DEVELOPING A USER INTERFACE FOR SMART RAINWATER BUFFER SYSTEMS

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Bachelor thesis for Creative Technology

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AUGUST 9, 2018

Abstract

The region of Twente, and particularly the municipality of Enschede, are facing frequent flooding. These problems have multiple causes, including urbanisation, geographical location, design choices made during the construction of the sewage system and environmental changes. The floods cause a large amount of costs for citizens of the city. In order to alleviate the stress on the sewage system, the smart rainwater buffer system is being developed. These buffers are placed at homes of citizens, where they take the place of a rainwater barrel, and temporarily store water collected on roofs. Two hours before expected rainfall, the buffers empty themselves to make capacity available to buffer the expected rainfall. Water can also be used locally by using a tap on the buffer's front. A user interface for the buffers is needed to provide insight into the buffer's autonomous operations. The user interface should also encourage the user to use the collected water locally.

This bachelor thesis describes the application of the Creative Technology Design Process used for developing a user interface for the smart rainwater buffer system that is being designed by co-developers at the University of Twente. A literature research into influencing user behaviour was done, as well as state of the art research into related user interfaces. After this, a web-based user interface was developed. Most requirements were full filled, but due to design changes made to the smart rainwater buffer system itself, the influence on user behaviour part of the project was dropped after the ideation phase.

The user interface was evaluated with Creative Technology students, and the evaluations were used to create a second iteration of the prototype. The test results of this second prototype were better than the first result, and tested positively with the participants. Not all suggested changes from the evaluations were implemented, but are instead left as recommendations for future work.

Acknowledgements

In this acknowledgement, I would like to thank several people that have played an important role during the process of this graduation project. Firstly, I would like to thank my supervisor, Richard Bults and my critical observer, Hans Scholten, for their supervision, guidance and valuable input throughout the project. I would also like to thank Hendrik-Jan Teekens from the municipality of Enschede and Jeroen Buitenweg from the Waterschap Vechtstromen for their feedback during multiple stages of the project.

I would also like to thank my co-developers within the Climate Adaptive City project that this project is a part of. Their input during group meetings was invaluable, and the collaboration with them was a great experience.

Furthermore, I would like to thank Felicia Rindt and Gelieke Steeghs for the work they did on the previous version of the user interface for the smart rainwater buffer. Their work was an important part of this project.

Contents

List of Figures

List of Tables

1 | Introduction

1.1 The problem

The region of Twente, and particularly the municipality of Enschede, are facing rainwater-related problems. Enschede is built on a push moraine, resulting in a height difference of 44 meters between the highest and lowest part of the city[1]. The city of Enschede also has a large amount of impermeable surfaces, mainly consisting of streets and buildings. This means that rain can't sink into the ground at the place where it falls, but instead flows from a higher part to a lower part of the city. Enschede also has a mixed sewage system, meaning that the sanitary water and rainwater end up in the same sewage system[2]. During heavy rain, this puts a lot of stress on the sewage system, resulting in it being incapable of handling the amount of water that enters the sewage system in the lower parts of the city.

The main problem is that the sewage system doesn't have enough capacity to handle the large amount of water that ends up in them during heavy rainfall, particularly in the lower parts of the city. This results in floods in Enschede, which in turn results in large costs for citizens and (insurance) companies.

1.2 Smart rainwater buffer

One of the solutions currently being worked on are smart rainwater buffers. These buffers are storing rainwater that is collected in the gutters of houses. This water is then available for citizens to use. When heavy rainfall is anticipated, the buffers will automatically dispose of water to ensure that enough capacity is available to store the amount of water collected during the anticipated rainfall. If rolled out at a large scale, this will decrease the amount of water the sewage system has to handle at peak moments.

As stated earlier, the water collected by the smart rainwater buffer is available for use by the citizen. When not using this water, it is eventually disposed into the sewage system in order to make capacity available for upcoming rainfall. It is preferable that the water is used instead of disposed, either for flushing toilets[3] or for using in the garden. The second option is preferred in many cases, as the high coverage of pavements and asphalt in urbanised areas is leading to dry ground[4].

In order to allow the citizen to view information about their smart rainwater buffer and to allow control over the valves on the buffer, a user interface is needed. While during previous projects[2], [5], [6] work has begun on a user interface for the buffer, there is currently no fully developed user interface available for this purpose.

1.3 Research question

In this research project, a user interface for the citizen will be proposed that allows them to view information about their rainwater buffer. It will also allow the citizen to open or close valves on the buffer, in order to, for example, run a drip hose in their garden. The user interface should stimulate the user to use the water for this kind of purpose.

This brings up the following research question: "How to implement a user interface for users of a smart rainwater buffer system?"

The following sub questions arise: "How to give insight into water collection and usage?" and "How to promote environmentally friendly usage of the collected water?"

1.4 Report outline

This report is structured in the following way. Chapter 2, the state of the art, will focus on background research into smart rainwater buffers, user interfaces, data visualisation and persuasive technology. It will also include previous research into user interfaces for smart rainwater buffers. Chapter 3, the methods and techniques, will focus on the methods and techniques used during this project. Chapter 4, the ideation, will focus on stakeholder analysis, their requirements and the creation of a concept. Chapter 5, the specification, will specify the project based on the concept from chapter 4, and will form the final requirements for the next chapter. Chapter 6, the realisation, will focus on the actual creation of the prototypes used in this project. Chapter 7, the evaluation, will evaluate these prototypes. Chapter 8 will conclude with report with a conclusion and recommendations.

2 | State of the Art on User Interfaces for Smart Rainwater Buffer Systems

This chapter will focus on the state of the art of the subsections of this project. This includes a literature review on the usage of data for influencing behaviour, as well as the current state of smart rainwater buffers, the current state of user dashboards and how they can motivate a user to actively use a smart rainwater buffer. Suitable data visualisation techniques for this project will be discussed, as well as commonly used technologies for dashboards and data visualisation.

2.1 Literature review

These days, more and more smart devices have entered people's lives. Smart meters measure the energy and water usage and transmit these data to utility companies. Smart thermostats control the heating and cooling in our homes and enable us to control them from our mobile phones. On top of this, cities are also becoming smarter with the help of more and more sensors distributed throughout cities.

Smart systems like the ones mentioned above generate a large amount of data that can be used for a variety of purposes. One possible application is steering people towards a more environmentally conscious and healthier life. This literature review will focus on finding out how the data from smart systems can be used to influence the user's behaviour.

To help answer this question, a look will be taken at three possibilities for influencing user behaviour, the way these possibilities can be applied to influence behaviour and the potential pitfalls of these possibilities.

2.1.1 Persuasive Technology

Persuasive technology can be used to influence user behaviour. Davis [7] defines persuasive technology as the design of computer systems to change behaviours and attitudes. Orji and Moffatt [8] state that 64 out of 85 reviewed studies report positive outcome from using a persuasive technology to influence health behaviour, and thus showing that persuasive technology can indeed be used to influence behaviour.

There are multiple guidelines for creating a persuasive technology. Lehto and Oinas-Kukkonen [9] argues that he Persuasive System Design Model ([10]) is the most sophisticated persuasive design and evaluation method available. Oinas-Kukkonen and Harjumaa's Persuasive System Design Model presents a way to analyse, design, and evaluate the context of the persuasion and it's related techniques. However, Fogg [11] proposes an eight-step design process for creating persuasive technologies as a response to many failed attempts at persuasive technologies. Fogg eight-step design process focuses on finding a simple desirable behaviour, looking at what prevents the target from already performing the behaviour and finding a technology already familiar to the target. After these first steps, successful examples should be imitated, tested and iterated upon. The two methods presented are different: the first one focuses more on finding new persuasive technologies, while the second one focuses on new applications for and iterations on existing persuasive technologies.

There are multiple persuasive strategies used in persuasive technology. Orji and Moffatt [8] list the strategies used in 85 studies. The most commonly used strategy is *tracking and monitoring* is being used by 34 studies. *Audio, visual and textual feedback* is being used in 28 studies, with *social support, sharing and comparison* being applied in 23 studies. Orji and Moffatt state that often a combination of strategies is being used.

There are ethical concerns associated with persuasive technology. Lehto and Oinas-Kukkonen [9] list many persuasive features utilised, including self-monitoring to help the user to keep track of their behaviour, simulation to show the user the result of different behaviours, reminders to remind the user to perform or not perform a behaviour and rewards and praises. Davis [7] states that, while it can serve social good, persuasive technology can make people feel under duress or under social pressure to take a particular action. Harris, Qadir, Khan, *et al.* [12] add that changing behaviour by use of technology might encounter several ethical issues like privacy when sharing user personal data. In order to account for these problems, Davis [7] lists two methods that can be used for ethical design of persuasive technology. First, Value Sensitive Design, a theoretical and methodological framework for looking at values of moral importance for both direct and indirect stakeholders. Second, Participatory Design, where users are involved in all parts of the design process of a persuasive technology. Davis [7] argues that Value Sensitive Design and Participatory Design have great potential for the design persuasive technology, but that further research into the ethical aspects of Persuasive Technology is required.

It can be concluded that persuasive technology is a good methodology for influencing user behaviour, and has been successfully applied in the past. Multiple guidelines exist, and allow for guidance during development of such a technology. Multiple strategies and features are available, most of which are focused on analysing the user and informing them about the impact of their behaviour. There are ethical concerns associated with persuasive technology, but guidelines and frameworks have been developed to recognise and prevent unethical applications of persuasive technology. These frameworks are a good start, but ethics for persuasive technology is a relatively new subject and more research needs to be conducted regarding this topic.

2.1.2 Gamification

Gamification uses elements from (computer) games to motivate users. Groh [13] defines gamification as the use of game design elements in non-game context. Levels, badges and leaderboards are used to provide status and reputation within a community, while interesting challenges and fresh and encouraging feedback can give the user a sense of improving competence ([13]). Rizzoli, Castelletti, Fraternali, *et al.* [14] mention that SmartH2O has applied these elements to encourage people to save water. Users were shown a gamified interface telling them how much water they had used, combined with encouragements and compliments based on the comparison with other users. The platform also provided users with achievements and points for achieved savings.

Gamification is a type of persuasive technology. Muntean [15] leans heavily on Fogg [16] when explaining the theory applied for gamification in e-learning, a paper also often referred to in the context of persuasive technology. Hamari, Koivisto, and Pakkanen [17] mostly agree with Muntean that the conceptual core of both gamification and persuasive technology is largely the same, but state that while persuasive technology focuses mostly on social and communicative persuasion, gamification aims to invoke users' (intrinsic) motivations.

Gamification can be used to influence user behaviour. Hamari, Koivisto, and Sarsa [18] show that the success of the application of gamification greatly depends on the game-like motivational affordances that have been implemented in a specific project. Rizzoli, Castelletti, Fraternali, *et al.* [14] shows with the SmartH2O project, targeted at saving water, that using a gamified platform led to 20% savings for users of the platform compared to non-users in the same area.

There are many ethical concerns associated with gamification. Kim and Werbach [19] argue that applying systems like leaderboards within organisations can lead to exploitation. For example, a leaderboard system for housekeeping staff at Disneyland caused workers to become panicked about losing their job, resulting in them skipping bathroom breaks is given as an example. Additionally, Kim and Werbach [19] argue that incentives (like offered in gamified experiences) can have a negative effect on people's character traits. Kim and Werbach [19] provide parents using candy as a reward for a child showing wanted behaviour as an example, as this can have negative effects on the child's social character traits. A lot can be said about the ethical issues associated with gamification - more than is relevant for this literature review. This paragraph should be seen as a cautionary remark before simply applying gamification to a problem.

It can be concluded that gamification is a useful tool for influencing user behaviour. It can be used to present user data in a format that stimulates people towards a certain behaviour by encouraging the competitive nature of humans. As with persuasive technology, gamification also raises ethical concerns.

2.1.3 Visualising data

Data visualisation make it easier to comprehend large amounts of numbers and gain insights from them. Friendly [20] states that a data visualisation can allow the viewer to see patterns, trends or anomalies that other forms (like text and tables) do not allow. Kelleher and Wagener [21] agree and add that it is easier for the brain to comprehend an image versus words or numbers.

There is research indicating that data visualisations can be used to change behaviour. Pandey, Manivannan, Nov, *et al.* [22] demonstrate that data presented by the use of a chart has a larger likelihood of having a positive change than data presented through a table. Pandey, Manivannan, Nov, *et al.* state, however, that the findings of their research are experimental and further research is necessary.

Simplicity is an important aspect of data visualisations. Kelleher and Wagener [21] list ten guidelines for effective data visualisation. These include, among others, the advice to create the simplest graph that conveys the information that needs to be conveyed. Chittaro [23] states that data visualisations need to take into account human perceptual and cognitive capabilities. Meloncon and Warner [24] points out that multiple studies have found that excess information that is not key to the data visualisation is not necessary, and conclude that the statement "less is more" seem quite true. Keeping the visualisation focused on one specific option seems to improve preference and understanding.

2.1.4 Conclusion

The aim of this literature review was finding out whether the data generated by smart systems can be used to influence user behaviour. To answer this question, a literature study was performed to look into influencing user behaviour through the use of technology.

Persuasive technology and gamification are both useful techniques for influencing user behaviour. When looking at the data generated by smart systems, it seems very likely that these principles can be applied. There is a large amount of overlap between persuasive technology and gamification, as gamification applies many of the principles of persuasive technology. The main difference is the use of game elements in gamification.

Influencing behaviour through data can lead to ethical discussions. While guidelines and frameworks exist for creating ethical persuasive technologies and gamification applications, more research on this topic should be done.

Data visualisation can be a good tool for gaining insight into data and can be used to influence behaviour. Data should always be presented in the simplest way possible, as this makes a visualisation easier to be understood.

It can be concluded that data generated by smart systems can be used to influence behaviour, as literature found during this literature review indicated that using data to influence behaviour is possible. It is recommended that research into the usage of smart devices for the purpose of influencing behaviour should be performed in the future to better understand the subject.

2.2 Smart rainwater buffers

The University of Twente is, in a collaborative project with Gemeente Enschede and the water board Vechtstromen working on the development of a smart rainwater buffer. The project this report is about is also part of this larger project. Two smart rainwater buffer system prototypes have been developed in the past. On the one hand the model built by Gelieke Steeghs[2] and Felicia Rindt[6], on the other hand the prototype developed by Boaz Vetter[5].

(a) The smart rainwater buffer prototype designed by Steeghs and Rindt

(b) The smart rainwater buffer prototype designed by Vetter

Figure 2.1: Smart rainwater buffer prototypes built at the University of Twente

Steeghs and Rindt Firstly, the prototype made by Steeghs and Rindt (see Figure 2.1a). A rainwater barrel for domestic use was used in this project, and adapted to provide smart functionality. This included water flow sensors to measure the amount of water entering and leaving the barrel, a distance sensor to measure the water level in the barrel, electronic valves, a micro controller and small computer. During this project, a dashboard was built. This will be discussed in section 2.3.

Vetter Secondly, the prototype made by Vetter (see Figure 2.1b). This prototype is using a more industrial water container, which has a much larger capacity than the rainwater barrel used by Steeghs and Rindt. The main differences include not using flow sensors to measure in and outgoing water flows, and thus only measuring the amount of water in the barrel. The prototype is equipped with temperature sensors to measure when water is about to freeze, but also when the risk of growth of Legionella bacteria is present due to prolonged high temperatures. This prototype also includes a, albeit simpler, dashboard (see section 2.3).

(a) A public smart rainwater buffer by Bas Sala

(b) One of 25 consumer oriented smart rainwater buffers installed by Bas Sala

(c) A public smart rainwater buffer by Bas Sala

Figure 2.2: Smart rainwater buffer prototypes built by Studio Bas Sala (Source: [25])

Studio Bas Sala Another party outside of the University of Twente that has worked on a smart rainwater buffer is Studio Bas Sala. One of the smart rainwater buffers currently being worked is the 'De Slimme Regenton' project by Studio Bas Sala[25]. These buffers are mostly placed in public spaces and have only been deployed at small scale in the west of the Netherlands, and seem more focussed on art than on functionality (see Figure 2.2a and Figure 2.2c). Studio Bas Sala has also deployed 25 smart rainwater buffers to citizens (see Figure 2.2b). The public rainwater buffers can be controlled by the water board, the buffers owned by the citizens can be controlled by the citizens and the water board. No autonomous action is currently taken when rain is expected; the command to empty the buffers needs to be given by a person. No information on the user interface of this project was available.

2.3 Dashboards

In this section, a look will be taken at dashboards. This will be done in both the broad sense of dashboards, as well as a dashboard specifically designed for use with smart rainwater buffers.

2.3.1 Smart rainwater buffer

In this category, the only research currently available is by two of the projects preceding this report[2], [6]. During the project of Steeghs and Rindt, two functional dashboard prototypes were built.

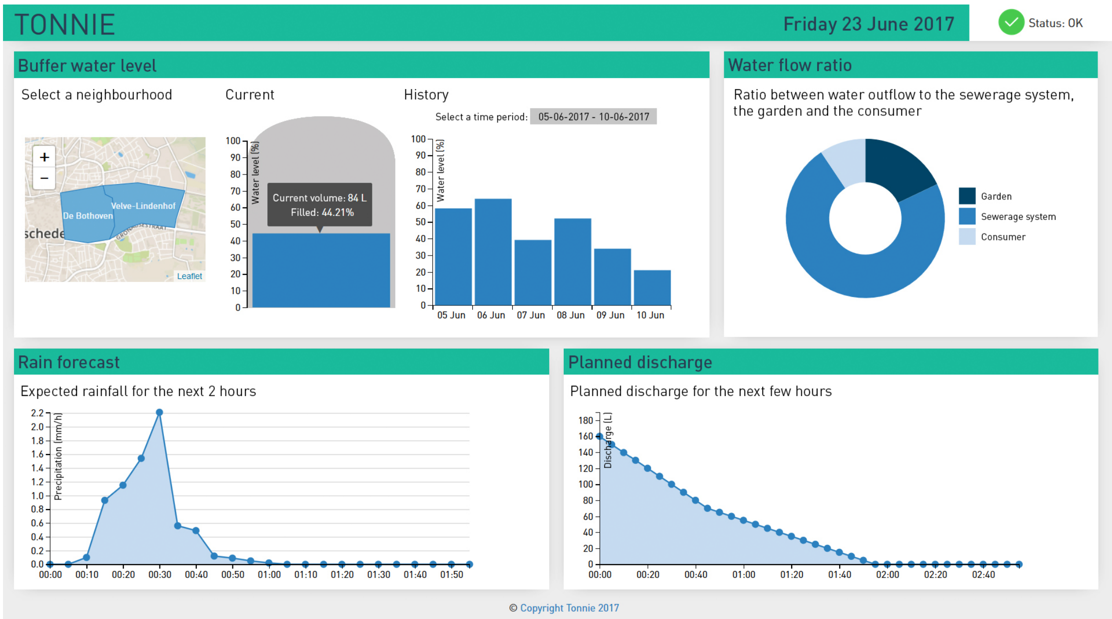


Figure 2.3: Interface for municipality built by Steeghs (Source: [2])

Steeghs and Rindt The first dashboard prototype, built by Steeghs[2] for her smart rainwater buffer with Rindt, was meant for use by the municipality, not by the owner. In this interface, information about the water level of individual buffers and averages of neighbourhoods are presented (see Figure 2.3). This includes a bar graph styled like a rainwater barrel for current fill level, a bar graph for historic fill level, a pie chart for the water flow ratio, and line graphs for rain forecast and planned discharges. The interface didn't offer any control over the functions of the rainwater buffer.

The second dashboard prototype, built by Rindt[6], was meant for use by the owner of the smart rainwater buffer. In this interface, information about the water level in the owner's buffer and historic discharges are displayed (see Figure 2.4). A date range can be chosen for both the history of water discharges and the history of the fill level of the buffer. The user can also choose to manually discharge water to either the sewage system or their garden.

An interesting part of both interfaces is the use of a status (see Figure 2.5). This makes it very easy for the municipality to see whether the system is functioning normally, and, in case something is wrong, to see the severity of the issue at a glance. Testing

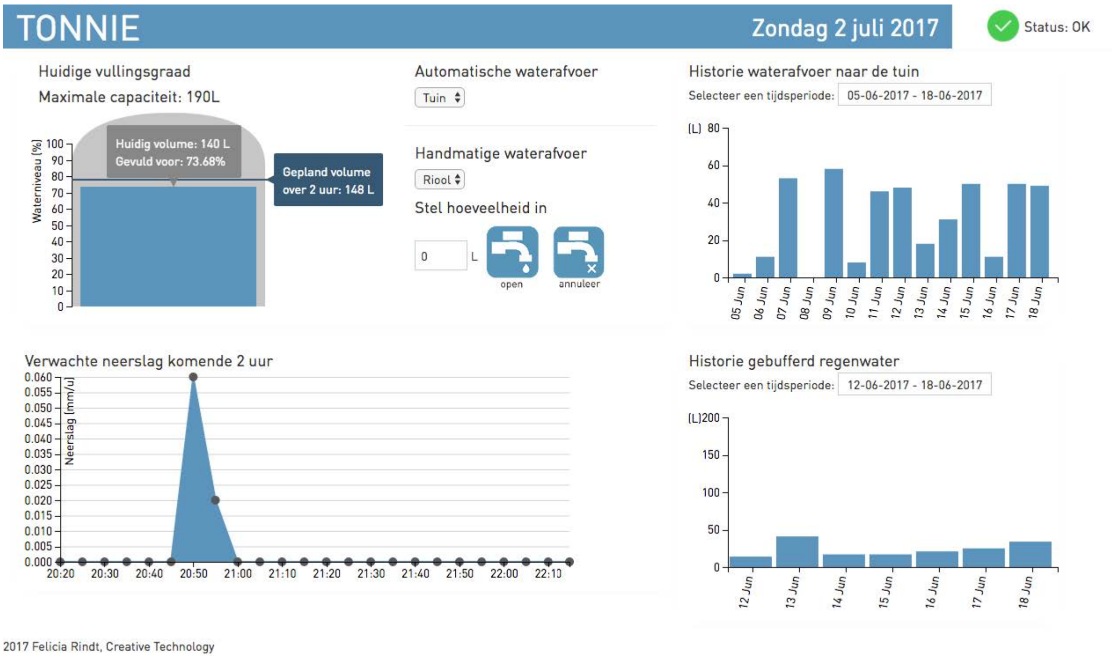


Figure 2.4: Interface for owner built by Rindt (Source: [6])

revealed that this status should be accompanied by a notification, clarifying the status' meaning.

Both the dashboard by by Steeghs and the dashboard by Rindt were evaluated by the municipality of Enschede and the waterboard Vechtstromen. The outcome of these evaluations was positive.

Figure 2.5: Different statuses in interface by Steeghs and Rindt (Source: [2])

Vetter The prototype built by Vetter[5] was mostly focused on the physical prototype, with the dashboard only being a means to control the physical prototype. It consists of a simple web page, providing the user with information about the location of their smart rainwater buffer, the temperature of the water, the amount of water in the buffer. One notable feature is the inclusion of a field where the square footage of the roof the smart rainwater buffer is connected to can be entered. This allows the buffer to calculate the amount of water collected based on the size of the roof and the amount of millimeter of rain the is expected.

Conclusion The prototypes by Steeghs and Rindt show a clear direction for the design of a dashboard for a smart rainwater buffer. Both interfaces were however not the main focus of their research, and no extensive testing with a larger group was performed. The data shown in these interfaces was indicated by Steeghs and Rindt as important.

The dashboard by Vetter was mostly functional, as a way to control and monitor the smart rainwater buffer was needed. The focus of the project was not on the design and creation of the dashboard. The project does however show one variable that is not incorporated in the prototypes of Steeghs and Rindt: configuring the size of the roof for calculation of the amount of rainwater that will be collected.

2.3.2 Energy and weather related dashboards

In this section, several dashboards built for energy and weather monitoring will be discussed, as they are also used to monitor and control a utility device or service.

Eneco Toon The Toon by Eneco is an example of a dedicated physical dashboard (see Figure 2.6)[26]. It is marketed as a smart thermostat, but also provides many other features, including monitoring of energy and water usage within the home, and power generated by a solar installation. It also offers controls for temperature, and integrates with many smart appliances and light bulbs, allowing the user to switch them from the device. It provides a quick, glanceable data overview the user can view when walking past the device, and more in-depth graphs and information when pressing these items. Toon also provides a companion app for the user, where they can view information, adjust temperature and switch on and off lights and appliances.

A more physical dashboard like the Toon could be interesting for the smart rainwater buffer. It could, for example, be attached to the buffer and allow the user to quickly release water with just a tap. Depending on the requirements, a physical dashboard could be combined with a companion app. An integration with a dashboard like the Toon, allowing the user to view information from the smart rainwater buffer on their physical home dashboard, could also be an interesting option.

Sense Sense offers a platform where users can see how much energy they use and where that energy is used[27]. The data is collected by connecting a clamp meter to the incoming power line, and the isntallation of the device can be performed in minutes. The system uses machine learning to identify specific power signatures for different appliances, and gives the user clear information on what power is used where and when. This information is shown in the form of a timeline (see Figure 2.7), where events that happened are shown. A timeline like this could be interesting to integrated into the smart rainwater buffer interface to show to the user when which events are happening or are expected to happen.

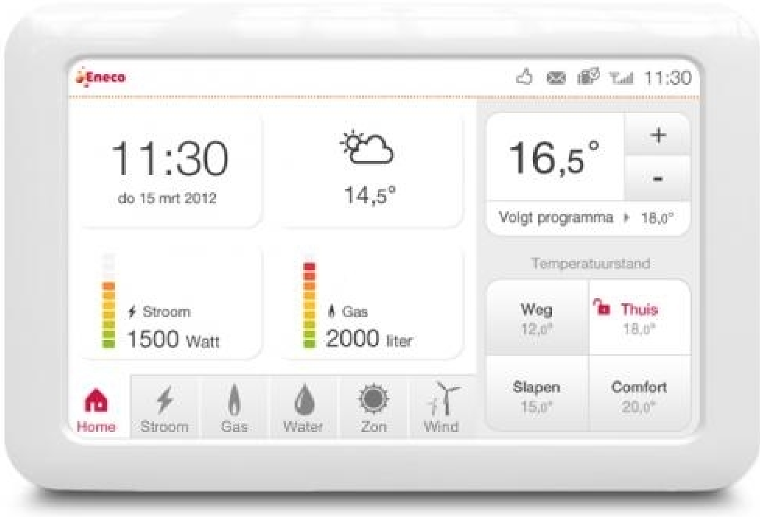


Figure 2.6: Eneco Toon (Source: [26])

WeatherLink This application is used to connect a Davis weather station to a computer, and provides desktop, mobile and web applications for users to view the data from their weather station [28]. WeatherLink looks very much like classic dashboard application with widgets that can be placed freely by the user (see Figure 2.8). What is interesting to see here are the types of data representation that is used for rain data: bar graphs. This will be discussed further in section 2.5.

Figure 2.7: The timeline provided by Sense (Source: [27])

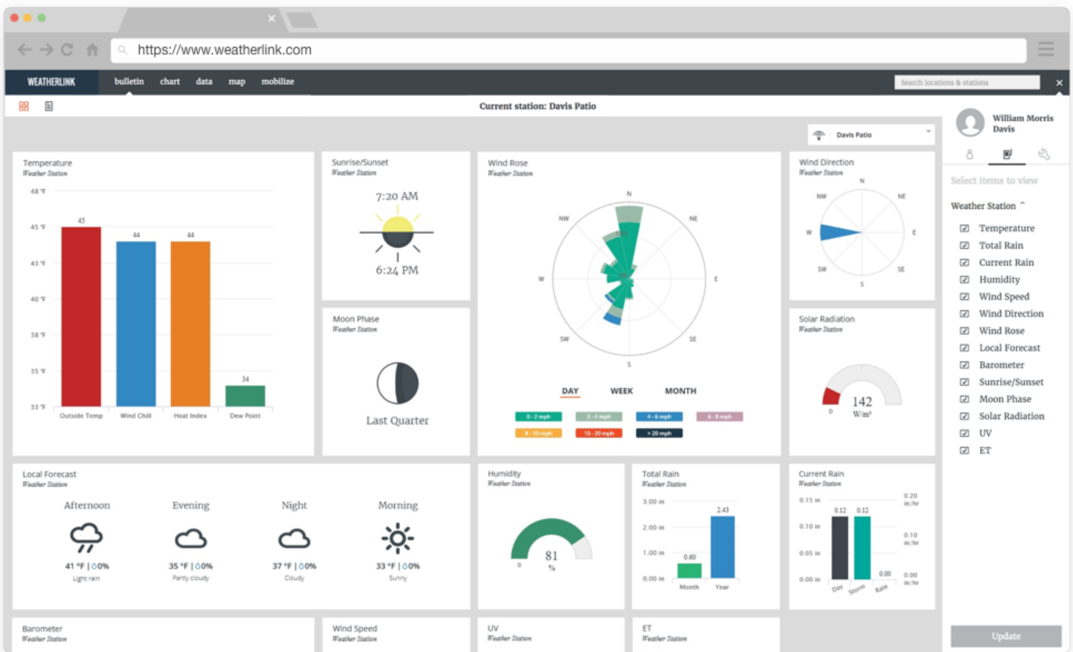


Figure 2.8: The timeline provided by WeatherLink (Source: [28])

2.4 Persuasive Technology

In this chapter, gamification and persuasive technology elements from other apps that can be applied to influence user behaviour will be discussed.

(a) The Nest leaf as shown on the thermostat interface

(b) The Nest leaf as discussed in the monthly report

Figure 2.9: The Nest Leaf element of the Nest thermostat (Source: [29])

2.4.1 Nest and the Nest leaf

Nest, a subsidiary of Google, provides smart replacements for smoke detectors, security cameras and thermostats[29]. Their thermostats are known for their self-learning ability, for adjusting the heat based on whether somebody is at home and for their ability to be controlled remotely by smartphone.

Nest thermostats employ a persuasive technology to encourage the user to adjust their heating and cooling settings just a little bit in order to lower their environmental impact. They do this by displaying a green leaf whenever the user has made an adjustment that caused a lower usage than their own average (see Figure 2.9a).

Nest also uses a different tactic for influencing user behaviour: they send the user a monthly e-mail informing them about the amount of leafs they have earned during the past month, and how they are doing compared to other 'Nesters' in the region. This comparison is done based on the amount of hours that heating in the home was enabled, in order to eliminate factors like house insulation and heating efficiency. This creates a sense of accomplishment if the user performed better than their neighbours, and encourages competitiveness.

Research[30] has shown that users of a Nest thermostat use less energy than users with a conventional thermostat. The research does however not cover what part of this is due to the gamification applied or due to other features of the thermostat.

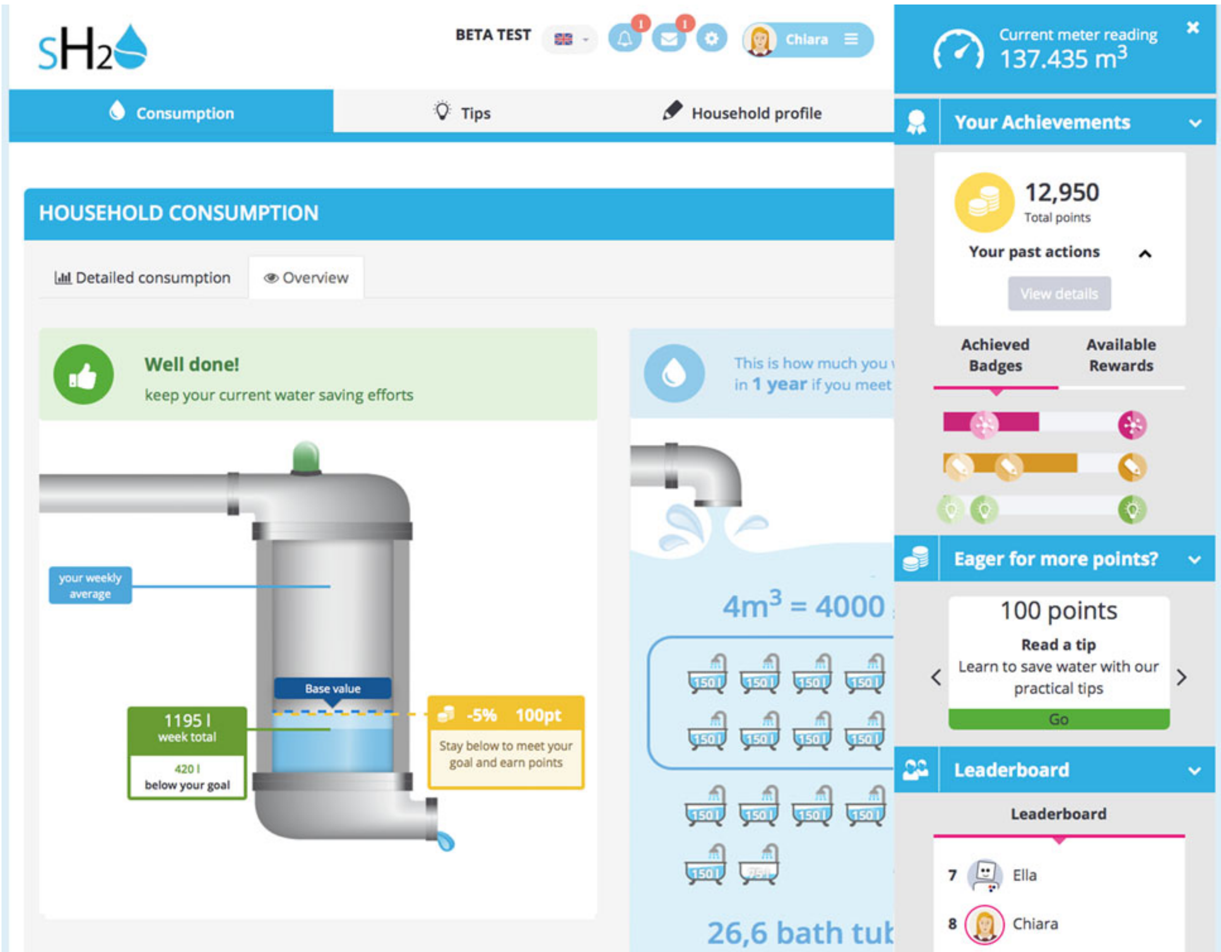


Figure 2.10: The gamified interface provided by SmartH$_2$O (Source: [31])

2.4.2 SmartH$_2$O

SmartH$_2$O[31] is a project for smart water meters in the EU. One part of this project is creating a virtuous feedback cycle between water users and the utility companies[31]. The platform uses gamification to achieve this.

SmartH$_2$O provides the user with a gamified user interface (see Figure 2.10), showing them how much water they have used and are expected to use. The interface actively encourages the user with affirmations when they have saved more water than before. The project also includes leader boards, a points system and achievements. With the points the user earns, they can claim physical rewards, like a board game that was developed for the project. The project was deployed in two real world case studies, which resulted in a 20% water saving for users compared to non-users in the same area.

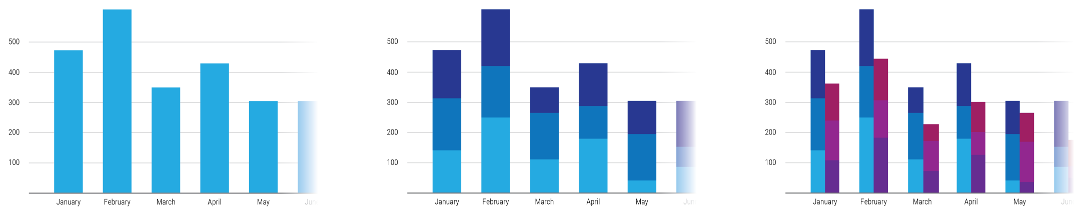
The type of gamification employed in the SmartH$_2$O project might be useful for a smart rainwater buffer, albeit in a more limited fashion. Points could be awarded for desired usage of the collected rainwater, and providing achievements or physical rewards could be an interesting way to guide the user towards the desired use of rainwater.

2.5 Data visualization

For this section, a look was taken at possible data visualization types for use in a dashboard for a smart rainwater buffer.

2.5.1 Bar graphs

Bar graphs seem to be a logical way of representing amounts per month, day or year. For the smart rainwater buffer, bar graphs (see Figure 2.11a) could be used to represent the amount of water in the buffer or the amount of water discharged for different moments in time. Stacked bar graphs (see Figure 2.11b) could be used to represent the amount of water that was discharged, separated into the water that went into the sewage system and the amount of water that was used by the owner. Grouped stacked bar graphs (see Figure 2.11c) could combine this with averages for the neighbourhood to allow for easy comparison.



(a) Bar graphs (b) Stacked bar graph (c) Grouped stacked bar graph

Figure 2.11: Different types of bar graphs

2.5.2 Area graphs

Area graphs area often used to visualise flows over a certain amount of time, and could be used to show historic and future discharge. A separation between historic and future data could be made by using an area graph with changing color, making it possible to display both in one graph. This distinction could be made even clearer by using a separator line (see Figure 2.12).

Figure 2.12: Area graph with changing colour and separator

2.6 Conclusion

From the state of the art review it can be concluded that there are few smart rainwater buffering systems available, and even fewer user interfaces developed for these systems. The interfaces by Steeghs and Rindt show a clear direction, and limited user testing was performed with positive feedback by Steeghs and Rindt. There are many user interfaces of energy and water related products available that provide elements that can be incorporated into an interface for a rainwater buffering system.

Gamification in this area is still relatively new. Companies like Nest do show promising results by incorporating game elements into their applications, and are able to steer user behaviour in a desired direction. Projects like SmartH_2O go a bit too far for a project like this by introducing heavy gamification, but still show interesting elements that could be used.

The state of the art review shows that research into the development of a user interface for a smart rainwater buffer system is novel, as there are no fully developed user interfaces for this type of application available at the moment. Further research should be put into the requirements for a user interface like this, and testing should be performed to see whether or not an implementation of persuasive technology can be used to stimulate specific use of the collected rain water.

3 | Methods and Techniques

This chapter will focus on the methods and techniques that have been used during the graduation project. Brief descriptions of the methods and techniques will be provided, and their application within the project will be explained.

3.1 Creative Technology Design Process

This graduation project will follow the Design Process for Creative Technology [32], as this process is being taught during the bachelor Creative Technology. The process start with a design question, which is then answered using multiple phases: ideation, specification, realisation and evaluation. The model is based on the Divergence-Convergence and Spiral models, resulting in a emphasis on iterative design. Iterations are made within the different stages, as well as between the stages. This can be seen in the diagram in Figure 3.1.

The structure from this design process is also reflected in the structure of this report, with chapters dedicated to all phases of the process. Below, these phases will be described. The Creative Technology Design Process was applied in a different way than usual during this graduation project. The main changes are within the ideation and specification phase of the project. These changes will be discussed below.

3.1.1 Ideation

During the ideation phase, the design question is used as a starting point for finding a solution to the question. During this phase, a creative idea will be generated to satisfy the user and stakeholder needs, and preliminary requirements are established. In the original Creative Technology Design Process no high-level concepts are developed during this phase. For this graduation project, it was deemed useful to move the creation of a high-level concept prototype from the specification phase to the ideation phase, to ensure that the stakeholder requirements are included in the design at the end of this phase.

3.1.2 Specification

During the specification phase, the preliminary requirements created during the ideation phase will be extended. A functional architecture is created, and the different components of the system are described. While in the original Creative Technology Design Process this phase is characterised by creating small prototypes, in the altered version used during this project, an early prototype has been created at the end of the ideation phase.

3.1.3 Realisation

During the realisation phase, the requirements and functional architecture from the specification are used to build the product. This phase also includes the selection of the required technology to build the product.

3.1.4 Evaluation

During the evaluation phase, the product built during the realisation phase will be tested to see if the requirements defined during the specification phase have been met. If not, the realisation phase will be entered again, and a new iteration of the product will be made. After the evaluation has been completed in a satisfactory way, the Creative Technology Design Process is completed.

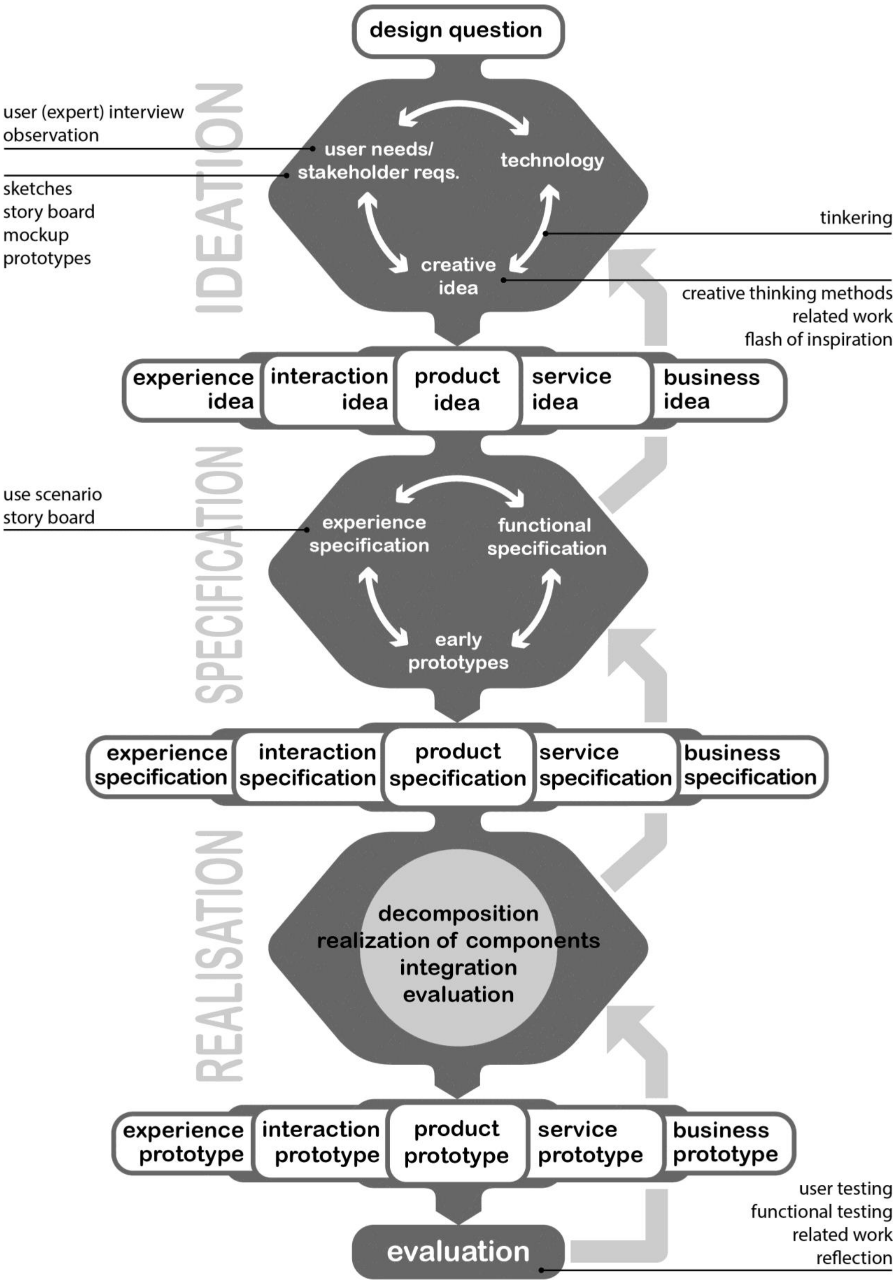


Figure 3.1: Creative Technology Design Process (Source: [32])

3.2 Stakeholder analysis

In order to find the requirements for this project, the stakeholders that influence these requirements need to be identified. Kotonya and Sommerville define a stakeholder in the context of software engineering as people or organisations who will be affected by the system and who have a direct or indirect influence on the system requirements[33]. Dix, Finlay, Abowd, *et al.* elaborate on this, and add that this includes anyone whose jobs will be altered, who supplies or gains information from it, or whose power or influence within the organisation will increase or decrease[34].

Sharp, Finkelstein, and Galal present a method to categorise stakeholders in a project. The following groups of stakeholders can be identified:

1. Users
2. Developers
3. Legislators
4. Decision-makers

Mendelow provides a method to classify stakeholders in a power-interest matrix. This method is used in the project to prioritize the stakeholders.

3.3 PACT analysis and scenario

A PACT analysis can be used to create user scenarios, which in turn enable the designer to better understand the users [37]. PACT stands for People, Activity, Context and Technology. A PACT analysis can be used to create a profile of the potential users of the product, the activities they will provide using the product, the context within which these activities will be performed and the technology they will use to perform these activities [38].

After the PACT analysis has been performed, the results of this analysis can be used to easily create a scenario within which the product is being used.

3.4 Requirements Elicitation

During any project, finding out the requirements is a very important aspect. In the ideation chapter, the preliminary requirements are written down after meetings with the stakeholders of the project. After this, a PACT analysis will be done, which will be combined with the preliminary requirements in order to create a concept. This concept will be evaluated with the stakeholders, and will result in the final requirements being written down during the specification phase of the project.

3.4.1 Functional and Non-Functional Requirements

During this project, two types of requirements will be written down: functional and non-functional requirements. Functional requirements specify a functional that a system or system component must be able to perform [39]. Non-functional requirements, on the other hand, are requirements that are not directly related to a function the system performs, but rather look at quality of the system or constraints of certain operations[39].

3.4.2 MoSCoW

The MoSCoW method[40] is used to prioritse requirements into different categories. These categories are reflected in the capitalized letters in the name of the method, and are the following:

1. **Must have**
   These requirements are vital for the project. When these requirements are not met, the project should be cancelled.

2. **Should have**
   These requirements are still important for the project, but don't result in a total failure for the entire project if not met. Some (temporary) workarounds may be required to finish the project in a functional manner.

3. **Could have**
   These requirements are still wanted, but the impact of them not being implemented is not very high. When the deadline for a project is at risk, these requirements are the first ones that should be left out.

4. **Won't have**
   These requirements are not going to be included in the current version of the project. They are still listed in the list of requirements, as they can be helpful for later work and help clarify the scope of the project.

3.5 USE Usability Questionnaire

For measuring usability, the USE Usability Questionnaire was used [41]. USE stands for for Usability, Satisfaction and Ease of use. As well as the three categories mentioned in the acronym, the USE questionnaire also includes questions about the Ease of learning. Each category includes several questions (see appendix C), which have to be answered using a 7-point Likert scale.

4 | Ideation

In this chapter, the ideation process for this graduation project will be discussed. The ideation phase will follow the phase description given in section 3.1.

Firstly, the design question revisited. After this, the stakeholders for the project are identified and described, and their power and interest is explored. After this, a PACT anlysis is performed in order to look at the user's perspective of the project. With this information, requirements are constructed and used to create a concept. This concept is then evaluated with the project stakeholders.

4.1 Design question

The design question for this report is the research question formulated at the end of chapter 1, and is the following:

"How to implement a user interface for users of a smart rainwater buffer system?", with the subquestions **"How to give insight into water collection and usage?"** and **"How to promote environmentally friendly usage of the collected water?"**.

4.2 Stakeholder Identification and Analysis

Multiple stakeholders have been identified for this project through meetings with the project supervisors. These are the municipality of Enschede, the water board Vechtstromen, the early adopters of the Smart Rainwater Buffer systems, the University of Twente, the project group working on the Smart Rainwater Buffer systems, the project group working on the central data repository for the Smart Rainwater Buffer system. These stakeholders and their respective contacts are listed in Table 4.1.

Stakeholder	Contact	Category
Gemeente Enschede	Hendrik-Jan Teekens	Decision-maker
Waterschap Vechtstromen	Jeroen Buitenweg	Legislator
Early adopters	-	User
University of Twente	Richard Bults and Hans Scholten	Decision-maker
Co-Developers Project group SRB	Jeroen Waterink and Sefora Tunc	Developer
Co-Developers Project group Data Repository	Joeri Planting	Developer

Table 4.1: Stakeholders for Smart Rainwater Buffer interface

In order to analyse the individual influences of these stakeholders, a power-influence matrix has been created, as described in chapter 3. This matrix can later be used to evaluate the importance of requirements made by these stakeholders. The municipality Enschede is the stakeholder with the most interest in the project, as well as the most power. The early adopters will eventually use this version of the project, and are, as is often the case with early adopters, very interested in the development of the project.

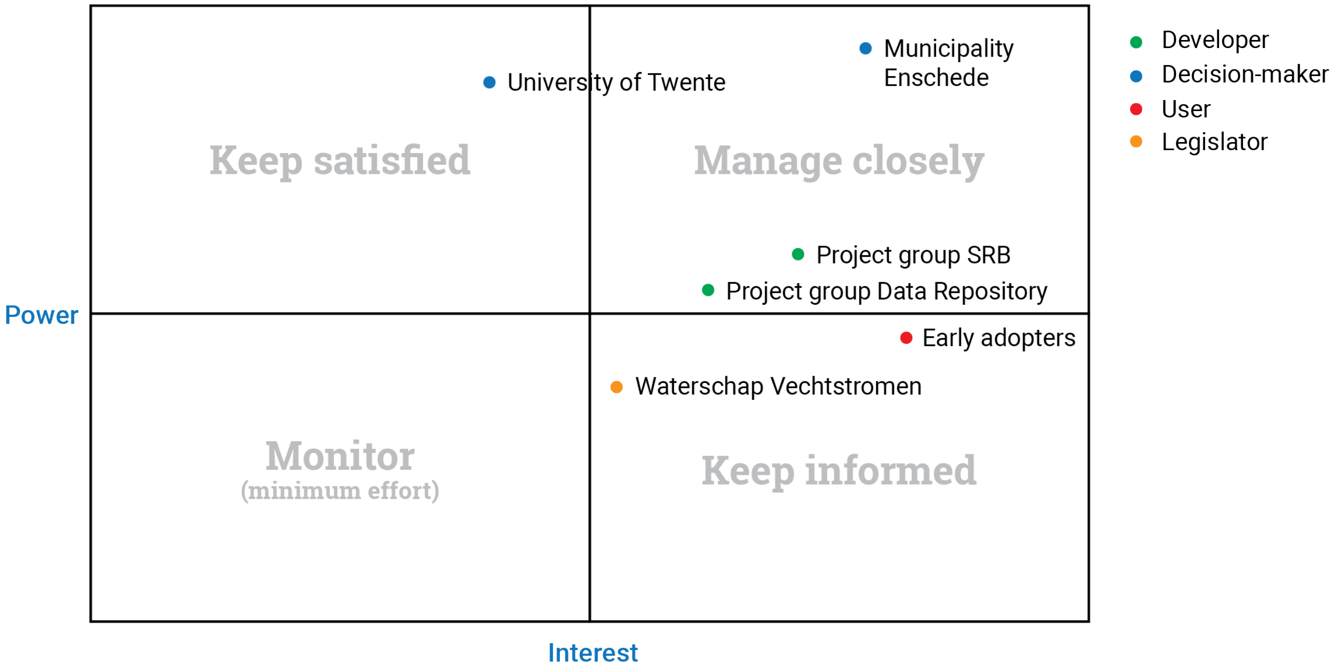


Figure 4.1: Stakeholder power-interest matrix

4.3 Interviews

During different stages of the project, interviews with stakeholders were performed. These interviews are listed in appendix A. The most important points from the interviews are listed below.

- Users should be able to gain insight into why the smart rainwater buffer is doing what it's doing.
- Users should be stimulated to use the water collected by their smart rainwater buffer locally.
- Users should only be stimulated to use the water collected by their smart rainwater in their garden during the summer when the groundwater level is low.

4.4 Meetings with University of Twente project

Regular meeting were held with the stakeholders working on other projects at the University of Twente. From these meetings the following additional preliminary requirements were distilled:

- **Co-Developers Project group Data Repository**
  - The interface needs to be able to request the required data from the data repository.
  - The interface needs to be able to send user and location data for a new smart rainwater buffer to the data repository.
- **Co-Developers Project group SRB**
  - The interface needs to be able to provide the user with reminders for required maintenance.

4.5 Preliminary Requirements

From the interviews performed with the stakeholders, preliminary functional requirements can be distilled. During the specification phase, these requirements will be worked out in greater detail. The preliminary requirements will be listed below, and will be classified according to their importance using the MoSCoW method.

4.5.1 Must have

- The interface shows the status of the system.
- The interface shows the amount of water in the buffer.
- The interface shows the planned discharges.
- The interface shows the expected rainfall.
- The interface shows which rainfall resulted in which discharge.
- The interface stimulates the local use of collected rainwater during the season where the ground water levels are low when the user is located in an area where this is preferable.

4.5.2 Should have

- The interface requests the required data from the data repository.
- The interface monitors the quality of the water in the buffer.

4.5.3 Could have

- The interface needs to be able to provide the user with reminders for required maintenance.

4.6 PACT Analysis and Scenario

In this section, the PACT analysis and scenario for this project will be described.

4.6.1 Analysis

People

The user interface for the smart rainwater buffer will be used by the citizens of Enschede with a smart rainwater buffer in their garden. This group includes people with different personalities and backgrounds. Initially, the buffer will be mainly used by early adopters. This group is often more interested in a lot of information about their new device, and is often quite tech-savvy. The interface should provide enough in-depth knowledge to keep this group interested.

The interface should also be usable by less tech-savvy people, as well as people that are not as interested in the smart rainwater buffer and just want it to perform it's tasks without them having to interact with it. For these people, it should be possible to limit the amount of interaction to the bare minimum, like unavoidable maintenance.

Activities

A large part of the operation of the smart rainwater buffer is autonomous. Since the users can't influence this behaviour, it is important to provide insights into what the buffer is doing and why it is doing this. A large part of the activities the user can perform in the interface is viewing what the buffer did or is going to do and why this happened. The user can also view the status of the system within the interface, and see whether actions need to be taken. Lastly, the interface will encourage the user to use the water collected by the smart rainwater buffer in their garden.

Context

The context of the interface will be digital, most likely on a smartphone when rain is expected or when it is raining, or on a computer when the user wants to have a more in-depth look at what their buffer has been up to. This can either happen at home or away.

Technology

The main technology used is a website that the user can visit to view information about the smart rainwater buffer. This can be done through any piece of technology that offers a web browser, but this is most likely either a smartphone or a regular personal computer. Another technology used is the central data repository, which stores the data from the smart rainwater buffer and makes it available to the interface.

4.6.2 Scenario

Henk is a 42-year old father of two kids. He lives in the west of Enschede, and experiences issues with rainwater at least once a year, often flooding his basement. During the day, he works at a small IT company. His interest into IT has always been more than just professional: at home, he likes to explore new technology, and he is often one of the first to buy a newly introduced device. When hearing about the smart rainwater buffer system, he is immediately enthusiastic and registers to receive one of the buffers.

The device is installed during the summer, and due do the dry weather the buffer remained empty for a while. He has opened the user interface a couple of times, but never paid that much attention to it as there wasn't that much to see during the weeks with no rain. Then, one day, he receives a notification on his phone from Buienradar, informing him of incoming rain. A heavy shower has been forecast. Henk immediately remembers the smart rainwater buffer in his garden, and opens the user interface on his phone. The interface reflects what Buienradar just told him: it's going to rain quite heavily! His buffer is big enough to buffer all the water collected on his roof, though, and his buffer will prevent 300 liters of rainwater from entering the sewage system.

An hour passes, and the rain falls. After the rain has finished falling, Henk once again decides to check in on his buffer. The rain was caught by it, and it is now completely filled.

4.7 Concept

To finish the ideation phase, a concept for the user interface for the smart rainwater buffer system was created, partly based on the interface by Rindt [6]. Due to time constraints, the choice was made to build one concept and use an iterative process to improve upon this concept later on in the project. The concept was built to evaluate with the stakeholders of the project. The concept user interface was built using Adobe Illustrator, and is not interactive.

4.7.1 Blocks

For building the user interface, is was chosen to make use of blocks. This makes it easy to rearrange parts of the user interface to suit different types of devices. On a mobile device, the blocks can be put below each other, while on a desktop or a tablet the blocks can be put next to each other in a grid. Below, the different blocks created will be discussed.

Status indicator

A part of the original design was the status indicator. This indicator offered the user a quick way to see whether their smart rainwater buffer was in need of attention, and if so, how urgent this was. This design element was seen as useful during testing with the municipality of Enschede.

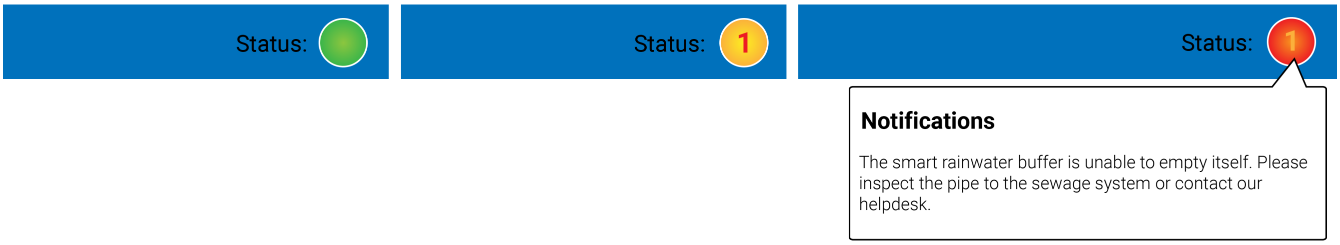


Figure 4.2: Concept of status indicators and notifications

The status indicator in the concept user interface (see Figure 4.2) includes a way to display notifications. The amounts of notifications can be displayed through a number in the status indicator. After selecting the status indicator, a popup will display the notifications.

Your Buffer

The *Your Buffer* part of the interface (see Figure 4.3) displays the most relevant information about the buffer in a larger form that can be viewed quickly. The information displayed includes the current fill level of the buffer, the health of the water in the buffer and the temperature of the water. The health of the water in the buffer is based on the freshness of the water and on the temperature the water has been since then.

Timeline

An important aspect of this version of the user interface is generating insight for users into the autonomous behaviour of their Smart Rainwater Buffer. One of the ways of showing clarifying this to the users is the timeline (see Figure 4.4). In the timeline, the events occuring to the buffer are listed. These include events happening through manual intervention by the user, but also include autonomous events. Events include water being drained by the user, water being collected by rainfall and water being flushed due to expected rain. Between the different events, the fill level after the event has happened is displayed. The timeline displays both events that have happened in the past, as well as events that are expected to happen in the near future.

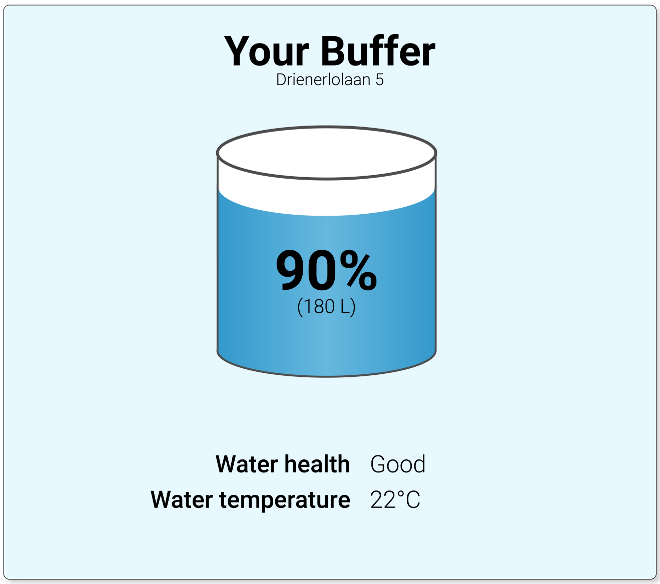


Figure 4.3: Concept of *Your Buffer* display

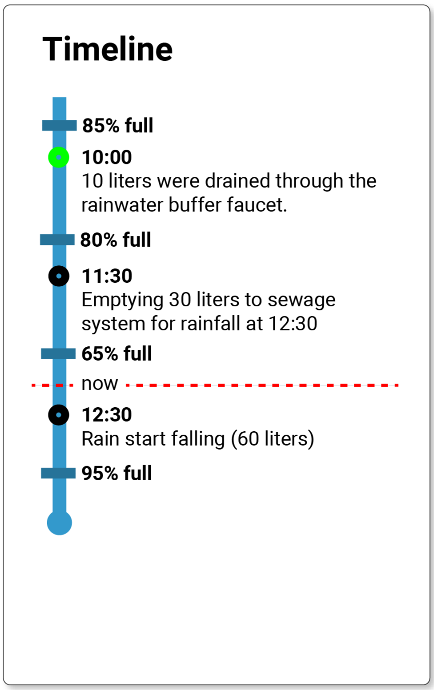


Figure 4.4: Concept of buffer timeline

Fill level

As mentioned before, clarity about the autonomous changes in the fill level of the smart rainwater buffer needs to be provided. This will be done using the timeline, but also using the fill level graph (see Figure 4.5). In the fill level graph, the amount of water in the buffer is shown over time. At points where the water changes, an events marker is shown. When selecting this marker, the user is presented with an explanation of why the water level changed at that time. The colors of the fill level graph depends on whether the data shown is past data, accurate future predictions or less-accurate future predictions.

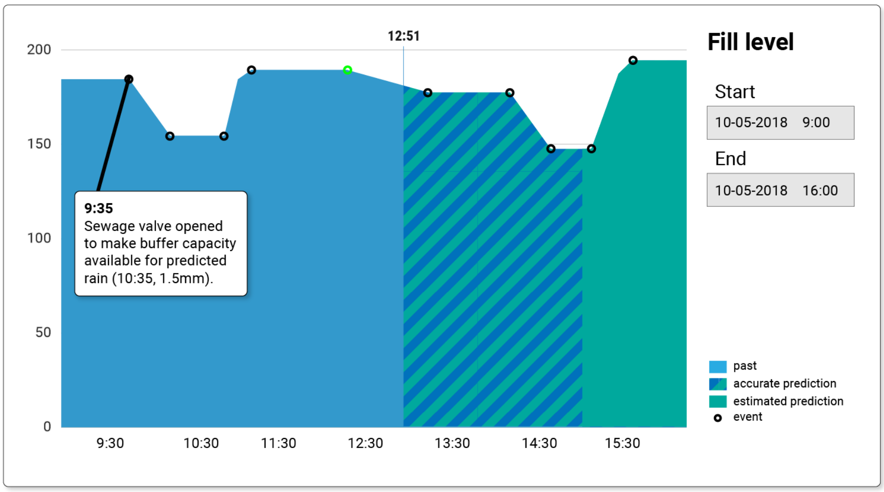


Figure 4.5: Concept of fill level graph

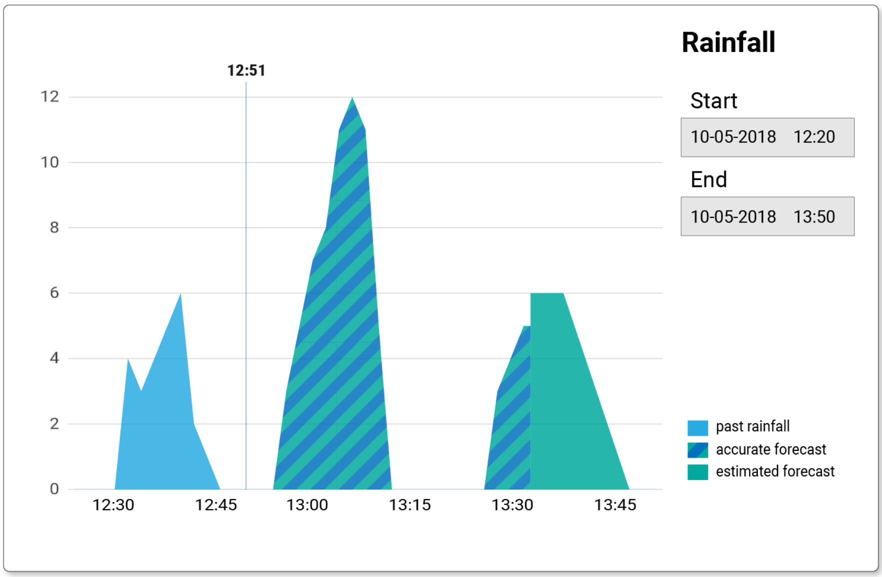


Figure 4.6: Concept of precipitation graph

Precipitation

The behaviour of the smart rainwater buffer is based on precipitation prediction data. This data is shown to the user (see Figure 4.6) in order to give context to the information provided in other blocks. The same colors as the fill level graph are used to represent past data, accurate future predictions and less-accurate future predictions.

Performance

In order to stimulate local usage of the water, the performance graph has been designed (see Figure 4.7). In this graph, the user can see the percentage of their collected water that they used in their garden, and compare this to an anonymized average of their neighbours. The user also gets appointed a benchmark score, based on the earlier mentioned percentage.

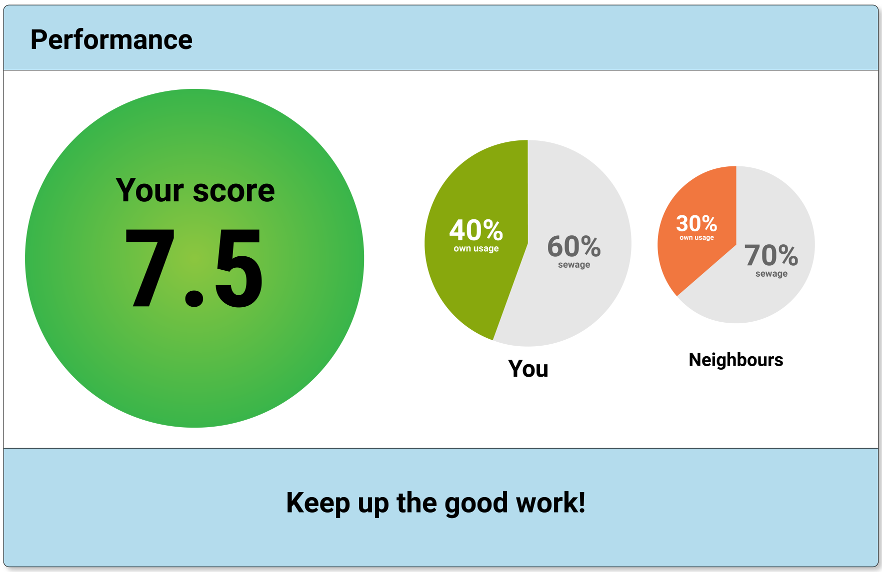


Figure 4.7: Concept of performance graph

4.7.2 Grids

A grid is used to combine the blocks and present them in a single user interface. Two grids have been designed for this concept: one for use on a mobile device, one for use on a larger screen (e.g. desktop, laptop and tablet).

Small screen

In the mobile interface, the grid is restricted to one column. This allows for displaying the information in a large enough manner to be understandable on a smaller screen, like the screen used on a smartphone. An example of a grid on a mobile device can be seen in Figure 4.8.

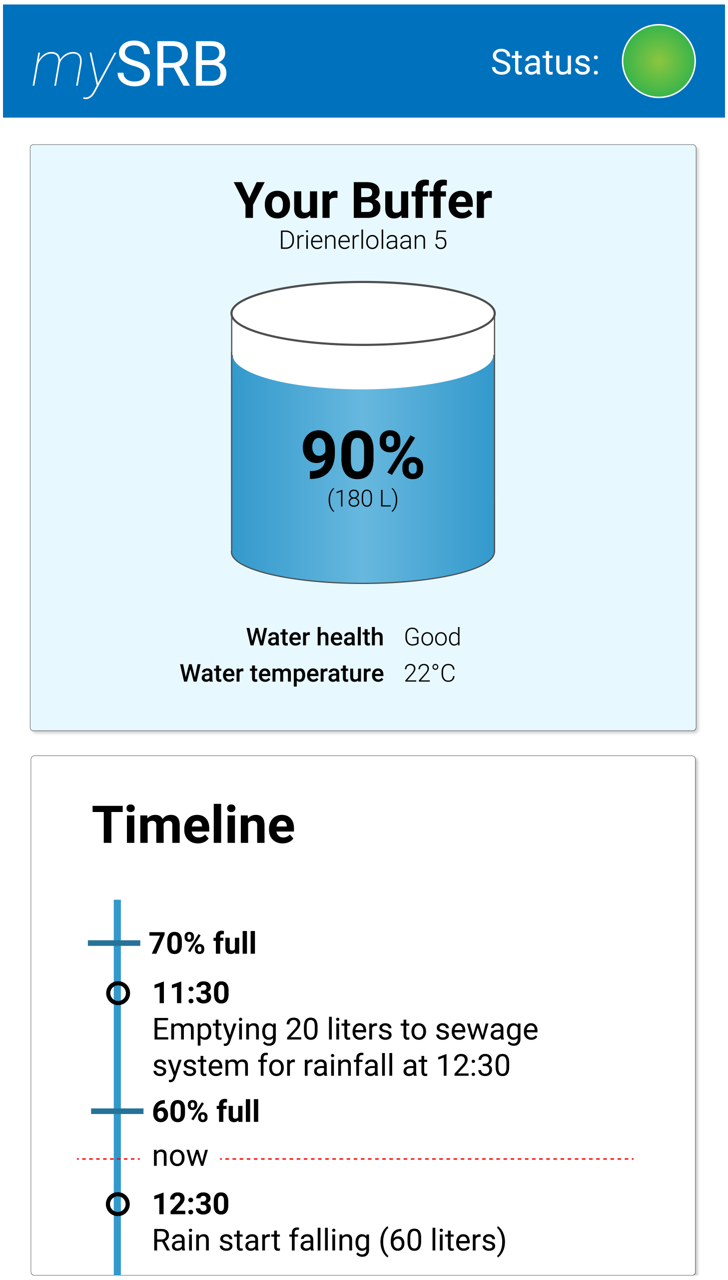


Figure 4.8: Concept of interface for small screens

Larger screen

In the interface for larger displays, a 4-column wide grid is used. This allows for displaying blocks in different width, for example 1 column wide for the timeline, 2 columns wide for the fill level graph. An example of the interface for larger screens can be seen in Figure 4.9.

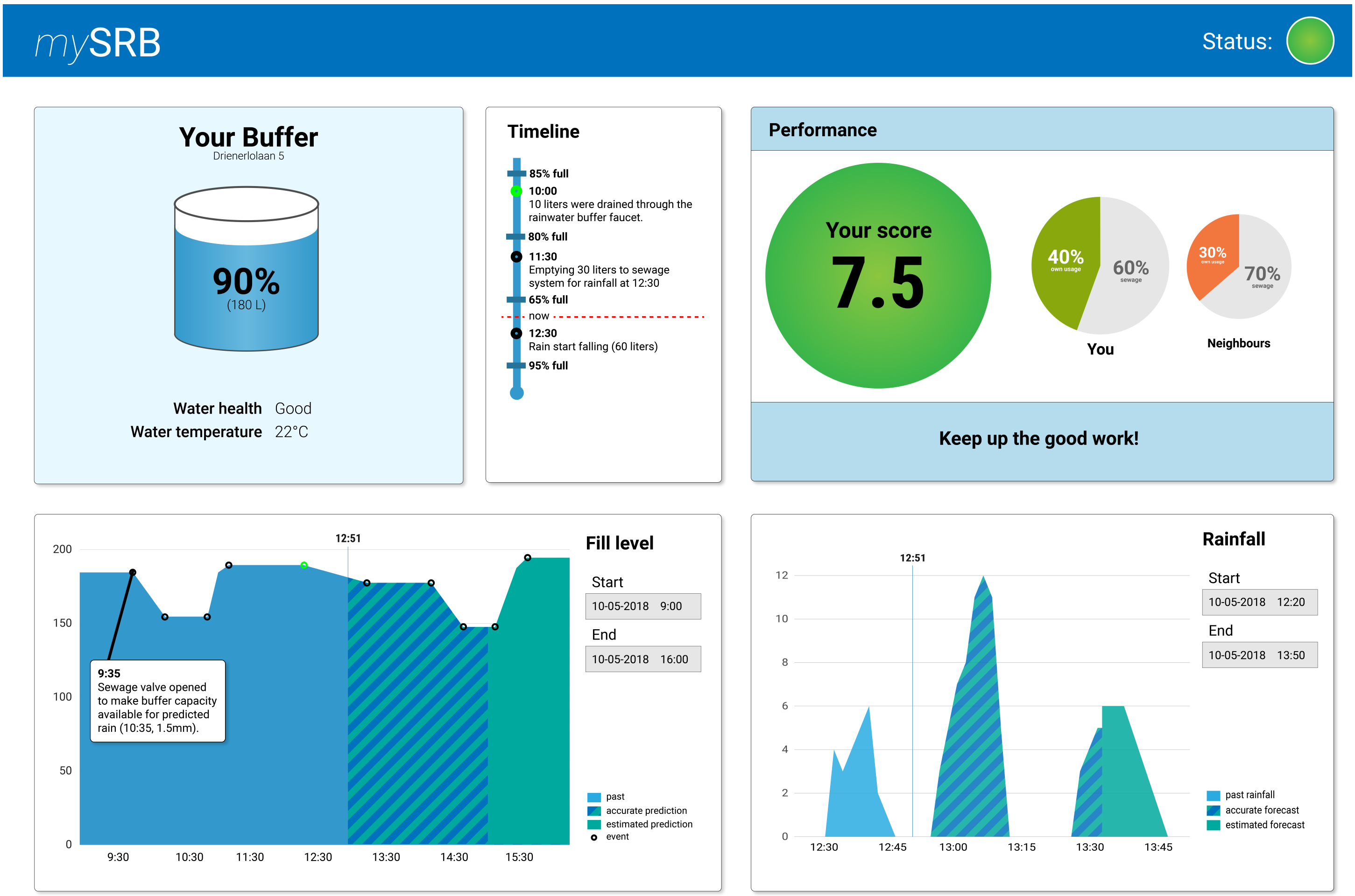


Figure 4.9: Concept of interface for larger screens

4.7.3 Evaluation

The concept created during the evaluation phase was presented to the stakeholders from the municipality, the water board and the University of Twente. The stakeholders indicated that the concept was in line with their expectations and gave the green light to continue with the further development of this concept.

5 | Specification

In this chapter, the User Interface for the Smart Rainwater Buffer project will be specified. This will be done according to the specification phase from the Creative Technology Design process, as described in section 3.1.

5.1 Requirements

In this section, the requirements for the Interface for the Smart Rainwater Buffer project will be listed. The requirements will be split using the MoSCoW method.

5.1.1 Functional Requirements

Must have

F1 The interface shows the status of the system

F2 The interface shows the amount of water in the buffer

F3 The interface shows the planned discharges

F4 The interface shows the expected rainfall

F5 The interface shows a timeline of the events occurring in the smart rainwater buffer

F6 The interface shows which rainfall resulted in which discharge

F7 The interface shows the amount of water that has been taken through the faucet on the smart rainwater buffer

F8 The interface can display notifications

F9 The interface shows a graph of the historic fill level of the smart rainwater buffer

Should have

F10 The interface needs to be able to request the required data from the data repository

F11 The interface monitors the quality of the water in the buffer

F12 The interface allows for setup of the system from within the interface

F13 The interface shows the reason for a change in water level in the historic fill level graph

F14 The interface shows a graph of the historic rainfall in their location

F15 The interface offer the choice for a date range for the historic fill level graph

Could have

F16 The interface automatically discharges the water when the quality becomes too low

F17 The interface provides instructions for assembling the DIY smart rainwater buffer within the interface

F18 The interface can send notifications to the user's smartphone

F19 The interface sends notifications reminding the user to use the water when the weather is sunny for multiple days, the season is either summer or autumn and there is water in the buffer

Won't have

F20 The interface shows an anonymised version of the user's neighbours local usage of rainwater to compare with their own usage[1]

F21 The interface gives a benchmark score for their local usage of the collected water

F22 The interface shows the local usage from the year before in comparison to the current year

[1] This requirement, as well as other won't have requirements, was initially a must have requirement. Due to the removal of separate outlet valves for the sewage system and the garden in the implementation of the smart rainwater buffer system, this requirement was no longer possible with the current iteration of the smart rainwater buffer and was therefore moved to a won't have requirement.

5.1.2 Non-functional Requirements

Must have

NF1 The interface is available in English

NF2 The interface can be used on a desktop or laptop computer, a tablet and a smartphone

NF3 The interface should load quickly

NF4 The interface should be easy to use

NF5 The interface should be usable without written instructions by people familiar with smartphones

NF6 The interface should display a warning when it can't connect to the data repository

Could have

NF7 The interface is available in Dutch

5.2 System architecture

In this section, the system architecture for the user interface for the smart rainwater buffer will be described. This will be done by using graphical representations of the architecture, combined with explanatory text.

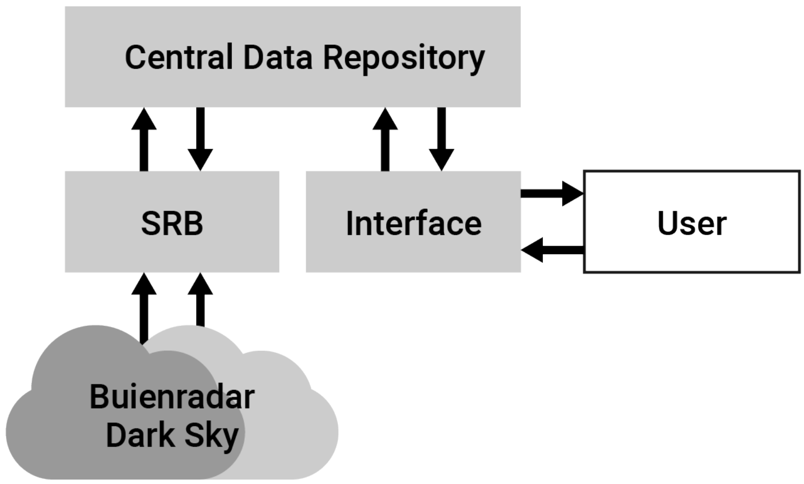


Figure 5.1: Overview of communication between interface and other systems

The interface communicates with various other systems, as can be seen in Figure 5.1. This communication happens through the central data repository. Precipitation data is collected by the smart rainwater buffer (SRB), and is used to decide when a discharge of water should occur. This data is then sent to the central data repository, where the interface receives it.

Within the user interface, separate components are responsible for generating different parts of the user interface (see Figure 5.2). The parse discharges component receives the fill level measurements and events, and uses these to generate to the past and future fill level, as well as the discharges. These are then passed to the fill level graph, the timeline and the rainfall graph. The characteristics are received and used by both the Your Buffer display, the status symbol and the notifications. Lastly, the total amount buffer for both the city as a whole and the individual smart rainwater buffer are received and used to generate the encouragement graphic.

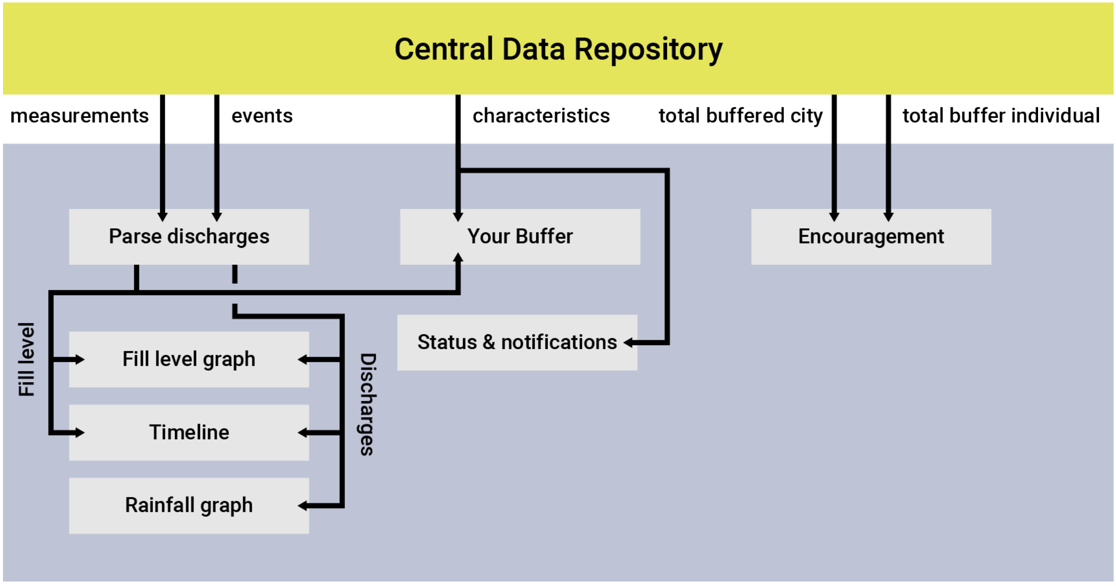


Figure 5.2: Flow of data within user interface

5.3 Data structures

As seen in the previous section, the interface exchanges data with the central data repository. The endpoints used to transmit and receive data are provided by the creator of the data repository, and are listed below. Each endpoint is a URL that can be accessed by using an HTTP GET-request. The URLs listed below omit the hostname and port, as this might change in the future.

Please note! In order to quickly build a prototype, security was not an important aspect of the development of the data repository and smart rainwater buffer. The data is accessible to anyone with the ID of the smart rainwater buffer, and the username/password combination is only used to achieve very basic login functionality for users. It is very important that this is changed before rolling out the system to a larger group.

The following abbreviations are used:

- **dt**
  A point in time formatted as *YYYY-MM-DD:HH:MM:SS*
- **sid**
  The sensorsystem ID associated with the smart rainwater buffer the interface is currently displaying information about
- **stid**
  The sensorsystem type ID. This is necessary because the central data repository is also used for other projects in the Climate Adaptive City project. For the smart rainwater buffer, this ID is 1.

The following endpoints are relevant to the interface:

- **/cons/locations/sid/stid**
  This endpoint returns the current location of the system.
- **/cons/measurements/sid/stid**
  This endpoint returns all measurements.
- **/cons/daymeasurements/sid/stid**
  This endpoint returns the measurements (fill level and water temperature) for the current day.
- **/cons/datemeasurements/sid/stid/start-dt/end-dt**
  This endpoint returns the measurements (fill level and water temperature) in a given time range.
- **/cons/events/sid/stid**
  This endpoints returns the events (planned and manual discharges) for the current day. For both planned and manual discharges, the capacity available after the discharge is given.
- **/cons/events/sid/stid/start-dt/end-dt**
  This endpoints returns the events (planned and manual discharges) in a given time range. For both planned and manual discharges, the capacity available after the discharge is given.
- **/prod/registersensorsystem/sid/stid/latitude/longitude/username/password**
  This endpoint is used for registering a new system. Latitude and longitude of the system need to be provided, as well as a username and a password used for accessing the dashboard belonging to this system.

- **/cons/id/username/password**
  This endpoint returns the sensorsystems belonging to a username and password combination. This is used when first opening the user interface to retrieve the ID of the buffer. This ID is then used in further requests.

- **/cons/location/sid/stid**
  This endpoint returns the current location of the smart rainwater buffer.

- **/cons/characteristics/sid/stid**
  This endpoint returns the characteristics of the smart rainwater buffer.

5.3.1 Data processing

The interface displays fill levels for both past and future. These fill levels are available for the past, but predicted fill levels in the future are not stored in the data repository. Expected rainfall is also not stored in the database.

In order to calculate both the future fill level and the future rainfall, the planned discharges can be used. The values returned by the data repository for a planned discharge are the capacity that has to be available after the discharge. This capacity matches the amount of rain that is expected to fall onto the roof the buffer is connected to. With this knowledge, the amount of rain falling at specific times can be calculcated, as well as the future fill levels.

This flow of data can also be seen in Figure 5.2.

6 | Realisation

In this chapter, the realisation process for this graduation project will be discussed. The realisation phase will follow the phase description given in section 3.1.

6.1 Choice of technologies

While a multitude of technologies are available for developing a user interface, it was chosen to develop the user interface as a website. This was done for a multitude of reasons: a website is multi-platform by nature, as any device with a web browser can view it. This means that there is no need to develop a separate application for different types of devices and operating systems. A website also does not require installation, which might be necessary for a 'real' application. Lastly, the author already had prior experience with web development, reducing the time necessary to learn new technologies.

Bootstrap was chosen as a layout framework. This framework makes it easy to build responsive websites, meaning that they adjust their layout when viewed on different devices with different screen sizes. This is done by constructing the layout with blocks that are then ordered in a grid. This grid is then changed for the differing screen sizes.

For interaction and data retrieval, the programming language Javascript and the library jQuery where used. jQuery is a library for Javascript that provides functions for easy manipulation of HTML elements and data retrieval.

For generating graphs, the graphing library Chartist.js was chosen. This library allows for easy creation of graphs, like line charts and area graphs. Chartist.js was chosen over other libraries, as it was the only library that offered all needed features while being free and open source.

6.2 First prototype

With the requirements and the technologies mentioned above, a first prototype was built (see Figure 6.1, Figure 6.2a, Figure 6.2b and Figure 6.3). This prototype was not linked to the data repository, but instead used demo data. The demo data was formatted in a similar way to the data the data repository would provide, and processed in the same way the data from the data repository would be processed. The prototype was built using different blocks for different parts of the interface. Below, these blocks will be discussed.

6.2.1 Parsing discharges

As discussed during the specification stage, the data received from the data repository doesn't have all the data in the necessary format for the different graphical representations. The discharge parsing function is responsible for multiple things. Firstly, it uses the planned discharges in the future to calculate the future fill levels. Secondly, it uses the planned discharges to generate the expected rainfall. Lastly, it it uses the planned discharges to generate the data necessary for displaying the event dots on the fill level graph and displaying the timeline.

6.2.2 Blocks

Status bar

The status bar on top displays the buffer status. The status is indicated by a colour, and can be either green (everything's OK), orange (warning) or red (error). A status other than green is always accompanied by a notification. The system can display more than one notification: if this is the case, the status circle will take the colour of the 'worst' notification. When one or more notifications are available, the status circle will display the number of notifications. The user can click the status circle to view the available notifications (see Figure 6.2a).

Your Buffer

The *Your Buffer* block is used to display basic information about the smart rainwater buffer. This includes the location, the current fill level (both in percentage and in liters), the water health and the water temperature. The water health in this first prototype has only two states: *Good* and *Risk of legionella*. The latter is shown when the water temperature is above 20 degrees, as legionella is likely to develop when the temperature is higher than 20 degrees.

Fill level graph

The fill level graph shows fill levels of the smart rainwater buffer for both the past and the future. The future fill levels are based on two types of predictions: accurate two hour predictions from Buienradar, and less accurate but longer term predictions from Dark Sky. The accuracy of the predictions is shown by the colour of the area graph. To make it clear to the user why a change in fill level is occuring, events are shown in the fill level graph as black dots. The user can hover over these black dots, and is presented with a popup describing why the change in fill level occured (see Figure 6.2b). The current time is shown by a black line.

The logic in the function that generates the fill level graph is also responsible for taking the data parsed in the discharge parsing function discussed above and modifying it so that it can be displayed by the graphing library (Chartist.js). This includes splitting the measurements into the three time periods, and calculating where the event points should be displayed.

Timeline

In addition to the fill level graph, a timeline is provided, showing the the events that happen to the smart rainwater buffer. The timeline shows the fill level between events, so the user can see what the resulting fill level was after an event has happened.

Rainfall

The rainfall graph shows the predicted and past showers in a line graph. As with the fill level graph, the accuracy is indicated by the colour of the line. The rainfall is shown in the amount of liters that are expected to enter the smart rainwater buffer.

Gamification element

A gamification element is included to inform the user of the performance of their smart rainwater buffer, and introduce a competitive element. It informs the user of the total collected rainwater of their buffer, and compares this to an anonymized average of their neighbours buffers. This is displayed using a donut graph and an accompanying text.

——*This prototype is evaluated in section 7.3*

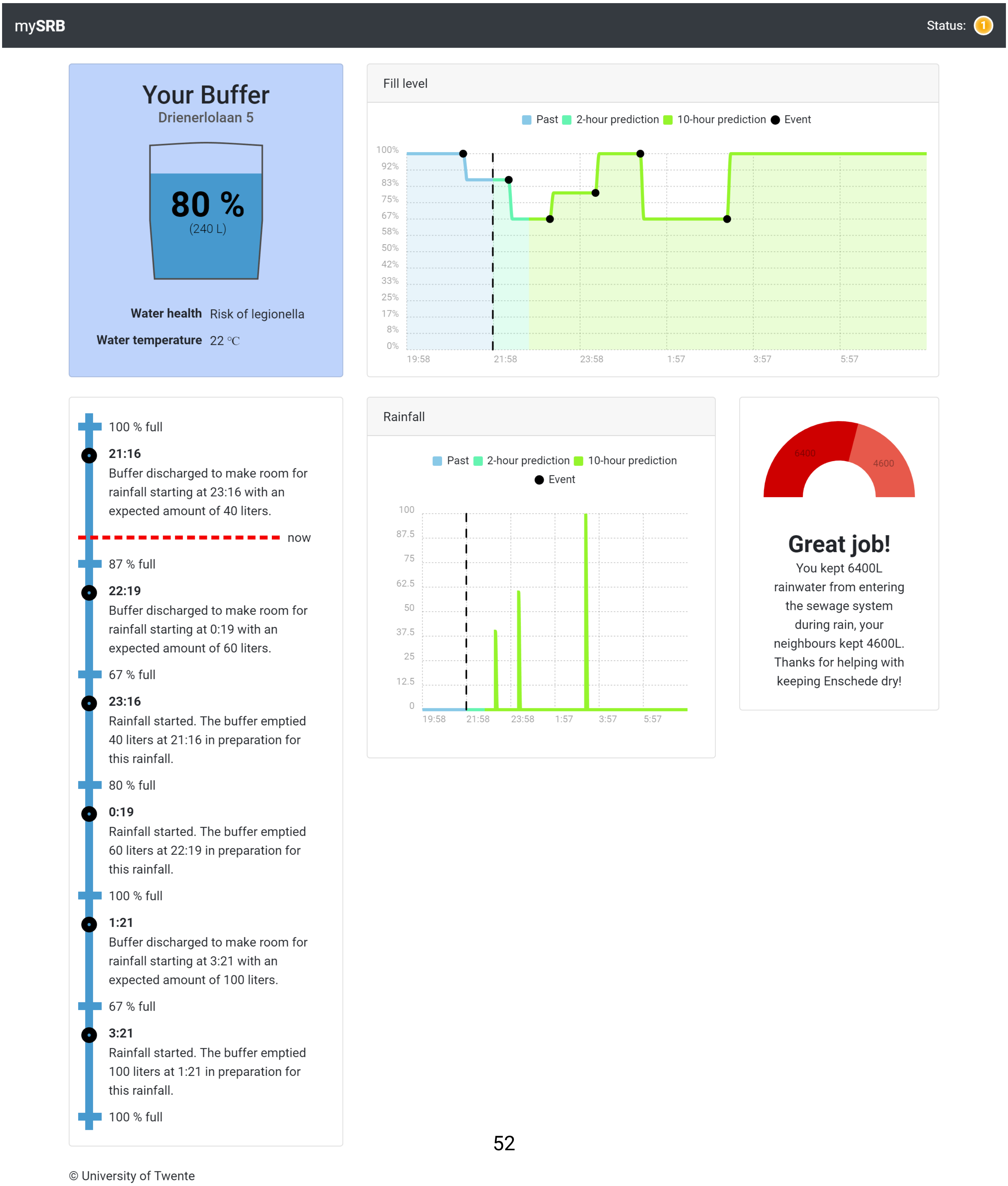
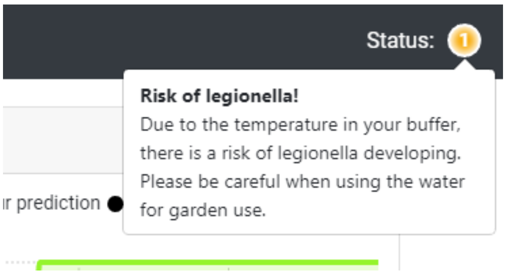
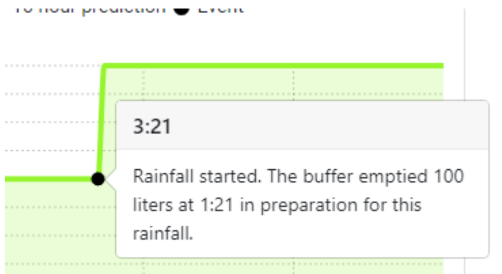


Figure 6.1: Screenshot of the first prototype on a desktop, laptop or tablet



(a) Screenshot of a displayed notifications in the first prototype



(b) Screenshot of a information popup in the first prototype

Figure 6.2: Screenshot of details of the first prototype

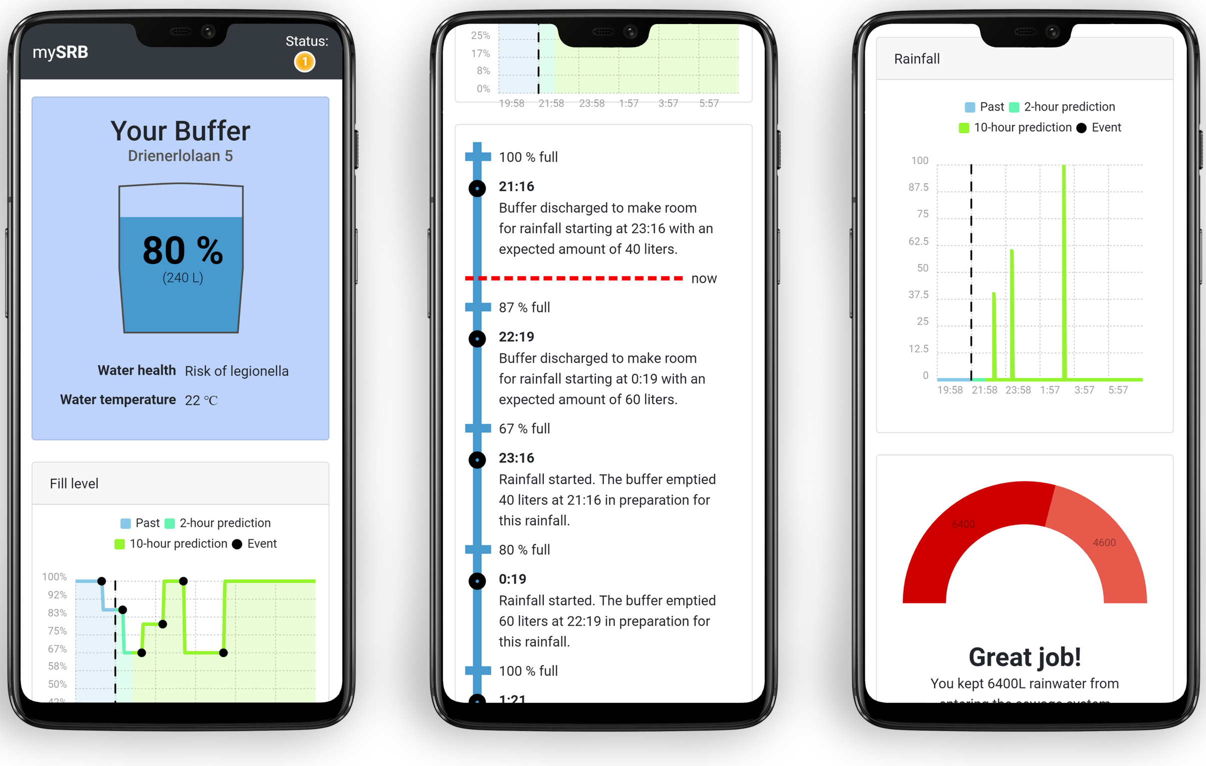


Figure 6.3: Screenshots of the first prototype on a smartphone (screenshot template by Amrit Pal Singh, amritpaldesign.com)

6.3 Second prototype

Using the results from the evaluation of the first prototype, a second iteration of the prototype was built. This was done by firstly deciding on the required changes to alleviate the issues found during testing, and then deciding whether these could be implemented in the time available. The changes that were chosen to be implemented were then implemented. This prototype was initially not linked to the data repository, but instead used demo data. The demo data was formatted in a similar way to the data the data repository would provide, and processed in the same way the data from the data repository would be processed. After the evaluation of this prototype was completed, this prototype was eventually succesfully linked to the data repository.

6.3.1 Suggested changes

In this section, the changes suggsted by the evaluation done in section 7.3 will be listed and classified based on whether they will be implemented or will become recommendations for future work.

To be implemented

- **The rainfall graph should be merged into the fill level graph, and display when the buffer doesn't have enough capacity.** This will make the rainfall graph easier to read, as both graphs now share the same time axis. The shared y-axis will also make sure that it easy to see when the buffer can't handle the expected rainfall, as the peak will exceed the 100% full mark in the fill level graph.
- **Merge status display into the Your Buffer screen and remove the top bar.** This will remove the confusion caused by the top bar, as well as moving the status display to a more prominent place in the interface.
- **Bad weather health should be displayed clearer.** To achieve this, the water should be coloured in a different colour to indicate clearly that something is wrong with the water and get the user's attention.
- **Remove the timeline on desktop devices.** On these devices, the fill level graph with it's event dots is very easy to use, and the timeline is not necessary. While not tested, the timeline does seem more useful on mobile devices due to difficulties with pressing the small dots on smaller screens. On these devices, the timeline will be displayed.
- **Add total liters to the fill level in Your Buffer.** During testing, users were confused by whether the number below the fill percentage was the total capacity of the buffer or the current amount in the buffer. To clarify this, the total amount will be added.

- **Improve colour use.** The colour palette used previously was the default palette of Chartist.js. For the second prototype, a more optimized colour palette for the smart rainwater buffer will be used.
- **Change gamification element to reflect the total amount of water buffered by all smart rainwater buffers, and show the part the user's smart rainwater buffer played in this.** This will show the user their system is actively helping in solving the problems their city is facing.

For future work

- **Show exact values when hovering the fill level graph.** While extensively requested during the tests of the first prototype, it is difficult to implement this feature with Chartist.js. For this reason, it was decided to not implement this feature at this time.
- **The rainfall graph should show the amount in millimetres, as well as the amount in litres.** This feature will currently not be implemented, as this data is currently not being stored in the data repository, and reliably retrieving this data in the user interface was impossible due to time constraints.
- **Weather information should be overlaid over the fill level graph.** This feature will currently not be implemented, as this data is currently not being stored in the data repository, and reliably retrieving this data in the user interface was impossible due to time constraints.

6.3.2 Blocks

In this section, the blocks the user interface consists of will be discussed again. For the blocks that were also present in the previous iteration, the changes will be discussed.

Your Buffer

This block experienced a couple of changes. Firstly, the colour of the water inside the buffer now changes to an orange colour when the water health is anything else than good, in order to grab the user's attention. Secondly, the *risk of legionella* text is now accompanied by an information icon that display's information about the risks associated with the warning (see Figure 6.5a). Lastly, the total capacity of the buffer is now displayed next to the current amount of liters in the buffer.

Buffer Status

The buffer status has been moved from the top bar to a separate block. This block shows the general status in the header of the block, and displays the notifications within the block. The notifications have a border in the colour of the severity associated with the notification. The buffer status is always completely visible on a desktop or tablet, but will collapse on a mobile phone, requiring a tap in order to view the notifications.

Encouragement

The gamification element has been replaced by an encouragement block, that informs the user of the total impact of all smart rainwater buffers in their area, and the impact their buffer had on this.

Fill level graph

The fill level graph has been changed to include the rainfall graph. This is done by displaying peaks within the fill level graph. The peaks will become red when the shower exceeds the buffer capacity. The colours of the graph have also been changed to more suitable colours. The event dots now show when a shower is bigger than the capacity available in the buffer, and show how much water will overflow (see Figure 6.5b). The event dots will disappear when using a mobile device, as this information is then shown by the timeline (see Figure 6.6).

Timeline

The timeline has been removed from the desktop version of the interface, and is only displayed on a mobile device as the event dots on the fill level graph become difficult to use when using a mobile device.

——*This prototype is evaluated in section 7.4*

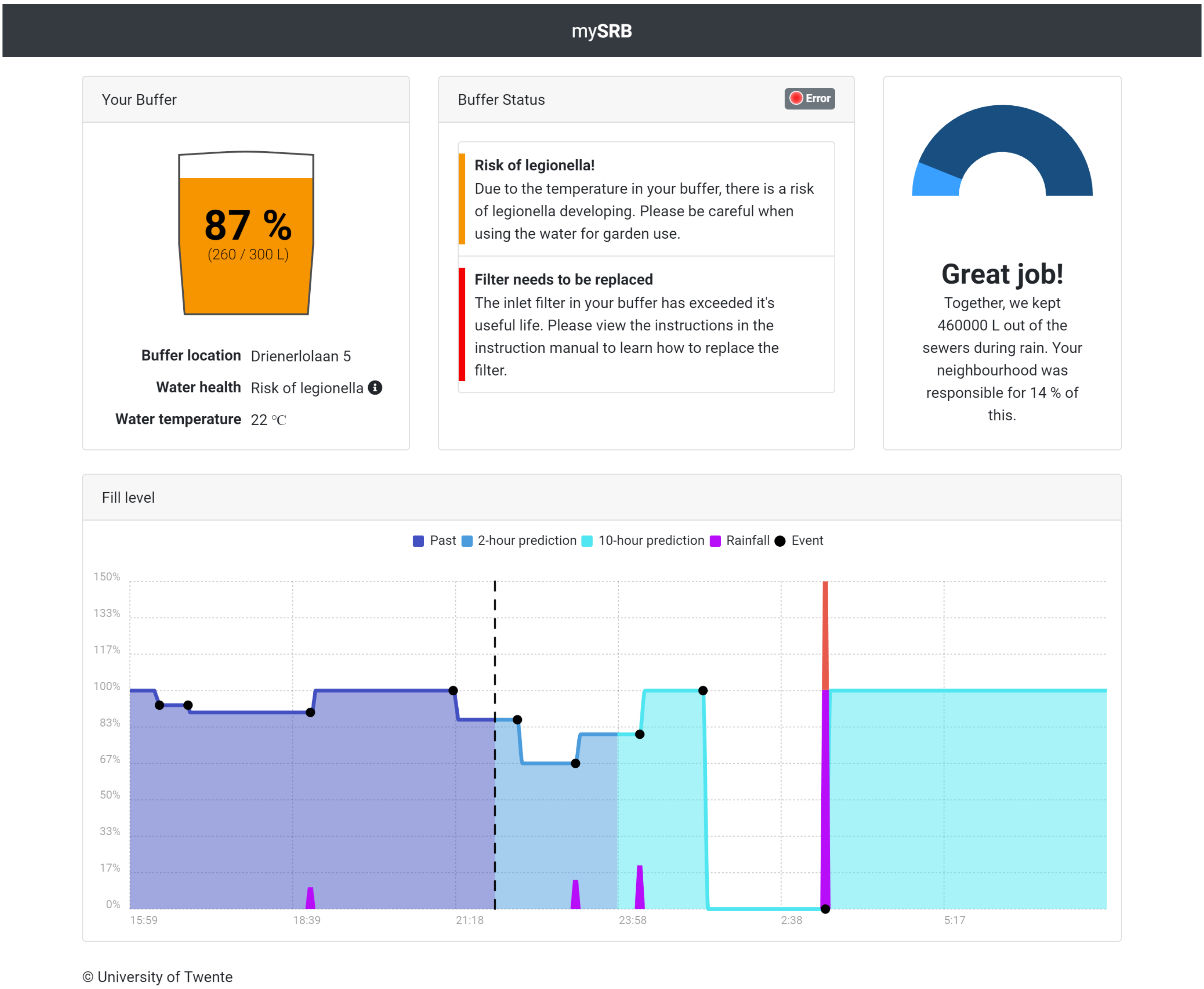
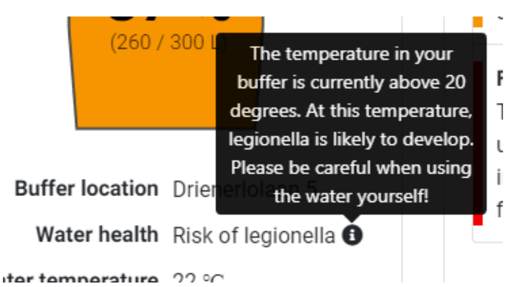
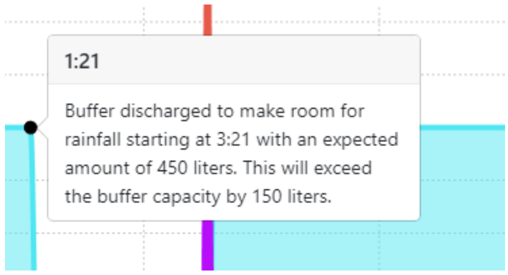


Figure 6.4: Screenshot of the second prototype on a desktop, laptop or tablet



(a) Screenshot of a the information popup about legionella



(b) Screenshot of a information popup in the second prototype, showing that the buffer will overflow

Figure 6.5: Screenshot of details of the second prototype

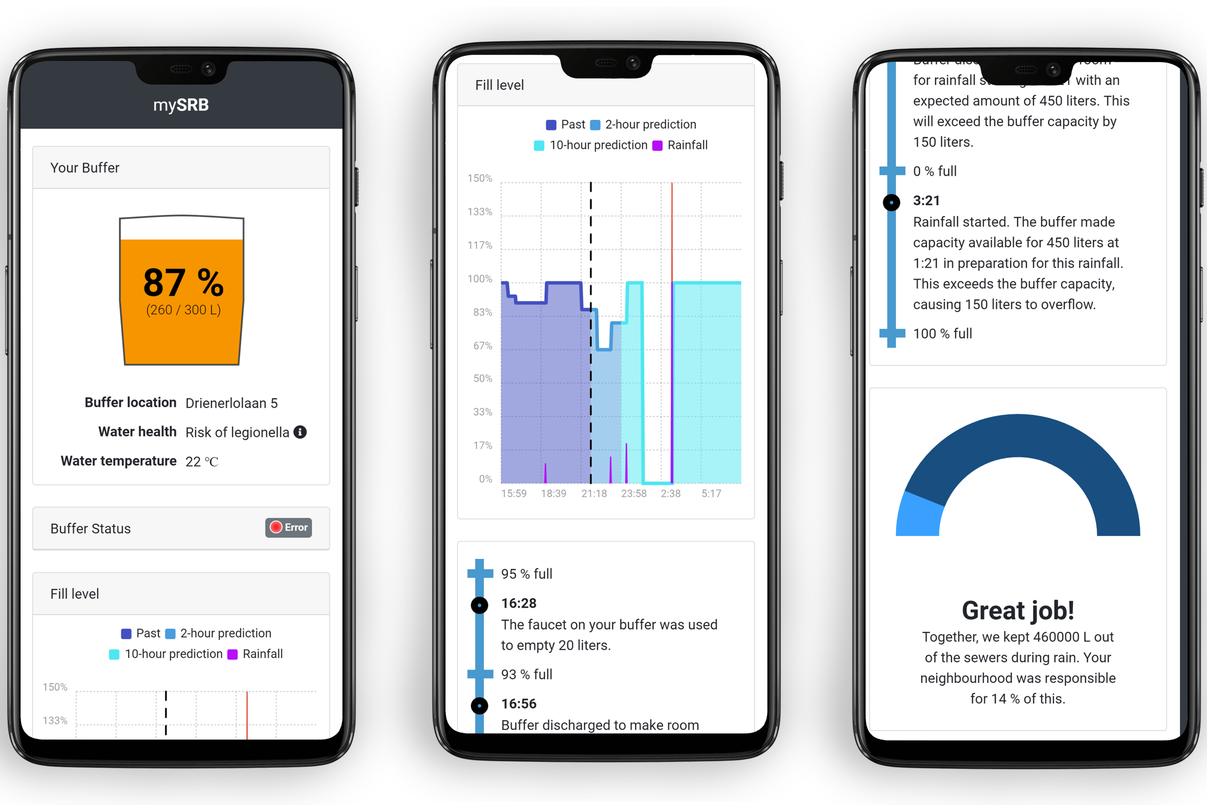


Figure 6.6: Screenshots of the second prototype on a smartphone (screenshot template by Amrit Pal Singh, amritpaldesign.com)

6.4 Connection to Data Repository

Both prototypes before this were not connected to the central data repository. After the user testing was completed, the second prototype was connected to the data repository. This was done by replacing the static demo data by requests to the data repository. A *very* crude login solution was also designed, where a username/password combination returns the ID of the smart rainwater buffer belonging to the user. This ID can then be used in all further requests.

A registration form was also added. This form can be used to register a smart rainwater buffer on the central data repository. The registration form also performs the conversion from a street, housenumber and city to the latitude and longitude information location data expected by the central data repository. This conversion takes place by utilizing the Nominatim API by OpenStreetMap.

7 | Evaluation

In this chapter, the evaluation of the user interface for the smart raiwater buffer system will be discussed. The work in this chapter has been done in accordance to the Creative Technology Design Process, as discussed in section 3.1.

7.1 Testing procedure

The testing procedure for both versions of the user interface was the same. The procedure started with the participants being presented with a project description and a consent form (see B). After signing the consent form, the users were presented with the user interface on a laptop. The user interface was presented full-screen, in order to not have elements of the operating system influence the user experience. The users were asked to explore the user interface, all while thinking out loud. After exploring the interface, they were asked to answer a couple of questions that could be answered with information provided by the user interface.

- What is the status of the system?
- How much water is currently in the tank?
- Is the system planning on discharging water in the future?
- If so, why is the system going to discharge water?
- How does your setup compare to your neighbours setup?
- Is it safe to use the water?
- How much water is going to be in the system at 2 o'clock?
- When is it going to rain next?

These questions were followed by some questions about the clarity of the information.

- Was it clear what the status of the system was?

- Was it clear how much water currently in the system?
- Was it clear when the system was going to discharge water?
- Was it clear what caused the system to discharge water?
- Was it clear that caution was required when using the water?
- Was it clear how to view notifications?

After the participant had finished answering these questions, they were asked to fill in a standardised usability questionnaire (USE). After completing the survey, the participant was thanked for participating and the test concluded.

7.2 Participants

The initial aim was to test with a group of early adopters of the system, as formed by the municipality. Due to time constraints, arranging this was no longer a possibility. This led to choosing to test with fellow students of the bachelor programme Creative Technology at the University of Twente.

7.3 First Prototype

The observations and semi-structured interviews of the tests with the first prototype resulted in a lot of information. The notes from these tests were distilled down into overlapping points, which are listed below.

- **It was unclear how to view the notifications.** This was a recurring problem during almost all of the tests. Most participants didn't discover the status indicator and thus also not the associated notifications drop-down.
- **It was unclear what the status was.** Most participants didn't discover the status indicator at all. One participant misidentified the status indicator, and thought 1 (the amount of notifications) was the status.
- **It was unclear how to use the bar on top, containing the status indicator.** Some participants confused this bar with a bar presented by a development environment. Most participants did not think the bar belonged to the user interface.
- **The gamification element was generally ill-received.** Most participants thought it was an unnecessary addition to the user interface. The value of the information was questioned.
- **The rainfall graph was generally ill-received.** Participants either simply ignored this graph, or noted that it's information could also easily be gotten from the fill level graph.

- **It was unclear what the exact values at different times were.** All participants had difficulty with reading the exact values in the fill-level graph.
- **It was unclear that the liters below the percentage in the Your Buffer block represented the current fill-level.** All but one participant thought this indicated the total capacity of the buffer, and manually calculated the current amount in liters when asked what the current amount of water in the buffer was.
- **The timeline was not used extensively.** All but one user used the fill-level graph to find information about rainfall, and didn't resort to using the timeline.

Next to the points from the tests with the Creative Technology students, the prototype was also discussed with the stakeholders from the University of Twente. The changes that were requested by the stakeholders also listed below.

- **It should be clear when the buffer is not able to handle all water falling during a shower.** For some showers, the amount that falls is more than the capacity the buffer can make available. In these cases, this should be shown to the user.
- **The gamificiation element should show the total amount buffered by the smart rainwater buffer and the total amount buffered by the surrounding area.** This will show the user how large their share in the buffered amount was. This is meant to show to the user that they're helping with solving the rainwater problems in their area.
- **The rainfall graph should also show the strength of the rainfall in millimetres.** With this information, the user can see the amount of rainfall that was predicted in the more common format of millimetres, and see in how much water in their buffer this will result.
- **Weather information should be overlaid over the fill level graph.** This will show the user what the general weather was during the time, or what the predicted weather was.
- **Bad water health should be displayed more clearly.** The health risks associated with using the water under some circumstances are serious, so bad water health should be displayed more prominently.

——*This evaluation is used to build a second prototype in section 6.3*

7.4 Second Prototype

For testing the second prototype, the same procedure was used as for testing the first prototype. A new pool of participants was selected. Below, the distilled points from the observations and semi-structured interview are listed.

- **It was unclear why the overflowing rainfall was red.** Participants figured this out after a while by reading the text in the popups, but the red colour should be added to the legend to make this easier to understand.
- **The alignment of some of the labels is incorrect.** This problem was also present in the previous prototype, but was only now noted.
- **More information about the specific cases when extra caution is required when using the water with a risk of legionella should be added.** Some participants noted that water that was infected with legionella was still perfectly usable for some applications, and caution was only required for specific uses, like spraying. More information should be added to explain this more in-depth.
- **It was unclear what the current time is.** The current time should be added below the indicitator bar in the fill level graph, to make it more clear what the current time is.
- **The labels in the fill level graph should be on the whole hours.** Currently, the position of the labels is based on the current time. This makes reading the graph less intuitive.
- **The colour of the water barrel is unclear.** The barrel should remain blue (instead of orange), and another part of the interface should be coloured to indicate the bad water health.

All things considered, the remarks received during this round of testing were a lot more focussed on the details instead of on the clarity of big parts of the interface. Most participants were able to find the information asked during the semi-structured interview without problem, while this often was a problem during the tests with the first prototype. There do however remain a couple of interesting points that should be considered when creating a next iteration or a final version of the user interface.

7.5 USE Questionnaire

As mentioned before, a USE Questionnaire was given to participants after completing the test. They were asked to fill in this questionnaire from the mindset of being owners of a smart rainwater buffer. The averaged results of this questionnaire can be found in appendix D.

When looking at these results, the small sample size should be taken into consideration. Ideally, these tests and the questionnaire would be performed with a larger audience.

The results from the questionnaire show improvements when using the second prototype for most questions. Especially the questions concerning ease and pleasantness of use show improvements.

7.6 Evaluation of requirements

In this section, the requirements from section 5.1 will be evaluated to see whether or net they were met.

7.6.1 Functional Requirements

Must have

F1 **The interface shows the status of the system**
This requirement was met. The interface shows the status of the system, but the smart rainwater buffer is currently not capable of submitting a status change. The interface offers one automatic status change as a warning for legionella.

F2 **The interface shows the amount of water in the buffer**
This requirement was met.

F3 **The interface shows the planned discharges**
This requirement was met.

F4 **The interface shows the expected rainfall**
This requirement was met.

F5 **The interface shows a timeline of the events occurring in the smart rainwater buffer**
This requirement was met.

F6 **The interface shows which rainfall resulted in which discharge**
This requirement was met.

F7 **The interface shows the amount of water that has been taken through the faucet on the smart rainwater buffer**
This requirement was partially met. The system does show when water was taken from the faucet and how much was taken at that point, it does however not provide a total for a time period.

F8 **The interface can display notifications**
This requirement was met, but is currently only in use for the legionella warning notification.

F9 **The interface shows a graph of the historic fill level of the smart rainwater buffer**
This requirement was met.

Should have

F10 **The interface needs to be able to request the required data from the data repository**
This requirement was not met for the prototype that was used during the user

tests due to the data repository not being ready. The requirement was met at a later point.

F11 **The interface monitors the quality of the water in the buffer**
This requirement was partially met. The interface monitors the temperature for one quality parameter: the risk of legionella.

F12 **The interface allows for setup of the system from within the interface**
This requirement was partially met. The interface offers a registration form for new users. This was added after the user tests.

F13 **The interface shows the reason for a change in water level in the historic fill level graph**
This requirement was met.

F14 **The interface shows a graph of the historic rainfall in their location**
This requirement was met.

F15 **The interface offer the choice for a date range for the historic fill level graph**
This requirement was not met.

Could have

F16 **The interface automatically discharges the water when the quality becomes too low**
This requirement was not met.

F17 **The interface provides instructions for assembling the DIY smart rainwater buffer within the interface**
This requirement was not met.

F18 **The interface can send notifications to the user's smartphone**
This requirement was not met.

F19 **The interface sends notifications reminding the user to use the water when the weather is sunny for multiple days, the season is either summer or autumn and there is water in the buffer**
This requirement was not met.

Won't have

F20 **The interface shows an anonymised version of the user's neighbours local usage of rainwater to compare with their own usage**
This requirement was not met due to changes in the features of the smart rainwater buffer itself that made measuring the required data for this feature impossible.

F21 **The interface gives a benchmark score for their local usage of the collected water**
This requirement was not met due to changes in the features of the smart rainwater buffer itself that made measuring the required data for this feature impossible.

F22 **The interface shows the local usage from the year before in comparison to the current year**
This requirement was not met due to changes in the features of the smart rainwater buffer itself that made measuring the required data for this feature impossible.

7.6.2 Non-functional Requirements

Must have

NF1 **The interface is available in English**
This requirement was met.

NF2 **The interface can be used on a desktop or laptop computer, a tablet and a smartphone**
This requirement was met, but user testing was only performed on a laptop computer.

NF3 **The interface should load quickly**
This requirement was met. The user interface loads quickly on any modern device.

NF4 **The interface should be easy to use**
This requirement was met, as testing with users proved.

NF5 **The interface should be usable without written instructions by people familiar with smartphones**
This requirement was likely met, though not thoroughly tested. The participants of the user tests were all Creative Technology students, who have a high affinity with technology.

NF6 **The interface should display a warning when it can't connect to the data repository**
This requirement was met, but only in a later version of the interface.

Could have

NF7 **The interface is available in Dutch**
This requirement was not met.

7.7 Conclusion

The evaluation phase shows that prototype created during this project met all of the must have requirements created during the specification phase. All but one of the should have requirements were met, but the could have or won't have requirements were not met. Some of the requirements had to be moved due to feature changes in the smart rainwater buffer this user interface is built for, and couldn't be integrated even though stakeholders had requested these features.

The semi-structured interviews and observations showed an improvement between the first prototype and the second prototype, with a large increase in the clarity of the information presented to the users. The remaining points of criticism are all smaller points, and it is recommended that these are integrated into the final product when it is eventually developed.

The USE usability survey, while not particularly relevant due to the small sample size, still showed an improvement in user satisfaction and ease of use. This confirms the conclusions of the semi-structured interviews and observations.

8 | Conclusion and Recommendations

In this chapter, a conclusion will be given to the research questions stated in chapter 1. It will also include recommendations for future work on user interfaces for smart rainwater buffer systems.

In this project, the Creative Techology Design Process (see section 3.1) was used to answer the research question stated in the first chapter. This research question was the following:

"How to implement a user interface for users of a smart rainwater buffer system?"

With the following sub questions: "How to give insight into water collection and usage?" and "How to promote environmentally friendly usage of the collected water?"

To answer these questions, firstly an ideation phase was applied, during which the stakeholders were analysed, a PACT analysis and scenario were created and a concept was created. After this, the specification phase was used to specify the project further and create final requirements. This was followed by the realisation phase, during which a prototype was built. This prototype was then evaluated, a second iteration was made, and this second iteration was once again evaluated. After this process, the research questions can be answered.

The final product should be the answer to the main research question, as it performs as a user interface for a smart rainwater buffer system and was positively tested, albeit with Creative Technology students as participants instead of early adopters. The second question was partially answered. Due to choices made during the development of the smart rainwater buffer itself, monitoring of the usage was impossible. The insight into the water collection was achieved, as the user interface provides multiple ways to view the amount of water in the system, and see when and why water entered or left the system. The last question was only answered during the ideation phase, and was not worked out completely due to the earlier mentioned choices made during the development of the smart rainwater buffer. The work done during the ideation phase should however be a good start for future work on this subject.

While the project as a whole went smooth, some hiccups were experienced. The main reason for these hiccups were time constraints as well as changes to the project. Due to the position of the user interface project within the larger smart rainwater buffer project, parts had to be adjusted due to changes made in other parts of the project. This was mainly a problem for the gamification part of the project, as due to the omission of a second valve on the buffer it was no longer possible to know whether water was flowing to the sewage system or the user's garden. Due to time constraints, it was not possible to test with the early adopters of the project, and tests were therefore performed with Creative Technology students.

For future work, it is highly recommended to test the prototypes with the early adopters of the smart rainwater buffer system. It is also recommended to look further into the use of gamification as a method to stimulate local usage of collected water, as this has the possibility to have a positive impact on the water situation in cities like Enschede. Furthermore, some of the suggested changes from the second evaluation were not implemented (see subsection 6.3.1). It is also recommended to implement these changes in the future.

A | Interviews

A.1 Interview with Hendrik Jan Teekens on April 12 2018

On April the 12th 2018 a meeting Hendrik Jan Teekens of Gemeente Enschede was held. During this meeting, the preliminary client requirements for the Smart Rainwater Buffer project were discussed. This section will focus on the information discussed during this meeting that is relevant for the User Interface. Other subjects that are not included in this section were also discussed during this meeting.

Is it preferable that water is used locally instead of flushed to the sewage system? Teekens indicated that this greatly depends on the season and area were the smart rainwater buffer is placed. In some areas drainage (either into the garden or into a dedicated drainage system) is preferable, in other areas this should be avoided due to an already high groundwater level. Local drainage should also be avoided in the winter. The ground water level behaves like a sine-wave, with the water level being the highest in April.

Should the user be stimulated to use the water locally? During the summer, most users should be stimulated to use the rainwater (see remark above about location). During the winter, no users should be stimulated to do this. Peak showers occur during the summer. Due to the dry ground the water that falls onto the ground doesn't drain into it. Using the water locally keeps the ground wet even during dryer periods, also increasing natural drainage.

Some areas don't need a smart rainwater buffer with a pipe to the garden. This mainly concerns buildings with a small garden, buildings located in the city centre and buildings with a paved garden. A basic model with just the buffering and flushing to the sewage system capability would suffice.

What is your opinion about showing average collected amounts to users? Data is also shown to users in other projects, examples of this are Waterlabel, and a participation project in Bornerbroek[42]. In all these projects, data about houses is shown. It is important to look at the privacy aspects of presenting data to users. The data should be anonymised in some way before being provided to other users. Data could, for example, be shown per street or per postal code area. During the early stages this will depend on the amount of users of the system.

How much control should the user have over the system? The user should be able to provide the system with information that allows it to accurately estimate the amount of water that will be collected during an expected shower. The user should also be able to manually empty water towards their garden or the sewage system. The user shouldn't have any control over the amount of water that is being discharged before expected rainfall - instead, the system should make it clear how much and when water will be discharged.

How much control should the municipality have over the system? The municipality shouldn't have any direct control over the buffers. The algorithm deciding when the buffers discharge should be transparent, and should be developed together with the municipality. They should be able to have access to information about the amount of water collected in the buffers, and when and how it was discharged. As stated earlier, this information needs to be anonymized in some way.

B | Project Description and Consent Form

Enschede, 21 / 06 / 2018

User Interface for Smart Rainwater Buffer

The city of Enschede has problems with flooding during heavy rainfall. This is caused by a multitude of reasons, with one being that the sewage system is unable to handle the flow of water caused by the rain. The smart rainwater buffer project aims to alleviate the stress on the sewage system by buffering the water during the rainfall and emptying itself before the rain starts in order to make capacity available for the predicted rain.

This project is focussed on creating a user interface for the smart rainwater buffer. During the test, you will use a prototype of this user interface. Firstly, you will be allowed to explore the user interface on your own. Secondly, the researcher will provide you with some tasks in the user interface. The test will be concluded with a short questionnaire.

During the test, some data will be collected. Firstly, the researcher will observe your actions while you are using the interface and will make notes of their observations. Secondly, the survey you filled in will be stored and processed for usage in the research project. These findings will be published publicly on the University of Twente essay website. No personal data will be published.

Consent Form for Smart Rainwater Buffer User Interface

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated 21 / 06 / 2018, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves written down observations while I conduct the test, as well as filling in a questionnaire afterwards.	○	○
Use of the information in the study		
I understand that information I provide will be used in the report for this project and for improving the project.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○
Future use and reuse of the information by others		
I give permission for the observations and answers to the questionaire that I provide to be archived in the University of Twente essay database so it can be used for future research and learning.	○	○

Signatures

______________________ ______________________ ________

Name of participant Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Thijs Dortmann

______________________ ___________________ ________

Researcher name Signature Date

Study contact details for further information:
Thijs Dortmann, m.l.dortmann@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl

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C | USE Questionnaire [41]

Usefulness

- It helps me be more effective.
- It helps me be more productive.
- It is useful.
- It gives me more control over the activities in my life.
- It makes the things I want to accomplish easier to get done.
- It saves me time when I use it.
- It meets my needs.
- It does everything I would expect it to do.

Ease of Use

- It is easy to use.
- It is simple to use.
- It is user friendly.
- It requires the fewest steps possible to accomplish what I want to do with it.
- It is flexible.
- Using it is effortless.
- I can use it without written instructions.
- I don't notice any inconsistencies as I use it.
- Both occasional and regular users would like it.
- I can recover from mistakes quickly and easily.

- I can use it successfully every time.

Ease of Learning

- I learned to use it quickly.
- I easily remember how to use it.
- It is easy to learn to use it.
- I quickly became skillful with it.

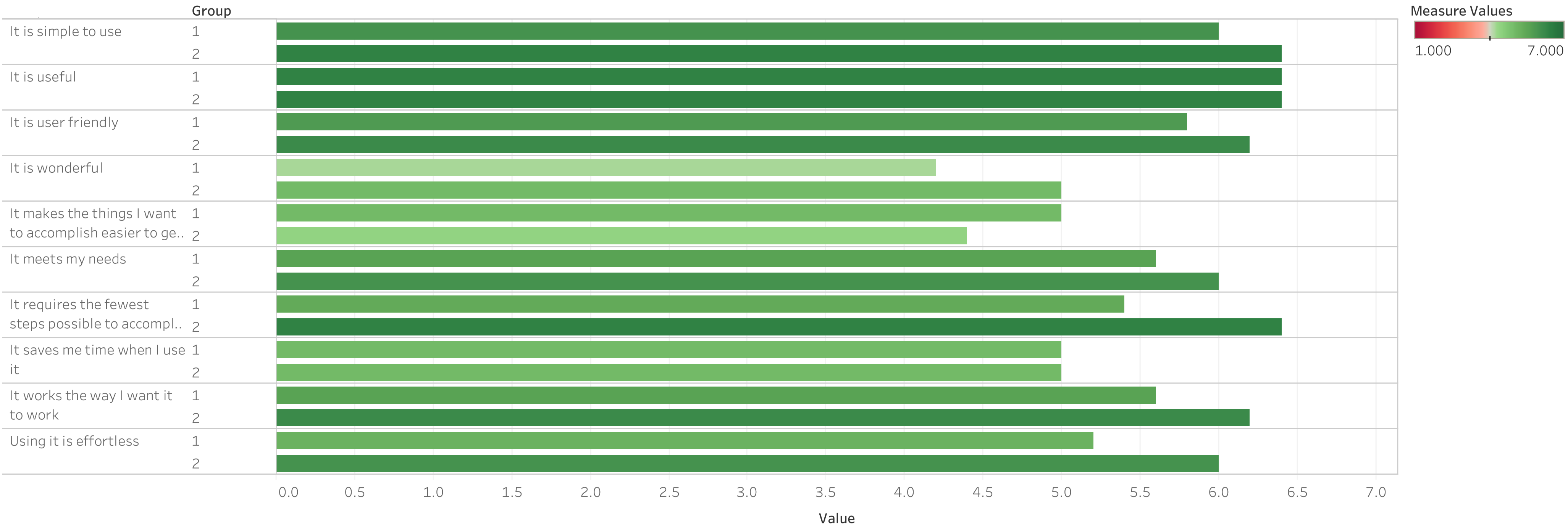
Satisfaction

- I am satisfied with it.
- I would recommend it to a friend.
- It is fun to use.
- It works the way I want it to work.
- It is wonderful.
- I feel I need to have it.
- It is pleasant to use.

D | Evaluation of USE Questionnaire

Evaluation of USE Questionnaire

Evaluation of USE Questionnaire



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