the graph the only the time of that day need to be shown. So from the date, hh:mm is extracted and placed into a two-dimensional array. This two-dimensional array has the access point ID as index value and is filled with the time a measurement was taken and the number of students present in that area of the library

When the data is transformed into the correct format, the graph is made. This is where highchart.js does its magic, in the code, it is said to create a line chart, with this data and this x-axis and the graph is made. Then some function calls can be used to tweak the graph into the ascetics and interaction that is desired.

7.1.3 The interaction:

The good and bad thing about JavaScript is that if a variable is defined global, this variable can be called outside that sketch, so variables from the graph can be called in the map sketch and vice versa. This makes the interaction between the two different visualizations easier. Calling the variables or functions that does the interaction in one visualization when the user interacts with the other visualization.

7.2 THE FIRST PROTOTYPE:

Through all, this the first prototype was ready to receive feedback. Because of time constraints, not all the requirements or functionality that in an ideal world would be in the final version are in this prototype. The functionality that shows the estimated number of chairs available is now a static number so that it can be tested to see if people will like the placing of the functionality. All requirements that are indicated as a must in the specification phase are in this first prototype to see if the implementation of those requirements is logical and work.

7.2.1 The product:

In figure 7.3 through 7.6 the website can be seen on a desktop computer and on a mobile device.

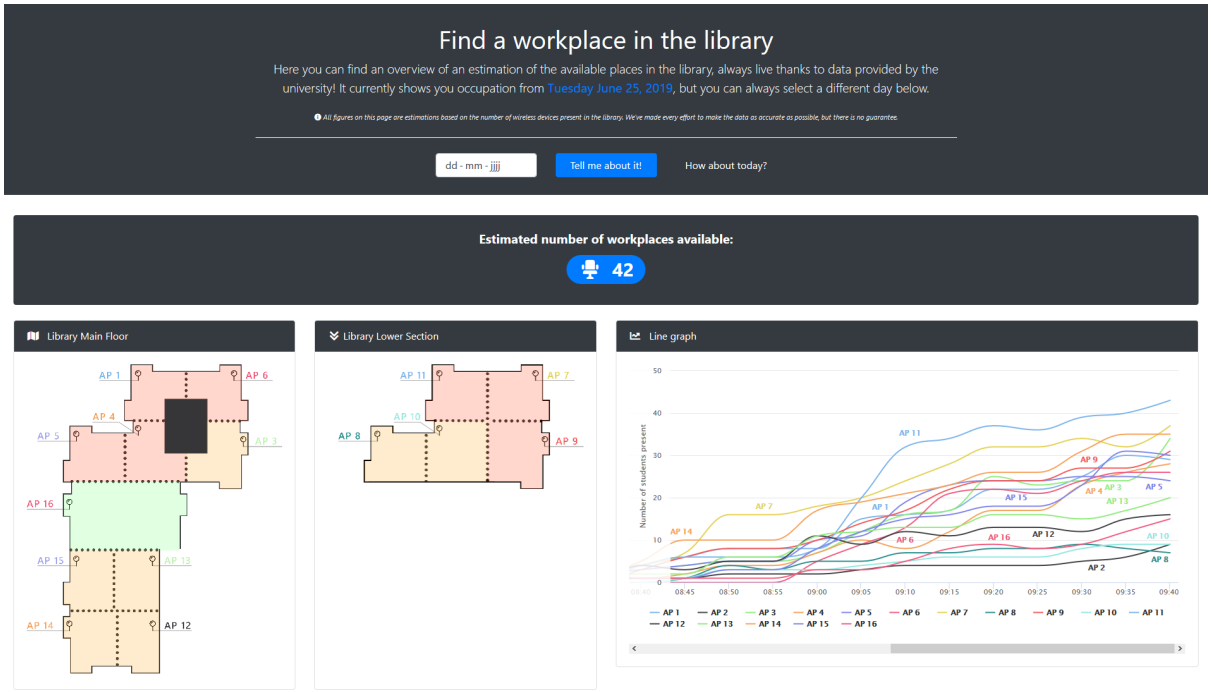

Figure 7.3 The user interface of the first prototype on a computer screen

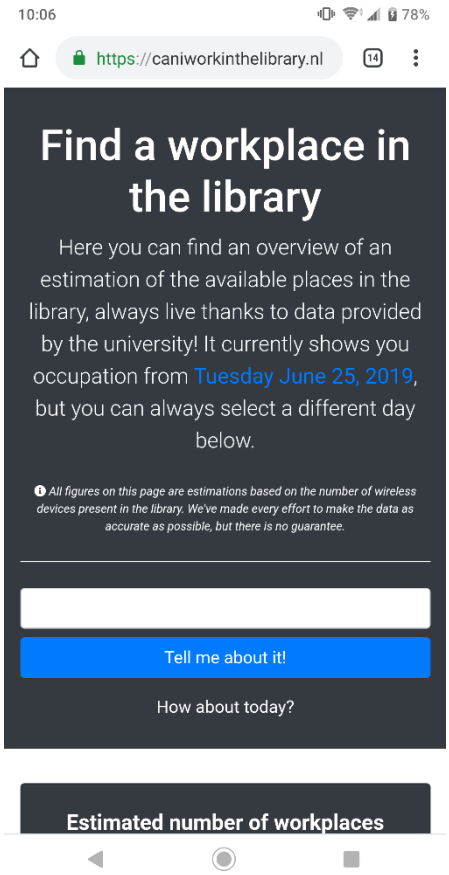

Figure 7.5 The user interface of the first prototype on a mobile device. When going to the website this the first thing to see

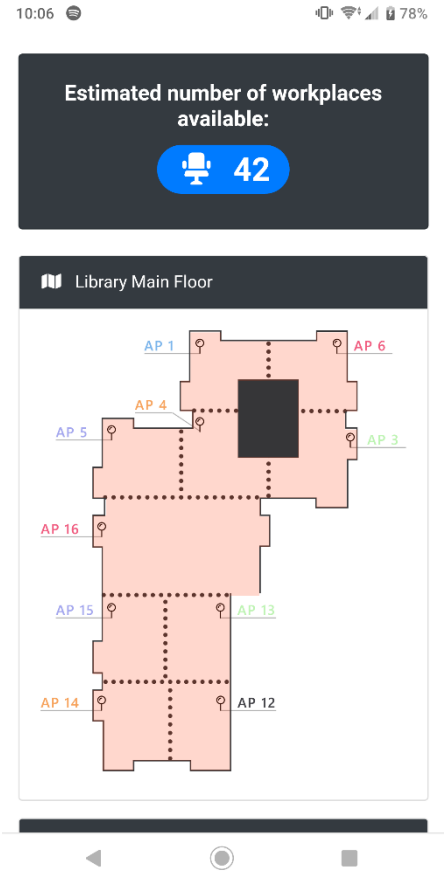

Figure 7.4 The user interface of the first prototype on a mobile device, when the user scrolled down a bit

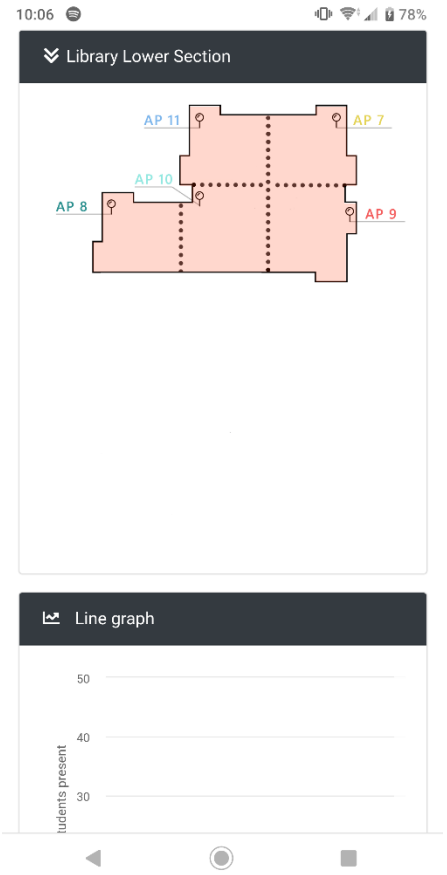

Figure 7.7 The user interface of the first prototype on a mobile device, when the user scrolled down more

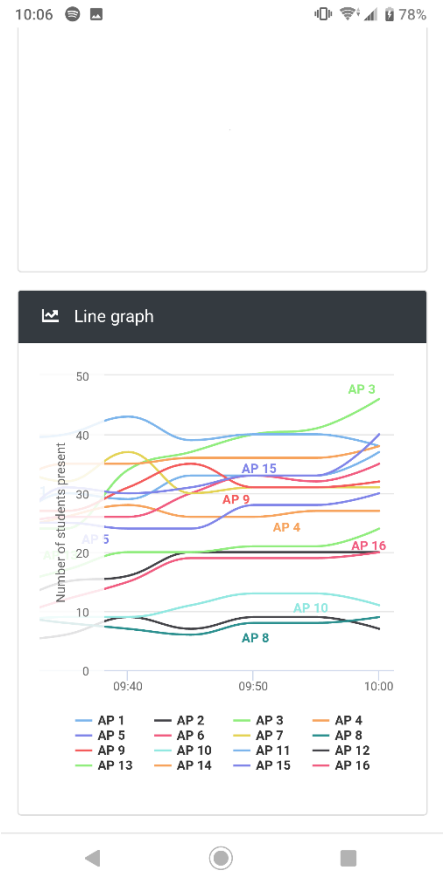

Figure 7.6 The user interface of the first prototype on a mobile device, when the user scrolled down to the bottom of the page

7.2.2 The feedback:

During the creation of the application, constant feedback was asked. When the prototype was finished a google form with a link to the website where people could leave feedback was send to students to figure out what problems were still there and what was not clear. The feedback can be divided into two categories. The first category is technical problems, where the website did not work as intended, and the second category, user interaction problems.

7.2.2.1 The technical problems

The first problem that was identified was that on a mobile phone, the interaction with the map did not work as intended. When clicking on an area on a mobile device, it is only selected for a small amount of time, and then it deselects itself again.

The second problem is that is identified is that the line chart does not work in the safari browser.

7.2.2.2 The user interaction problems

The problems with the user-interaction can be divided into smaller categories. These categories are the different visualizations (map and line graph) and layout and other problems

7.2.2.2.1 The maps

There are some interactions with the map that are not clear to the user. The main problem is that it is for the user not clear that they can click on the different areas and that than the areas are highlighted. It would be more logical if the user could hover with the mouse over an area and that then that area is highlighted instead of clicking on an area.

Another element that people wanted was that they would like to know how many chairs there are available in each area of the library, it was suggested that by hovering over an area a tooltip (in the same way as in the line graph) which shows how many chairs there are still available.

In the map, it is not clear what the different colors mean, so it would be a good idea to explain this somewhere on the page. Which specific data (which timeframe) is used to generate the map is also not clear on this page, but this is important, and thus it would be a better idea to indicate what information can be learned from the map.

7.2.2.2.2 The line graph

The main problem with the line graph is that shows how many people are in the library, and the users felt that it would be more logical to show how many chairs are free. The reason for this, students said is they are looking for a place to work and thus want to see how many empty desks there are.

Another problem is that the y-axis could be bigger so that the lines have a little bit more spacing and would be easier to select a line.

The third problem that is identified is that some of the colors in the line chart are too similar, and thus people can have problems distinguishing these colors. This made linking the lines to the chart harder than it should be and should be changed.

7.2.2.2.3 The layout and other problems

There were also some general problems. The naming of the lines and the areas do not have any meaning to the users. AP does not mean anything to them and only makes them more confused. Instead, AP should be changed to either a logical name or to something like area 1, area 2, et cetera.

Changing the date is also not as intuitive as desired. Some users found the date in the text of the header hard to find. The date should also be in the box where the different dates can be selected. It should also not be possible to select a date in the future; some users thought that that was the intended interaction. They said because it said “from date” so this sentenced needs to be changed where it does not say from anymore. On a mobile device, the header takes too much screen space. The first time going the website the extra information could be useful but going to the website more often it would not be as useful. It would be better if the header could fold out to show the information but that as default the header is folded in.

7.3 THE SECOND PROTOTYPE:

7.3.1 The improvements:

With the feedback gotten from the first prototype, a second prototype was made with the implementation of the feedback. Most of the feedback was about the interaction of the application and not on the look of the application. The feedback that was about the visual look of the application is implemented into the second prototype:

- There was an information icon added to the title of the maps to explain the different colors that the map can be
- The colors of the lines in the line graph were changed to be more friendly to color blind people. The chosen colors should be able to see at least 95% of the population [30].
- The names of the different area where changed from ap to area.

Some of the interaction with the website was not clear, to make some of the interaction clearer, the interaction was changed.

- Instead of clicking on an area to select that area, now the user can hover their mouse over an area, and the correct line that belongs to that area is highlighted when the mouse hovered over an area. By doing this, the mobile phone problem that came forward in the feedback was also solved
- An interaction was added, by hovering over an area in the map or by hovering over a line in the line graph, the estimated number of chairs is updated to the estimated number of chairs available in that area.
- It was added so that it is not possible to select a date in the future anymore only in the past
- The current date that the data is showing is also placed inside the date select balk to make it clear which date the data is showing.
- Which time the map visualization is made is added to the header of the map to make it more clear which data the map is showing.
- The header on a mobile phone is collapsed, and if the user wants some more information, this header can be folded out to see more information.
- The problem that the line graph was not showing, on an apple devices is solved.

7.3.2 The final product

In the images (7.8 till 7.11) below the new user interface can be seen.

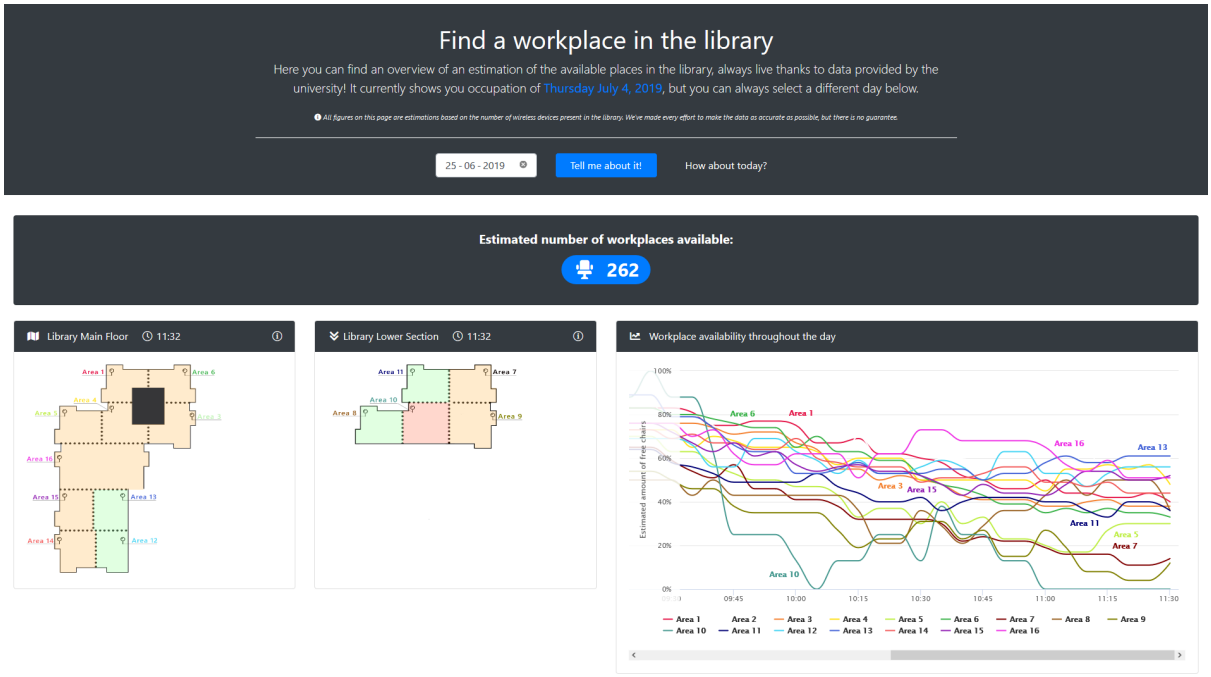

Figure 7.8 The user interface of the second and final prototype

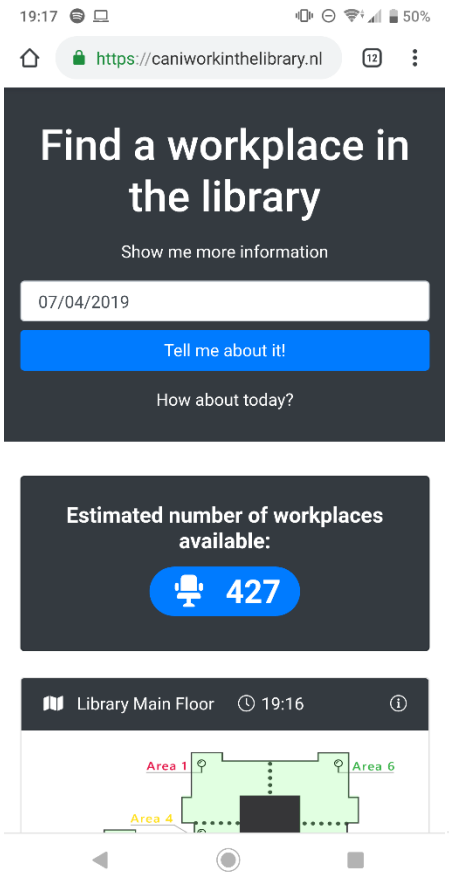

Figure 7.9 User interface of the second and final prototype on a mobile device

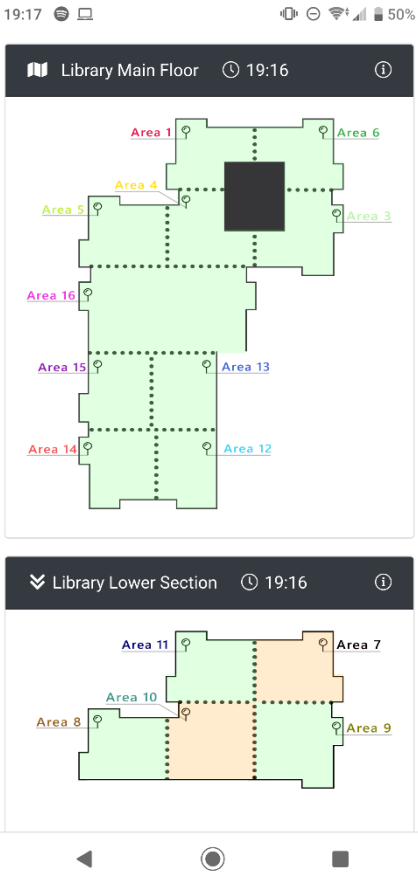

Figure 7.9 The map visualization on a mobile device for the second prototype

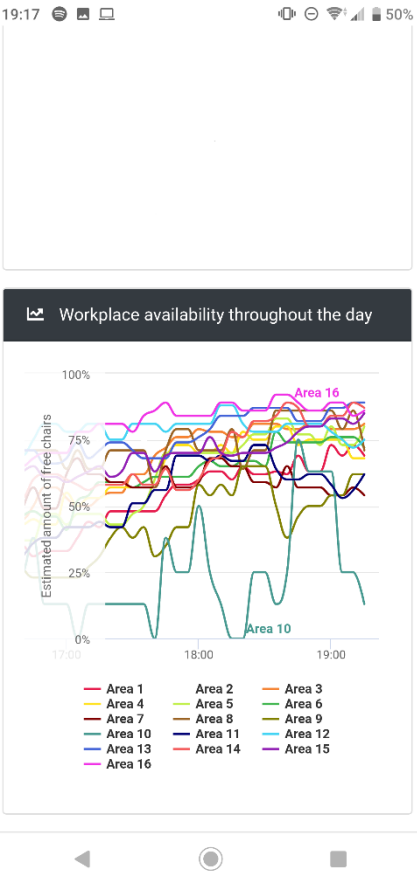

Figure 7.11 The line graph on a mobile device for the second prototype

7.4 THE CODE STRUCTURE:

The structure of the application can be found in figure 7.12. The code used in this application can be found on GitHub[1], and an explanation on what the different classes do is explained in appendix E.

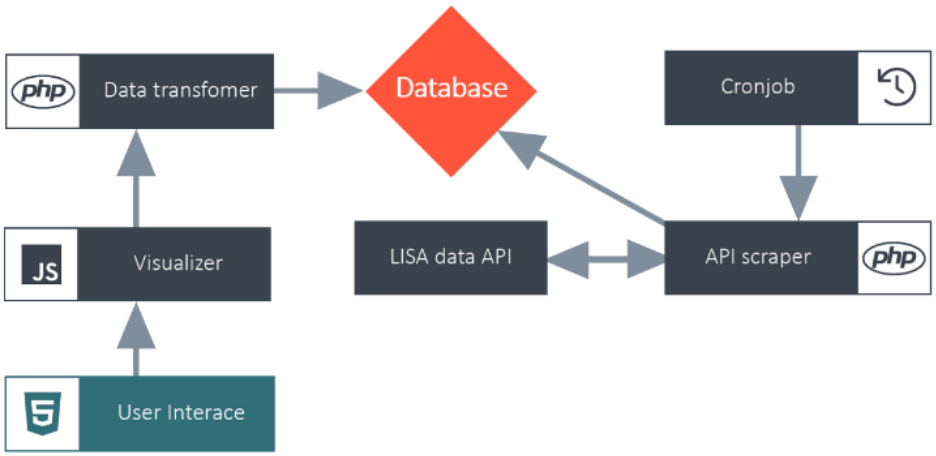

Figure 7.10 The structure of how the different elements work together

The cronjob calls the API scraper every 5 minutes, which means that new measurements are put in the database because the API scraper talks to the LISA data API. The user interface makes the layout of the website and uses visualizers to generate the different visualizations. To generate these visualizations, data needs to be gotten from the database and transformed into the correct format.

[1] https://github.com/marloes21/finding-a-workplace-in-the-library

8. EVALUATION

8.1 CONCLUSION:

How to design an application that helps students find a workplace in the library, it is a hard question to answer, and this question could be answered in a lot of different ways. If someone else would be making the same application, with the same data and talked to the same users, a different application would be built. However, by researching how to design an application in a user-friendly way, the outcome of this application should help students find a workplace in the library.

8.1.1 How to design an application in a user-friendly way?

The answer to this first sub-question, varies from person to person, but most people will say that to create something user-friendly, the creator should talk to the users. The more the creator talks to different users, the more user-friendly a product becomes. This is also what was done in this application to make the application as user-friendly as possible. From the start of the design process until the final product at all stage's user-input was asked and all conversations that were held about the product can be used to better the application. During the ideation phase, a focus group was held to help generate different ideas of what this application could be. At the specification phase, random users were asked in-person to provide feedback, and in the realization phase user gave feedback without being asked, or they filled in a google form on their own without any extra information to see how the application worked and if the users used the application in the intended way. By asking the user for feedback in different ways, different insights into the application could be gathered. To get the most out of the user feedback, it was tried to match the way the feedback was gathered to the type of feedback that was needed. By doing all of this, it is believed that this application is user-friendly.

8.1.2 How to use the data provided for the intended application?

The data that could be used in this application was only real-time data. For this application, historic data was needed. To have this historic data, the data needed to be saved somewhere. The data also only showed how many people there were in one area. However, during the user-testing, it became clear that this is not an intuitive way of showing where a student could work. So, the data needed to be transformed into a number of empty chairs. Each visualization does this transformation on its own since each visualization needs a different transformation of the data. Each visualization calls a PHP script that gets the correct data from the database and transforms it into something the visualization can use.

8.2 LIMITATIONS AND FUTURE WORK:

One of the limitations of this application is that it only shows current and historic data. Which means that the user of the application must decide for themselves if it is going to be busy at the time they want to go to the library. From a user-friendly perspective, it would be better to have a prediction on how busy it is going to be. For future research, it would be a good idea to see if and how machine learning could be applied. To see if it is possible to predict when the

library is busy and which part of the library is busy. Instead of just showing the current and historic data.

Another limitation is the accuracy of the data. The data may not be as accurate as it sometimes needs to be. Two different reasons can explain this, the first one is that some students (or other people working in the library) may not connect to the Wi-Fi in the library, or they connect to a different network that is also available in the library. When these students are not connected to the Wi-Fi network of the University, they are not counted and thus are not shown as taking up a workplace when they are. The second reason is that students that are working in the project rooms are also counted since there was not a way to distinguish when students are working in the project rooms or are working in the open space. Most project rooms can be reserved and thus, when students are working in there, they are not taking up any of the free workplaces. This decreases the accuracy of the data.

It would be a good idea for future work to look into how to improve the accuracy of the data used in this application. The improving of the accuracy can be divided into two different parts. For the first part, there could be looked at counting the people that are not connected to the University Wi-Fi network. For the second part, there could be looked at how to use the sensors that are in some of the project rooms of the library. With these sensors, it may be possible to detect whether people are studying in these project rooms and with how many people they are studying. Combing this data with the dataset used in this application could improve the accuracy of the application.

A third recommendation for future work is to research what is possible with the sensors in the library project rooms. This was something that came forward often during the conversations that were held with students. By using these sensors, it would give them more insight into when project rooms are free to work in. If there was enough time, this feature would have been added to this version of the application. However, there was not enough time to do this well, and thus, it was decided not to add this feature.

8.3 Final evaluation with the library:

When the final prototype was finished, a final conversation with the library staff was held. The goal of this conversation was to see what the library staff thought about the application and what could be improved about the application to be also functional for the library staff. During this conversation, it became clear that the third floor of the library that is not in this application because it was thought to be only reservable rooms are not reservable rooms but first come – first serve rooms. This floor should be added to the application to show if there are places available. The library staff thought they could use the line graph to detect which places in the library are always full and try to find out why that area is always full. The library staff thought that it might be a good idea to improve the accuracy of the data to implement sensors underneath the tables to see if someone is sitting there.

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I would also like to thank all the people that provided feedback that was needed to bring this graduation project to what it is now whether you were willing to talk and help me think about the different possibilities in the beginning. Saying that I should not use that color in the final product, all the input kept me thinking and improving what I was making. As last, I would like to thank all the people that told me in the end that it was good enough, that I need to set my own finish line and except that, that is the finish line. Without all of you, I would still be moving the finish line and not finish this graduation project.

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APPENDIX A INTERVIEWS STAKEHOLDERS:

A.1 STUDENTS:

The opinions on the library differ between the students. One student said that reason student study in the library is because of its big open space and it is quiet, which helps students focus. Because in the library there is not much activity. Where another student does not want to study in the library because it is dark and kill, one student only likes studying there when the work needs to be finished because there are not many distractions in the library.

In both the interview and the focus group, the library was divided into two parts by the participants. The first part is the open space where students can work, and the second part is the project rooms. For the open space, the student from the interview and the students in the focus group did agree on specific aspect but not on all. Both agreed that it would be nice to see how many people are working there and how many spaces it is left. The student from the interview said that this would be especially nice when this would be possible for all the other study areas of the university so that deciding where to study the whole university can be considered. In the focus group, the students did not need to know a number of students studying but more a scale on how many people, so it is busy; it is quiet.

An idea that came forward in the focus group was a to categories study places, for example, a study place with a window, big table, close to the coffee machine, et cetera. That a wizard would be built that students could specify what type of place they want to study at, and the system decides what a good place would be.

In both the focus group and the interview, the students were asked if they would be interested in seeing historical data. In the interview, the student said it would be interesting to see if there is a pattern when it is busy et cetera. However, it would not change but would still study in the library. In the focus group, they thought it would be interesting to see the same week in the previous module or more in a predictive manner so instead of saying last week it was busy, saying that it is expected to be busy today.

The second part, the project rooms in the library, all the students agreed, and that was that the system that is used now does not work well. The students in the focus group said that it is not clear when a room is free and it almost impossible to book a room when they are there because the system is not intuitive. It is also not possible to sit in a project room for half an hour because as a student it is not possible to see if the room is booked and they do not want to risk being sent away. The same problems were said in the interview. In the focus group, a solution was offered by having screens by each project room where it was possible to see when it was reserved and that it was possible to reserve there. In the interview, the students said that project rooms are often longer reserved than needed because the students do not want to risk not having enough time. With the current system, it is not possible to unreserve the room and thus making it available again.

This system should be accessible on a smartphone because during breaks it is possible that students do not have their laptop with them. However, it would also be nice to have visuals

queues in the library, so that with each project room, there is a led strip which indicates if it is reserved within the hour, it is free or if it is occupied so that there is no need for a phone.

A.2 LIBRARY STAFF:

What does the library want? With which part could be helped by this graduation project?
There are a couple of different aspects that could help the library. For example, the project rooms. It would be great if with the data there would be more information about the actual usages of the project rooms. How often are they used? How often do people leave early? How often do people not show? How often do people show up late? How many people are in a project room? How healthy is the air in the project rooms? If these questions could be answered the library could innovate maybe the project rooms. Another thing that the library wants is to have specific alerts on how busy it is, or what the air quality is, so that the climate control system is better used and thus save energy. A problem that happens now in the library is that when a student is looking for a workplace, they are taking other students out of their concentration so if the system could help with decreasing the number of students that are walking around.

Project rooms:

There are 2 phases in which the project rooms are used. During exam weeks the project rooms are used for a group of students that are working alone on the same subject. Every student is working individual, and when they have a question, they ask the others. The library does not see this as working together, and it would be great if this were done in the non-silence area of the library. During non-exam weeks the project rooms are used for working together on a project. People are talking, writing on the wall, a beamer is used to project et cetera.

For the project room, it would be a good idea if the system that is used to reserve rooms and the new system could work together. So that through the sensors it is possible to check whether people are there when space is reserved, if that is not the case than cancel the reservation so that other people could sit and work the space.

The non-silence area:
In the non-silence area of the library it always quiet, people do not talk there. The idea is that because of peer-pressure people do not talk there. With psychologist that is specialized in how rooms affect people, the non-silence area was redesigned. In this redesign, the goal was to stimulate collaboration. There where plants added, these plants were placed in squares with tables in them, a whiteboard was added, but still, people do not talk in the non-silence area.

Wi-Fi tracking in the library:
It would be good if people could enter different characteristics and that they are then guided to the perfect place to study. Since everyone is different and learns different, they have different preferences in their study space; the student needs to find a place that fits them. It would be great if it were possible to visualize how busy it is in the library, that the situation where a student walks from the O&O square to the library and then walks around in the library trying to find a place, that is not there because the library is full, will not happen anymore. It

would even be better if not only the number of students can be visualized but also different characteristics so that students also know if their preferred space is available.

How busy is the library?

A couple of years ago it was the case that during exam weeks it was full and during the other weeks it was pretty empty. However, this is not the case anymore. During non-exam weeks it does become a little bit quieter but not much. The way that people work in the library does change. During exam weeks students are studying and working alone; during non-exam weeks students work more on projects and work more together.

There is a sensor at the entrance of the library which counts the number of people that are walking in and out. This is not that accurate since it counts everyone twice and if someone goes to drink a cup of coffee, they are also counted, but it is a good indication on how many people use the library. In January which is a less busy month because of Christmas break and the counter was on 80000, so around 40000 people visited the library.

Why do students come to the library?

There was an extensive study done two years ago on why students come to the library. This study was done to help create a vision on how to improve the library. Out of this study, it became clear that most students come to the library to study (41%), but students also go to the library to write (17%). Other activities include reading, have a meeting and collaborate.

A.3 Privacy and Security expert:

The data from the access-points how GDPR no is that?

Tracking people through Wi-Fi is not allowed. A month ago, the municipality of Enschede was told that it was not allowed to do crowd management. They wanted to track people and not count how many people are on one spot (which is this project), so there is a difference there. With Wi-Fi tracking it hard to do it under the GDPR, many companies do it; however, it is watched closely.

There is a difference between anonymization and pseudonymization. Pseudonymization is that it is still possible to track someone with anonymization; this is not possible anymore. The data than because of a little bit random but the usefulness of the data also decreases.
It is essential to use as little data as possible to accomplish the goal. Even if it is easier to use more data to accomplish the goal, this not a valid reason to use more data.

The data from the project rooms how GDPR no is that?

It is said that that data is sensitive data, but to accomplish the goal of the system it is needed to see if people are present yes or no. It is hard to determine with which data this should be done. The NS for example also uses sensors that measure how busy it is in certain parts of the train. By collecting the data digitally, there is less allowed than when the same data was collected analog, purely because digital data is simpler to analyze. It is easier to detect patterns and collect information that may not necessarily be the intended information that was supposed to be collected out of this data.

Does the data need to be saved in a special way?
Because the data that is used in this project the data should not be saved in a special way, what could be done to make the data more save is to not work with numbers but use a probability distribution. If a normal distribution is used, it is possible to identify if it busy yes or no. With this, some randomization is added to the data, but that is not necessarily a problem.

Is the sensor underneath the table better?
It would be better than the Access Point data since the only information that can be collected from those sensors is if someone is present. With the Access Point data, a lot more information can be collected, which could be used in a bad way.

Is it allowed to show history?
As long as that are global trends, it should be allowed. It should be made sure that it is not possible to see that pietje was there first and that jantje is sitting there now.

Is it allowed to combine data of the project rooms?
The data on when there are reservations should only be at what times the room is reserved, and it should not contain any names of who reserved the room. It will be in a very dark grey area if it is possible to match how many people are in a project room and for how many people it is reserved.

However, the data is combined in a way that is not allowed; it is more the universities fault. Because if the data could be combined and then used for a goal that is not allowed the data should not be collected. An example of this is, in New York city they made the data public on all the taxi rides, from where to where, how much that trip costs and if there was tip given. However, some people on the internet combined this data with pictures taken of celebrities, the places they got in a taxi and figured out which celebrity never gave a tip. The city of New York did not think this data could be used in such a way.

Is allowed to show statics of the data?
If the data is provided, it is allowed to show the information that can be taken from the data. However, it could be a good idea not to show statics if there are not many people. To not show a number but use green, orange and red to indicate how busy it is.

What can I do to have more privacy-aware smart space?
Minimize the data that is used and when building the system use synthetic data instead of real-time data. If the data becomes pseudonymized instead of anonymized than make sure to use a hash function too has the mac addresses.

APPENDIX B IMAGES DATA ACCURACY TEST:

Figures B.1 through B.8 show the results from the data accuracy test. The results are discussed in section 5.3.

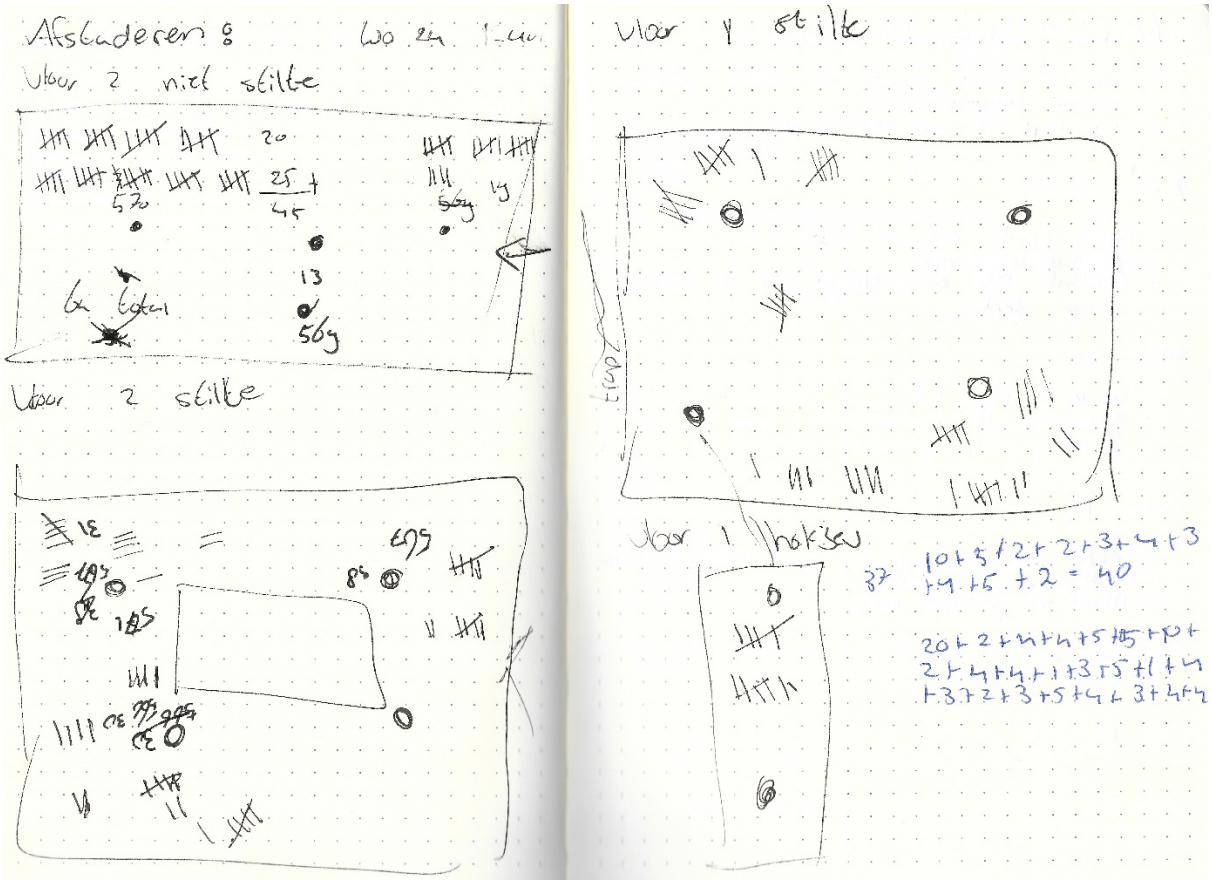

Figure B.0.1 First counting try, map is drawn by hand. The second floor is on the left handside of the picture, the first floor is on the righthand side of the picture

Figure B.0.2 Second counting try of the first floor. The first time using google maps to generate the map

Figure B.0.3 Second counting try of the second floor. The first time using google maps to generate the map

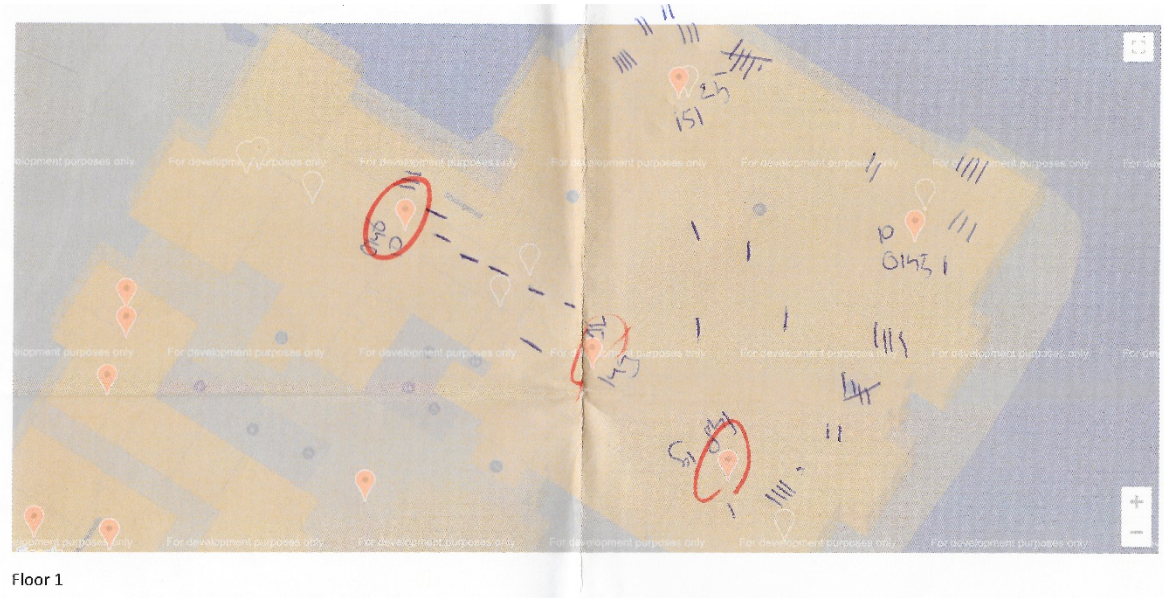

Figure B.0.4 The third counting try of the first floor. The red circles is where the counted number does not match with the number given by the access points

Figure B.0.5 The third counting try of the second floor. The red circle is where the counted numbers does not match with the number given by the access points

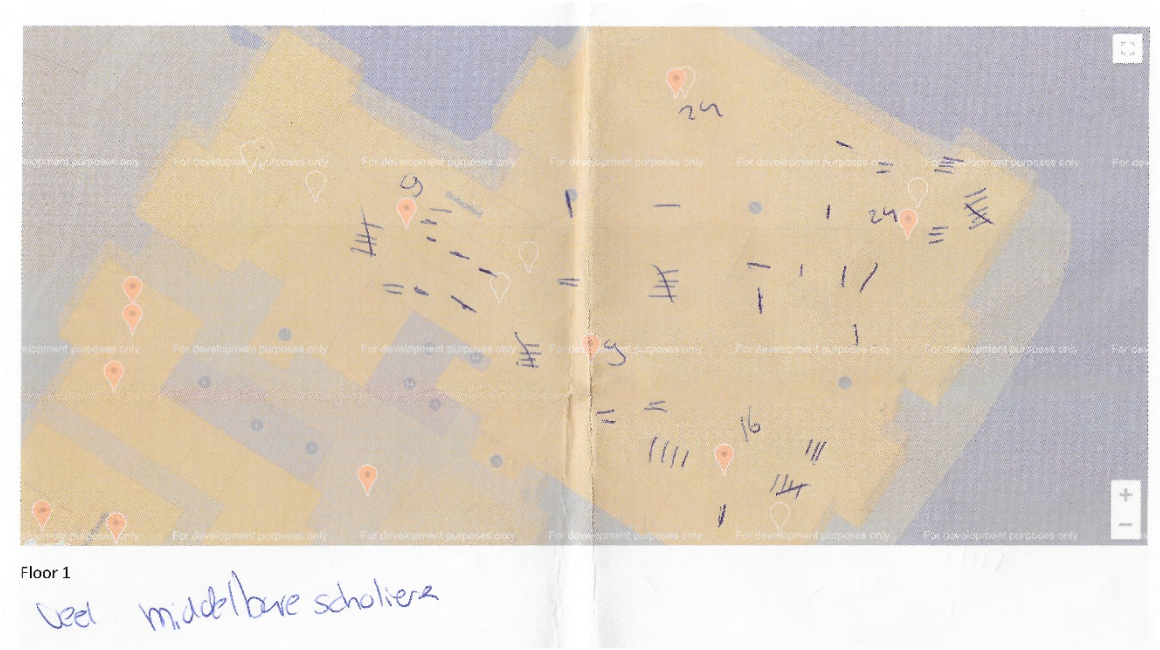

Figure B.0.6 The fourth counting try of the first floor. A lot of high school students where working in the library

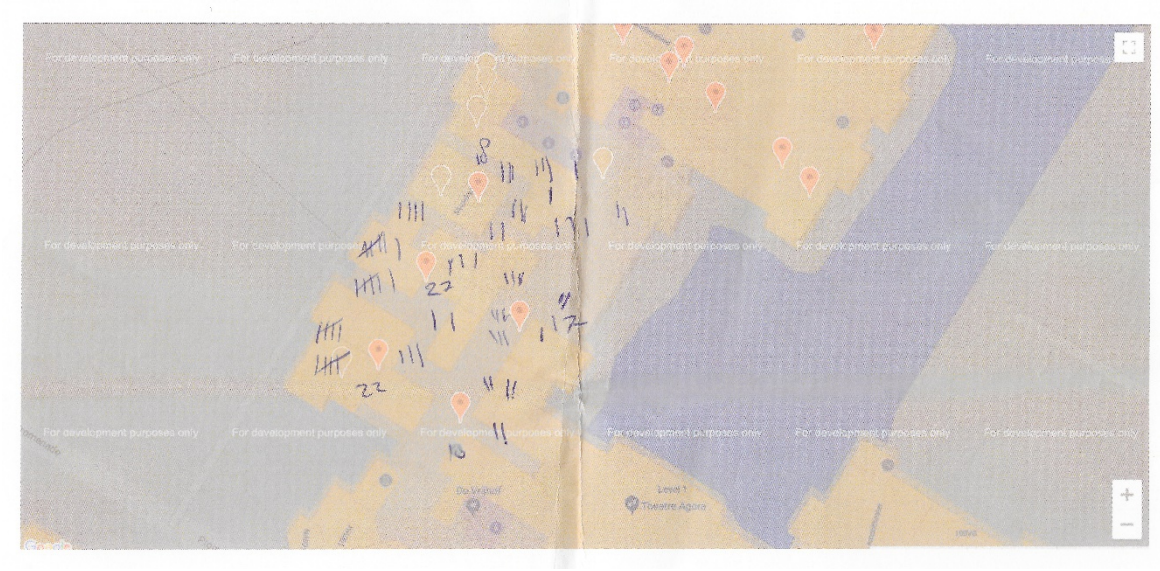

Figure B.0.7 The fourt counting try of the second floor, the non-silence part

Figure B.0.8 The fourth counting try of the second floor, the silence part

APPENDIX C DOCUMENTS ETHICAL APPROVAL:

C.1 CHECKLIST:

(See Chapter 3)

Checklist for the principal researcher when submitting a request to the EC or the EC member for an assessment of the ethical permissibility of a research proposal

1. General

1. Title of the project:
   Help students find a workplace in the Library
2. Principal researcher (with doctoral research also a professor):
   Angelika Mader
3. Researchers/research assistants (PhD students, students etc. where known):
   Marloes ten Hage
4. Department responsible for the research:
   Creative Technology/HMI
5. Location where research will be conducted:
   University of Twente
6. Short description of the project (about 100 words):
   For this project the data from the library is used to create an application that helps students find a workplace in the Library. The data used in this project is data which is called Wi-Fi data, and it is number of devices connected to an access point and because the university works with accounts to connect to the Wi-Fi the number of unique users can be identified. During this research I would like to know what requirements these visualisations have.
7. Expected duration of the project and research period:
The duration of the project is till 5th of July, the research period will be from the 3rd of June till the 17th of June

8. Number of experimental subjects:
As many as are willing but at least 15

9. EC member of the department (if available):
Dennis Reidsma

2. Questions about fulfilled general requirements and conditions

Has this research or similar research by the department been previously submitted to the EC?
☐ No

Is the research proposal to be considered as medical research (Also see Appendix 4)
☐ No

Are adult, competent subjects selected? (§3.2)
☐ Yes, indicate in which of the ways named in the general requirements and conditions this is so
Explanatory notes:
By standing in front of the library, students passing by will be asked for their opinion on example visualizations. It will be mentioned that it is for research purposes.

Are the subjects completely free to participate in the research, and to withdraw from participation whenever they wish and for whatever reason? (§3.2)
☐ Yes

In the event that it may be necessary to screen experimental subjects in order to reduce the risks of adverse effects of the research: Will the subjects be screened? (§3.4)
☐ No
Explanatory notes:

Does the method used allow for the possibility of making an accidental diagnostic finding which the experimental subject should be informed about? (§3.6 and Appendix 4)
☐ No, the method does not allow for this possibility

Are subjects briefed before participation and do they sign an informed consent beforehand in accordance with the general conditions? (§3.2, §3.3, §3.7, §3.8)
☐ No, explain why not
Explanatory notes:
Subjects will be briefed before participating but they do not sign a consent form since the consent form adds more personal data to the data collection. For this study it is important that participating is as easy as it can be. Since it is just asking a couple of questions like, do you like this visualization? What would you change about this visualization? What information do you miss? Adding a consent form would make it for the participants more troublesome, without improving their situation.

Are the requirements with regard to anonymity and privacy satisfied as stipulated in (§3.8)?
☐ Yes
Explanatory notes:
No personal data will be saved, only the suggestions and opinions.

If any deception should take place, does the procedure comply with the general terms and conditions (no deception regarding risks, accurate debriefing) (§3.10)?
☐ No deception takes place
Explanatory notes:

Is it possible that after the recruitment of experimental subjects, a substantial number will withdraw from participating because, for one reason or another, the research is unpleasant? (§3.5)
☐ No

3. Questions regarding specific types of standard research

Answer the following questions based on the department to which the research belongs.
Does the research fall *entirely* under one of the descriptions of standard research as set out in the described standard research of the department? (Chapter 4)
☐ Yes, go to question 12

If yes, what type of research is it? Give a more detailed specification of parts of the research which are not mentioned by name in this description (for example: What precisely are the stimuli? Or: What precisely is the task?)
The department Human Media Interaction applies. The task is to answer the following questions:
What do you think about these visualizations?
What would you change?
Which information is missing but would be interesting to have?

If no, or if uncertain, give as complete a description as possible of the research. Refer where appropriate to the standard descriptions and indicate the differences with your research. In any case, all possible relevant data for an ethical consideration should be provided.

C.2 INFORMATION FOLDER:

For my graduation project I was asked to do something with the data available on the campus of the University of Twente. During different conversations, with different people it became clear that, the library could use help with guiding students to a workplace. This was also

something seemed possible with the data available. Out of this idea, the following research question was formulated.

How to design an application that helps students find a workplace in the library?

To answer this question there are two important sub questions that needs to be answered:

How to design an application in a user-friendly way?
How to use the data provided for the intended application?

To be able to answer the first question it is needed to do some user testing and see what users would want. For this I would like to stand outside the library, with printed out pictures and ask students that are coming out of the library if they would like to answer a couple of questions. If they are willing to participate the following procedure will be followed.

As a participant you will be asked to look at visualizations, these visualizations are about how busy it is in the library. After looking at these visualizations, you will be asked a couple of questions about the visualizations. These questions are for example:

- What do you think about these visualizations?
- What would you change?
- What information do you miss in these visualizations?

Only the answers a participant gives are recorded. There is no personal data saved. With the answers, requirements for the visualizations are made to improve the end product.

Contact information:
Marloes ten Hage m.y.s.tenhage@student.utewnte.nl
Angelika Mader a.h.mader@utwente.nl

APPENDIX D RESULTS USER TESTING THE VISUALIZATIONS:

D.1 OPINIONS ON 6.1

- Figure 6.1 is not intuitive. How do you know where which AP is.
- There should be better names of the different access points
- This figure does not show any more information than figure 21 and 22. That figure is more intuitive.

D.2 OPINIONS ON FIGURE 6.2

- Quite useless

D.3 OPINIONS ON FIGURE 6.3

- Only show when the library is open. This gives more room to show it more in detail. Then maybe figure 6.2 is not needed anymore.
- Is good to show, especially if historic data is also showed. Than people would change their behavior accordingly.
- Use better scales so that it is easier to understand what the user is supposed to read.

D.4 OPINIONS ON FIGURE 6.4

- Use dotted lines instead of solid lines. Now they look to much like walls
- Maybe use a color to show that is a zone
- Give each zone a name and use this name in the other areas
- Black lines look a lot like walls.
- It hard to see where in the map the entrance is
- It takes too long to see what the map is and what the layout of the map is
- Take away all the grey lines they are only distracting and not that useful
- Maybe have a pop screen when hovered over an area with a picture of the area and with the amount of chairs in that area.

D.5 OPINIONS ON FIGURE 6.5

- Prefer figure 6.4, is nicer to look at.
- This figure does show that is not exact. Figure 6.4 make it seem like it is exact

D.6 GENERAL OPINIONS

- Shows estimations how busy it is expected to be
- Show how many chairs are free.
- It is not clear where the different access points are in the library and how they correspond to the different areas
- Use percentages instead of numbers, a student does not know if 30 people in one area is a lot.

- Maybe print out pages with the names of the different zones and hang them up in the library so people now to which area is where in the library.
- Make the different visualizations interactive so that when a user selects on area in one visualization than the other will also show that selected visualization.

APPENDIX E CODE CLASSES EXPLANATION

E.1 USER INTERFACE

E.1.1 index.php

This class combines all the different components into the user interface. This class can be divided into three parts. The first part makes sure that all the different classes and libraries are loaded so that they can be used in the interface. The second part is where bootstrap does its magic, and the layout of the user interface is created. In this second part, an ID is given to all the different elements that the visualizers need to fill. The third part is some JavaScript, which calls some of the visualizers to start the visualization.

E.2 VISUALIZER

E.2.1 Map visualization

The map visualizations are created with five different classes. The map visualization is called in the JavaScript part of the index.php and is run twice but with a different image to create the visualization of the main floor and the lower floor

E.2.1.1 plattegrond.js

This class is responsible for getting the data from the data transformer and then calling the visualization class to generate the visualization. There are here also a couple of functions that allow the makes it possible to interact with the map. These functions are: `draw`, `getPolygonID`, `highlightArea`, `clearHighLight`, `highlightLineChart`, `clearHighlightLineChart`, `mouseInPolygon`

E.2.1.2 AccessPoint.js

This class is used to save the data about the access points which the data transformer gives. There are a couple of functions that help the calculation class and the visualization class to distinguish different access points from each other.

E.2.1.3 Measurement.js

This class is used in the same way as the AccesPoint.js, but instead of saving data from the access points, this class is used to save the data from the measurements.

E.2.1.4 Calculation.js

This class is used to do different calculations that are needed to generate the visualizations. There are functions on getting the floor `getFloor`, calculate averages, calculate the color which are needs to be, and check whether or not the mouse is in an area.

E.2.1.5 visualisatie.js

This class generates the visualization. To create the visualization three functions are needed. The first one `calculateOverlayColor`, calculates the average amount of students of that hour. With this average, the correct color of that area is decided and is added to the access point class. Then there is the `drawOverlay` function which draws the overlay, to show the

different colors of the different areas. The last function is the `drawAreasClicked` function that changes the opacity of the colors when the mouse hovers over an area.

E.2.1.6 lineChart2.0.js

This class is used to create the line graph. How the line graph is generated can be divided into two parts. The first part makes sure that the data needed for the line graph is in the correct format and the second part draws the line chart and finetunes the look and interaction of the line graph.

E.2.1.6 estimatedChairs.js

This class calculates how many chairs there are still available and then displays updates the number in the index.php. The counting up animation is done by a library called countUp.js, which animates the counting up by changing the speed that the counting up or counting down is done.

E.3 DATA TRANSFORMER

The data transformers can be divided into two categories, the data transformers from the access points and the data transformers for the measurements.

E.3.1 Access points

There is one access point transformer, namely get_access_points.php. This transformer connects to the database and with a SQL query to collect the needed information from the database, the data is placed into an array which the different visualization can use.

E.3.1 Measurements

There are three measurements transformers. This is because of the time frame that the visualizations need differs. The measurements transformers are get_measurements_chairs.php, get_measurements_graph.php, get_measurements_map.php. They all work in the same way, but the SQL query is different for all of them.

E.4 API SCRAPER

The API scraper is responsible for getting the data from the LISA data API and placing this data into a database. This is done by a PHP script called scrape_api.php. First, a connection is made with the database. Then a connection is made with the LISA data API. The data from the LISA data API is placed in a JSON object, and the different elements of this JSON object are placed in the database through an SQL query.