Development Of A Web Based Smart Rainwater Buffer Dashboard

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BACHELOR THESIS CREATIVE TECHNOLOGY

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Abstract

During recent years, the city of Enschede is faced with more frequent and heavier rainfall, often resulting in flooding. These floods cause damage to the city and additionally pose a health risk to the citizens. To resolve this issue, a smart rainwater buffering solution was developed: conventional rain barrels are equipped with a smart control unit that discharges the barrel when anticipating rainfall, making sure sufficient buffering capacity is available. Buffering rainwater reduces strain on the sewage system, potentially preventing flooding in the lower areas of Enschede.

To give owners of such a Smart Rainwater Buffer insight into and control over their system, a web-based dashboard was needed. This dashboard should also engage the Smart Rainwater Buffer owner with their device, keeping it operational and spreading the word about the Smart Rainwater Buffer project.

This bachelor thesis focuses on the development of a web based Smart Rainwater Buffer dashboard. For this purpose, previous Smart Rainwater Buffer dashboards have been studied, together with general utility device dashboards, and weather related dashboards. Research into behavioural reinforcement was also done, to find out how users can be kept engaged with the dashboard, and therefore the Smart Rainwater Buffer.

Stakeholders were identified and interviewed to obtain preliminary requirements, which were used to design dashboard concepts. These concepts were discussed with stakeholders to obtain feedback, from which new concepts were created. After several iterations, the final concept was realised as a functional prototype. This prototype was responsive, gave insight into the SRB's status, past and future precipitation, fill level and temperature, and incorporated gamification elements using behavioural reinforcement by means of competition and self improvement.

Due to interfacing complications with the database server, the prototype used its own local preprocessed dataset. This meant the prototype was bound to simulating a set past date. This prototype was then evaluated with stakeholders. Evaluation with stakeholders proved the prototype to be aesthetically pleasing, easy to use, and to a certain extent also engaging: the competition and self improvement gamification elements in the dashboard proved to positively impact user engagement, al be it lightly. It also became apparent that users were more motivated by self improvement than competition.

Future recommendations include improvements to the dashboard as well as more thorough testing.

Acknowledgments

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1 Introduction

This introductory chapter will explain the problem and challenges that this project seeks to solve. A research question will be formed, after which the report will be outlined.

1.1 RAINWATER PROBLEM OF ENSCHEDE

Enschede is having trouble with rainwater management, occasionally resulting in flooding. The city is built on a push moraine: the upper parts of the city are about 44 meters higher than the lower parts[1], as illustrated in Figure 1.1.1.

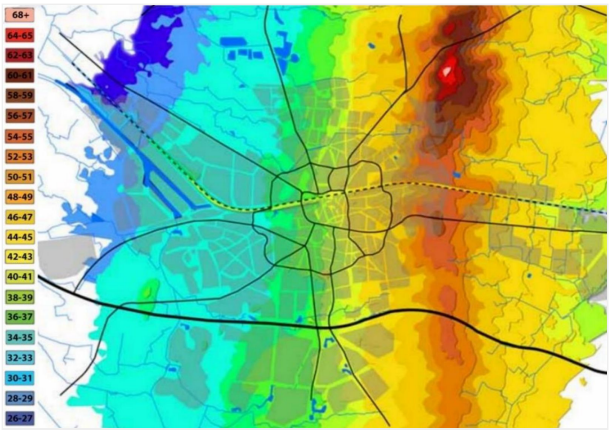


Figure 1.1.1: Height map of Enschede: from high to low; from NAP + 68 m to NAP + 24 m, 44 m difference in altitude. [1]

Since Enschede is full of buildings and streets that do not allow rainwater infiltration, most rainwater has to be drained via the city's sewer system. The increasing amount of rainwater in recent years has puts too much stress on the (currently mixed) sewer system [2]. This results in a lot of rainwater flowing down the slope of the city, towards the lower areas, consequently flooding these areas. This poses a health risk, and causes a lot of water damage related costs both for citizens and (insurance) companies.

1.2 SMART RAINWATER BUFFER

To tackle this problem, the municipality of Enschede is investing in several rainwater management projects trying to solve this problem. The consensus is that buffering rainwater during rainfall in the higher areas lowers the strain on the sewage system in the lower areas. The Oldenzaalsestraat is being equipped with a 700m long, 2m wide sewer tube below the surface, that will be able to store 3.5 million liters of rainwater[3]. In multiple parts of Enschede, 'wadis' are realised, capable of buffering another 3.5 million liters. Wadis are patches of grass that will buffer rainwater by flooding during rainfall[4]. From there, water can infiltrate the soil, where it is collected by a drainage pipe. To prevent wadis from

overflowing their bounds, they are often connected to surface water nearby. The stadsbeek project builds a brook through the north of Enschede since streams and ponds also act as buffers during rainfall.

Another buffering project is the Regentoren project: a network of Smart Rainwater Buffers (SRB)[5]. The Regentoren project aims to upgrade conventional rain barrels with a smart monitoring and control device. The SRB will then discharge rainwater before rainfall, making sure it has the capacity to buffer the incoming rainwater. If these units are rolled out en masse, a lot of rainwater that would normally have to be transported by the sewer system, is stored till after peak moments, reducing stress on the sewer system [6].

The SRB can still be used as a regular rainwater barrel by the owner; e.g. collected water can be used for watering the garden, keeping the soil moist. SRBs can also offer solutions for the sewage system. For example, emptying a full SRB into the sewer will give a huge burst of water, that can blast away clots that build up in the sewers, particularly in the capillaries of this system. For economic and environmental reasons, it is preferred that the owner of the SRB uses the water themselves, rather than flushing it down the sewage system. To motivate an SRB owner to actually do so, the owner needs to feel that his efforts are meaningful, either for themselves or for the community.

SRB owners need to have insight in and control over their SRB. This will be provided via a web based dashboard. That dashboard is a leverage to keep the SRB owner engaged with the Regentoren project, allowing them to see what they accomplish by owning and using an SRB. This should motivate them to use the SRB in their daily lives.

1.3 RESEARCH QUESTION

The goal of this research project is to make a user dashboard for the SRB owner. This dashboard should provide insight into the performance of the owned SRB, and give control over it, and keep a user engaged with the product. This brings up the following research questions:

“How to develop a web-based dashboard that keeps the owner engaged in using their SRB?”

> “What are the most important gamification elements for behavioral reinforcement to stimulate engagement?”
>
> “How to incorporate these elements in the dashboard?”

1.4 REPORT OUTLINE

To answer these questions, first a state of the art research is conducted in chapter 2. Topics that will be discussed include gamification, previous work on SRBs and general utility device dashboards. This research will be aided aided by a literature review on behavioural reinforcement. Then in chapter 3 the methods and

techniques used to create the dashboard will be laid out. Chapter 4 will address research of the stakeholders, to find their needs and requirements. From this, chapter 5 will decide on the exact specifications of the project, for it to be realised in chapter 6 as a prototype. This prototype will be evaluated in chapter 7. Finally, conclusions will be drawn in chapter 8, followed by recommendations for further research.

2 State Of The Art

In this chapter, the state of the art on Smart Rainwater Buffer dashboards will be discussed. This includes previous work on SRBs and their dashboards, but also general utility device dashboards (e.g. dashboards of smart home systems) will be discussed. Since the SRB is a weather bound product, dashboards related to weather will also be explored. To engage users with the Smart Rainwater Buffer dashboard, gamification with behavioural reinforcement to stimulate engagement is addressed in a literature review.

2.1 SMART RAINWATER BUFFERS

Firstly, already existing dashboards for Smart Rainwater Buffers were studied. Dashboards included in this research where concepts for the Regentoren project,

University of Twente

As part of the Regentoren project, the municipality of Enschede is investing in the development of SRBs. This is done together with the waterboard Vechtstromen. The SRBs are developed by the University of Twente.

The first version was developed by Vetter[7], as shown in Figure 2.1.1. This version used an industrial container, to have a big capacity. Vetter did not include flow sensors, meaning only the held amount of rainwater could be measured. Temperature sensors were added: when water was about to freeze or at risk for contamination with bacteria like legionella, owners could be notified. Another option would be to automatically discharge the SRB when its content is at risk.

Figure 2.1.1: prototype developed by Vetter[7]

Vetter[7] also made a dashboard for his version of the SRB, as seen in Figure 2.1.2. Since his project was more focussed on the physical aspects of the SRB, this dashboard was more of a functional engineering prototype. It consists of a basic webpage, showing the SRB's location, water temperature and the amount of collected water. One interesting statistic that Vetter added is an expectation for how much water will be collected during the next rainshower. For this purpose, the user has to fill in the size of their rooftop in square meters.

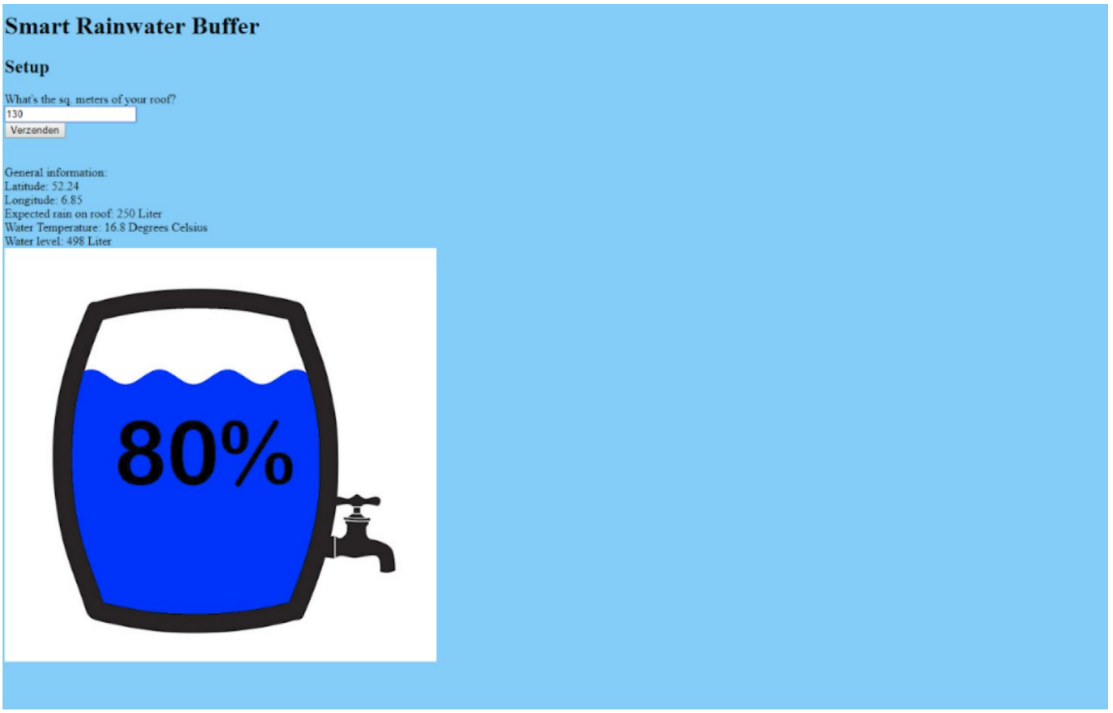


Figure 2.1.2: functional engineering prototype dashboard developed by Vetter[7]

Steeghs[2] and Rindt[6] also developed an SRB, but focused more on household sized barrels to better fit and suit people's gardens (shown in Figure 2.1.3). Their version used a regular rain barrel that was modified to work as an SRB: it was equipped with a sensor to measure water levels, electronic valves for rainwater output control, flow sensors to measure rainwater going in and out, and a small microcontroller. The SRB would discharge when rainfall was expected, or when requested by either the consumer dashboard or the administrative dashboard. These dashboards where developed by Rindt and Steeghs respectively.

Figure 2.1.3: prototype developed by Steeghs and Rindt[6]

Steeghs' dashboard, for the municipality, is shown in Figure 2.1.4. Rather than showing rainwater collection levels per buffer, the collected water is expressed per area, both in liters as well as percentage of the total holding capacity of that area. Averages of the neighborhood are presented using bar, pie and line graphs, to show how much rainwater has been collected, how it was used, as well as what the weather and subsequent SRB behaviour will look like. This interface does not offer any control over the privately owned SRBs.

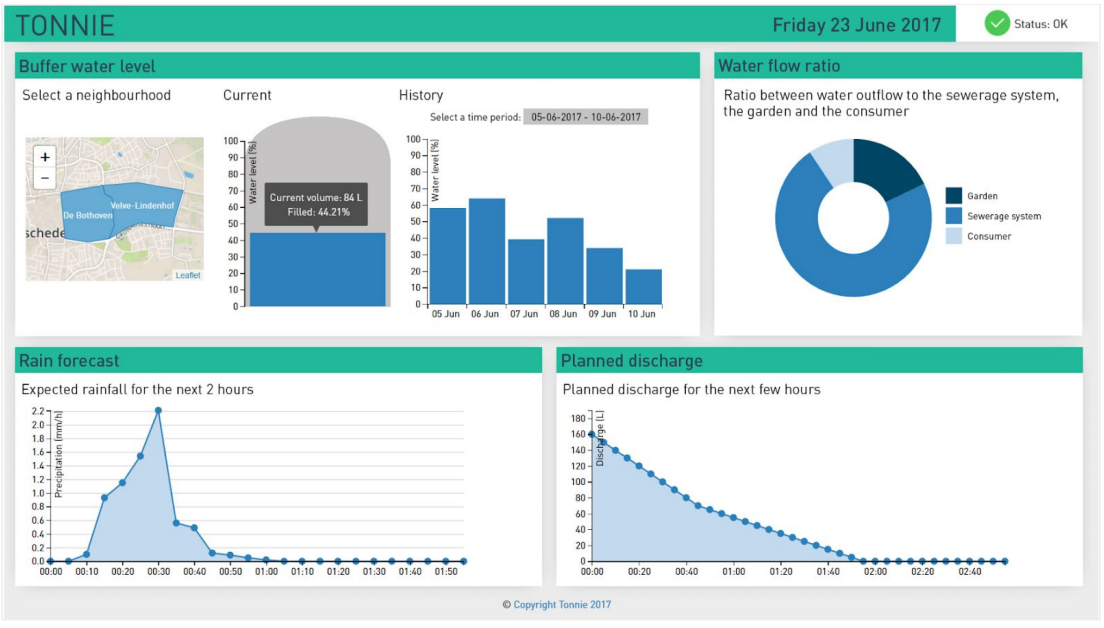


Figure 2.1.4: The dashboard for the municipality developed by Steeghs[2]

Rindt developed a dashboard for the private owner of the SRB, as shown in Figure 2.1.5. This interface shows the current content of the SRB, both in liters and percentage wise. It also shows how much rainwater has been used for the garden, how much has been buffered in the past, and how much rain is expected.

Furthermore, it offers control over where automatic and manual discharged water is routed to (garden or sewer). Lastly the user can manually open or close the discharge mechanism, as well as request a specific amount of collected water to be drained.

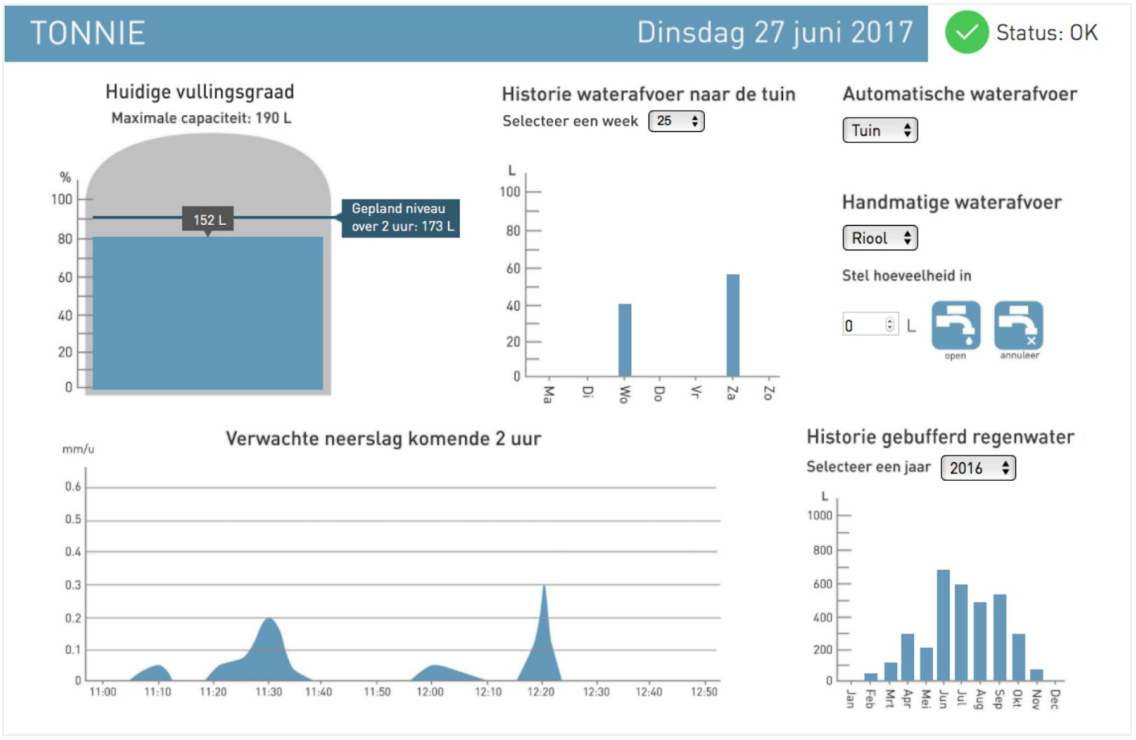


Figure 2.1.5: dashboard for the SRB owner developed by Rindt[6]

The dashboard developed by Rindt was overhauled by Dortmann[8] in 2018, as shown in Figure 2.1.6. This version also shows the fill level of the SRB in percentage, but also as a fraction filled over maximum (e.g. 260/300L). All the graphs showing past, present and future data have been merged into one graph. Rainfall and the SRB fill level are layered on top of each other, showing how the fill level compares to the rainfall. Notable are the area dedicated to warnings and errors, and the area dedicated to encouragement. The warning area shows messages about water safety and contamination, as well as messages informing the user about required maintenance of the SRB. The encouragement area informs the user of some statistics, showing how much the SRB project and the owners neighborhood contributed to rainwater buffering. In the accompanying report, Dortmann explains that early adopter testing was not possible due to time constraints, and advices to do so for any future development. He also notes that exact values are desired in the fill level graph, rather than just percentages. Early in the report, gamification and promotion of environmentally friendly usage is addressed. These ideas were never implemented due to earlier development choices, but Dortmann recommends to look into those for future development.

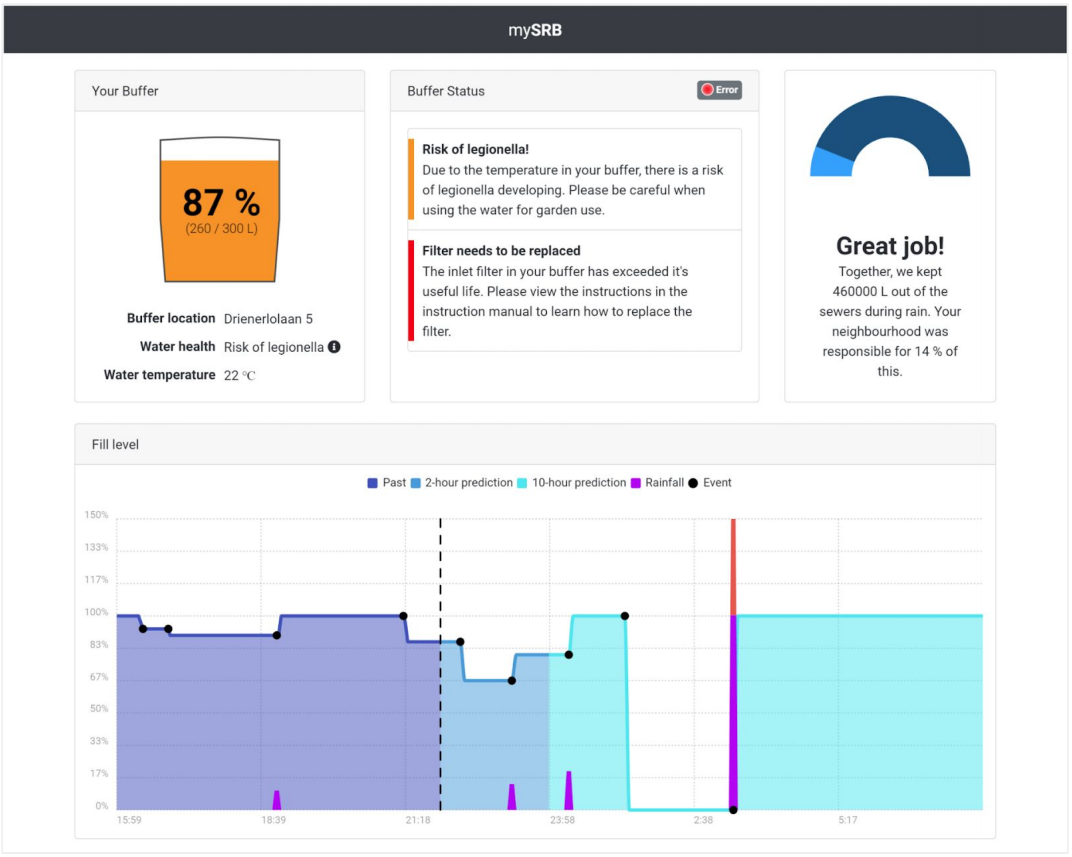


Figure 2.1.6: SRB owner dashboard by Dortmann[8]

Non University of Twente rainwater collection systems

The University of Twente is not the only organisation working on rainwater buffering systems. Another rainwater buffering project in the Netherlands is “Slimme Regenton”, a project by Waterschap Amstel Gooi en Vecht and Studio Bas Sala[9]. This project mostly aims at custom made public space buffers, often having a double function as art or decoration. The “Slimme Regenton” is also deployed at consumers, though not yet on a large scale. No public imagery regarding their consumer dashboard was found.

In Ontario, Canada, an organisation called RiverSides developed the RainGrid[10]. The RainGrid team has since split off from RiverSides, now being its own separate company. Their setup is very similar to the previously named SRBs, with one notable difference being that the buffer container is part of the product. This means people do not get to choose their own barrel, style and capacity.

The RainGrid effort from RiverSides also has a dashboard for the owner of the rainwater buffer (Figure 2.1.7). Their dashboard only shows the amount of water in the buffer as a percentage, only giving liters for the total amount of water that was diverted using their SRB. A big part of this dashboard is dedicated to the weather forecast, rather than statistics about the SRB. This means the user engages with the dashboard also for their own needs, rather than just for the SRB. The user is also given control over the drainage functionality.

Figure 2.1.7: RainGrid dashboard snapshot, taken from the official website [10]

2.2 GENERAL UTILITY DEVICE DASHBOARDS

Several dashboard of other utilities where studied, including the Nest smart thermostat[11], the Strava social fitness network[12], the Tesla app[13] and the Fitbit activity tracker[14]. Each utility is discussed in its own section, with a focus on customisation, gadget appeal and persuasive design.

Customisation can be a good way to make an experience tailored to the user. Customisation can increase the effectiveness of an interface, or ease of use for users. Think of dark modes for certain apps: these can reduce strain on the eyes for people using them in dark environments, while a light mode still offers a clearly visible app to those using it outside, during the day. Customisation can also allow a user to express themselves to others, or change an interface to appeal to them. These kind of customisation options can keep users interested and engaged with a product.

Gadget appeal can engage users with a product in more situations, either because of the functionality or because of the social aspect of showing off new technology. People sharing their fancy new tech with others also works as an advertisement for the product, popularizing it. Gadget appeal is often added by implementing helpful little functionalities, to make products just a bit more interesting.

Persuasive design can encourage users to act wisely, engage users and stimulate usage of a product. Persuasive design can also be used to get users to invest more time. This can be done by adding a social aspect, encouraging more interaction, and therefore more product usage.

Nest Smart Thermostat

The Nest Smart Thermostat, shown in Figure 2.2.1, is a thermostat that tries to optimize for environmentally friendly heater usage. To do this, it tracks the requested heating, as well as when users are not at home, or asleep. Then a smart algorithm slowly takes over control of the heating from the user, optimizing it not only to fit the users desires, but also to perform as environmentally friendly as possible. The interface of the Nest Smart Thermostat is kept fairly simple, only showing the requested temperature and the actual temperature. A green leaf is displayed when the Nest Smart Thermostat detects that heating is done more efficient than a regular thermostat.

Figure 2.2.1: Nest Smart Thermostat [11]

The Nest smart thermostat allows for custom use rather than custom design. The thermostat can be conFigured and trained to operate on a customized schedule, which is its main selling point. If the user does not feel like going up to the device itself, the Nest thermostat can be controlled remotely using a phone app. By having these options available, the user can customize their experience to suit their needs.

The Nest smart thermostat also made efforts to have a gadget appeal. The design is very sleek and small, using a color display with fancy animations. The device is controlled with a rotating ring on the outside, and the entire device also functions as a button. To make the device feel even more interactive, the screen lights up as soon as the device is approached. This all makes the Nest smart thermostat feel like a very polished and premium device.

The Nest thermostat uses a similar implementation: the screen of the Nest thermostat will show a distinct green leaf when the thermostat is performing environmentally friendly, or when the user has made adjustments to the heating and cooling that decrease energy usage. This is both good for the environment, as well as for the user's energy bill. Since this leave clearly signifies good, the user is persuaded to act accordingly, trying to always have the green leaf showing. Each month the user is also given a report of that month's performance, showing how many leaves they earned, and how their usage compares to other Nest

thermostat owners in the area. This also encourages competitive behaviour: people will try to be better than average, thus reducing energy use even further.

Strava fitness app

Strava is a fitness app that tracks a sporter's route, speed, distance, etc. The phone app can also be connected to a wide variety of smartwatches, GPS trackers and activity wristbands. During activity, it can show stats like how long you've been active, your heart rate, spit average pace, and distance travelled, as shown on the right in Figure 2.2.2. The Strava app can be used to compare and compete with both your own previous workouts as well as your friends and other nearby users. For this purpose, the Strava app also contains user profile functionality (center of Figure 2.2.2), which can be visited and viewed by other users. Activities can also be posted. This will publish them in a feed showing all activities of friends, shown on the left in Figure 2.2.2.

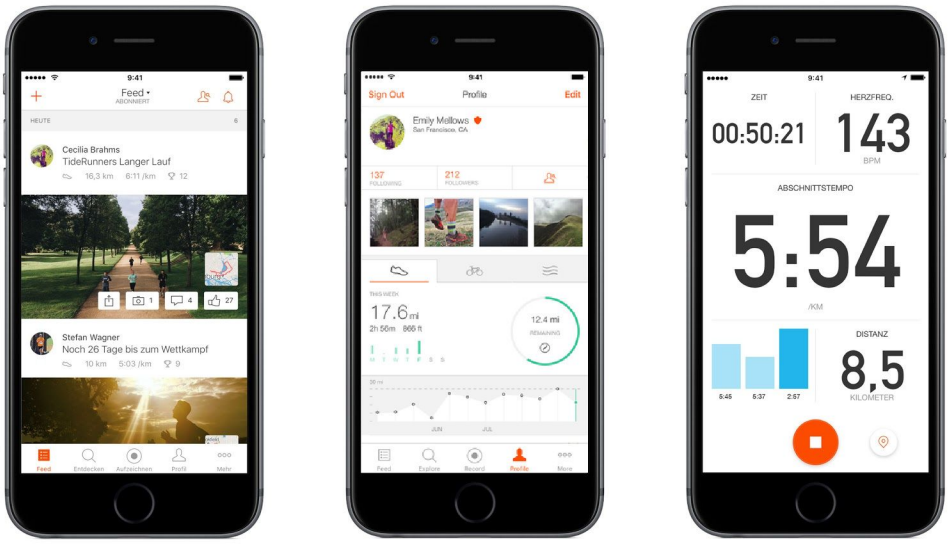


Figure 2.2.2: Strava social fitness app [15]

Strava does not allow for a lot of customisation. The only customisation users get is options to customize their profiles.

For gadget appeal, Strava itself does not do much either. Most of Strava's gadget appeal rather comes from the devices you connect to it. The app allows for all kinds of smartwatches and fitness devices to be connected to measure the user's performance. This can bring a lot of extra functionality to the app. After sporting, users can also show others their course: by carefully picking their path, users can 'draw' something on the map, often resulting in showcases on social media.

The Strava fitness app adds a social aspect by allowing users to view each other's profiles, seeing their workouts and performance. Users can comment, compliment or even befriend others, persuading both of them to compete. Even if the user does not have any friends that use the app, Strava encourages

competition by a functionality called ‘segments’. Segments are parts of the road network that are detected to often be part of workouts. Everybody that crosses such a segment will be recorded on a scoreboard, as seen in Figure 2.2.3. The user that traverses such a segment the fastest will be the ‘top of the hill’. After each workout, users will also be shown a list of other strava users that they passed closely during their workout. Another function offered by Strava are challenges, where users worldwide can compete to e.g. climb the most distance by bike, or run a half marathon as fast as they can. Lastly users can create ‘clubs’, where similar competitions can be held between groups of friends. As means of persuasion without other people involved, Strava offers users to set a fitness goal, making them compete with themselves.

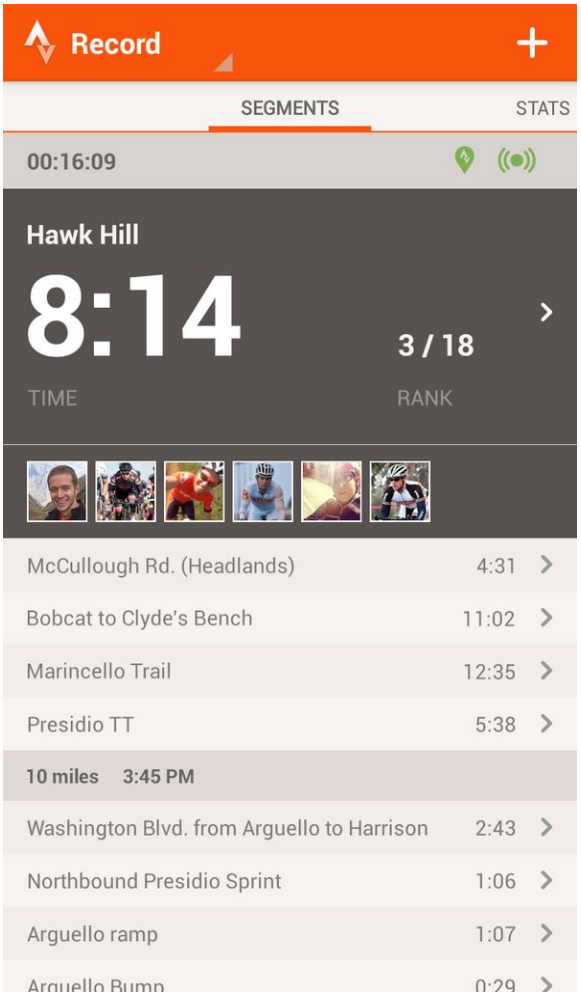


Figure 2.2.3: A leaderboard in the Strava Fitness app [16]

Tesla App

The Tesla app allows owners of a Tesla car to monitor and control their ride. When opened, the Tesla app first and foremost shows the car it is associated with. Above the image, at the top of the screen, a battery icon shows the fill level of the car’s battery, followed by a predicted cruising range. Below the image, three buttons to toggle ventilation, key access and car locking are displayed. The bottom half of the screen contains some buttons to go to specific screens dedicated to finer

control over things like climate, or more detailed information about things like charging.

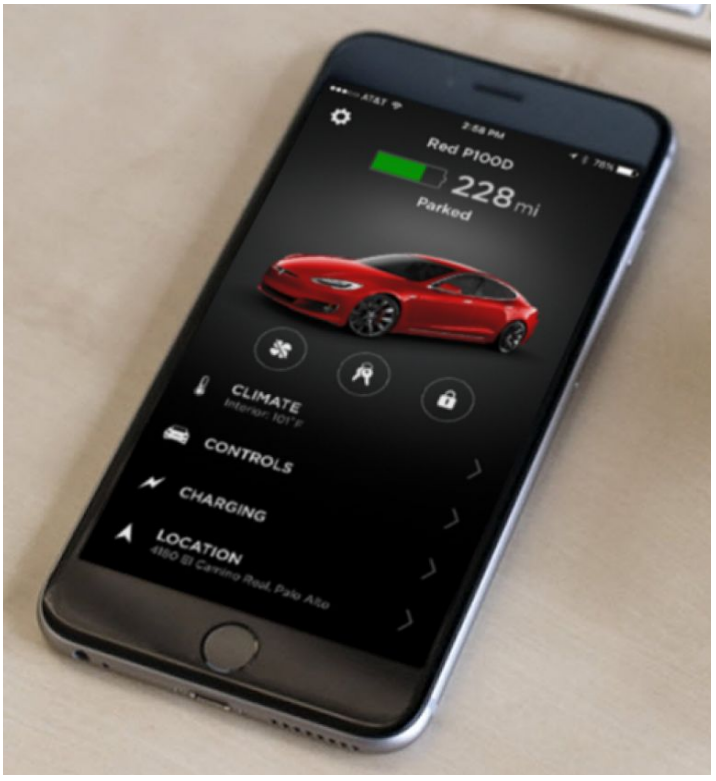


Figure 2.2.4: Tesla Motors app [13]

The Tesla app itself does not have much of customisation for the interface, but instead Tesla provided an API allowing third party developers to make their own apps for the same purpose. This has sprung up numerous apps that look and function differently from the official app developed by Tesla. A notable example is the Remote S app[17], visible in Figure 2.2.5, an app developed by an active community member of Tesla. Remote S includes all functionality form the official Tesla app, but is also capable of planning a route, finding the closest charging point, and integrating with the apple watch and siri.

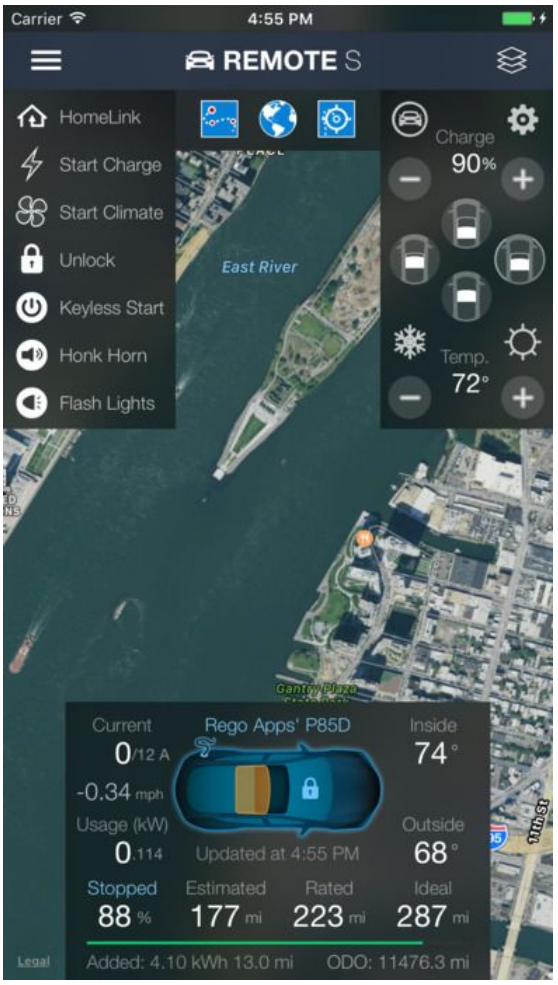


Figure 2.2.5: interface of the Remote S app [18]

The app of Tesla motors is helpful, but for a big part just a gadget appeal feature of the Tesla car itself. The app is not necessary: every function can be done using the car itself. The app just makes them easier, and possible from anywhere. The owner is granted full control over the car via the app: doors can be unlocked, the roof can be opened, the climate can be controlled, and even the car can be moved, all from within the app. Everything that happens is also fed back into the app: full insight is given into every aspect of the car. The owner is also given a prediction of the estimated performance, given the current charge level.

Persuading users to act wisely is done by the Tesla app. The user can set a goal charge level for their car, so that they only have as much energy stored as they need. This encourages users to think about the environment and their energy bill when charging their Tesla car.

Fitbit

A Fitbit is a wearable device (shown in Figure 2.2.6) that can measure steps, location, heart rate, quality of sleep, and other personal metrics involved in fitness. Users can download an accompanying app onto their smartphone, or can visit a web based dashboard on the computer, shown in Figure 2.2.6, to inform themselves about recorded statistics. Said dashboard shows the user's step

activity over the last two days, including whether the user met their step goal that day. The amount of steps taken that day are also shown separately, measured with a gauge, again to show whether the daily goal is reached. Next to this, the amount of calories the user burned that day are displayed. Also shown are the total distance the user has walked/run, how much sleep they got that night, and how many floors they climbed. Users are also given a comparison of their calorie intake and their burned calories.

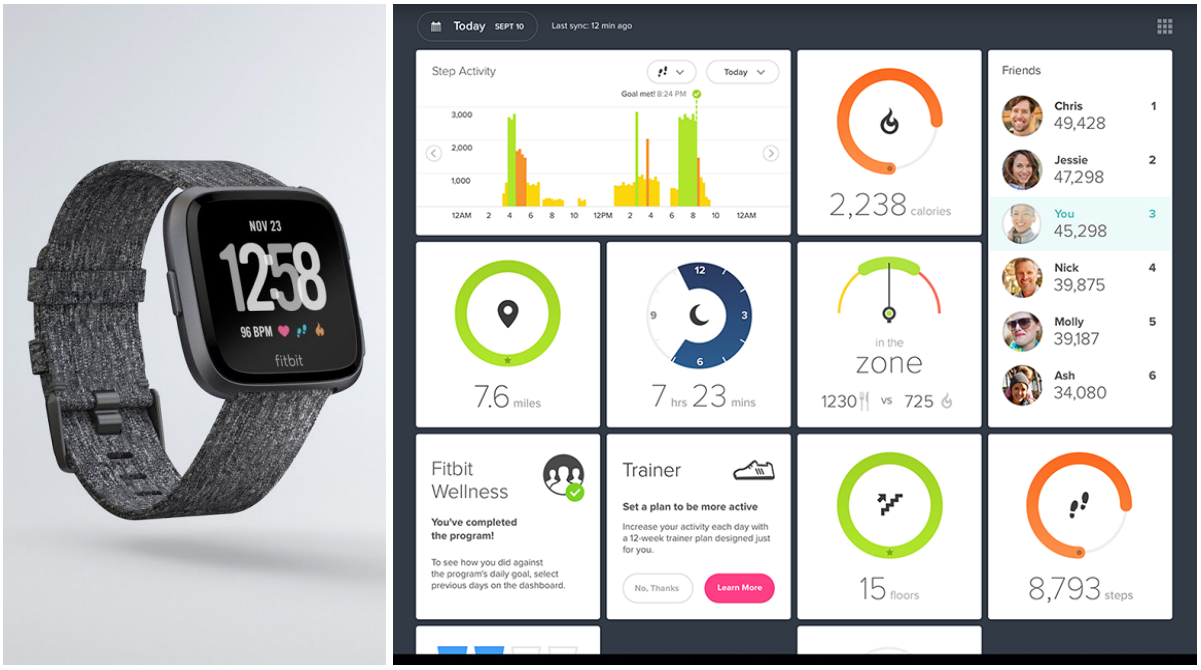


Figure 2.2.6: Fitbit bracelet and web dashboard[14]

The Fitbit dashboard allows the user to customize their experience by changing the layout of the dashboard, as well as what elements are displayed. There are also options to allow users to switch how their performance is indicated. The Fitbit bracelet offers customisation by allowing the user to pick their own background, as well as changing the strap of the device. This also allows users to express themselves using their Fitbit, by choosing how they present themselves to others. A black leather strap gives an entirely different impression than a woven pink strap.

The Fitbit activity tracker has a lot more functionality built in than needed for just sports tracking. Helpful things during sport include a stopwatch and alarm, but Fitbit also includes a weather forecast, a message system for your smartphone, and contact payment using only the device. The device is not only controlled by a touch screen, but also has a contact button that has a haptic click, making it feel like an actual button, and very high tech.

The Fitbit also persuades users, to act healthy in this case. The Fitbit shows a flower that grows and develops when the user is making healthy progress, and decays when the user is not taking enough activity. This simple reminder of activity motivates people to address their physical behaviour, and to make a healthy choice by doing something active.

2.3 WEATHER RELATED DASHBOARDS

Existing weather related dashboards were studied. These include the interface of a home weather station, and online weather forecast websites.

Alecto WS-4800

The Alecto WS-4800 is a weather station that measures temperature, wind direction and speed, humidity, air pressure, wind chill and dew point[19]. It also tracks rainfall, and has an interface where it can show these stats. The downfall can be toggled to be shown over the past hour, day, week or month. This data is shown as a plain number, with its unit (1, 2 and 5 in Figure 2.2.7). The user is also shown the downfall per day, for the past five days. This data is depicted as small bar graphs, labelled 3 and 4 in Figure 2.2.7. No power is granted to customize how this interface displays its data.

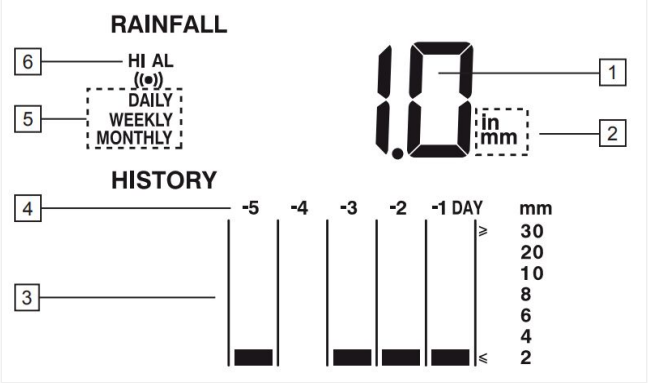


Figure 2.2.7: The Alecto WS-4800 interface as shown in the instruction manual [19]
1: rainfall
2: rainfall unit being in (inch) or mm (millimeters)
3+4: rainfall over the past 5 days
5: indication over what timespan rainfall has been measured
6: lights up if the max rainfall alarm has been set

Yr

A norwegian weather forecast website, yr.no[20], defaults to showing the user the forecast of a city per day as shown on the left side of Figure 2.2.8. To the side, a small map is shown that animates downfall as a heatmap, 60 hours into the future, as seen on the right side of Figure 2.2.8. But upon request, the forecast will be shown per day more elaborately: weather can be shown as a graph over time, shown in Figure 2.2.9. The website also grands some additional information, like the times when the sun and moon rise and set. Yr.no also looks for webcams in the area of attention, so if the user wants to see the weather for themselves they can check out a live feed.

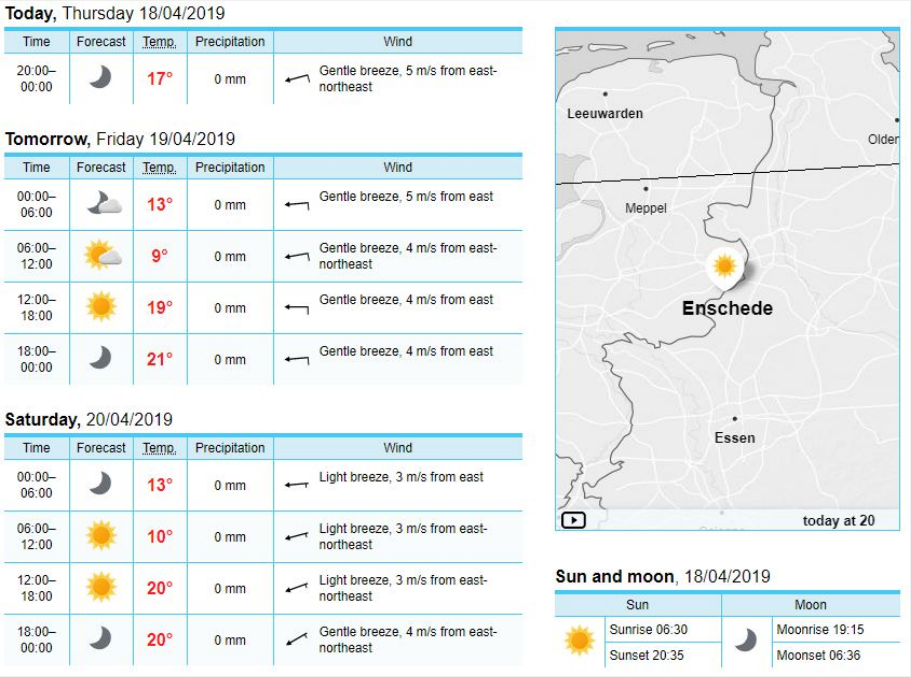


Figure 2.2.8: yr.no default interface [20]

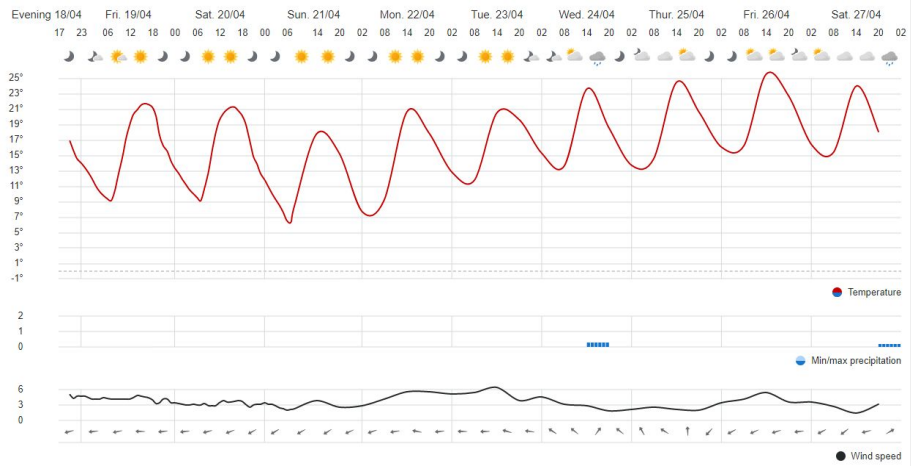


Figure 2.2.9: yr.no graph interface [20]

Weatherbug

Weather forecast website weatherbug[21] focuses less on weather forecast, but instead mostly shows stats about the current weather, as seen in Figure 2.2.10. Only small descriptions are given about the weather of the coming night and the next day. The “now” page stats are very elaborate, not just including temperature, rainfall and wind speed, but also informing about air quality, pollen and lightning strikes. If more info is desired, a forecast per hour or per 10 days is also available in a different tab, al be it less detailed. Weatherbug also offers a few dedicated pages to specific topics like regional alerts, hurricanes and even cold and flu spreading.

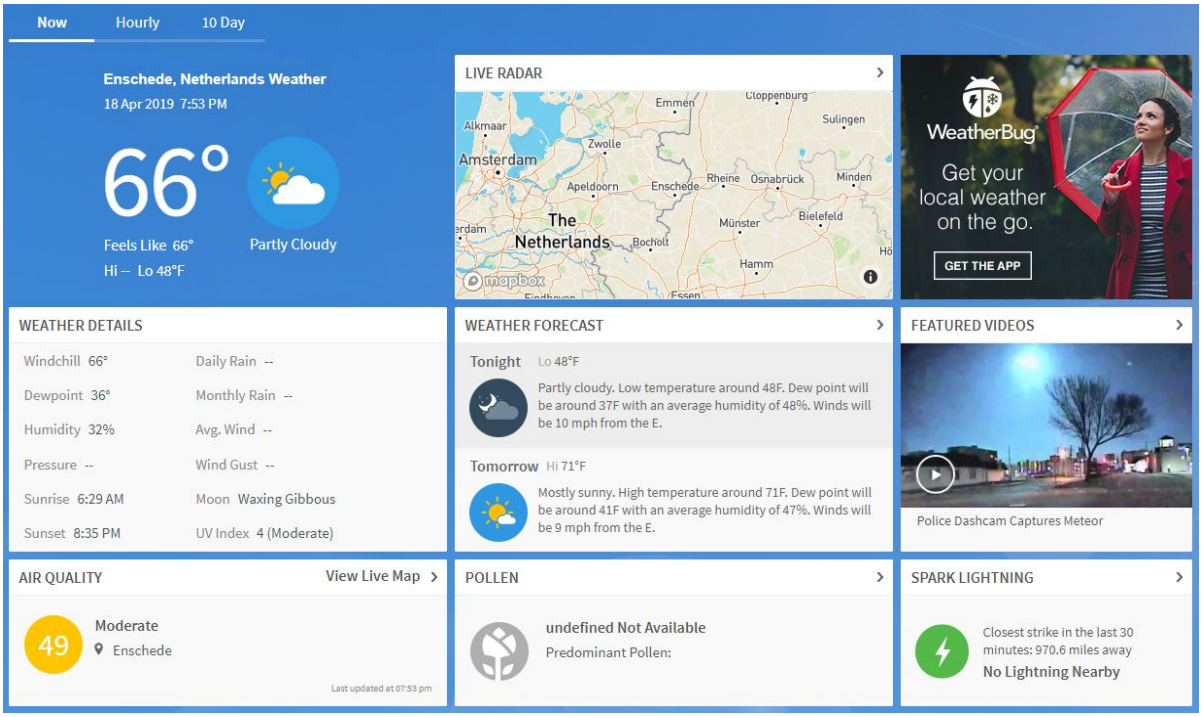


Figure 2.2.10: Weatherbug's web interface [21]

Buienradar

The buienradar[22] website keeps its interface rather minimal on opening, as seen in Figure 2.2.11. Only a three day weather forecast and an hourly downfall graph and heatmap are shown. On request, buienradar will show the weather forecast for 14 days. The website also offers to show heatmaps of wind and temperature, and even UV radiation. As a service to developers, buienradar offers weather data in both JSON and RSS formats. For even easier implementation, buienradar offers widgets that can show either a map

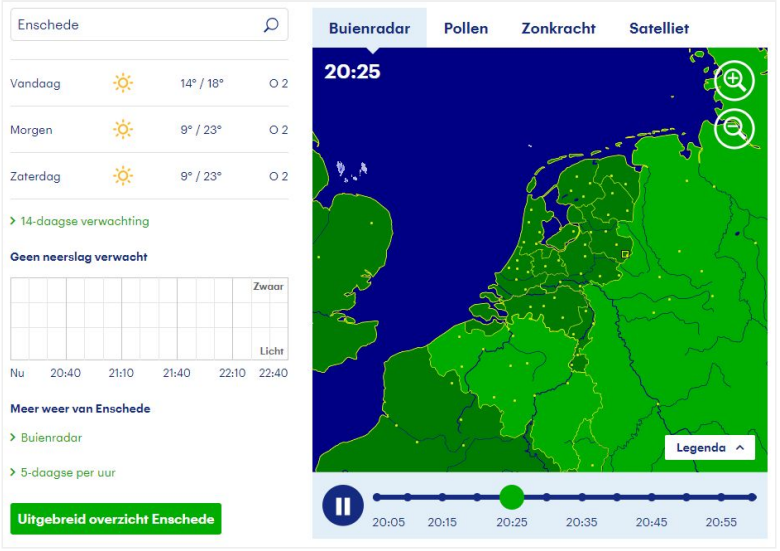


Figure 2.2.11: the web interface of buienradar [22]

2.4 GAMIFICATION ELEMENTS TOWARDS USER ENGAGEMENT

The dashboard that informs the owner of the current status of their SRB, as well as gives them control over it, is an opportunity to engage users. For this purpose, gamification is considered. Gamification allows for elements of video games to be used for different kinds of applications. One way videogames keep people engaged is by using behavioural reinforcement. In behavioural psychology, a reinforcement is a consequence that is given to an organism based on their actions, to strengthen their future behaviour. This conditions the subject to act towards the desired behaviour. Behavioural reinforcement knows a variety of schedules, differencing in when the reinforcement is actually applied. Reinforcers can both be negative or positive. Both will guide the behaviour towards the desired outcome.

The goal of this literature review is to find how behavioural reinforcement can be applied to this dashboard to engage users with the SRB. The main research question is: “How can gamification with behavioural reinforcement keep people engaged with digital media?” This question will be supported by three other questions: “How does behavioural reinforcement relate to gamification?”, “What reinforcement schedule is best fitted for keeping people engaged with gamification?” and “What factors influence behavioural reinforcement?”.

Relation between behavioural reinforcement and gamification

An important feature to implement in video games is reward and punishment, to reinforcing the player in their skillful play, engaging the user. Chubley and Griffiths [23] connect gaming addiction to these reinforcement features. They also describe how players often consider reward and punishment one of the most important and enjoyable features in video games. King et al. [24] outline a feature model of video game structural characteristics, including reward and punishment, that influence excessive video game playing behaviour. They explain that these features may facilitate initiation, development, and occurence of video game playing.

Video game addiction might not be like other addictions, like gambling addiction, but rather a result of separate mental issues. Wood [25] questions the concept of video game addiction, arguing that most of the recent concerns are less based on scientific research, but more based on media hysteria. Then Wood brings forward a case study, showing how claims of video game addiction can be accurately applied. For the ‘addictive’ behaviour, Wood blames ineffective time management skills, or symptomatic responses to underlying problems causing players to try to escape into different worlds, rather than any inherent addictive properties of the actual games. Jerome [26] defends a similar view, saying that describing different addictions, such as video game addiction and gambling addiction, may we risk the trivialization of some of the commonest and most destructive of human problems.

Most research does agree video game addiction is similar to other addictions though, rather than a result of separate mental issues. In an article discussing wood's work, Griffiths [27] provides further thoughts and observations saying that very few arguments presented by Wood actually negate the existence of video game addiction. He then goes on to criticize Wood for not giving his own definition of an addiction. Griffiths has been researching the relation between video game addiction and reinforcement in multiple papers, drawing similarities between gambling and gaming, and describing it as a non-financial way of gambling [28][29]. Mathews et al. [30] also connects video game addiction to other behavioural addictions. This research builds forth on the discovered similarities in effect and presentation to other behavioral addictions. Gaming addiction and other addiction forms like gambling addiction activate similar brain regions as drugs of abuse, including the mesolimbic reward system and amygdala[31][32][33]. This means the medical world also sees video game addiction as something similar to gambling addiction. As Kuczmierczyk et al. [34] and Keepers[35] describe, video game addiction is treated the same way as gambling addiction.

Reinforcement schedules for digital media engagement

In behavioural reinforcement, the effectiveness of the conditioning varies strongly on the pattern of the reinforcement. This is called the reinforcement schedule. Different schedules show varying rates of learning behaviour, as well as how long behaviour continues once reinforcement is seized. In the case of gamification, it is preferred that response rates are as high as possible, and that behaviour post-reinforcement lasts as long as possible. Fester and Skinner [36] lay out several simple reinforcement schedules. The first category is based on ratio: the reinforcement depends on the amount of responses of the subject. This includes continuous (every response), fixed (every *n*th) or variable (average on every *n*th). The second category is based on interval: the reinforcement is delivered after a time interval. This interval can be fixed, or change with every reinforcement. The third category is time: reinforcement is delivered on a timer, independent of behaviour. This timer too, can be either fixed or variable.

It has been found that use of a combination of schedules, rather than a single one, can increase response rates, while decreasing chances of extinction. The preference seems to be on combining at least two specific schedules, being fixed ratio and variable ratio reinforcement. Layering more schedules on top could improve response rates even further. King [24] notes that existing video games often use both fixed ratio and variable ratio schedules on their players at the same time. This keeps players engaged, as reward is always "just around the corner". King [24] also notes that video game players may employ irrational logic similar to the gambler's fallacy, keeping them from quitting a game. Dunniway [37] also outlines that a combination of several schedules is preferrable, describing that using multiple schedules combined can be rewarding to players by itself, as they will notice a change in the rate of rewards, or even a change in rewards themselves.

Behavioural reinforcement factors

The effectiveness of behavioural reinforcement in gamification can be influenced by four factors. The first factor is thinning. When using a variable rate reinforcement schedule, the subject can be made to respond more and more before receiving each consecutive next reward. This means the next reward is always just a tiny bit more work than the previous one. Subjects are drawn in using a lot of reinforcements, but will have to respond more and more to keep receiving reinforcements. This concept is called thinning. Implementing thinning in a variable ratio reinforcement schedule will increase response rates, and decrease the chance of extinction [38][39].

The second factor that influences behavioural reinforcement is the "Near-Miss" experience. When implementing behavioural reinforcement, near win situations should be taken into consideration. Video game players perceive a close defeat attempt as one that came very close to winning, rather than purely perceiving the attempt as a loss. Griffiths [40] proved this to be the case on fruit machine gamblers, describing the "Near-Miss" experience. King et al. [24] points out these experiences can be made to occur on purpose in video games, as an added feature. Wadhwa and Kim [41] conducted further research, showing that nearly winning can kindle motivation within the player.

The third factor to influence behavioural reinforcement is the event frequency. To maximize the effect of a reinforcement schedule, a subject should have the possibility to respond again as soon as possible after each reinforcement, and reinforcements should be kept small. Larger wins were associated with disrupt response rates causing bigger post-reinforcement pauses, decreasing event frequency [42]. The event frequency and reinforcement schedules like fixed interval reinforcement are inherently tied together. This means that a change in either one can affect the outcome both of the behavioural reinforcements as well as the willingness of the subject to respond. The event frequency, or how fast a subject can try make another attempt after a previous reinforcement, has an effect on the subject's will to do so [43][44]. Parke and Griffiths [45] explains that because of the high event frequency, the loss period is very brief. This means the player does not put much thought into investment, and lost money could be won back almost immediately.

The fourth factor influencing behavioural reinforcement is the reinforcer type. Depending on the goal, the reinforcer for conditioning has to be picked carefully. For gamification, positive reinforcement is preferred over negative reinforcement. Chumbley and Griffiths [23] found that using negative reinforcement caused increased frustration and reduced excitement in players, while the use of positive reinforcement resulted in higher rates of return to gameplay. Sault [46] speculates that players might prefer positive reinforcement over negative reinforcement because negative reinforcement is accompanied by an additional unwanted state of mind, while people play video games voluntarily for their enjoyment. Dunniway [37] also notes that extinction is a reinforcer just like positive or negative reinforcement, as not giving the player any reaction to their behaviour signals that they do not show the desired behaviour.

Conclusion/Discussion

To persuade users to upgrade their rain barrel to an SRB, as well as persuade users to spread the word, they must be engaged with the SRB. The web-based dashboard that gives them information and control could be a way to offer this engagement. The task of this literature review is to find how gamification using behavioural reinforcement can be applied to a Smart Rainwater Buffer dashboard to engage the user with it. The goal of the literature review is to determine how gamification with behavioural reinforcement can keep people engaged with digital media. To Figure this out, this literature review looked into the relation between behavioural reinforcement and gamification, the best fitted reinforcement schedule for gamification, and the factors that influence behavioural reinforcement. It was found that behavioural reinforcement in video games lead to very engaging and addictive experiences. To maximise engagement, it is advised to use several reinforcement schedules, preferably including fixed ratio and variable ratio reinforcement. When picking reinforcement schedules, the effect of the near-win should be taken into account, as well as the event frequency of the gamification element. To minimize extinction in the subject, thinning should be implemented in the variable ratio schedule. As reinforcer, it is advisable that positive reinforcement is used in gamification, rather than negative reinforcement. This is not because one is better than the other, but because positive reinforcement is associated with joy, while negative reinforcement is associated with frustration. Deliberate extinction should also be taken into consideration.

Some literature questions the concept of video game addiction; if it is found that video game addiction is not similar to (gambling) addiction, several used sources are not relevant for this review's purpose. Further research is advised to look into the similarities and differences between (gambling) addiction and video games, and between video games and gamification.

3 Methods And Techniques

This chapter describes the methods and techniques used in this project. First, the main design process, the Design Process for Creative Technology will be discussed. Then, stakeholder identification will be described, followed by semi-structured interviews and User Centered Design. Finally, the requirement elicitation using MoSCoW and Functional/Non-Functional categorisation will be explained.

3.1 DESIGN PROCESS FOR CREATIVE TECHNOLOGY

The study of Creative Technology has its own design process that is woven into the curriculum. This is why the Creative Technology Design Process[47] is the main method of this bachelor thesis. The Creative Technology Design Process is based on the Divergence and Convergence model of Jones[48]. Jones' model consists of a divergence phase followed by a convergence phase. The divergence phase allows the design space to be defined and opened up, after which the convergence phase reduces said design space to find the best fit solution. The Creative Technology Design Process is also a spiral model; the process of exploring possibilities and finding options is iterated to find multiple solutions. There are four main phases to the Creative Technology Design Process: ideation, specification, realisation, and evaluation, each of which is elaborated on in the coming subsections. The full structure of the Creative Technology Design Process can be seen in Figure 3.1.1.

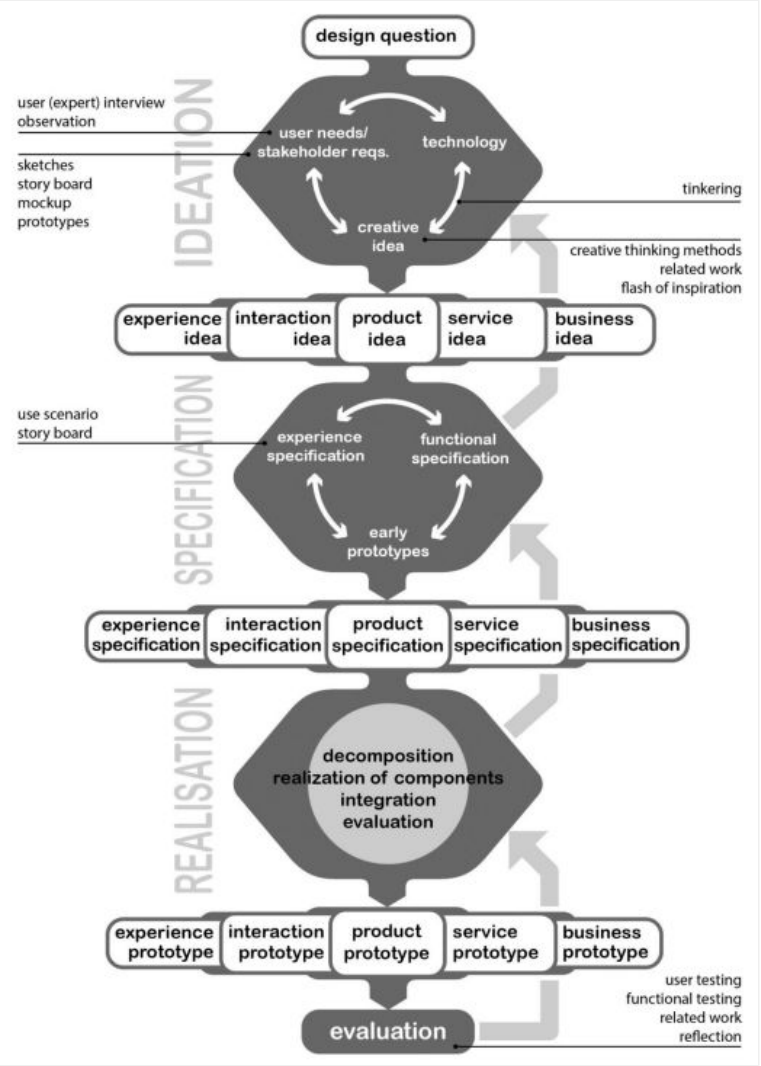


Figure 3.1.1: Design Process for Creative Technology, by Mader and Eggink[47]

Ideation

The first phase of the Creative Technology Design Process is the ideation phase. This phase was started by finding stakeholder requirements. First, stakeholders are identified and categorised using the method of Sharp et al.[49]. Then, preliminary requirements are found using semi structured interviews. From there, many ideas are generated, using knowledge gained through the State of the Art research. The resulting ideas are considered and narrowed down using preliminary requirements and feedback obtained from stakeholders. The chosen idea is then iterated on to form the final outcome of the ideation phase.

Specification

The second phase of Creative Technology Design Process is the specification phase. The specification phase focuses on defining the specification of the product. This is done by detailing the preliminary requirements from the ideation phase into a product specific set of Functional and Nonfunctional requirements. After that, they are also categorised using MoSCoW. This phase was started by

creating low-fi prototypes, using User-Centered Design, after which feedback was retrieved from stakeholders. The low-fi prototype was iterated on with stakeholder feedback, till all requirements were met, and all stakeholders were positive about the design concept.

Realisation

The third phase of the Creative Technology Design Process is the realisation phase, where a functional product prototype is realised. The specification from the previous state is decomposed into components that can be realised and tested separately. They will be evaluated against the set requirements from previous phases and iterated until all requirements are met. Lastly, they can be integrated into a full prototype.

Evaluation

The fourth and last phase of the Creative Technology Design Process is the evaluation phase. Now that a functional prototype is realised, it will be evaluated against the functional requirements from previous phases. All requirements in the "Must" category of the MoSCoW categorisation have to be met by the prototype. Any requirements from the "Should" category will need to be met as well, but failing to do so will still result in a successful evaluation. Any met requirements from the "Could" category add to a positive evaluation, but really do not have to be met. Requirements from the "Won't" category are not expected to be met. If all functional requirements are met, stakeholder input or user testing can determine whether Nonfunctional requirements are met as well. User testing can also tell whether the user experience is as desired. At last, the entire project will be evaluated, including a commentary of proposed improvements for further research.

3.2 STAKEHOLDER IDENTIFICATION AND ANALYSIS

Part of the ideation phase is the stakeholder identification and analysis. To identify the stakeholders of this project, the stakeholder identification method of Sharp et al.[49] will be used. Sharp et al. propose a method that divide stakeholders into four groups:

- Users
- Developers
- Legislators
- Decision-makers

Users are the people that actually end up using the product. The developers are stakeholders because they influence the development, but will not use the product once it is finished. Legislators do not have to be individual people, but can also be any instance that command and control any regulations. Lastly, the decision-makers are people in charge of the development process, like managers

or supervisors. All identified stakeholders will be mapped on Mendelow's power versus interest matrix[50], shown in Figure 3.2.1. This makes clear which stakeholders are important for the development of the new product.

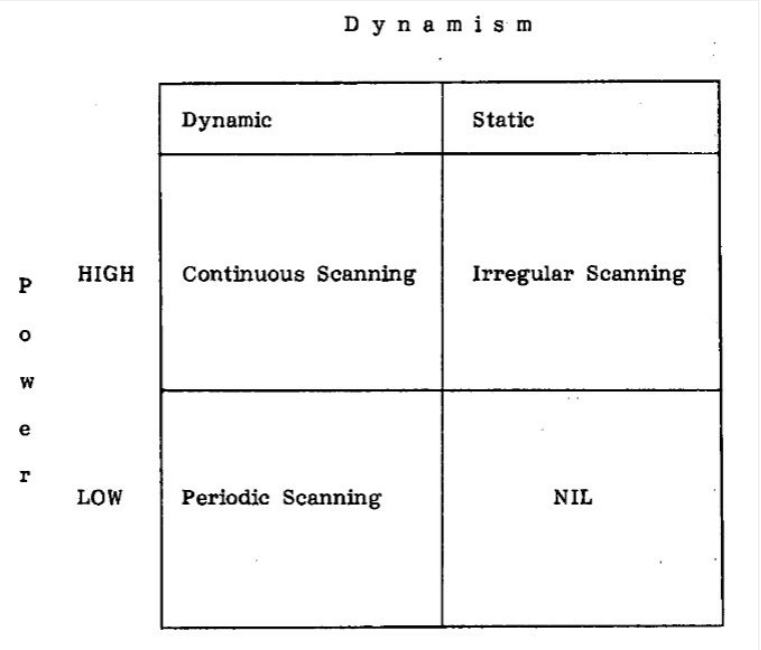


Figure 3.2.1: Mendelow's Power vs Interest (Dynamism) matrix [50]

3.3 INTERVIEWS

To obtain preliminary requirements from the stakeholders, they will be interviewed. Interviews can be done in five different ways[51]: structured, semi-structured, unstructured, informal, and focus groups.

Structured interviews make use of questions that are created prior to the interview. During the interview, a guide is used to steer the discussion. This leaves little room for open answers, but leads to very efficient interviews producing consistent data that can easily be compared across interviewees.

Semi-structured interviews are also steered by an interview guide, with earlier created questions. However, when a researcher senses a user can give more helpful response when following a different trajectory, they can deviate from the interview guide.

An unstructured interview is conducted in a formal setting. However, no prearranged questions or guides are used during the interview. The interviewer has a clear plan in mind regarding the focus and goal of the interview.

An informal interview takes place in a casual setting. During an informal interview, the interviewer talks with the interviewer in a normal way, resembling a regular conversation. This allows the interviewee to really speak their mind openly.

Focus groups is a data collection method. Data is collected through a semi-structured group interview process. Focus groups are used to explore new research areas, or to explore topics that are difficult to observe.

For obtaining preliminary requirements, a structured interview will be used. Doing so will ensure that important aspects are considered by every stakeholder, while the possibility of exploring interesting answers is available.

3.4 USER-CENTERED DESIGN

User-centered design is an iterative design approach, in which the developer is focussed on the users and their needs[52]. This is different from participatory design, where users are also closely incorporated in the development process. Their respective differences are visualized in Figure 3.4.1.

In this project, user-centered design is implemented by getting feedback of stakeholders for each iteration in the ideation phase. Firstly, preliminary requirements are retrieved from stakeholders, in the case of this project using semi structured interviews, from which dashboard concepts are developed. These concepts are discussed with stakeholders again, to select the most, the best 'matching' concept. During the Ideation phase, these steps are repeated until all stakeholders are happy with the dashboard concept. During the specification and realisation phase, stakeholders are not involved.

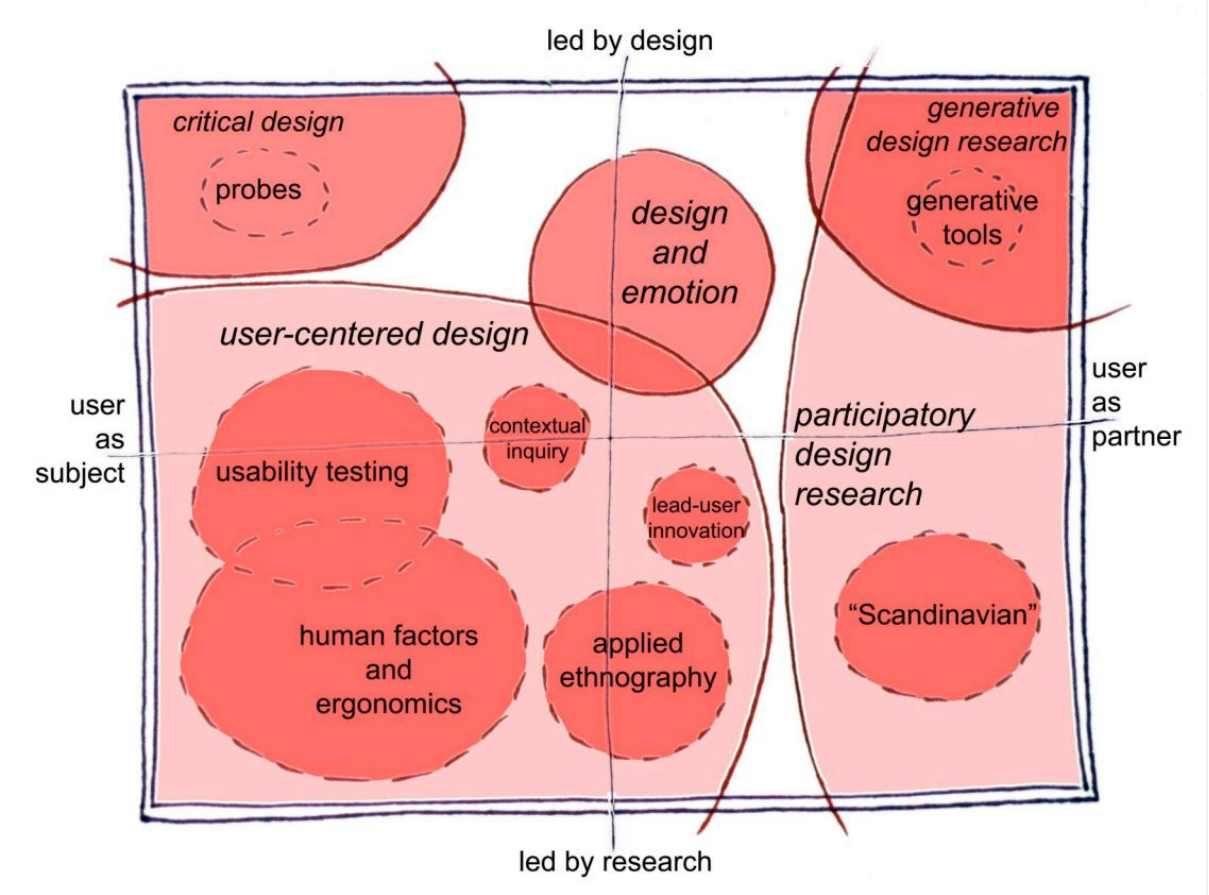


Figure 3.4.1: "The current landscape of human-centered design research as practiced in the design and development of products and services" [52, p2]

3.5 REQUIREMENT ELICITATION

After identifying the stakeholders and obtaining the preliminary requirements in semi-structured interviews, it is important to categorize them. This project has a limited timespan, and so it might occur that there is not enough time to implement all preliminary requirements.

MoSCoW

One method to categorize requirements is MoSCoW[53]. The MoSCoW method does so by using four categories:

- Must Have
- Should Have
- Could Have
- Won't Have

Requirements that are vital for the project are marked as Must Have. If the project does not meet those, it might as well be cancelled. Requirements that are not vital to the product but still very important are marked as Should Have. When requirements are still desired, but do not affect the success of the product, they are marked as Could Have. Any requirement that will not be implemented this development cycle will be marked as Won't Have. This means work effort has to focus on Must Have requirements, while also trying to complete as many Should Have requirements as possible. Any spare time will be dedicated to Could Have requirements.

Functional and Non-Functional Requirements

All requirements either classify as Functional or Nonfunctional. Functional requirements describe what a product should do, while Nonfunctional requirements describe how this should be done[54]. Nonfunctional requirements are often related to quality or system constraints. Whether a requirement is Functional or Nonfunctional, should be described in such a way that they are verifiable in testing, and can be evaluated on pre-established criteria.

4 Ideation

This chapter describes what happened during the Ideation phase of the project. First, a stakeholder analysis was conducted. Said stakeholders have then been interviewed in a semi-structured interview, to obtain a list of requirements. These requirements are categorised to form preliminary requirements. From those preliminary requirements, concepts are developed. The concepts are then iterated on. Each iteration builds on the feedback that stakeholders have on the previous iteration.

4.1 STAKEHOLDER ANALYSIS

Using the method of Sharp et al.[49], the stakeholders have been identified (see Table 4.1.1). Each stakeholder is explained further in their specific subsection.

Stakeholder	Contact person	Category
Municipality of Enschede	HendrikJan Teekens	Decision-maker
Waterschap Vechtstromen	Jeroen Buitenweg	Legislator
Developer	Pepijn Peeters	Developer
University of Twente	Richard Bults Hans Scholten	Decision-maker Legislator
Pre-pilot participants	Jeroen Waterink Jeroen Buitenweg HendrikJan Teekens Hans Scholten Eddo Pruim Richard Bults	User

Table 4.1.1: Identified stakeholders and their category in the Sharp et al.[49] method.

Municipality of Enschede

The municipality of Enschede is one of the partners in the development of the Smart Rainwater Buffer and its accompanying systems. This means that the municipality has a good amount of power in the development of the Regentoren project. The interest of the municipality is equally high as its partners: it is their responsibility to resolve the rainwater drainage issues in the lower areas.

University of Twente

The development of the Smart Rainwater Buffer, and its accompanying systems is performed by the University of Twente. This means that the University of

Twente has a lot of power over the project, even though they will not use the product themselves. As one of the partners of Regentoren, the University of Twente has a high interest in the project.

Waterschap Vechtstromen

The Waterschap Vechtstromen is also one of the partners of the Regentoren project. The Waterschap Vechtstromen is responsible for the water in the area. Just like the other partners, their interest is high. Waterschap Vechtstromen is also the only legislative stakeholder. This means that their power is also moderate.

Developer

As the party that actually applies all decisions and findings, the developer has a moderate amount of power. As the developer is not a party that facilitates or requires the development of the project, it is important to keep a neutral stance. Taking too much of this power can negatively influence development. The project has been chosen as a bachelor thesis by the developer. Hence, their interest is just as high as the project partners.

Pre-pilot participant

Pre-pilot participants are the target group of this project. These people are the innovators that like to try their hands on new technology. Having signed up as pre-pilot participants themselves, they have a very high interest in the Regentoren project, including the accompanying dashboard. As representatives of end users, the pre-pilot participants have a high amount of power.

Power vs Interest Matrix

Using the method of Mendelow[50], a power-interest matrix can be made, as shown in Figure 4.1.1. Note that even though the Developer has a high interest, they are not assigned to a category. Given the position of each stakeholder on the matrix, we can conclude the priority groups as shown in Table 4.1.2.

Priority Group	Stakeholders
Manage Closely	Municipality of Enschede Pre-pilot participants Waterschap Vechtstromen University of Twente
Keep Satisfied	None
Keep Informed	None
Monitor	None

Table 4.1.2: Identified stakeholders assigned to Priority Groups

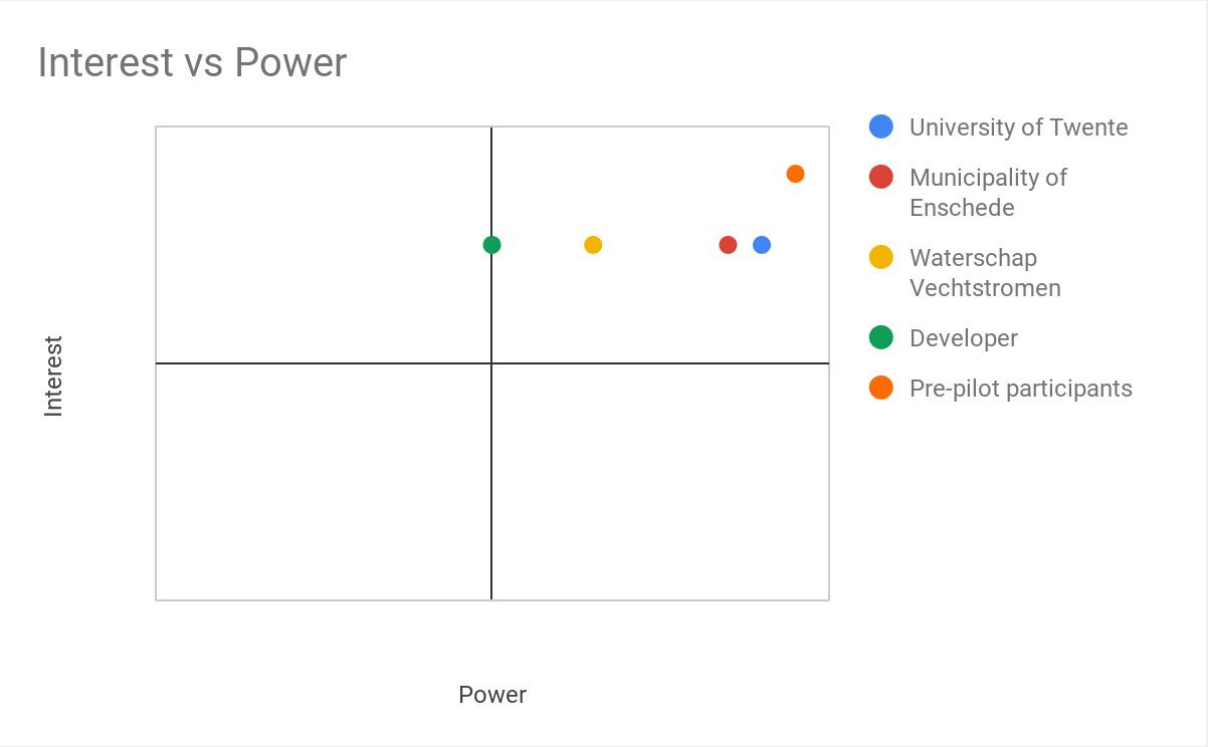


Figure 4.1.1: The Interest vs Power Matrix using Mendelow's method[50]

4.2 INTERVIEWS

Several semi-structured interviews were conducted with all pre-pilot participants, to find out what is needed from the dashboard. Each individual was interviewed separately, while notes were taken of the answers. These notes can be found in appendix A till F. As the interviews were conducted in dutch, the notes are in dutch too. After finishing all interviews, all the collected notes where interpreted and laid out next to each other in a spreadsheet, which can be found in Appendix G. This spreadsheet too, was made in dutch. Doing this allowed trends to be discovered, leading to preliminary requirements.

4.3 PRELIMINARY REQUIREMENTS

The trends discovered after processing the interviews are categorised using MoSCoW, making up the preliminary requirements, shown in Table 4.3.1. Note that each requirement is also listed as Functional or Nonfunctional. During the Specification phase of the project, these requirements will be refined.

Must Have

Functional	Nonfunctional
FR01: The dashboard must display a history and forecast of precipitation, temperature and the SRB's fill level	NFR01: The dashboard must have a responsive layout: users must be able to comfortably view the dashboard on any device.
FR02: The display of history and forecast must be scalable to fit the user's desires, e.g. day, week, month, etc	
FR03: The dashboard must display the SRB fill level	
FR04: The dashboard must display the water's temperature	
FR05: The dashboard must display the current time and date	
FR06: The dashboard must show the location of the SRB	
FR07: The dashboard must show the status of the SRB and its subsystems	
FR08: If the SRB status changes, then an explanation should be given of the situation and how to resolve it when applicable	
FR09: A rain forecast map must be available in the dashboard, displaying the same data as used by the SRB	
FR10: The calculation constant of the volume of the SRB must be adjustable in the dashboard	
FR11: The calculation constant of the size of the collection area/roof must be adjustable in the dashboard	
FR12: The user must be able to set a desired fill level in the dashboard: this will ensure a certain amount of water	

is left behind after an automatic discharge	
FR13: Users must be able to understand the SRB and its actions: each event should have an explanation available	

Should Have

Functional	Nonfunctional
FR14: Information about water throughput should be displayed: how much water was discharged, manually used, or overflowed during a rainshower	NFR02: Users should find the dashboard professionally looking
FR15: The users should be able to cancel and plan automatic discharges on their own	NFR03: Desktop and mobile phone versions of the dashboard can change the layout of elements, but not the elements themselves
FR16: Insight should be given into average performance of all SRBs in a given search radius	

Could Have

Functional	Nonfunctional
FR17: Functionality to see information about SRBs of friends could be provided	NFR04: A simple layout that only shows info about the here and now could be provided
FR18: The dashboard displays how the SRB network has helped to relief Enschede's sewer system	
FR19: The dashboard could provide functionality to customize the layout	

Won't Have

Functional	Nonfunctional
FR20: The dashboard won't have a console like log that displays every single action of the SRB	NFR05: An API to program own widgets for the dashboard, or to link the data to one's own services won't be provided
FR21: Data export functionality won't be provided	
FR22: A possibility for garden sensors won't be provided	
FR23: Functionality to share one's SRB performance with friends will not be provided	
FR24: The dashboard won't provide a live chat or another implementation of a helpdesk	

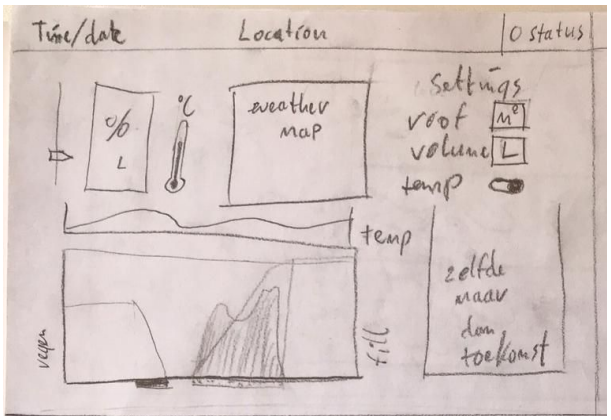
Table 4.3.1: All identified preliminary requirements, categorised by Must, Should, Could and Won't have, divided into Functional and Nonfunctional.

4.4 CONCEPT CREATION

The found preliminary requirements are used to create several iterations of concepts to find the final design of the dashboard. Each iteration is discussed with all stakeholders to refine a next version.

Sketches

To get an idea of what the layout should be like, sketches were made to find what fits the requirements. Several layout ideas for desktop use were considered, as shown in Figure 4.4.1 till 4.4.4. Since a Should Have requirement is that the dashboard is responsive (NFR01), sketches were made of how the dashboard could look like on a mobile phone, as shown in Figure 4.4.4. Because a simple layout as in desktop layout sketch 4 (Figure 4.4.5) was only a Could Have requirement(NFR04), it was not chosen to be iterated on. After discussing with stakeholders, it was decided that it is preferable that the desktop and mobile phone versions of the dashboard show information in the same way(NFR01). Because of this, and its clarity, the second desktop layout (Figure 21) was chosen, together with its mobile phone variant (Figure 4.4.5, left side), to be iterated on.



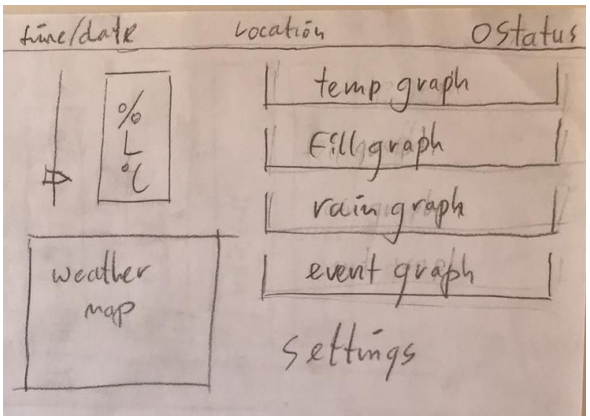
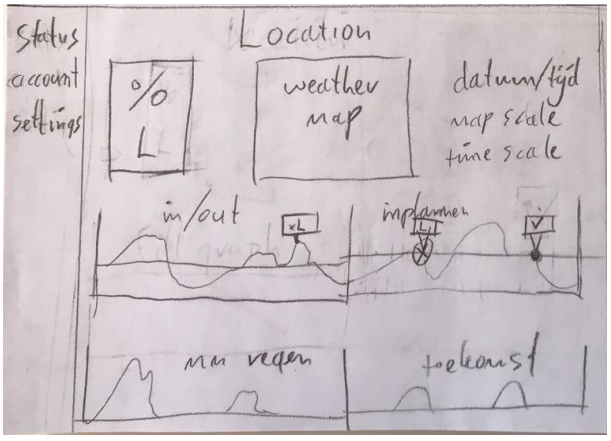


Figure 4.4.1(left): desktop layout sketch 1
Figure 4.4.2(right): desktop layout sketch 2



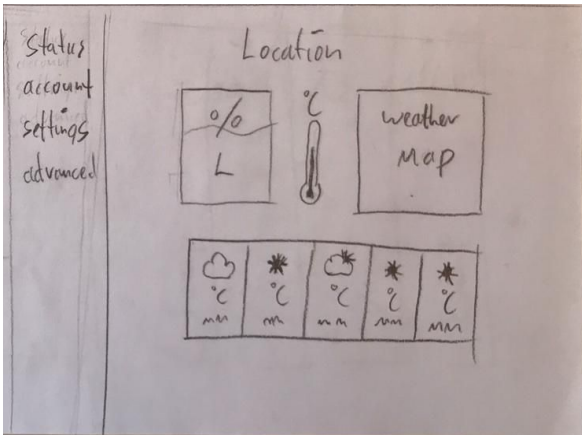


Figure 4.4.3(left): desktop layout sketch 3
Figure 4.4.4(right): desktop layout sketch 4

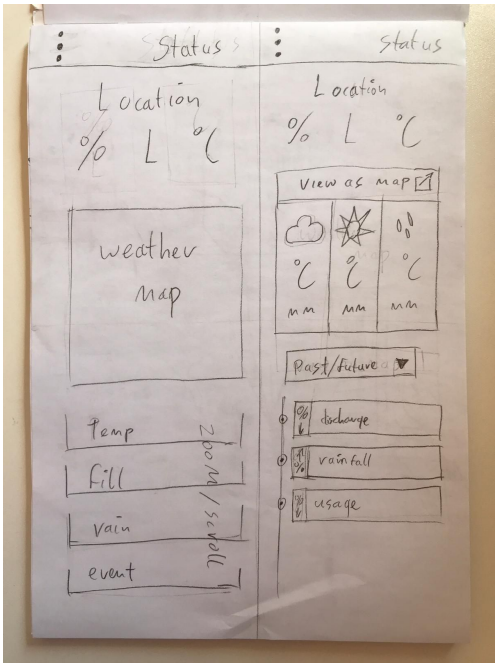


Figure 4.4.5: mobile phone layout sketches

Corporate design

The Regentoren project has developed a corporate design. The Regentoren project design style is very spacious, using a lot of white. The layout is build up of squares. For styling, elements are rounded and use drop shadows for depth. This design style is applied to everything connected to the Regentoren project, as can be seen in the concept of the project's website shown in Figure 4.4.6. This corporate design serves as a source of inspiration for the design style of the dashboard.

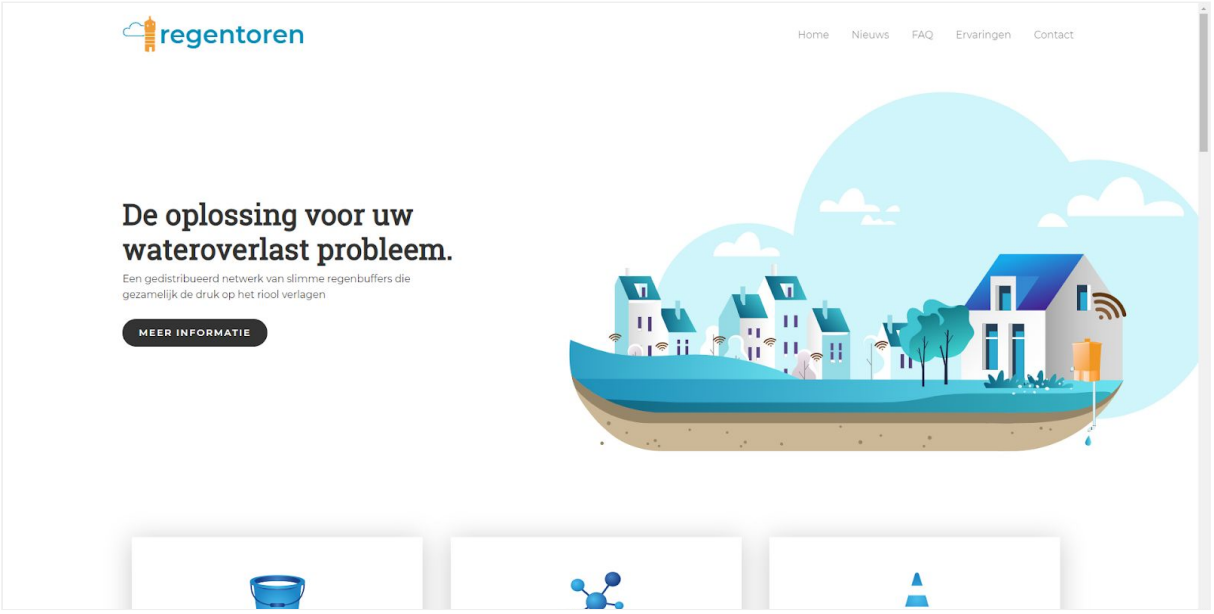


Figure 4.4.6: the concept information website of the Regentoren project[55].

First concept iteration

Since the mobile version should only change the layout of the dashboard, but not the functionality (NFR01), only the desktop version is made during the concept iterations. Combining the selected layout sketch (Figure 4.4.2) and the corporate design style, a first concept was created digitally, as an image (Figure 4.4.7). The layout was not altered, but each element, especially the graphs, where refined and further worked out.

The top bar shows the time and date (FR05), the location of the user's SRB (FR06), and the status of this SRB (FR07). The top left shows information about the current fill level (FR03) and temperature (FR04). The slider to the left of the current fill level is used to set a desired minimum fill level (FR12) prior to automatic discharge. The bottom left holds a buienradar[16] widget (FR09): a city plan that shows a heatmap of rainfall. Buienradar is used, as the SRB system uses it as a source for localized precipitation data: for clarity it is preferred that the user gets the same information as the system (FR09). The concept idea is that the 3 graphs and event graph (first step for FR13) should all be aligned above each other, using the same x axis.

When the dashboard is opened, the “NOW” hair is in the center of the graph, showing each value for the present time (FR01). The graphs are zoomed to show two more days of prediction, and two more days in the past (FR01). The shadows on the sides of the graphs signal the user that the borders are not fixed: the graph can be moved further into the past or future by dragging (FR02). By hovering the mouse over the graphs, the hair that is displayed in the middle in the image will jump to the x position of the mouse, giving a reading at that point. “NOW” will update to the selected point in time.

Since each graph is linked by x axis (time), a certain continuation should be kept between them. But since they are separate graphs with separate y axis, they should not be shown as one graph. As a middle way between totally disconnected graphs, and one graph with multiple data lines, the four graphs are put up separately while connected by every other vertical grid line. The y axis of each graph should automatically scale appropriately to the data that falls within the currently visible timespan (FR02).

Zooming the graphs (FR02) will be done by scrolling while hovering the mouse on the graphs. The fourth graph utilises the graphical “metro line” info system to display at what points in time an event happened, defined by which line such an event sits on.

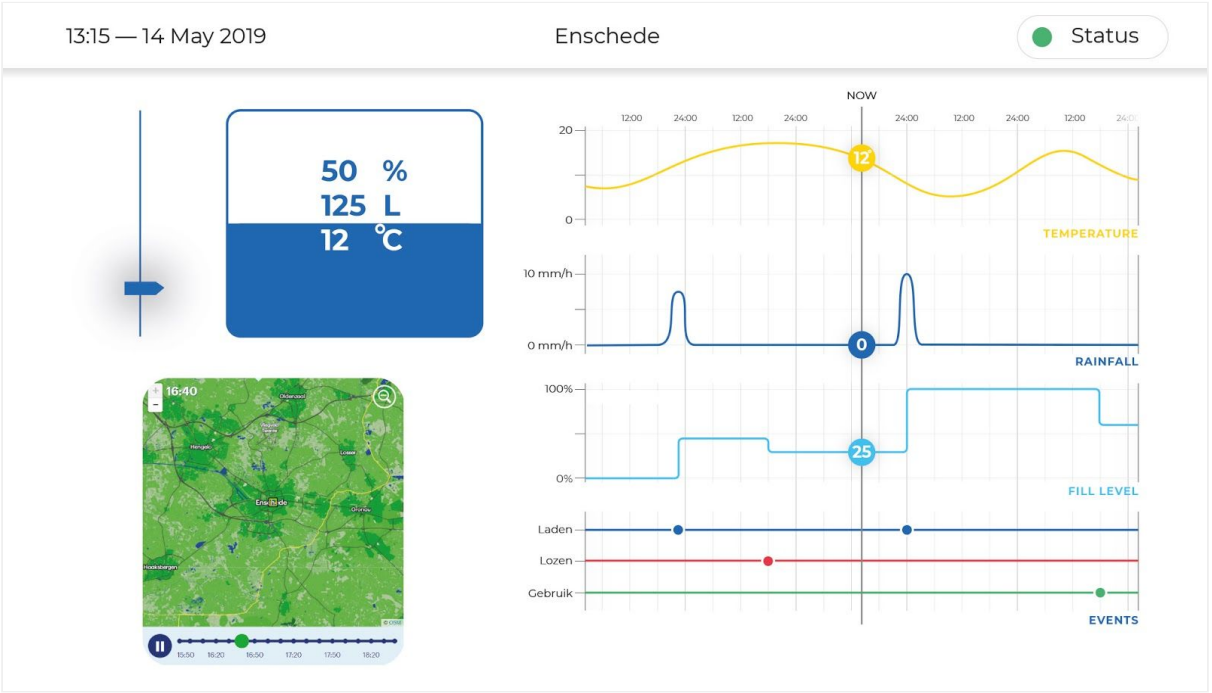


Figure 4.4.7: the first concept iteration

First concept evaluation

This concept version of the desktop was discussed with all stakeholders, to gather feedback. Stakeholders were positive over the cleanliness of the concept, as well as how easy the graphs read.

A point of discussion was the event graph. Not all event types are accounted for in the first concept event graph (e.g. critical temperature events

are not shown), and there was no way to investigate further details of each event. It was discussed that it would be clearer if there would be one event line for each corresponding graph, as well as if events could be inspected to get further detail. Even though there was already an idea on how the graph should look and behave when scrolling, this was not visible in the first concept iteration. It was decided that zooming the graphs with the mouse wheel would cause problems, as the page itself should also permit scrolling on smaller screens.

The current fill level in the top left turned out to be visually too heavy for the desired look. The minimum fill level slider next to it was determined to be illogical: in the first concept iteration, every setting has to be set in the settings, except the fill level. It was also found that the intensity of the shadows can vary greatly from monitor to monitor, even completely vanishing on some.

Second concept iteration

A lot of functionality was not accounted for in the first concept iteration. The second concept, as seen in Figure 4.4.8 till 4.4.11, implements some missing features such as a menu. This menu allows the user to navigate to a settings page, where the calculation constant of the volume of the SRB and the calculation constant of the size of the collection area can be adjusted (FR10, FR11). A display for comparing your SRB's performance to an average of other SRB's within a search radius was also added (FR16). This element is placed such that it is always seen by the user, assuming that the user always uses the precipitation, fill level, temperature and event graphs: when on computer, the element is shown to the left (as visible in 4.4.8), while on mobile devices it is placed above the four graphs, forcing the user to scroll past it. Next to that is a small display that tells the user how much water has been buffered collectively last rainshower (FR18). The graph got a way of showing missing data, by using a dashed line. Feedback from the previous iteration was also incorporated. To improve the event graph, each graph is represented in their own line. This means that all event types that belong to one graph will be put on the same line. Each event on the line is not only marked as a dot, but will be drawn out over the affected time period to form a line. Each event is also selectable. This will open a popup that gives more detailed information about the event (FR13).

The second concept is shown in a situation where the user has scrolled into the past. This way the concept can show how the "NOW" marker is displayed when 'now' is off-screen. To make sure the user is able to zoom the graphs (FR02) without losing the ability to scroll the web page on a small device, a zoom in and zoom out button were added.

To improve on the current fill level display in the top left, the design of the display section was totally redone. To fit the soft rounded aesthetic of the design style, the bar graph like area was replaced with a gauge, with the absolute values in the center (FR03, FR04). The desired fill level slider was replaced by a small notch that clips onto the fill level gauge (FR12). This still informs the user of the currently set desired fill level, but does not allow for setting it. When hovered, the absolute values in the center of the gauge are overlaid by a small card that displays the exact value for the desired fill level.

The second concept iteration also contains some minor tweaks and touches to layout, design and shadows to further enhance the design, clarity and readability (NFR02).

Figure 4.4.8: the second concept iteration, without overlays

Figure 4.4.9: the second concept iteration, with desired reserve overlay

Figure 4.4.10: the second concept iteration, with information popup

Figure 4.4.11: the second concept iteration, with menu overlay

Second concept evaluation

The second concept was also discussed with all stakeholders. The new event graph iteration was well received, but still got some points to improve. For clarity, the names of the graphs and the names for the event lines of the graphs should use the same title, and really all events of that graph should be shown its corresponding line. In contrast, concept two only showed discharges on the fill level event graph line. The dotted line was found to be perceived as a prediction rather than a lack of available data. Suggested was to use the dotted line for predictions, and just leave the graph empty when no data is available. To accommodate these predictions to be interpreted as predictions instead of as

measured values, the name of the rainfall graph was suggested to be changed to precipitation.

It was requested that all data in the popup that is not a conclusion, is grouped above the divider. This means the confidence of a rain shower should appear above the line, rather than below it. It was asked that the comparison display element would allow for changing the time span, just like the distance. It was found though, that the distance would most probably hardly be used. For this reason it was suggested that the search radius is moved into the settings panel. It was also suggested that the element would more resemble the current fill level element rather than the four graphs. Since the comparison display element shows simplified/similar data to the collective water gain display, it was requested that the latter is removed.

The newly available space would then be used to display a larger buienradar widget. This would require a minor layout rearrangement. Lastly, some stakeholders noted that they would like the buienradar widget to be zoomed in more.

Third concept iteration

In the third concept iteration (Figure 4.4.12 till 4.4.15), all missing functionality from the main dashboard page has been accounted for, with the inclusion of a status overlay (FR07, FR08). It was decided that messages in the status overlay should be ordered by severity, rather than date of occurence. It was also decided that these messages should not be dismissable by the user, instead making the system get rid of them when it detects that the corresponding issue is resolved. During the development it was noted that the way of using shadows in the first two concepts gave a lot more darkness than desired for the light and open corporate design style. For this reason shadows were lightened and shrunk in the third concept iteration, together with a few other minor layout and design choices (NFR02).

The feedback of the second concept iteration was also incorporated: the names of all graphs and event graph lines are synchronised, fill events are shown on the fill level event graph, missing data is not represented in the temperature graph, and all incoming data in the popup is grouped above the divider while conclusions are displayed below.

When getting to work on the comparison display element (FR16), a few issues were found with the previously proposed changes. First off, a gauge using two bars would be visually more present than the current fill level gauge in the top left. This would make it seem more important, claiming immediate attention when visiting the dashboard. As a workaround, the two bars could each get their own gauge. This also poses a problem though, as this would make it harder to compare the bars to each other. After all, the entire point of a visualisation is to make understanding data easier. An additional problem with gauges is that the current design style is not suited to show value markers: the comparison display element will have unpredictable values, meaning the visualisation has to scale to the data dynamically. This is not a problem with the current fill level gauge, as the fill level is always between 0% and 100%. So instead of implementing gauges, the

comparative display was kept with a bar graph. To make it more readable, a display for each value, as well as the difference was added below. With the search radius prompt moved to the settings, the space above the graph was used for a time span prompt.

Figure 4.4.12: the third concept iteration, without overlays

Figure 4.4.13: the third concept iteration, with information popup

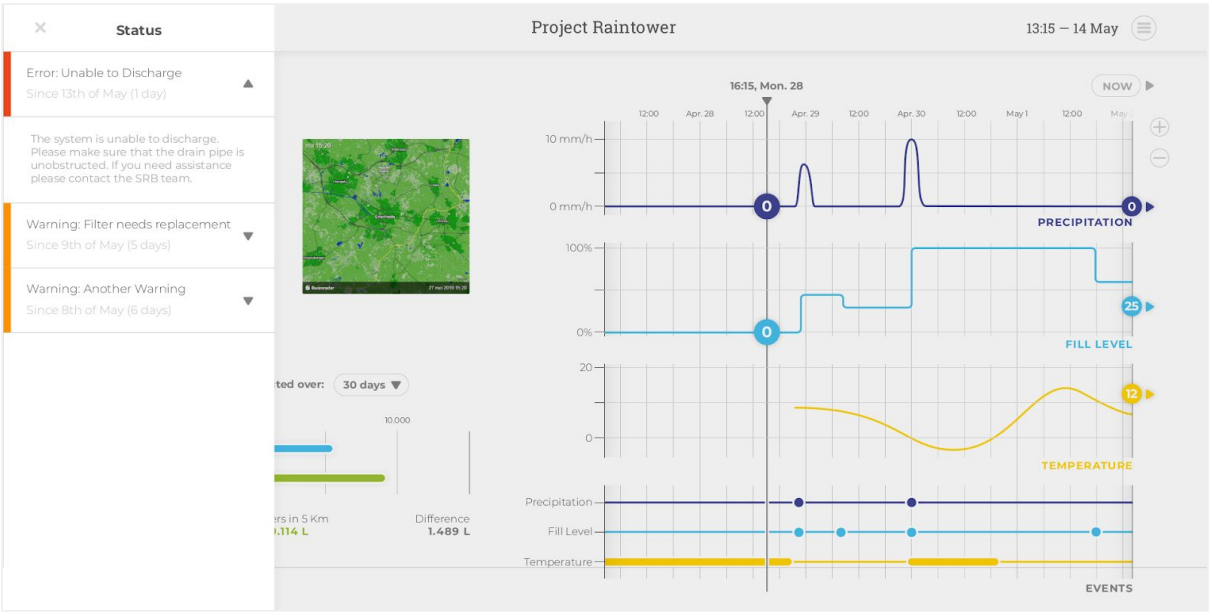


Figure 4.4.14: the third concept iteration, with status overlay

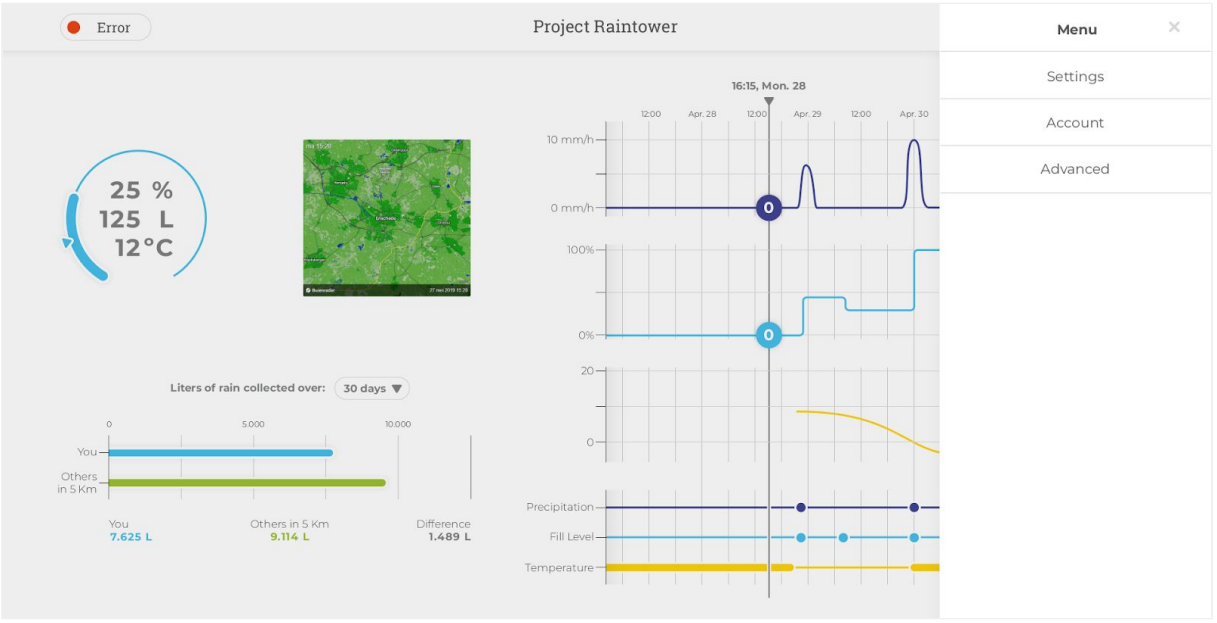


Figure 4.4.15: the third concept iteration, with menu overlay

Third concept evaluation

The feedback on the third iteration concept was nearly all positive. The only thing that still sparked discussion was the comparison display element. Firstly, a consistency issue was identified: the comparison display bars do not have guiding lines behind them in their respective color. Secondly, the label with the select box was thought to be too much of a title. To better fit the design style of the rest of the dashboard, it should be shortened to something like “Interval:”. This should not take away any clarity of the function of the comparison display element, as it is very straight forward in its functionality. It was suggested “You” was exchanged for “Me”, to give owners a more possessive feeling. With these label changes,

"others in 5 Km" was suggested to be shortened to "Radius: 5 Km". Lastly, stakeholders desired a bit more information from the comparison display element, specifically: a minimum and maximum on the "others in 5 Km" line, and a visualisation of the used amount of collected water.

Final Concept Iteration

Incorporating the feedback of the third concept iteration, a final concept was created. All suggested comparison display element label changes where incorporated, and the missing guidelines behind the comparison display bars were added. To display the additional desired information without cluttering the element, it was decided to display the desired information using the little arrow tick, as used for the desired fill level on the current fill level element. A new entry in the menu was added for "Help", though its exact functionality is undecided at this point. The changes can be seen in Figure 4.4.16.

Figure 4.4.16: the final concept iteration, showing the improved comparison display element.

Conclusion

The final dashboard concept incorporates all functional requirements from the "Must" category (FR1-FR13), and functional requirements FR15 and FR16 from the "Should" category. During the concepting, new requirements where found. These requirements are shown in Table 4.4.1.

Functional	Nonfunctional
FR25: Graphs must have a way to inform the user about the exact value of a certain point	NFR06: When no data is available, no data must be shown
FR26: All time bound graphs must scroll and zoom together, keeping temporal unity	NFR07: Any information that can be displayed for multiple points in time, should span over the entire range
	NFR08: Messages in the status overlay must be ordered by severity, rather than date of occurence
	NFR09: Status messages should not be dismissable by the user, but only by the system when it detects that the corresponding issue is resolved.

Table 4.4.1: New requirements found during concepting

5 Specification

This chapter describes the specification phase of the project. First, a description of the system architecture will be given. Then, the final requirements will be listed. This will be sorted by Functional and Nonfunctional, categorised using MoSCoW.

5.1 SYSTEM ARCHITECTURE

The system architecture is described by the block scheme shown in Figure 5.5.1. The core script is responsible for retrieving all necessary data from the server, after which is initialises the dashboard by calling on several other scripts to actually form content. Said scripts create visualisation elements to the user via the display. The user can then interact with certain elements. The user's put will be captured by the script responsible for the element that is interacted with, which will then communicate with the core script to either store or obtain information from the data repository.

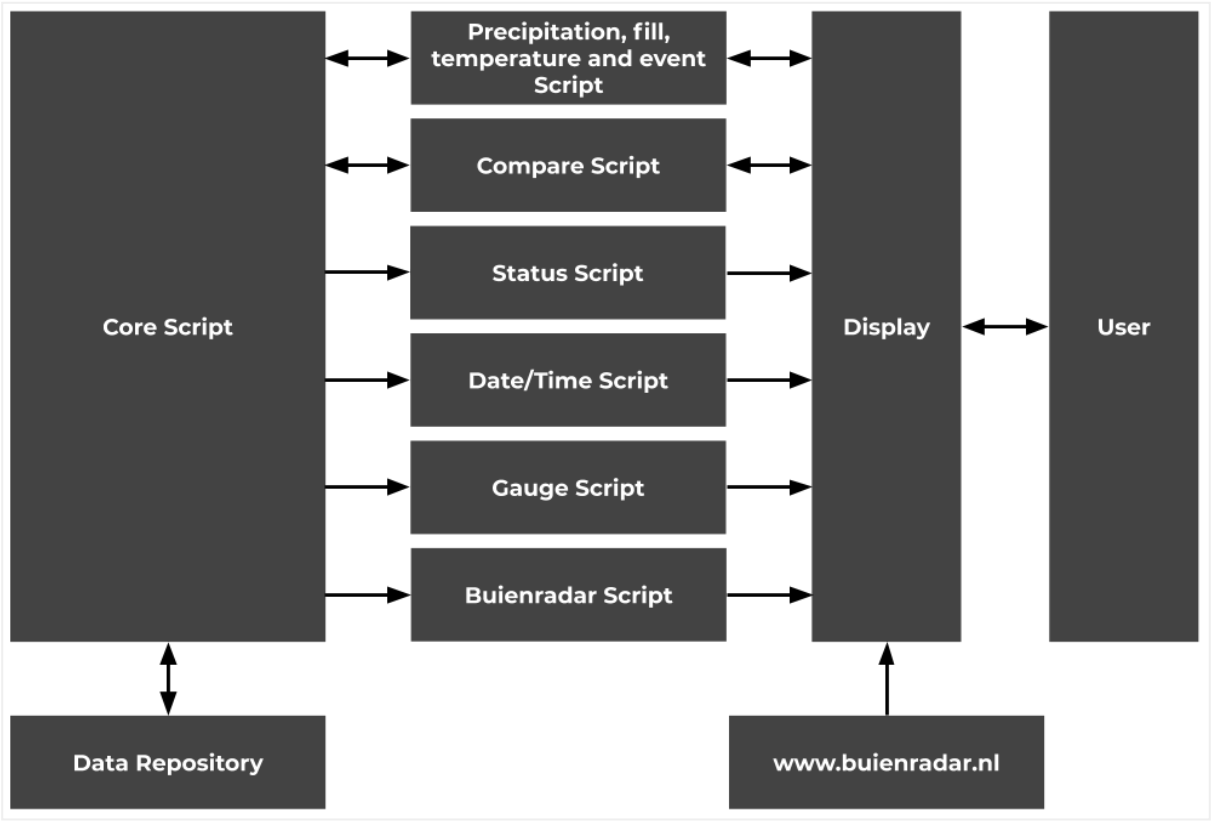


Figure 5.1.1: overview of the dashboard functional architecture

Core script

The core script is the script that controls what happens when with the dashboard. It is also the script that does all communication with the data repository, whether it is for initialisation of the dashboard, or because some other script requires

additional data. The SRB team already has a test database available, that the dashboard can make use of. This database offers a Postman[56] HTTP GET-request based system to serve JSON data. Due to privacy concerns, the Postman endpoint will not be further explained.

Precipitation, fill, temperature and events script

The script that controls the four graphs for precipitation, fill, temperature and events will receive input from the user to zoom and scroll the graphs. When the user moves the graph view further forward or backwards than currently loaded by the dashboard, the script will request the missing data from the core script, which in turn will request it from the data repository. The core script receives the data, and hands it forward to the script responsible for the four graphs, which will update the view. Users can also interact with the event graph, to plan discharges. These will also be captured by the script responsible for the four graphs, which will ask the core script to store them in the database.

Compare script

The compare script is responsible for the comparison display element. The user is able to request several different time periods, which the compare script will capture. The compare script will then request the needed data from the core script, which in turn will request it from the data repository. The data is then handed forward through the same chain, where finally the compare script will process it into the comparison display element.

Status script

The status element only receives data, and displays it. This might sound confusing at first, as an option to dismiss warnings is often expected. However, the SRB system will be able to tell by itself when issues are resolved. Till then, the user is informed of what is wrong. This means no way of dismissing warnings will be implemented, which in turn means that the status script will not need two way communication with the display and the core script.

Buienradar blocks

The buienradar script only runs on initialisation. After the core script receives the location of the SRB from the data repository, it will ask the buienradar script to create the buienradar widget for that location. The buienradar script then forms the right link for the iframe that hosts the widget. Once the iframe is loaded into the browser, the browser should load the widget from buienradar[22].

5.2 FINAL REQUIREMENTS

This section lists the final requirements for the Smart Rainwater Buffer dashboard in Table 5.2.1. These requirements consist of the preliminary requirements together with all requirements found during concepting. The requirements will be sorted into Functional and Nonfunctional, and be categorised using MoSCoW.

Must Have

Functional	Nonfunctional
FR01: The dashboard must display a history and forecast of precipitation, temperature and the SRB's fill level	NFR01: The dashboard must have a responsive layout: users must be able to comfortably view the dashboard on any device.
FR02: The display of history and forecast must be scalable to fit the user's desires, e.g. day, week, month, etc	NFR07: Any information that can be displayed for multiple points in time, should span over the entire range
FR03: The dashboard must display the SRB fill level	NFR08: Messages in the status overlay must be ordered by severity, rather than date of occurence
FR04: The dashboard must display the water's temperature	
FR05: The dashboard must display the current time and date	
FR06: The dashboard must show the location of the SRB	
FR07: The dashboard must show the status of the SRB and its subsystems	
FR08: If the SRB status changes, then an explanation should be given of the situation and how to resolve it when applicable	
FR09: A rain forecast map must be available in the dashboard, displaying the same data as used by the SRB	
FR10: The calculation constant of the volume of the SRB must be adjustable in the dashboard	

FR11: The calculation constant of the size of the collection area/roof must be adjustable in the dashboard	
FR12: The user must be able to set a desired fill level in the dashboard: this will ensure a certain amount of water is left behind after an automatic discharge	
FR13: Users must be able to understand the SRB and its actions: each event should have an explanation available	
FR25: Graphs should have a way to inform the user about the exact value of a certain point	
FR26: All time bound graphs should scroll and zoom together, keeping temporal unity	

Should Have

Functional	Nonfunctional
FR14: Information about water throughput should be displayed: how much water was discharged, manually used, or overflowed during a rainshower	NFR02: Users should find the dashboard professionally looking
FR15: The users should be able to cancel and plan automatic discharges on their own	NFR03: Desktop and mobile phone versions of the dashboard can change the layout of elements, but not the elements themselves
FR16: Insight should be given into average performance of all SRBs in a given search radius	NFR06: When no data is available, no data should be shown
	NFR09: Status messages should not be dismissable by the user, but only by the system when it detects that the corresponding issue is resolved.

Could Have

Functional	Nonfunctional
FR17: Functionality to see information about SRBs of friends could be provided	NFR04: A simple layout that only shows info about the here and now could be provided
FR18: The dashboard displays how the SRB network has helped to relief Enschede's sewer system	
FR19: The dashboard could provide functionality to customize the layout	

Won't Have

Functional	Nonfunctional
FR20: The dashboard won't have a console like log that displays every single action of the SRB	NFR05: An API to program own widgets for the dashboard, or to link the data to one's own services won't be provided
FR21: Data export functionality won't be provided	
FR22: A possibility for garden sensors won't be provided	
FR23: Functionality to share one's SRB performance with friends will not be provided	
FR24: The dashboard won't provide a live chat or another implementation of a helpdesk	

Table 5.2.1: final requirements, categorised by Must, Should, Could and Won't have, divided into Functional and Nonfunctional.

6 Realisation

This chapter discusses the realisation of the prototype based on the final concept of the ideation phase in chapter 4, specified in the specification in chapter 5. This prototype can be seen in Figure 6.0.1 as it shows on desktop, and in Figure 6.0.2 as it would show up on mobile devices.

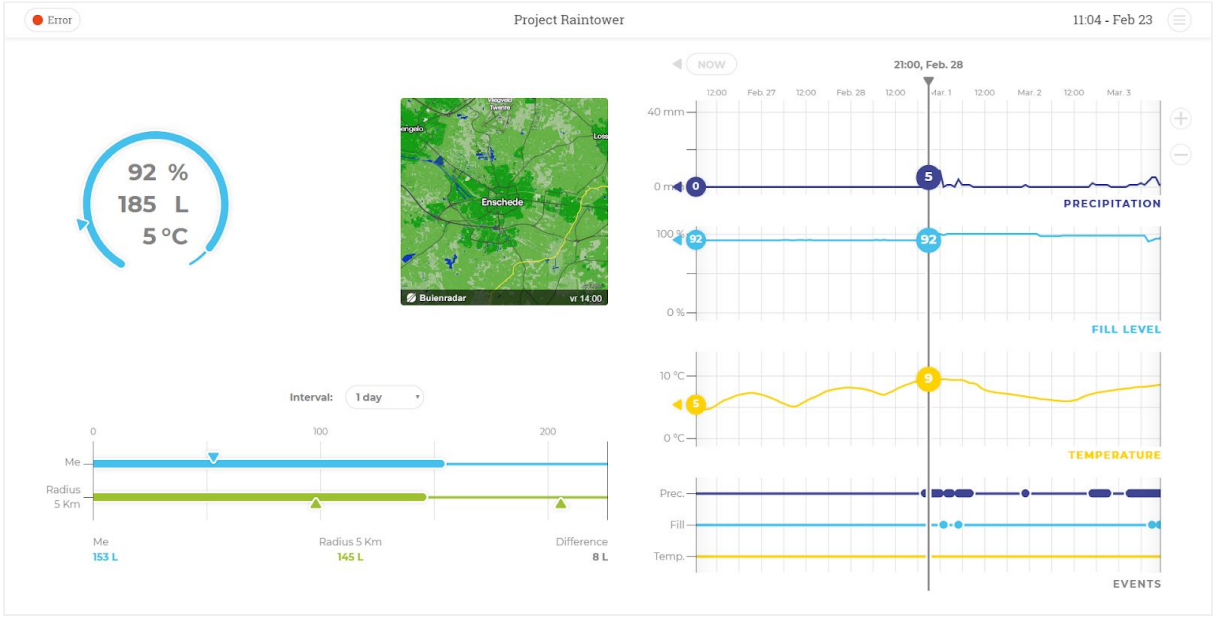


Figure 6.0.1: the fully functional prototype as seen on computer

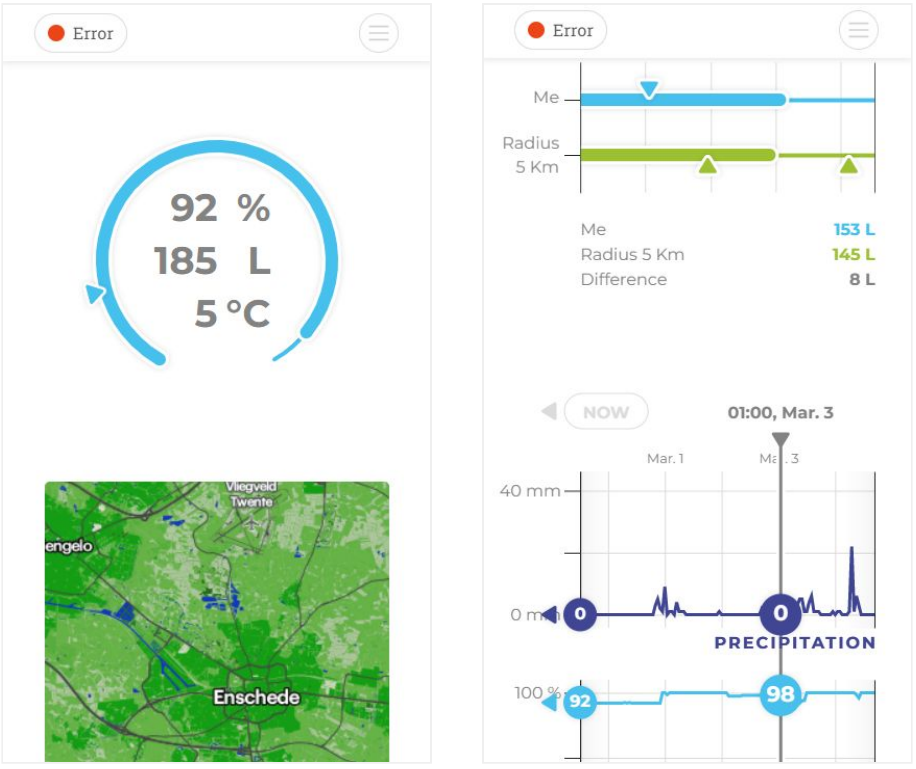


Figure 6.0.2: the fully functional prototype as seen on mobile devices

6.1 CHOICE OF TECHNOLOGIES

As the challenge of this bachelor thesis is to make a web-based dashboard, the prototype has to consist of Hyper Text Markup Language (HTML). Cascading Style Sheets (CSS) are used to style the HTML, and JavaScript (JS) is used to script all dynamic content. As it is required that users can look forward and backwards in time (FR01), it was decided that precipitation, fill level, temperature and event data should be loaded dynamically. As a consequence, the display elements that visualize this data must also be dynamically generated. For this reason it was decided that all scripting will be done client side using JS, where the web server only serves the HTML, CSS and JS files without doing any preprocessing on them. To simplify the creation of a responsive layout, the Bootstrap[57] framework was used. To assist in styling the dashboard, the SASS[58] version of Bootstrap was customised. For the generation of many data dependant elements, the javascript library D3.js was used. To assist in scripting all functionality in JS, the libraries Moment.js[59] and jQuery[60] were also utilised. Each addition is explained more in its respective subsection.

Bootstrap and SASS

Bootstrap is a cosmetic framework that makes it easy to develop responsive web pages. Bootstrap also comes with JS code that allows for easy implementation for things like hamburger menus, collapsible elements and modals. Once the functional implementation is as desired, the aesthetic look of bootstrap can be changed in two ways: by overwriting existing styles per element, and by rebuilding bootstrap from the SASS code using different variables. SASS is a CSS preprocessor that allows for generating CSS based on variables and basic scripting. Changing the SASS variables used by Bootstrap allows for general overwrites: e.g. changing the text color variable applies it to all text elements, while using style overwrites, all text elements would have to be targeted explicitly.

D3.js

D3.js is a JS library that specializes in building Scalable Vector Graphics (SVG) elements from datasets. This means that any text generated using D3.js will still be considered text once it shows up on the users screen, in contrast to text that is displayed using a canvas element. SVG elements also scale very well with resolution and pixel density changes. D3.js was not chosen for simplicity, but rather for its flexibility, as it only incorporates low level functions, not binding the developer to any predetermined design choices.

Moment.js, jQuery

To make scripting in JS easier, the libraries Moment.js and jQuery were used. Moment.js allows for easy parsing and formatting of any form of timestamps, while jQuery is a library that includes functions for nearly all standard procedures,

making them easier. E.g. selecting elements, applying styles or removing elements from the webpage.

6.2 DATA RETRIEVAL AND WRANGLING

During early development of the prototype, it was discovered that the database server the prototype was supposed to communicate with was not ready for use. The delivery of data did not only take very long, but also unprocessed. The server currently delivers way denser data points than both usable and practical. Certain data that is needed for the dashboard prototype is also not currently stored in the server database. E.g. the precipitation data for the selected Smart Rainwater Buffer is not available to the web endpoint.

To resolve this issue, it was decided that the prototype would not make use of the current database server. Instead, data was taken from different sources.. These datasets were then preprocessed to contain the desired density of datapoints, stored in formats that could easily be read by D3.js. When the dashboard loads, the datasets are served as JS variables, together with the rest of the dashboard. Then once a script that makes use of the datasets loads, it combines the datasets into one x axis.

Because of this implementation, the prototype can only simulate the date at the timestamp halfway the preprocessed dataset. As the preprocessed dataset is built from data from the database server, the preprocessed dataset only consists of old measurements. As a result, the prototype can only simulate a date in the past.

6.3 DESIGN CHOICES

During the realisation of the prototype, a few more design choices have been made that have not been thought of previously.

First off, the hover hair on the precipitation, fill level, temperature and event graphs snaps to the center of the view during dragging. This allows the user to see what timestamp is currently in the center of their view. This is important to know, as the zooming functionality of the graphs is always centered on the middle timestamp of the view. The added functionality allows for easy scrubbing to a date on a zoomed out view, after which the user can look in more detail at said date by zooming in on it.

Secondly, the values beneath the comparative display element were found not to fit side by side on small screens. For this reason, it was chosen to put said values beneath each other when not enough space was available. The result can be seen in Figure 6.3.1.

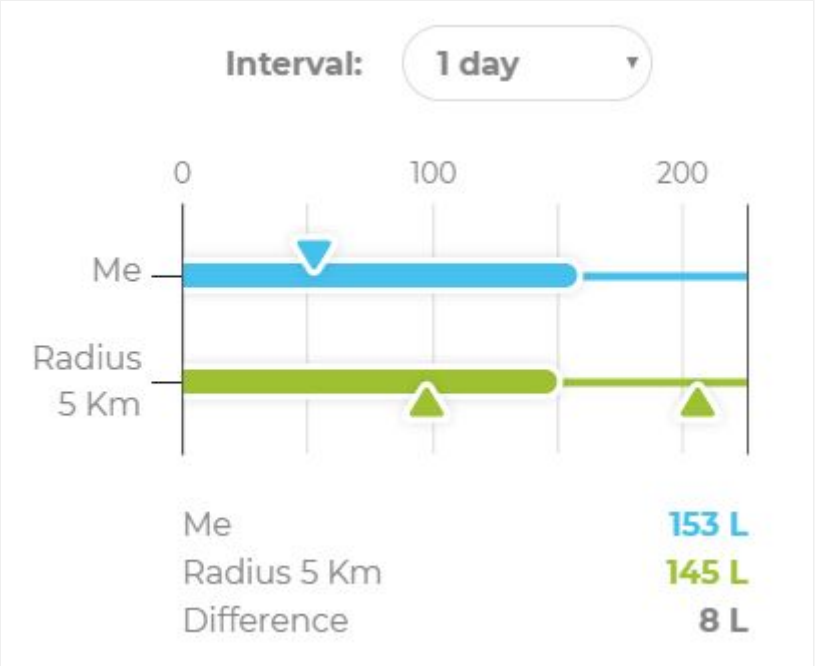


Figure 6.3.1: the comparative display element on narrow mobile devices

Thirdly, user friendliness was improved on by the addition of several hover cursor changes. When hovering over the precipitation, fill level, temperature and event graph, the mouse cursor is changed into a grab hand, to signal the user that they can grab the graphs. This should help users in discovering how the graphs can be controlled. Of course, when a user actually grabs the graphs, the cursor is changed into a grabbing hand, to signal that the graphs are now constrained to the mouse cursor. The same mentality was also continued towards the events in the event graph: when hovering on an event, the user's cursor changes to a pointer, signalling that the user can click events to inspect them. To signal that a user can plan a discharge by clicking on the fill level line in the event graph, the mouse is changed to a pointer there too. To make this even more clear, a 'ghost' event is shown beneath the mouse pointer, signalling the user that an event could be placed there. This feature can be seen in Figure 6.3.2.

Figure 6.3.2: the fill level event line in the event graph (second line) showing an event (left mark) and a plannable 'ghost' event (right mark) on hove

7 Evaluation

In this chapter, the prototype will be evaluated against the requirements discussed in chapter 5. Firstly, the functional requirements are evaluated using functional testing. After this, a user test is performed with the stakeholders. This user test will show how the design choices of the ideation phase in chapter 6 affect the user. This user test also provides feedback from the stakeholders about the dashboard. The user test is followed by the evaluation of the nonfunctional requirements. Finally, an evaluation conclusion is given.

7.1 FUNCTIONAL REQUIREMENTS EVALUATION

In this section, the functional requirements decided upon in chapter 5 are evaluated. This was done by considering each functional requirement against the prototype, asking whether the prototype fulfills it. In Table 7.1.1, each functional requirement is listed, followed by an explanation whether it has been met in the prototype (see Figure 6.0.1). All functional “Must Have” and “Should Have” requirements are met by the prototype. It is important to note that certain requirements are considered met because their function in the dashboard is fulfilled in the prototype, even though the dataset used by the prototype is frozen. E.g. the current fill level in the gauge is hard-coded in the prototype.

Must Have

FR01	**The dashboard must display a history and forecast of precipitation, temperature and the SRB’s fill level**
	This requirement was met, to a certain extent. As the prototype dashboard uses a local pre-processed dataset, the displayed data is not up to date. Simulated from a certain date a forecast is shown, even though all data is from the past.
FR02	**The display of history and forecast must be scalable to fit the user’s desires, e.g. day, week, month, etc**
	This requirement was met. Scale is not defined in steps: as users can zoom freely, any time scale can be displayed.
FR03	**The dashboard must display the SRB fill level**
	This requirement was met.
FR04	**The dashboard must display the water’s temperature**
	This requirement was met.

FR05	**The dashboard must display the current time and date**
	This requirement was met, all be it for the simulated date.
FR06	**The dashboard must show the location of the SRB**
	This requirement was scarcely met. The dashboard focuses the buienradar on the location of the SRB, but the actual address is currently not named anywhere on the main page.
FR07	**The dashboard must show the status of the SRB and its subsystems**
	This requirement was met.
FR08	**If the SRB status changes, then an explanation should be given of the situation and how to resolve it when applicable**
	This requirement was met.
FR09	**A rain forecast map must be available in the dashboard, displaying the same data as used by the SRB**
	This requirement was met.
FR10	**The calculation constant of the volume of the SRB must be adjustable in the dashboard**
	This requirement was scarcely met: the prototype of the dashboard only includes the main page, while for consistency and clarity it was chosen to have all settings (including calculation constants) in a separate settings page, which is reachable from the menu incorporated in the prototype.

Should Have

FR14	**Information about water throughput should be displayed: how much water was discharged, manually used, or overflowed during a rainshower**
	This requirement was partially met: how much water overflowed during a rainshower is currently not displayed, as the SRB does not currently have a way of measuring this data.
FR15	**The users should be able to cancel and plan automatic discharges on their own**
	This requirement was met.

FR16	Insight should be given into average performance of all SRBs in a given search radius
	This requirement was met.

Could Have

FR17	Functionality to see information about SRBs of friends could be provided
	This requirement was not met.
FR18	**The dashboard displays how the SRB network has helped to relief Enschede's sewer system**
	This requirement was not met.
FR19	**The dashboard could provide functionality to customize the layout**
	This requirement was not met.

Won't Have

FR20	The dashboard won't have a console like log that displays every single action of the SRB
	This requirement was not met.
FR21	**Data export functionality won't be provided**
	This requirement was not met.
FR22	**A possibility for garden sensors won't be provided**
	This requirement was not met.
FR23	**Functionality to share one's SRB performance with friends will not be provided**
	This requirement was not met.
FR24	**The dashboard won't provide a live chat or another implementation of a helpdesk**
	This requirement was not met.

Table 7.1.1: functional requirements and whether they are met in the prototype, categorised by Must, Should, Could and Won't have.

7.2 TESTING PROCEDURE

After evaluating the functional requirements, it has to be determined whether the prototype meets the nonfunctional requirements, and the goals set for this bachelor thesis. To test this, and get some feedback from the stakeholders, an individual user test was conducted with each stakeholder. Each stakeholder was asked to answer questions and complete a series of tasks in the prototype dashboard, getting as little assistance as possible from the researcher. The questions and tasks were as follows:

- What is the desired fill level?
- How do you feel about the SRB performance of today?
- How do you feel about the SRB performance of this quartile?
- How much water was reused today?
- What is currently wrong with the SRB system?
- Is the error/warning order logical to you?
- Can you give me a 24h view of the 10th of march?
- What was the water temperature at 21h on the 12th of march?
- Why is temperature marked on the event line at 21h on the 12th of march?
- What kind of discharge event took place at 7h at February 11?
- Can you plan a discharge at 9h on march 13?
- How many liters of water is expected on the 9th of march at 14h?
- How many liters of water were collected at 23h on february 8?

After all tasks were completed, any questions that remained were answered and explained by the researcher. Now with the full knowledge of the interface, the users were asked to rate their experience by providing their opinion on some statements. Users were asked to answer using the numbers 1 till 5, where 1 is strong disagreement, and 5 is strong agreement. The statements were as follows:

- The dashboard is of professional grade
- The dashboard as has been properly adapted to mobile devices
- The dashboard is easy to use
- I can see myself using this dashboard often

After giving a rating and possibly a motivation for their ratings on each question, the users were given one final open question, asking them what they would change about the dashboard. Most stakeholders already pitched some feedback earlier during the user testing. This feedback was also noted under this open question.

7.3 USER TESTING

During testing it was found that even though most users can Figure out the dashboard on their own, some users still require assistance to find all functionality

of the dashboard. Most users had confusion surrounding the “used water” notch on the “Me” line in the comparative display element, as seen in Figure 7.3.1. This notch suggested users that the entire element was about how much water was reused, both by them and by others. To make the comparative display graph clearer, it was suggested to move the “used water” information out of the comparative display element, to a new element. How this new element should look or work was not suggested. Another element that confused some users was the status button reading “Error”, as seen in Figure 6.0.1. Some users wrongly assumed that something was wrong with the dashboard or the status button, rather than the SRB system itself. To make it clear that the button describes the SRB system status, it was suggested that the word “Status” was to be displayed either to the side or inside the status button, as shown in Figure 7.3.2.

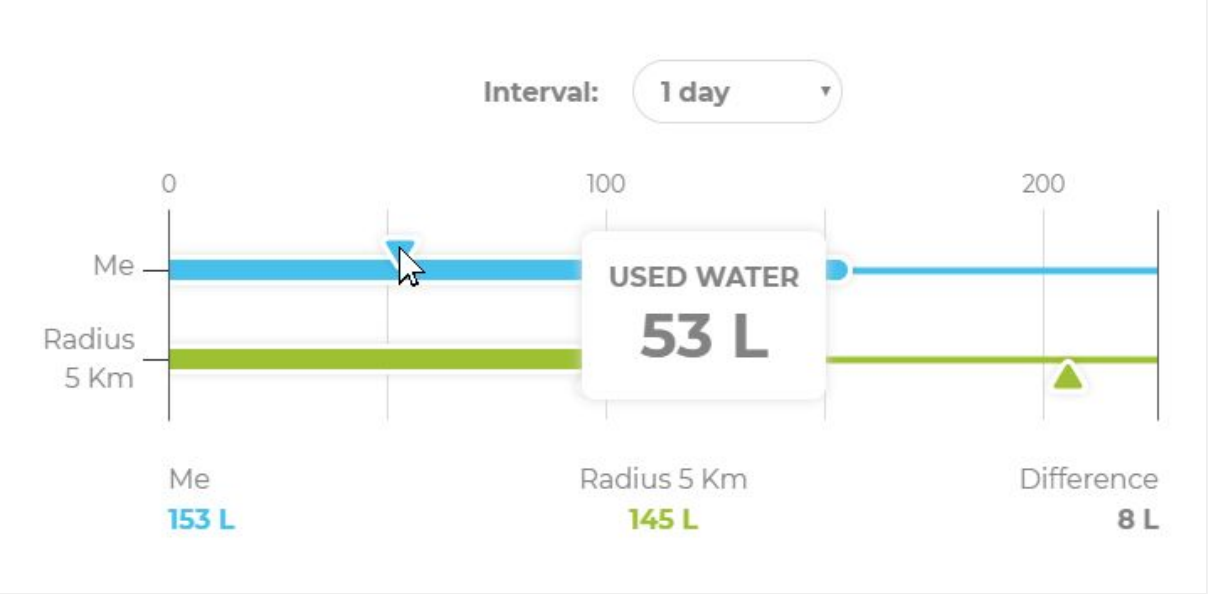


Figure 7.3.1: the comparative display element, showing used water when hovering on the cursor on the notch on the “Me” line.

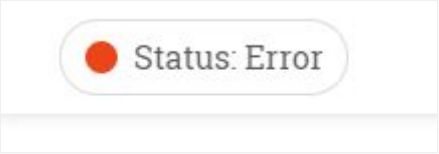


Figure 7.3.2: the status button as suggested by stakeholders (right)

On computer, control of the precipitation, fill level, temperature and events graphs time range was something that seemed to either come naturally to some users, while other users required some training. On touch devices, however, all users found it easy and intuitive to navigate the graphs. To better support navigation on computer, it was suggested that navigation using arrow buttons at the top of the graph would be implemented for computers, as shown in Figure 7.3.3.

Figure 7.3.3: the top of the precipitation graph, with the suggested arrow buttons to go backwards and forwards in time.

Most users did not pay much attention to the event graph at first, not really exploring its full functionality. Only when answers to tasks were repeatedly found by clicking events, did they Figure out that a lot of detailed information can be obtained by inspecting events. To better explain that the events can all be inspected by clicking on them, it was suggested that an information icon pops up next to the mouse pointer when hovering on events, as shown in Figure 7.3.4. This would mimic the functionality of the notches in the comparative display element and the current details gauge, which show their data when hovering them with the mouse pointer

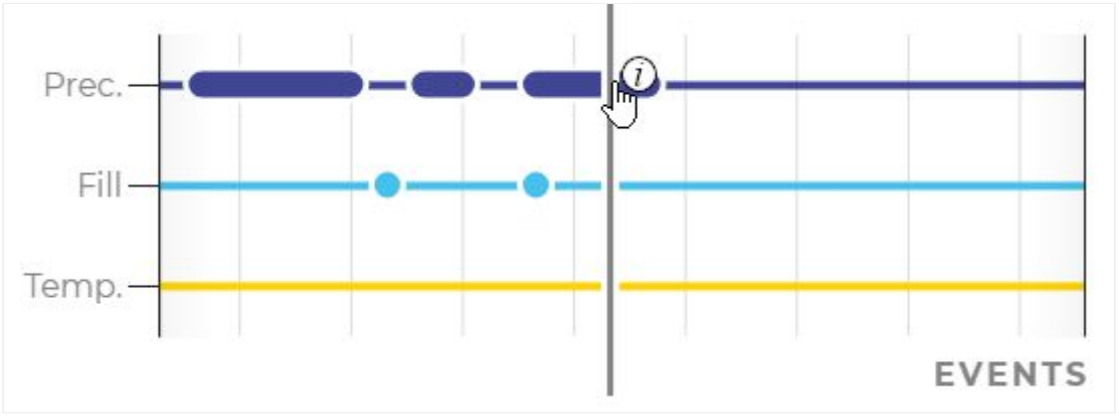


Figure 7.3.4: the events graph showing an information icon when hovering on an event, as suggested.

When users explained that they were motivated by the comparative display element, it turns out they were often motivated by seeing the amount of water they reused relative to the amount of water they collected, rather than seeing how their collection compares with that of others in the area. It was pointed out that users felt good about performing better than others in the area, while users did not feel bad about performing worse than others. Such cases where brushed off with statements like “They probably had more rain”.

With the tasks completed, users were asked to rate four statements, as discussed in the previous section. The statements “The dashboard is of

professional grade" and "The dashboard as has been properly adapted to mobile devices" were rated positively by all stakeholders. The statement "The dashboard is easy to use" was not rated positively or negatively by one stakeholder. Their reason for this was that they found it difficult to discover all functionality. Additionally, they had trouble navigating the precipitation, fill level, temperature and event graphs on computer. The statement "I can see myself using this dashboard often" also got one neutral response. The stakeholder that answered neutral motivated their rating saying that they are not really interested in neither the technology nor the competitive aspects of the SRB system. Their only reason to visit the dashboard would be to check how much water is currently stored, or to remotely water their garden if the drain valve is linked to their garden's irrigation system. The ratings for each statement are visualised in Figures 7.3.5 till 7.3.8.

The researcher's notes taken during the user tests can be found in appendix H to L. Since the interviews were conducted in dutch, the notes are in dutch too.

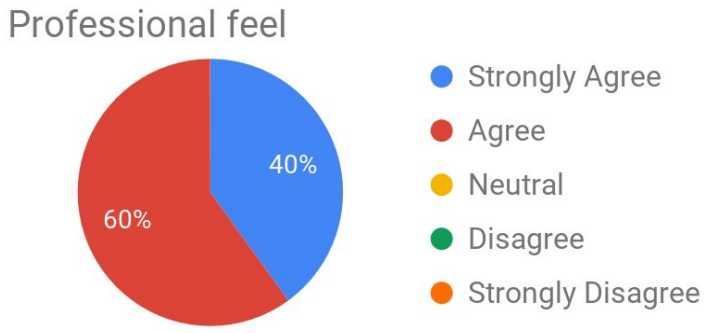


Figure 7.3.5: Answers to the statement "The dashboard is of professional grade"

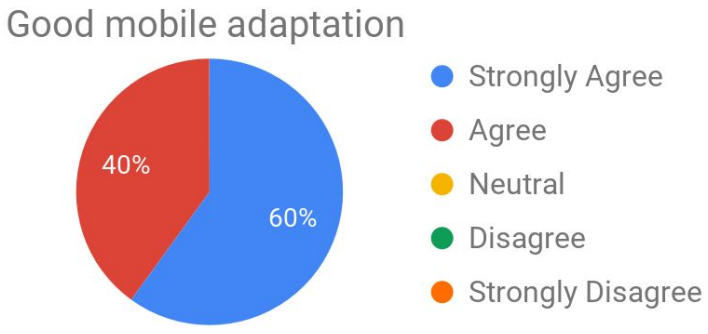


Figure 7.3.6: Answers to the statement "The dashboard as has been properly adapted to mobile devices"

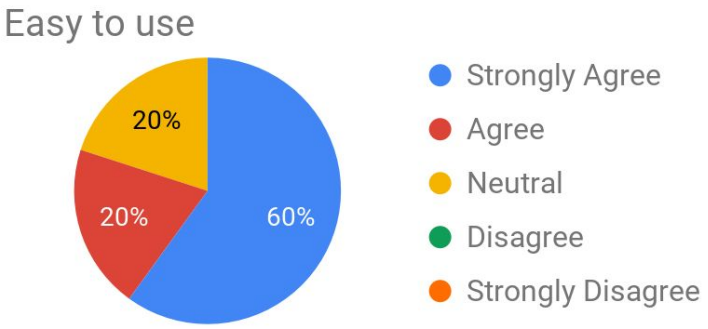


Figure 7.3.7: Answers to the statement "The dashboard is easy to use"

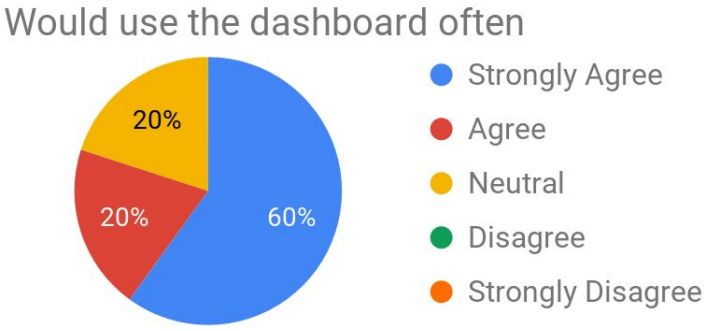


Figure 7.3.8: Answers to the statement "I can see myself using this dashboard often"

7.4 NONFUNCTIONAL REQUIREMENTS EVALUATION

Drawing from the results of the user tests discussed in the previous section, this section will evaluate the nonfunctional requirements decided upon in chapter 5. In Table 7.4.1, each nonfunctional requirement is listed, followed by an explanation whether it has been met in the prototype. All functional "Must Have" and two of three "Should Have" requirements are met by the prototype.

Must have

NFR01	**The dashboard must have a responsive layout: users must be able to comfortably view the dashboard on any device.**
	This requirement was met, though a bug was found when using an old version of safari on an ipad.
NFR07	**Any information that can be displayed for multiple points in time, should span over the entire range**
	This requirement was met.
NFR08	**Messages in the status overlay must be ordered by severity, rather than date of occurence**
	This requirement was met.

Should Have

NFR02	**Users should find the dashboard professionally looking**
	This requirement was met.
NFR03	**Desktop and mobile phone versions of the dashboard can change the layout of elements, but not the elements themselves**
	This requirement was not met, as implementing said functionality would cost too much time.
NFR06	**When no data is available, no data should be shown**
	This requirement was met.
NFR09	**Status messages should not be dismissable by the user, but only by the system when it detects that the corresponding issue is resolved.**
	This requirement was met.

Could Have

NFR04	**A simple layout that only shows info about the here and now could be provided**
	This requirement was not met.

Won't Have

NFR05	**An API to program own widgets for the dashboard, or to link the data to one's own services won't be provided**
	This requirement was not met.

Table 7.4.1: nonfunctional requirements and whether they are met in the prototype, categorised by Must, Should, Could and Won't have.

7.5 EVALUATION CONCLUSION

Through functional testing and user testing, it was found that all "Must Have" and "Should Have" functional and nonfunctional requirements are met by the prototype, except NFR03: Desktop and mobile phone versions of the dashboard can change the layout of elements, but not the elements themselves. This feature was not implemented due to time constraints. The "Could Have" and "Won't Have" requirements were not met.

During user testing with stakeholders, the prototype was well received by all stakeholders. However, some stakeholders were confused by the "used water"

notch in the comparative display element. The functionality of the event graph, and therefore the possibilities of the event graph was also not always understood without explanation. To solve these issues, stakeholders suggested moving the “used water” information to a separate element, and showing an information icon next to the mouse when hovering over an event that can be inspected.

Because the user tests were only conducted with stakeholders, the sample size of the research is only 5. The research gives a general idea about the state of the dashboard, but any findings of this research cannot be seen as representative of the general population.

8 Conclusion And Recommendations

In this chapter, a conclusion will be given of this bachelor thesis. The research questions stated in chapter 1.3 will be answered. The report is then concluded with recommendations for future work of the Smart Rainwater Buffer dashboard.

8.1 CONCLUSION

This bachelor thesis presents the development of a Smart Rainwater Buffer dashboard. The challenge was to engage users with their SRB. For this purpose, a main research question and two sub questions were formulated in chapter 1.3. These questions are as follows:

“How to develop a web-based dashboard that keeps the owner engaged in using their SRB?”

> “What are the most important gamification elements for behavioral reinforcement to stimulate engagement?”
>
> “How to incorporate these elements in the dashboard?”

The first step taken to answer the research questions named above was a state of the art research, looking into Smart Rainwater Buffer dashboards, general utility device dashboards and weather related dashboards. A literature research on behavioural reinforcement was also conducted, to answer the first subquestion. In this literature research, it was found that making use of several reinforcement schedules was advisory, specifically when including both fixed and variable ratio schedules. To extend the effect of the schedule, it is preferable that the schedule makes use of “thinning”. It was also found that for the case of the Smart Rainwater Buffer dashboard, positive reinforcement is preferred over negative reinforcement. This is because positive reinforcement is associated with joy, while negative reinforcement is associated with frustration.

After the state of the art, stakeholders were identified and interviewed to obtain preliminary requirements. These requirements were then categorised in functional and nonfunctional, and prioritized using MoSCoW. These preliminary requirements were used in the ideation phase to create concepts for the dashboard. These concepts were iterated, each iteration getting feedback from the identified stakeholders via interviews.

Once the dashboard concept was finalised, a specification was made. The system architecture of the prototype was decided upon, and the requirements of the prototype were set. These requirements were again divided into functional and nonfunctional, and categorised by MoSCoW.

With the concept, the system architecture and the requirements for the prototype in place, a prototype was realised. This prototype does not function as

the final version should, however. Since the database does not have all infrastructure available that was necessary for the prototype, it was chosen to use a local copy of a preprocessed dataset. Because of this, the prototype dashboard does not have any functionality to communicate with the central database, and does not have the possibility to load more data than available in the preprocessed dataset. This also limits the dashboard to simulating a set date in the past, so the user actually has to possibility to look at a forecast.

Once the prototype was realised, it was evaluated against the previously set requirements. It was found that all necessary requirements were met, proving that the dashboard prototype offers users satisfactory functionality by means of responsiveness, insight and gamification elements. Responsiveness allows the dashboard to be comfortably viewed on any device. Insight into the SRB's fill level, content temperature and precipitation expectation is given by the precipitation, fill level, temperature and event graphs. Insight into the SRB's status is given by the status button, which opens up a dialog providing further information about the SRB's current situation(s). Gamification elements are brought into the dashboard in the comparative display element by means of competition and self improvement.

User tests were also conducted with stakeholders, to obtain feedback on the prototype. The evaluation also functioned as a way of testing the challenge of this bachelor thesis: to engage users with the dashboard. After all, the prototype itself should be the answer to the main question formulated in chapter 1.3. From the user test it was derived that the self improvement and competition elements in the dashboard do positively impact user engagement, al be it lightly. It also became apparent during user testing that users were more motivated by self improvement than competition. All in all this means that the comparative display element in the dashboard, which hosts the competition and self improvement elements, is an answer to the second subquestion. The user tests also showed that not all features were completely self explanatory; the "used water" notch in the comparative display element, and the fact that events can be clicked for more information were not clear to all users. These elements are marked in Figure 8.1.1, where the blue mark contains the "used water" notch, and the red mark contains clickable events.

With the sub questions answered, an answer to the main question can be formulated. A web-based dashboard that keeps the owner engaged in using their SRB can be developed by involving stakeholders in the concepting phase of the development process, and by incorporating gamification elements employing competition and behavioural reinforcement in the dashboard.

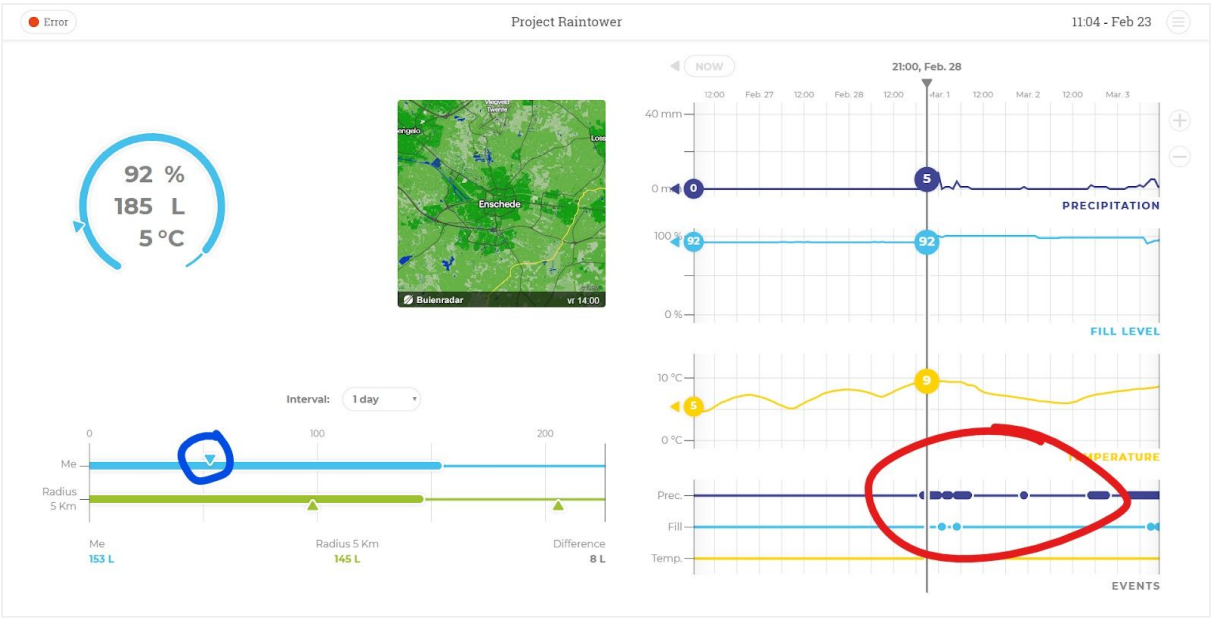


Figure 8.1.1: the final prototype, where the blue circle marks the "used water" notch, and the red circle marks clickable events

8.2 RECOMMENDATIONS

The realised prototype is a good basis to start for any future work. However, it is recommended that some changes are made, as some features did not prove completely self explanatory. These features are the "used water" notch in the comparative display element, as well as the fact that events can be clicked for further information. These elements are marked in Figure 8.1.1, where the blue mark contains the "used water" notch, and the red mark contains clickable events. To resolve the comparative display element issue, it is suggested that the "used water" notch is removed from the element, instead being split off into its own element. This should not confuse users anymore about what the comparative display element is about, while still maintaining the feature of self improvement. How this new element should look and work is not decided. To resolve the event graph issue, it is suggested that the events show an information icon when being hovered over by the mouse, as shown in Figure 7.3.4. This would signal the user that more information is available.

The user test that was performed was only conducted with five participants, all of which being stakeholders. To obtain data that is more representative of the end users, it is recommended that the user tests are redone on a larger group, actually consisting of end users. This would not only ensure more reliable data because the test subjects would be part of the target group, but also because a larger testing group would increase statistical reliability. It is also recommended that this user test is executed over a larger time span. This would ensure that users are not affected by the 'wow-factor': users' opinions can change if the dashboard is new to them.

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Appendix A - Interview Jeroen Buitenweg

Motivation to get SRB?
Vanuit project groep
Natuur en duurzaamheid
Water Bewust
Piekbelasting -> trager systeem
Eigenlijk een probleem in elke stad/wijk
Samen het probleem oplossen
Motivation to interact with SRB?
Vooral bij regenbuien, en in het begin om hem te begrijpen
Would you just like to start and forget it?
Je kijkt meerdere keren per dag naar het ledlampje
Liever app dan webpagina: niet veel handelingen, anders haken mensen af
What functionality do you expect to find in the dashboard?
Voor technische mensen: in hoeverre komt de voorspelling overeen met wat er is gebeurd?
Voorspelling van buienradar + wat de SRB gaat doen
Moet hij wel helemaal leeg?
'Veiligheid' instellen: hoeveel water mag er weg? (afhankelijk van confidence van weerbericht?)
And what info would you like to find?
Hoe hebben we een regenval piek afgevlakt? (zonder regenton/zonder slimme regenton)
Hoe veel water is er beschikbaar?
Hoeveel heb ik hergebruikt?
How is that visualized?
Grafiek: voorspelde piek naar voren en naar achteren
Only data about the here and now?
-2 tot +2 uur, en -5 dagen (instelbaar een week of jaar), misschien op cards
Alles heel lokaal: echt vooral de gebruiker
What additional functionality could you imagine in the dashboard?
Weersverwachting zonnetje/wolkje/druppeltje: doe maar zuinig het is nog 5 dagen droog
Wat zijn de gegevens van de srb? Volume, dak oppervlakte, waar gaat lozing heen? (kan ook interessant zijn voor gemeente)
Also apart from the SRB?
nee
Would you like customisation?
Cards: ik wil die 5 dagen grafiek niet zien
Luxe: waar staat welke card
How would you like to customize the dashboard?

Not cosmetic, look moet professioneel zijn (degelijk, niet zo zeer wetenschappelijk. Maar niet goedkoop, gaat ten koste van geloofwaardigheid product)

Own changes, or presets (day/night etc)?

Zelfde als vorige

Competition?

Wat is er gebeurt in een straal van 5km gemiddeld? (opbrengst, gebruikt)
Hoe dichter bij huis (kleinere zoekcirkel, hoe meer motivatie)
Misschien zoekcirkel ook zelf instelbaar

To others or as neighbourhood?

All vs nature: wat zijn de gemiddelden? Onderling ook: ben ik boven gemiddeld? (minimaal 4 mensen, geef ook straal van zoekcirkel)

Appendix B - Interview Jeroen Waterink

Motivation to get SRB?
Enthousiastelingen: water besparen (milieubewust, niet op geld), overstromen (sociaal)
Gadget appeal: inzicht, weer inzicht, band met regenton
Note: alleen sociaal is niet genoeg
Motivation to interact with SRB?
In/out, waarom in/out
Niet gemeente de baas: transparante redenen
Controle: waar gaat het water heen (automatische tuin)
Would you just like to start and forget it?
Sure, maakt de gemeente niet uit
Nee, controle op irrigatiesysteem
What functionality do you expect to find in the dashboard?
Overzicht: wat zit er in, zat er in, zal er in zitten?
Uitleg van events
Inzicht in verwachte gedrag
Weersvoorspellingen: alles dat met regen te maken heeft
1 centraal weer punt
And what info would you like to find?
Status: ok
Snel en kort, zonder grafieken. Temp, fill level, status
Inplannen van lozen (op bepaalde kraan). Periodiek?
Vorstbeveiliging, legionella
Instellen van valve. Stand = constant open (ook voor vorstbeveiliging, misschien op timer)
How is that visualized?
No clue
Misschien thijs versimpelen
Only data about the here and now?
Alleen een paar uur, misschien dag
Wel alleen eigen ton
What additional functionality could you imagine in the dashboard?
Weersvoorspelling
Inplannen
Sensor in plantenbak voor water on request, of notificatie he de rozen hebben water nodig
Also apart from the SRB?
Datum en tijd, staat bij grafiek
Plantenbak sensor, temperatuur
Would you like customisation?
Nee hoeft niet, zo lang het mooi is. (geen enschede rood)
Huisstijl van Regentoren project

How would you like to customize the dashboard?
Wisselen tussen tonnen
Account hangt aan 1 persoon
Delen: Public link, widget. Alleen bekijken niet delen.
Own changes, or presets (day/night etc)?
Woah niet echt nodig
Competition?
Wij vs de natuur
Overstroming met % voorkomen
To others or as neighbourhood?
Opbrengst per dag delen?

Appendix C - Interview Richard Bults

Motivation to get SRB?
Uberhaupt water opvangen
Interesse in iot, hobby factor
Professioneel mee bezig
Motivation to interact with SRB?
Planten water geven
Weten wanneer er weer regen komt, hoe veel je hebt, of je de tuinslang nodig hebt
Ook sociaal interessant, mocht dat nodig zijn
Geconfronteerd worden met eigen gedrag op gebied van watergebruik
Would you just like to start and forget it?
Monitoren is interessant (prestatie): is het voorspellen accuraat? (spelletje) komt hij wel weer vol?
What functionality do you expect to find in the dashboard?
Over bepaalde periode kunnen zien hoe de srb gevuld is, maar ook hoeveel kan ik nog hebben (niet zelf rekenen)
Uitleg van wat er gebeurt in die grafiek
X as schalen is belangrijk (misschien zelfs Y)
Watertemperatuur wil ik wel weten, lucht niet: geef dan een warning en geen temperatuur.
Status van elk component (achter status 'LEDje' overeenkomend met ECU, liever niet direct op display)
Events list
Planning discharge
Keuzes voor temperatuurbeveiliging
Eigenschappen dak: oppervlakte, punt of plat, orientatie, aantal regenpijpen
Instellen grootte van ton
Help desk contact (chat, email, whatsapp)
Reminder voor filters
And what info would you like to find?
Weerbericht buienradar
Oorzaak gevolg is heel belangrijk (ook in L)
Flush optie naar riool (dus niet discharge (riool of tuin), en niet manual kraan of deksel)
Minimaal fill level
How is that visualized?
Kaart voor weer
Fill level in grafiek: spikes eruit strijken
Only data about the here and now?
Standaard een dag
Ook data per week, maand, en per jaar (# of discharges, fill level, temp)
What additional functionality could you imagine in the dashboard?

Plugin support/API
Also apart from the SRB?
nee
Would you like customisation?
Yes, layout: cards
Responsive web
Verander kleuren: themes
How would you like to customize the dashboard?
themes
Own changes, or presets (day/night etc)?
Zou leuk zijn
Competition?
100m 250m 500m 1000m 2500m 5000m 10000m
Private, friends en public instelling
Voor vrienden zien: grafiek van prestatie, incl events
To others or as neighbourhood?

Appendix D - Interview HendrikJan Teekens

Motivation to get SRB?
Betrokken bij complot: kijken of het ook echt werkt
Wat kan ik er van leren
Gebruiksgemak
Motivation to interact with SRB?
Regen
Whatsapp groep
Controleren of alles werkt
(allemaal positief)
Would you just like to start and forget it?
Interesse vanuit watervak
What functionality do you expect to find in the dashboard?
Vulniveau, temperatuur (bruikbaar voor moestuin?)
Waar is water voor gebruikt? Overgelopen, gebruik, lozen.
Hoeveel water uit het riool gehouden?
And what info would you like to find?
performance ton t.o.v. bui: 50 geleegd voor bui maar had 100% moeten zijn
Moet er uitnodigend uitzien
Moet sturen op rendement: bergingscapaciteit showen, voelt goed (persuasion?)
How is that visualized?
Schijf: taartpunt zelf gebruikt, gebuffert, overgelopen naar riool/tuin
Only data about the here and now?
Wijk/staat ook belangrijk, vooral voor persuasion compliment
Een paar dagen vooruit/verleden
Per week, misschien per maand
What additional functionality could you imagine in the dashboard?
Neerslag overzicht (grafiek?)
Misschien vergelijking mm voorspeld en mm gevallen
Also apart from the SRB?
Wateroverlast overzicht (bewustheid benedenstrooms)
Would you like customisation?
Start met simpele layout, grafieken/zoomen etc voor geavanceerde gebruiker
Data exporteren naar excel
Geen cosmetische veranderingen (zorg wel voor kleurenblind ondersteuning, misschien zelf grafiek kleuren aanpassen)
How would you like to customize the dashboard?
Own changes, or presets (day/night etc)?
nee
Competition?
Per wijk: zullen we met zn allen zoveel ophalen deze maand?
To others or as neighbourhood?
Neighborhood vs neighbourhood

Appendix E - Interview Hans Scholten

Motivation to get SRB?
Eigen project
Willen sowieso regenton
Milieu, waterverspilling, tuingebruik
Motivation to interact with SRB?
Functioneert, wat doet hij, zelf overwrite
Would you just like to start and forget it?
Zet neer, werkt. Geen wifi opzetten ofzo
Houd minimaal x liter (50L?) voor persoonlijk gebruik, ook bij regenval. Want regen komt niet altijd.
What functionality do you expect to find in the dashboard?
Hoeveel zit er in, temperatuur van water. Alle technische dingetjes die mogelijk zijn. Inzicht in hoe de ton werkt. Ook zien waarom hij leegloopt etc.
And what info would you like to find?
Weersvoorspelling, hoe reageert de ton.
Integratie met huis automatie systeem
Vulpercentage van ton bepaald of en welke planten automatisch water krijgen.
API/MQTT vanaf de ton, geen IFTTT ofzo. (geen cloud)
How is that visualized?
Simpel metertje/getalletje, geen tijdsverloop. Wel tijdsverloop voor regenval/vulniveau, dag vooruit/achteruit
Only data about the here and now?
Ja
Hoe doen we het in de buurt/gemeente, wat doen we voor enschede. Maar ik weet niet welke info er precies beschikbaar is, wat ik interessant vind.
What additional functionality could you imagine in the dashboard?
Buienradar regenradar
Advanced page met diagnostische info als stroomvoorziening/uitvallen, hoe vaak is de computer restart, aan welk netwerk hang it, data versturen/ontvangen, raw sensor data. Ook handig voor helpdesk
Also apart from the SRB?
Klok is wel aardig
open/dicht vanuit de dashboard
Would you like customisation?
Cards, maar geen must, vooral als het goed gedaan is. Maar als het er in zit ga ik het sowieso gebruiken.
Layout met verschillende icoontjes.
Andere functionaliteit integreren, ook API om dingen in de regenton interface te zetten.
How would you like to customize the dashboard?
Functioneel, niet persoonlijk
Own changes, or presets (day/night etc)?

Gewoon nee.

Competition?

Globaal: zo veel regen per gebied

To others or as neighbourhood?

Als wijk/straat, gegeven dat er genoeg mensen deelnemen. Anders een globale wij, gewoon als heel enschede.

Appendix F - Interview Eddo Pruim

Motivation to get SRB?
Voorraad water voor droogte
Interesse in techniek
Vervelend dat hij open gaat, vooral als de bui toch niet doorgaat: overwrite. Is op het platteland ook anders dan in de stad.
Geen last van filters aub. Wordt onderschat. Misschien doormeten?
Motivation to interact with SRB?
Monitoren, techniek, ontwikkeling
Would you just like to start and forget it?
Zelf invloed hebben, confirm actions: ook een reden om bezig te blijven (omdat het moet)
Combi van wat interessant is en aanwijzingen. Ook voor competitie.
What functionality do you expect to find in the dashboard?
Regenradar, geschiedenis, fill level
And what info would you like to find?
Bacterie groei: temperatuur water. (ook bevriezen) (ook overwrite) (probleem van gebruiker) (ledje voor notificaties)
How is that visualized?
Staafdiagram, grafiek: mooist om naar te kijken, dat leer je wel snel lezen.
Only data about the here and now?
Alleen eigen ton, eigen gebied. Heel plaatsgebonden.
What additional functionality could you imagine in the dashboard?
Buienradar
Also apart from the SRB?
Would you like customisation?
Wat er bovenaan staat
How would you like to customize the dashboard?
Moet prettig lezen, niet show off
Own changes, or presets (day/night etc)?
Nee
Competition?
Nee, niet voor mij. Bij de stad zal het wel helpen denk ik.
To others or as neighbourhood?
Wij tegen de natuur. Individueel stats zal demotiverend zijn.

Appendix G - Interview spreadsheet + trends

	Jeroen Waterink	Jeroen Buitenweg	HendrikJan Teekens	Hans Scholten	Eddo Pruim	Richard Bults	Trends
Motivation	gadget/tech millieuvriendelijk sociaal aspect niet genoeg	milieubewust sociaal aspect	gadget/tech gebruiksgemak	milieu gadget/tech	gadget/tech niet sociaal (plattelandd)	gadget/tech gebruiksgemak	gadget/tech milieu
Reasons to engage	controle op irrigatie SRB begrijpen	monitoren SRB begrijpen vooral naar LED kijken	monitoren whatsapp groep controle status	controle status SRB begrijpen overwrite gepland gedrag	monitoren SRB begrijpen geef toestemming voor acties onderhoud: filters zijn een probleem	monitoren SRB begrijpen controle status	monitoren SRB begrijpen
Expected functionality	fill level temperatuur event uitleg (transparantie) verwacht gedrag voorspelling/geschiedenis weer & SRB alles dat met weer te maken heeft status	fill level hoeveel water heb ik hergebruikt? vergelijk voorspelling met werkelijkheid verwacht gedrag en weer	fill level temperatuur waar is water allemaal heen gegaan hoe veel water uit riool gehouden?	fill level temperatuur verklaring van gedrag alle mogelijke technische gegevens hoe werkt de ton	fill level geschiedenis regenradar	fill level over tijd en beschikbare ruimte event log en uitleg x as schalen watertemp, niet luchttemp settings: dak, volume, temp beveiliging planning zien en maken helpdesk	fill level temperatuur geschiedenis en vooruitzicht weer en ton
Additional functionality	Snel en kort versie: status, fill, temp inplannen van lozen	minimal fill level hebben we enschede kunnen helpen?	analyse van geschiedenis: 50 geleegd voor bui maar had	voorspelling weer en ton regenradar console log pagina	temperatuur vries en legionella beveiliging controle	buienradar oorzaak gevolg flush optie minimal fill level	analyse van geschiedenis minimal fill level overwrite

	(periodiek?) vost/legionella beveiliging, misschien ook handmatig of op timer sensor in plantenbak voor notificaties in dashboard	niet belangrijke data: volume, dak m2, waar loos ik op (ook voor gemeente)	100 moeten zijn hoe is water gebruikt?	controle over valve API/MQTT, maar geen cloud oplossing	overwrite van planning		vries en legionella beveiliging controle
How do things look	versimpeling van thijs dortmann opbrengst per dagdeel?	grafieken verschillende time spans op cards naast elkaar simper weer via icoontje: kan ik water opmaken? professioneel niet goedkoop, voor geloofwaardigheid	gebruik in pie chart neerslag over tijd in grafiek	simpel metertje/getalletje regen vs vulniveau grafiek met tijd moet er professioneel uit zien	ledje voor notifications in dashboard staafdiagram of grafiek. dat leer je wel lezen moet er professioneel uit zien	kaart voor weer grafiek voor fill (zonder spikes)	grafiek cards moet er professioneel uit zien
Desired info timespan	paar uur of een dag	paar uur, en 5 dagen verleden	paar dagen of weekoverzicht	3 dagen	vandaag, geschiedenis	standaard een dag optie week, maand, jaar	paar uur week
Desired info localisation	alleen ton en tuin	alleen ton en tuin	wijk/straat (voor persuasion)	wij allen gemiddelde	alleen ton en tuin		alleen ton en tuin

Customisation	Nee, design in huisstijl	liever app dan webpagina verschillende cards uit zetten. bonus = plaatsen	simple startpagina, stats verborgen export excel kleurenblind: grafiek kleuren aanpassen	cards eigen dingen toevoegen via API	nee	cards responsive web colorblind customisation themes	cards kiezen
Social/competition	wij allen vs natuur: overstroming met % voorkomen link/widget om te delen	gemiddelde opvang/hergebruik binnen bepaalde zoekstraal	wijk vs natuur: zullen we met zn allen xL ophalen? wijk vs wijk	regen per wijk gemiddelde van zo klein mogelijk gebied	gemiddeld van wij	100-250-500-1000-2500-5000-10000m Private, friends en public instelling vrienden: fill grafiek, events	gemiddelde binnen straal

Appendix H - User Test Jeroen Buitenweg

Wat zie je?
Met wat tijd is alles te vinden
Used water knippen

Wat is het huidige minimale watervoorraad?
Hoe voel je je over prestatie van vandaag?
Hoe veel hebben andere hergebruikt
Meer water hergebruiken: mijn driehoekje zit lager dan minimum
Hoe voel je je over prestatie van kwartaal?
Nog steeds meer water hergebruiken
Zal daar wel meer geregend hebben
Hoeveel water heb je vandaag hergebruikt?
Wat is er momenteel mis met het SRB systeem?
Leek er op dat de knop een storing heeft, ipv voor de status display. Misschien uitvouw pijltje, anders “status” voor de knop?
Status sluiten is linksboven, liever rechtsboven
Error volgorde logisch?
Kan je inzoomen tot je precies 10 maart in beeld hebt?
Wat was de watertemperatuur om 21h op 12 maart?
Waarom is het dan toch aangetekend?
Wat voor discharge event heeft er op 11 Februari om 7h plaatsgevonden?
Kan je een discharge plannen voor 13 maart om 9h?
Graag verschil zien tussen self planned en automatic discharge
Hoe veel water wordt er verwacht op 9 maart om 14h?
Hoe veel water is er verzameld op 8 februari om 23h?

Vind je het dashboard mooi/professioneel?
4
Is het dashboard fijn in gebruik op uw telefoon?
4
Is het dashboard makkelijk in gebruik?
4
Ziet je jezelf veel gebruik maken van dit dashboard?
4
Mis je iets/zou je iets veranderen
Titel bij compare
Compare driehoekjes anders? Ook van gauge
Used driehoekje uit compare naar hele nieuwe grafiek ook met compare
Driehoekjes zijn on hover, events zijn click. Misschien een *i* erbij, zodat mensen weten dat ze kunnen klikken.

Appendix I - User Test Jeroen Waterink

Wat zie je?
Gauge is niet duidelijk of het de hoeveelheid water opgeslagen of ruimte over is
---
Wat is het huidige minimale watervoorraad?
Percentage voor gauge is niet helemaal duidelijk, liever liter
Hoe voel je je over prestatie van vandaag?
Goed bezig geweest
Hoe voel je je over prestatie van kwartaal?
Momenteel niet echt 'mijn' ton, dus ook niet echt reden tot actie
Hoeveel water heb je vandaag hergebruikt?
Deze hoort niet in die grafiek
Wat is er momenteel mis met het SRB systeem?
Error volgorde logisch?
Kan je inzoomen tot je precies 10 maart in beeld hebt?
Wat was de watertemperatuur om 21h op 12 maart? / Waarom is het dan toch aangetekend?
Wat voor discharge event heeft er op 11 Februari om 7h plaatsgevonden?
Maakt geen gebruik van "NOW"
Kan je een discharge plannen voor 13 maart om 9h?
Hoe veel water wordt er verwacht op 9 maart om 14h?
Dat is niet duidelijk
Hoe veel water is er verzameld op 8 februari om 23h?

Vind je het dashboard mooi/professioneel?
5
Is het dashboard fijn in gebruik op uw telefoon?
5
Is het dashboard makkelijk in gebruik?
5
Ziet je jezelf veel gebruik maken van dit dashboard?
5
Mis je iets/zou je iets veranderen
Used water notch mag weg, waarde onder Me onder grafiek, ook voor radius laten zien
Fill level ook in liters, via settings

Appendix J - User Test HendrikJan Teekens

Wat zie je?
Comparative display is niet helemaal duidelijk

Wat is het huidige minimale watervoorraad?
Niet in liters, misschien andere kleur
Hoe voel je je over prestatie van vandaag?
5 Km is voor buienradar
Comparative display: “collected”
Used is verwarrend
Hoe voel je je over prestatie van kwartaal?
Hoe komt dat
Hoeveel water heb je vandaag hergebruikt?
Wat is er momenteel mis met het SRB systeem?
Kijkt er straal overheen
Error volgorde logisch?
Kan je inzoomen tot je precies 10 maart in beeld hebt?
Wat was de watertemperatuur om 21h op 12 maart?
Waarom is het dan toch aangetekend?
Dat is niet logish
Wat voor discharge event heeft er op 11 Februari om 7h plaatsgevonden?
Kan je een discharge plannen voor 13 maart om 9h?
Hoe veel water wordt er verwacht op 9 maart om 14h?
Hoe veel water is er verzameld op 8 februari om 23h?
Expected is niet bovenop collected

Vind je het dashboard mooi/professioneel?
4
Is het dashboard fijn in gebruik op uw telefoon?
4
Is het dashboard makkelijk in gebruik?
3
Ziet je jezelf veel gebruik maken van dit dashboard?
5
Mis je iets/zou je iets veranderen
Kaartje voor radius

Appendix K - User Test Eddo Pruim

Wat zie je?
5 graden is niet van buiten maar van water

Wat is het huidige minimale watervoorraad?
Hoe voel je je over prestatie van vandaag?
3 waarden er onder lijken voor pijltjes te zijn
Het zegt me niet zo veel
Minimum is niet minimal fill
Kan wel voorstellen dat andere mensen wel competitief zijn
Hoe voel je je over prestatie van kwartaal?
Het zegt me niet zo veel
Hoeveel water heb je vandaag hergebruikt?
Wat is er momenteel mis met het SRB systeem?
Filter replace moet error zijn, niet warning
Warning die lang staat moet error worden
Meldingen graag zelf dismissen
Error volgorde logisch?
Kan je inzoomen tot je precies 10 maart in beeld hebt?
Eerst zoomen dan slepen
Wat was de watertemperatuur om 21h op 12 maart?
Waarom is het dan toch aangetekend?
Wat voor discharge event heeft er op 11 Februari om 7h plaatsgevonden?
Zelf laten leeglopen
Kan je een discharge plannen voor 13 maart om 9h?
Zoekt in instellingen
Hoe veel L water wordt er verwacht op 9 maart om 14h?
Weer niet duidelijk dat verdere info in events grafiek is, maar vind het uiteindelijk
Hoe veel water is er verzameld op 8 februari om 23h?
Zelf rekenen met de grafieken, later pas bij events kijken

Vind je het dashboard mooi/professioneel? 1-5
5
Doet denken aan zonnepanelen
Is het dashboard fijn in gebruik op uw telefoon? 1-5
Dingen zijn niet gecentreerd op de ipad
5
Is het dashboard makkelijk in gebruik? 1-5
5
Ziet je jezelf veel gebruik maken van dit dashboard? 1-5
5
Commentaar? Mis je iets/zou je iets veranderen
Misschien fill level als optie ook in liters kunnen zien

Appendix L - User Test Kasia Zalawska

Wat zie je?
Comparison no clue
Events nog wat onduidelijk

Wat is het huidige minimale watervoorraad?
Hoe voel je je over prestatie van vandaag?
Boeit niet. 4
Hoe voel je je over prestatie van kwartaal?
Dan wel: meer water gebruiken
Hoeveel water heb je vandaag hergebruikt?
Wat is er momenteel mis met het SRB systeem?
Misschien is het iets anders, misschien met de website
Error volgorde logisch?
Kan je inzoomen tot je precies 10 maart in beeld hebt?
Niet intuitief
Wat was de watertemperatuur om 21h op 12 maart?
Missing?
Waarom is het dan toch aangetekend?
Why is there an event? Aah, clicking explains
Wat voor discharge event heeft er op 11 Februari om 7h plaatsgevonden?
Kan je een discharge plannen voor 13 maart om 9h?
Hoe veel water wordt er verwacht op 9 maart om 14h?
Hoe veel water is er verzameld op 8 februari om 23h?
Before and after what? Bit of explanation

Vind je het dashboard mooi/professioneel?
4
Is het dashboard fijn in gebruik op uw telefoon?
5
Is het dashboard makkelijk in gebruik?
5
Ziet je jezelf veel gebruik maken van dit dashboard?
3
Mis je iets/zou je iets veranderen
Headings voor comparative display, misschien ook voor gauge
Logo van Regentoren project moet er op!