Augmented Reality application to raise public awareness of the “Groene Linie” rainwater management project

Bachelor Thesis Creative Technology

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Abstract

The rainwater management infrastructure of the city of Enschede, the Netherlands, is being improved through several large rainwater management infrastructure projects executed by the Municipality of Enschede. The “Groene Linie” is one of these projects: a large rainwater buffering installation capable of temporarily storing 7 million litres of rainwater. The Municipality of Enschede wants to raise public awareness about (the necessity of) this installation. Therefore, this bachelor thesis describes a mobile Augmented Reality application prototype which is capable of showing a (simplified) overview of the inner (underground) workings of the “Groene Linie” installation at several physical locations known as Points of Interests along this installation. This is realized through animated 3D models, supported by an explanatory voice-over. This solution was evaluated together with several representatives of the Municipality of Enschede while adhering to constraints imposed by COVID-19. This evaluation showed a very positive attitude of the Municipality of Enschede towards the technical accuracy of the final prototype, as well as towards the way in which it translates the highly technical inner workings of the “Groene Linie” installation to a storyline that is comprehensible for a wide audience. Finally, the client intends to further develop the Augmented Reality application prototype into a final product outside the scope of this project.

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List of Abbreviations

AR	Augmented Reality
GP	Graduation Project
POI	Point of Interest
POIs	Points of Interest
RQ	Research Question
VR	Virtual Reality
QR	Quick Response
GDPR	General Data Protection Regulation

Chapter 1 - Introduction

This chapter gives an introduction to the graduation project. The context is the infrastructural project “Groene Linie” executed in 2019 in the city of Enschede. This project will provide the basis for this bachelor graduation project and therefore, the context in which this project will be executed. Afterwards, the challenges related to this project will be stated as well as the specific research questions.

1.1 Realization of a water storage solution at the Oldenzaalsestraat in Enschede

During times of heavy rain, the city of Enschede has to discharge millions of liters of rainwater. The current rainwater management infrastructure is not able to handle such a big quantity which causes the sewage system to overflow on the streets, causing dangerous situations and economical damage. Therefore, the municipality of Enschede has started working on several projects to increase the temporary rainwater buffering capacity, with a focus on the city centre. One of these projects is since 2018 being executed at the Oldenzaalsestraat: project “Groene Linie”. This project includes the installation of several wadis[1] and a drain pipe with a buffering capacity of 7 million litres of rainwater. The construction work of this state-of-the-art project will take more than a year and is divided in several stages to minimize public hindrance. [1] [2]

Despite the best efforts of the municipality to minimize hindrance, the construction work causes inconvenience for local residents, businesses and visitors of Enschede. The road closures cause detours, delays and parking difficulties, while the construction works themselves cause visual and aural discomfort. [1]

One of the methods the municipality uses to increase public understanding about the necessity of the construction works at the Oldenzaalsestraat is providing information on the construction works to those concerned: before, during and after the project. As described in the projects’ communication plan, this currently happens through traditional channels: a website, personal letters, walk-in information sessions, excursions, banners and flyers. The results of whether these methods are effective are not measured.

1.2 Challenges

The municipality wishes that the public awareness of this state-of-the-art rainwater buffering system and what currently happens in the construction works will be (further) improved. To increase both personal and (social) media engagement, the municipality is looking for a fitting solution that

[1] A wadi is a buffering ditch which can contain and infiltrate rainwater during rainfall

measurably increases public awareness and attracts users to take more detailed information about the project to themselves. Also, it would be preferred if such a solution can be used in (social) media channels and in presentations by the municipality.

Communication methods that are already being used at the present moment are not being measured and therefore the effectiveness of these marketing campaigns cannot be proven. To be able to provide a justification for the investment of the municipality in the fitting solution, this solution should provide a measurable result to prove its effectiveness.

1.3 Research Questions

Based on the description above, the main research question has been formulated. Besides, two sub questions have been formulated to give more structure to this research.

RQ1: What is the most effective way to raise public awareness amongst inhabitants of Enschede about realized large scale rainwater management projects?

The main question gives the possibility to research various methods of information provision. The first sub question focuses on researching a method to attract users to examine more detailed information about a certain project:

Sub RQ1: What are the principles in raising awareness to create a higher level of interest?

The second sub question enables to research the effectiveness of the chosen method:

Sub RQ2: How to measure the effect of applied principles?

Chapter 2 - State of the Art Research

In this chapter, the background literature research can be found, as well as research on visual design influences on effective communication. The last part of this chapter contains an analysis of multiple state-of-the art projects relevant to this graduation project.

2.1 Literature Research

2.1.1 Drawing and Conserving Attention

In the context of the project at the Oldenzaalsestraat, it is important for the envisioned solution to be able to get the attention of the inhabitants of Enschede. This is supported by Quester et al. [3], stating that a typical decision-making process in marketing is divided into four stages: attention, interpretation, evaluation and memory. As attention is seen as a critical aspect in the effectiveness of marketing campaigns [4] it is very important to consider this aspect in the design of the envisioned solution.

Also, it is very important to consider how consumers collect, process and act upon the information that is collected. The first aspect to take into account is that informing consumers should be a process, not an act, divided in at least the following stages:

Awareness - Collecting & Processing - Action - Update & Evaluation [5]

Only after a consumer has become *aware* of the relevance of the information, the consumer will start understanding (*collecting & processing*) the information, which might have an influence on the consumers' *actions.*

A method said to increase users' attention is interactivity. Interactivity is being widely used on the Internet, [6] as interactive digital marketing has seen an immense growth due to the capabilities of Web 2.0[2] [8]. For example, social media platforms are built on the technological and ideological foundations of Web 2.0. [8], [9] "Interactivity has been identified as one of the defining characteristics that sets new media apart from traditional media."

Both attention and interactivity are not present by default. "Consumers are no longer content with advertising as a bystander sport (i.e., where traditional media is controlled by the advertiser in a firm-consumer monologue of sorts) or as a hunting sport (created by the advertiser with the consumer controlling the interactivity)." [8, p. 267] Nowadays, consumers expect that they are active

[2] "Web 2.0 applications are those that make the most of the intrinsic advantages of that platform: delivering software as a continually-updated service that gets better the more people use it, consuming and remixing data from multiple sources, including individual users, while providing their own data and services in a form that allows remixing by others, creating network effects through an "architecture of participation" [7]

participants in the media process, using expansions of traditional media choices to capture reach, intimacy and increase engagement. [8] Although traditional media are mainly focusing on reach, which can be achieved in large numbers but usually does not translate into engagement [8], "marketing can no longer solely be about capturing attention via reach; instead, marketers must focus on both capturing and continuing attention via engagement."

In order to achieve this, Harris et al. [10] proposed an action-based approach; an approach in which the public is motivated to act, share, pledge or to complete a certain challenge. This form of active participation can be supported by providing entertainment, as this increases brand vs customer interaction which at its turn encourages active participation. [11] Such an approach generally has an emotion-based strategy, which helps to develop an emotional relation with the user. These emotional relations have "dominated marketing in preference to prior rational-based approaches that provide consumers with numerous facts and figures". [10] This shows some connection to interactivity as providing more engagement. According to Liu et al. [12] this interactivity often has direct connection with active control by the user. The Internet itself already provides a high level of active control, as the user itself chooses to go to a certain website in which they are interested. The user has direct control over which information to read. Email newsletters also provide some level of control as users who are already interested choose themselves to subscribe. So, a user being able to directly control what information to read often experiences a higher level of interactivity and therefore more engagement is created.

Such control over information and with that interaction and engagement are also very much present in social media. As interactive digital media is creating a 24/7 collaborative world, the methods for providing information are changing. Social media networks have opened a world of connecting, sharing, recommending and collaborating amongst customers, "creating spheres of influence that have fundamentally altered the way marketers engage in influencing activities". [8, p. 267] The tools that these social media platforms provide are presented as being necessary for influential and meaningful connections with customers. [8]

2.1.2 Increasing Campaign Effectiveness through Social Marketing

A different method to focus more on understanding consumer behaviour and motivations is social marketing. Social marketing has as its focus to improve individual well being through which it becomes the best approach to generate positive social change [13] [14]. This is achieved through targeting, informing and persuading the target audience, in order to change their behaviour or attitude towards the marketed product or service. [15] "It has a proven track record of effective consumer-driven behaviour change strategies with a dominant focus on the attainment of individual behavioural change." [16] In order to deliver societal and individual benefit, social marketing changes

marketing strategies through a specialization in changing behaviour voluntarily in targeted audiences, using commercial marketing tools, techniques and thinking. [17] In the context of the Oldenzaalsestraat, however, it is not the goal to change the attitude of the target audience, but to create awareness amongst the target audience and evaluate whether the target audience collects and processes the information successfully, aiming for acceptance of hindrance. Still, the tools used in Social Marketing to target and inform the audience effectively might be of help in this context. For example, social marketing also focuses on electronic Word of Mouth (e-WOM), "which plays a vital role as a form of buzz marketing that can become viral if a message is sufficiently persuasive or amusing" [18, p. 2]

2.1.3 Defining Target Audience

In order to know who to focus the campaign on, it is important to understand what our target audience is. Having a thorough understanding of the target audience is beneficial for the effectiveness of marketing campaigns. Getting to know the target audience can be done through a segmentation analysis [19].

Audience segmentation has been positively evaluated in research on communication campaigns. It has been successfully used in various domains, including commercial marketing. [13] In practice, audience segmentation is done by "identifying groups of individuals in a larger population of interest who share similar characteristics (e.g., attitudes, beliefs, behaviors) based on particular criteria and with regard to the specific objectives of a communication campaign or intervention" [15] So, it provides communication practitioners with a tool to become more knowledgeable about the target group (and subgroups). [15] This knowledge can be used to group the audience on relevant attributes, which allows for better campaign targeting. Therefore, segmentation analysis is a well suited tool to improve social marketing. [15], [20]

2.1.4 Information Framing

According to Helberger [5], the importance of framing is one of the most important findings in transparency research. Building upon finding the right target group, the information provided should meet some requirements for the audience to understand the information correctly. The information must be framed such that it corresponds with the personal environment, expertise, personal and professional background. As framing influences how an audience judges the information relative to their personal situation, it should also be taken into account that people care more about losses than gains and tend to memorize positive messages better than negative messages.

2.1.5 Positive message formulation

In a case study for raising awareness around dual flush toilets for effective water savings, Özel et al. [21] executed an awareness raising campaign and educational activities, measured by three rounds of surveys: prior to the campaign and 2 and 5 months after the first survey. To inform users, stickers and posters were placed around these toilets. In designing these posters, effectiveness of communication strategies were taken into account, as strong demands such as “don’t do it” were avoided, since these might have a counter-effect caused by psychological reactance. Instead, positive messages were used, such as “you can save 3L water at once if you use the correct button!”. On top of that, a slogan was added to motivate people in emphasizing their individual efforts in water saving. Özel et al. managed to increase the awareness among the users from 43% to 85% over a period of 5 months. Thus, forming the message to be conveyed in a positive way contributes to successful awareness raising, confirming the framing theory set by Helberger in section 2.1.4.

2.1.6 Community Building

Marine Litter in Europe's Seas Social Awareness and Co-responsibility (MARLISCO) [22] was a project which aimed to implement engagement activities in 15 European coastal countries, in order to raise awareness around reducing marine litter. The project was aimed at developing, implementing and evaluating mechanisms that could communicate a complex problem to society in order to create a deepened understanding of the problem. Also, it should bring together key stakeholders to create a collective vision and activate them to find viable solutions. The project was divided in national surveys, national fora, a video contest and educational activities & tools. The full outreach and impact of the MARLISCO project is not possible to fully assess, but it is mentioned that there is plausibility that it reached far beyond the directly involved. Overall engagement levels were exceptional. [22]

Another project initiated by MARLISCO [22] was a video competition in 14 countries aimed at students between 12 and 18 years old, in which the students were challenged to make videos focused on marine litter and what can be done about this issue. After a public voting period which also reached a wide audience, the videos had received a total of 33.500 views on YouTube and were screened at several (inter)national events, a multimedia project was developed which showed the winning video of every one of the 14 countries.

Both of these implementations show that a broad audience can be reached by creating engagement through actively involving people in challenges or projects, as both projects were successful in reaching a very broad audience by actively engaging them in activities related to the problem.

2.1.7 Factors in effective communication

Helberger [5] describes the effectiveness of communication to consumers as divided into five different categories which are complexly intertwined:

- Dynamic change of personal factors: level of knowledge of the consumer and technical sophistication of the information material.
- Technical factors: the form in which the information is presented (graphical, comparable, etc.).
- Institutional factors: expert involvement in the campaign, consumer associations.
- Contextual factors: level of media attention, expert communities, information campaigns etc.
- Social factors: Social interaction with experts, but also other consumers (creating communities) can be of high importance.

Also, Helberger describes that consumers usually gather information from multiple sources, including but not limited to the media, influencers, expert information, websites, other consumers or through their own social network. Every source might provide different parts of consumer information, presented in different forms. [5]

2.1.8 Cognitive Limitations

In information provisioning, it should also be taken into account that one is only able to process a limited amount of information. As stated by Miller, the average person can only receive, process and remember seven different pieces of information at a time. Miller calls this a limited 'span of immediate memory.' [23] Presenting the audience with more pieces of information will not have any effect on increasing interest, but too much information can instead confuse or distract the audience. On top of that, it should be noted that people often fail to remember a very significant part of the provided information. To overcome this, repetition of information has been proven to have a positive effect on information remembrance. [5]

2.1.9 Content vs Presentation

As stated by Helberger, both the information itself and the way in which the information is presented have an influence on how the audience interprets the information. It is stated that there have been several attempts to form concrete recommendations for effective consumer information. [5] In one of these attempts, some elements named are "information accuracy, relevancy, accessibility, adequacy, attractiveness, transparency and user-orientation" [5, p. 15] In another example, the

recommendations are “focusing more on the process of information provision, rather than (only) the information itself: awareness, and the communication of consumer information must be accessible, trustworthy, accurate, comparable, clear, understandable and timely” [5, p. 15].

The general recommendation is that information should be communicated, framed and provided in a form which is useful and effective for this specific target group. Providing the information in an engaging and interesting, aesthetically pleasing way has a positive effect on information remembrance. Next to that, the timing and contextualization of the information provision should be right to increase the feeling of information relevance in the audience. [5]

2.1.10 Measuring Campaign Effectiveness

Effectively measuring engagement levels or digital campaign effectiveness is stated by Voorveld et. al. as being a big challenge. It is generally based on quantitative measurements, such as likes, shares, comments, views, followers, etc. [24] In the case of video commercials, this is even a bigger challenge. For a very long time, marketing research has tried to explain and predict video commercial effectiveness, traditionally done by having face-to-face interviews or focus groups after showing the commercial in a confidential setting. Next to that, some research has also been done in the neuromarketing-field, where for example Kong’s ‘impression index’ [25] is being used in order to determine the effectiveness of video commercials. In order to do so, this model uses memory and attention, where ‘impression’ is determined by the duration in which the subject is “in status of both high attention and good memorization”. [25] However, neuromarketing is outside the scope of this project.

What we do see is that technological solutions commonly were secondary to the main campaign, increasing promotional effect or adding benefit to campaign effectiveness. [26], [27] For example, providing a website next to a ‘home visit’ campaign. In this case, the main campaign might use traditional, quantitative measurements. The numbers before adding such a secondary solution can be compared to the results afterwards, providing a comparison which can be used to prove the effectiveness of the secondary solution.

2.2 Visual Design Influences on Effective Communication

As Reyna et al. [28] mention in their paper, visual design has a great influence on the perception of information and its credibility. Several digital media principles can be applied to achieve an engaging digital artifact, as can be seen in figure 2. Neuroscience, psychology, visual design and multimedia learning have proven the digital media principles as shown, which can be applied during the production phase in order to create an engaging digital artifact.

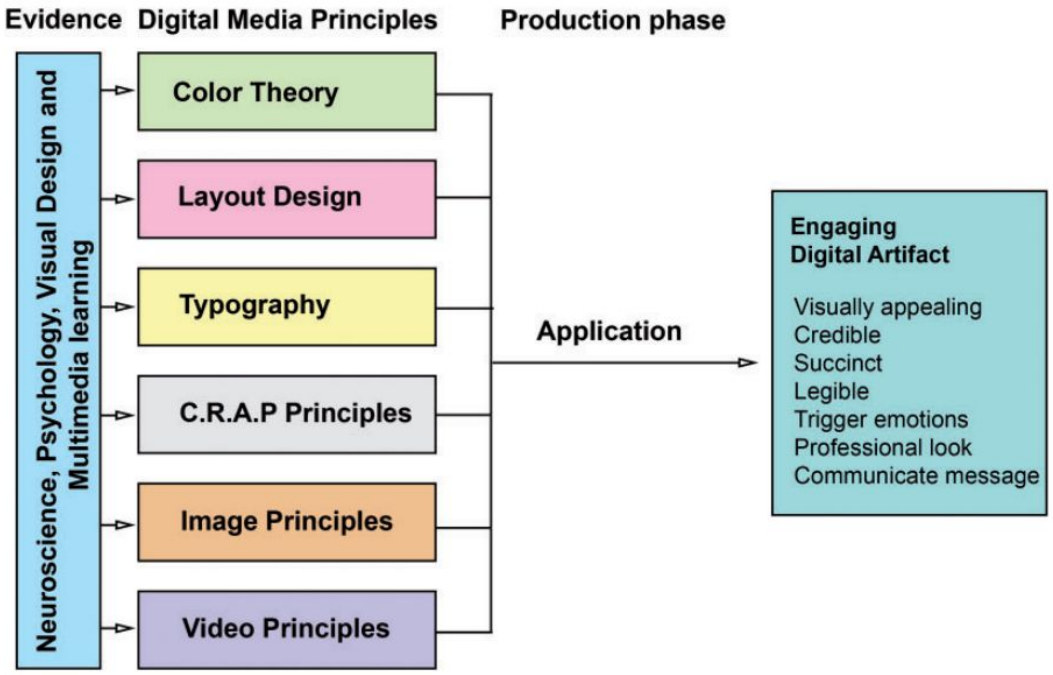

Figure 2. *Digital media principles and effective creation of a digital artefact [28]*

2.2.1 Organization of Elements

An experiment in web design showed that a website with inaccurate information was still recognized as credible, due to its aesthetically pleasing layout. [28] According to Koffka [29], the organization of design elements into structures has an influence on this, as this accomplishes effective visual results. “Some of these laws include balance/symmetry, continuation, focal point, closure, isomorphic correspondence and so on” [28] [30] A layout should be clean and easy to follow, as distracting elements or overwhelming aspects might cause a user to easily quit. This applies to a broad range of media forms.

2.2.2 Color Use

The use of colors can have an effect on emotions and behaviour. “Bright colors (blue, red, lime and pink) provoke more positive reactions (e.g., amusement, excitement) than darker colors (black, grey and brown)” Of course, unpleasing color schemes should be avoided. These color schemes often exist out of bright and saturated colors that compete with each other. [28]

2.2.3 C.R.A.P. Principles

One model of graphic design is the C.R.A.P. model. [28] It defines Contrast, Repetition, Alignment and Proximity as key factors in online or printed means of effective communication:

- Contrast: Objects should be distinguishable from other objects and the background, through color, size, shape and position.
- Repetition: To give the design more structure and identity, design elements should be repeated throughout the design, making it a more coherent layout.
- Alignment: Elements should be aligned with each other to create hierarchy or visual connection, avoiding chaos or complexity.
- Proximity: Similar items should be grouped together

2.2.4 Typography

In typography, clear fonts should be used consistently to increase readability. The size of the text should be coherent throughout the layout as well as text color and title design. [28] A difference is made between **Serif** and **Sans Serif** fonts. Sans Serif fonts can provide a more clean layout/look, while Serif fonts increase the readability of longer texts.

2.2.5 Image Use

Also managed by Reyna et al. [28] is that the use of images is only relevant if the image has a purpose, otherwise it won’t add any value to the information. Using images should make the artefact visually appealing and create engagement between the audience and the object. The message carried by the image should be considered, as well as whether it helps the reader to better understand the concept that is communicated or whether the image increases appeal for the subject. Filling up space has no benefit for the user.

2.2.6 Video Techniques

In videography, there are a few principles which can increase video credibility and audience engagement. One commonly sees what is called the Vertical Video Syndrome (the use of vertically oriented mobile phone screens nudges the user to filming vertically) which should be avoided, it should be tried to film horizontally instead. To be able to convey a clear message, it is important to plan the shots before the production and to make sure that a variety of shot types is used, in order to create a diverse, although coherent video. The rule of thirds, where two equally spaced horizontal lines and two equally spaced vertical lines divide an image in nine equally sized parts, should be taken into account, as placing elements along these lines or their intersections create a better composition. Next to that, the use of text and transitions should be thought about thoroughly. [28]

2.3 State of the Art

In the next part of this chapter, an analysis of multiple state-of-the art items relevant to this graduation project can be found, starting with an analysis of the current governmental communication policies, followed by three projects which contain aspects which might be useful to take into account in designing the end result of this research.

2.3.1 Current Governmental Communication Policies

The Dutch government has a public guideline for campaigns developed for governmental use, available on a special website called *Communicatierijk.* [31] It contains information about strategies and methods used in governmental campaigns and it has a special dossier for the newest developments in campaign development: *de Campagnekeuken*. [32]

2.3.2 Campaign Analysis

2.3.2.1 Amsterdam Rainproof

Amsterdam Rainproof [33] is an online platform, focused on making Amsterdam more “rainproof”, in other words, making Amsterdam more capable of handling more frequent high-intensity downpours, by creating a big community of individuals in Amsterdam that would like to make a difference on this matter. Just like Enschede, Amsterdam has to cope with heavy rainfalls which the sewage system cannot handle. As every small effort makes a difference, the community-based strategy is a well-chosen one, as all small efforts together can make a big difference.

The online platform contains not only information about what the city itself does to prevent flooding; it also provides information on what citizens, streets or even whole neighborhoods can do themselves. People can share their own ideas and finished projects on the website, which then again might be adopted by other citizens. Therefore, it actively involves people to participate in projects, which has been proven to increase engagement. The website is highly interactive, allowing for greater attention, more engagement and the possibility for an emotion-based strategy, building a relationship with the user.

Next to the benefit that it delivers for the rainwater handling, this broad range of information is also beneficial for the exposure of the website, as audience segmentation has been successfully applied: both medium interested people are targeted by the general information on the platform, as well as highly interested people, through the coworking/community-side of the platform. Multiple levels of information are covered, which means that the target group of the platform can be really broad, which then again has a beneficial result for the main project goal: getting as many people as possible to make an effort in increasing rainwater handling capacity.

Visual design aspects have been successfully taken into account, as the website has a clean and easy-to-follow layout, which positively influences the perception and credibility of the information. The website does not feel overwhelming or distracting, allowing for a greater user attention span.

A downside of this approach is that people already should have some sort of intrinsic motivation to go to the website (as this is a process of choice, described in 2.1.1.), and/or there was an initial need for a separate marketing campaign to increase the level of attention for this project, as it does not directly increase attention itself.

2.3.2.2 Waterlicht

On a more artistic side, Waterlicht [34] as shown in figure 3 is an installation by Daan Roosegaarde, which uses light, smoke and laser effects to grasp attention of bystanders, showing them how high the level of sea water would rise at that certain spot if the government stopped investing in dykes and other flood prevention solutions. It aims to raise awareness around the rising sea level.

Figure 3, *Waterlicht by Daan Roosegaarde*, source: Leeuwarder Courant [35]

Very strong points of this installation are that, even if people are not initially interested in the subject already, the installation grasps their attention fairly easily due to its presence, size, color and movement. It catches attention very easily, which according to the literature in section 2.1.1, is the first and critical step in the process of effective communication. The installation raises awareness around the issue very efficiently, as the target audience is very broad (every bystander) and the message is conveyed easily. There is no language, culture or knowledge barrier as the information (level of sea water) is provided in a non-verbal, non-textual, easy-to-grasp way. Next to that, people are immediately confronted with the message: there is no need for them to (have intrinsic motivation to) look it up themselves. Also, the information density is very low, making it very easy for the user to remember the information. The information is presented in a very aesthetically pleasing way, causing a higher amount of information remembrance and a higher credibility of the presented information.

A downside would be that in its current form, it is hard to use this project to provide in-depth, more detailed information about the underlying issue of climate change. Next to that, there is no interaction and no control over the installation on the user-side (it is not interactive). Therefore, the user might feel less involved, attention span is lowered and consumers are not an active part in the media process. This does not allow for community creation. On the artistic side, this might be a positive thing as the general citizen does not have direct control over flooding related consequences. Although indirectly, a user might have some level of control through governmental voting which could be influenced by the message that this installation transmits to the user.

2.3.2.3 Battle of the Beach

Battle of the Beach [36] is a campaign organised by multiple waterboards, provinces and municipalities. Groups of children around 11 years old are challenged against each other to build a

sand castle on the beach which can withstand the rising tide as long as possible. Multiple prizes can be won. During the game, the children can apply the knowledge they have gained beforehand during one of the guest lessons by a presenter from the water-sector.

The main goal of this campaign is to make future generations aware of the vulnerability of the Netherlands in terms of sea water levels, the importance of waterboards and water management solutions to prevent flooding.

Strong points of this project are that the website is designed in a minimalistic manner: it is very easy to absorb the information provided both through text as well as pictures. The main goal of the project is clearly stated as well as the target group and Call to Action (sign-up). Multimedia use is limited to pictures, but as the website successfully takes into account visual design aspects, the information credibility is high. The project really involves the participants in the information provision: instead of only lecture-style information provision, the information is also directly practically applied in the assignments that the participants of the project get. The assignments of building sand castles really seem to fit the target group, which makes the project a fun way of awareness raising amongst the target group.

Weaker aspects of the campaign are, considering the website, limited multimedia use. Also, it is not clear what should lead interested people to the website. Therefore, some kind of external promotion for this project is necessary. The activities themselves are successful at raising awareness amongst the target group but might not have an immediate impact on water management. Also, there seems to be no follow-up after the activity, so the principles of community creation are not taken into account. These principles might help in containing a level of interest amongst a larger group of participants.

2.4 Conclusion

A typical marketing process is divided into the four stages. Attention, interpretation evaluation and memory. For this graduation project, all these stages should be taken into account to allow for effective communication. Attention is seen as a critical aspect in the effectiveness of marketing campaigns. As in this project it is tried to make users aware of information that they are not necessarily asking for at that moment, it is very important that their attention is grasped by the solution. Attention can be increased by adding interactivity, which gives possibility for active control over information by the user. Consumers expect to play an active part in the media process, which creates reach, intimacy and engagement and allows for an emotion-based strategy. This development of a relation with users might allow for this project to actively create communities of users who feel connected to the project, creating opportunity for interpersonal interaction about the project, which can also be stimulated through actively involving people in challenges or projects.

For effectively focusing this projects' campaign due to the target audience possibly being very broad, the audience can be analyzed through audience segmentation, identifying groups of individuals in a larger population of interest who share similar characteristics. After identifying these groups, the information should be communicated, framed and provided such that it corresponds with the personal environment, expertise, personal and professional background.

In making sure that the provided information through this project is being remembered by the users, it is important for the message formulation to take into account that people care more about losses than gains and tend to memorize positive messages better than negative messages. Also, information density cannot be too high as the average person can only receive, process and remember seven different pieces of information at a time. To overcome that people often fail to remember a significant part of the information, repetition of information is important as this has a positive effect on information remembrance, as well as providing the information in an engaging and interesting, aesthetically pleasing way. Visual design also has a great influence on the perception of information and its credibility. Any layout in this project should therefore be clean and easy to follow, as distracting elements or overwhelming aspects might cause a user to easily quit. Too much information can confuse or distract the audience.

Finally, it is generally important to focus more on the process of information provision rather than (only) the information itself. The information should be provided in an engaging, interesting, aesthetically pleasing way as described in chapter 2.2 and the Crap Model in section 2.2.3.

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Chapter 3 - Method & Techniques

This chapter will give an overview of the methods and techniques used in this bachelor project. The methods and techniques will be described in short, as well as their application in this bachelor project.

3.1 Design Process for Creative Technology

This thesis is a bachelor graduation project from Creative Technology, a BSc study programme at the University of Twente. It makes use of the Design Process for Creative Technology [37] as this is being taught and used throughout the entire program. As can be seen in figure 4 the process starts with the design question, initiating the ideation phase, followed by the specification and realization phase. Finally, the evaluation phase is present, consisting of components like user testing and reflection. This model is describing an iterative design process and a divergence-convergence approach. In the case of this project, the design question is similar to the research question.

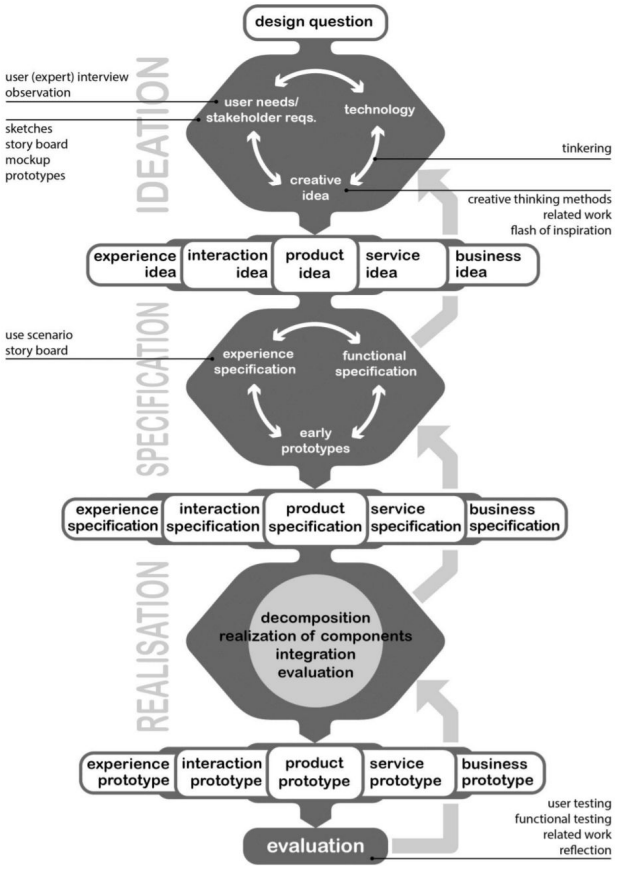

Figure 4, *A Creative Technology Design Process* [37]

3.1.1 Ideation

The ideation phase starts with a design question, which in the case of this bachelor thesis is similar to *RQ1: What is the most effective way to raise public awareness amongst inhabitants of Enschede about realized large scale rainwater management projects?* This phase consists of collecting relevant information through literature, observation, interviewing and stakeholder analysis while using this information as a source of inspiration in brainstorming sessions where ideas for possible solutions are being generated.

At first, stakeholders will be identified and analysed using the techniques as described in section 3.2. After that, street interviews will be conducted in order to better understand how visitors and residents of the Oldenzaalsestraat would like to be informed about the "Groene Linie", using the theory as described in section 3.5. Brainstorm sessions (section 3.4) will provide further creative input.

After collection and review of the obtained information, the preliminary requirements will be set using the MoSCoW method as described in section 3.6. Then, preliminary concepts will be made in a diversion phase, followed by a conversion phase in which these concepts are combined into a final envisioned solution. This envisioned solution will be described by a scenario and PACT analysis, following the scenario-based design approach as described in section 3.7

3.1.2 Specification

After the ideation phase, the specification phase will be entered where low fidelity prototypes are being used in setting the final project requirements together with the stakeholders. In this project, the low fidelity prototypes are a simple 3D camera overlay application and a description of the user journey of the envisioned solution through a designer perspective use scenario, application storyboard and storyline description. The prototypes are constantly being improved upon or discarded depending on the results of an iterative evaluation process with the stakeholders (through unstructured interviews, see section 3.1.4 and section 3.5.2). User experience is a central topic in this phase. This phase is closed off with, in the case of this bachelor project, a specification of the envisioned solution, interaction and experience.

3.1.3 Realization

Using this specification, the realization phase decomposes the functional requirements which can then be used to build a High Fidelity prototype of the envisioned solution. After selection of the tools that will be used for development of the envisioned solution, the decomposed components will

be built. Finally, the components will be integrated to create a fully working Hi-Fi prototype, which can then be evaluated during the evaluation phase.

3.1.4 Evaluation

The evaluation phase consists of testing the envisioned solution that has been built in the realization phase. Together with the client, the Municipality of Enschede, the Hi-Fi prototype will be tested against the project requirements as set in the specification phase in order to see whether these requirements have been met.

3.2 Stakeholder Identification & Analysis

To be able to determine the requirements for the solution provided by this thesis, the stakeholders that have an influence on this project must be identified through careful consideration. Newcombe [38] describes stakeholders: “Project stakeholders are groups or individuals who have a stake in, or expectation of, the project’s performance and include clients, project managers, designers, subcontractors, suppliers, funding bodies, users and the community at large” [38, p. 842] This project uses the power-interest matrix to analyze and position stakeholders, as described by Newcombe [38]. Groups of stakeholders that can be identified in this project are Users and Decision Makers. The focus will be on the top right quadrant of the power interest matrix (key stakeholders). The stakeholders in this quadrant should be managed closely.

3.3 User Centered Design

For this bachelor thesis the user centered design method [39] has been chosen. In designing a product, this approach focuses on understanding the end users and adapting the product to their needs. The process requires the designer to take an emphatic approach towards the user and to be thorough in design decisions, as “one cannot always trust that what a user says matches with what the user is really thinking or whether the user is aware at all of his or her true inclinations”. [40, p. 304] User centered design approaches are focused on interaction with relevant stakeholders through for example interviews, surveys, brainstorms, focus groups and user feedback testing. [40] In this project, this can be seen back in the street interviews, interviews with the Municipality of Enschede and University of Twente and brainstorm sessions during the ideation phase in order to create creative concepts.

3.4 Brainstorm Sessions

Brainstorming is a technique used in concept generation which can be done both individually and in a group. In group brainstorms, participants can share their ideas which can be cognitively stimulating and cause increased associative processes, which enhances idea generation. However, group sessions can distract people from their own thoughts as they also have to listen to the other group members. Therefore, it is also advised to have individual brainstorms where one can focus on ideas in a certain direction. In this project, a group brainstorm will be held to gather more insights in various design questions and to gather creative ideas, as can be read in section 4.3. In a later stage, an individual brainstorm will be held in order to converge all gathered information into creative preliminary concepts. [41]

3.5 Interviews

To get more insight into the perspective of others connected to this project, for example the stakeholders, interviews will be conducted throughout this research project. Both quantitative interviews [42] will be conducted which give an insight into the general points of view of a larger population (the street interviews, see section 4.2), as well as qualitative interviews [42] where there is a lot of focus on the opinion of one specific interviewee which is useful in client or stakeholder interviews, used for example to evaluate prototypes. The qualitative interviews are approached in a semi-structured or unstructured manner as the designer might want to focus on certain aspects of the presented prototype (semi-structured), while retaining room for general feedback (unstructured). The quantitative interviews are approached in a semi-structured manner to allow for easier analysis while also still retaining room for open answers.

3.5.1 Semi-Structured Interviews

Semi-structured interviews are useful in addressing a (list of) specific question(s) or discussing a specific topic while at the same time giving the interviewee enough room to speak freely about the topic. Using this technique makes sure that questions that need to be answered by the interview(s) are actually being answered, but it also gives room to discuss topics introduced by the interviewee. It also gives some room for standardization which makes analysis easier [42], by for example processing the answers in analysis tools such as Google Forms.

3.5.2 Unstructured Interviews

Unstructured interviews have a lot in common with a general conversation. A certain topic is introduced after which there will be an open discussion about it, without any prepared questions. It is a very flexible interviewing method focused on qualitative data and detailed answers.

3.6 Requirement Analysis

To set the requirements, both semi-structured and unstructured interviews will be done with the different stakeholders as defined in the stakeholder matrix, found in section 4.1. In the case of this bachelor project, a number of 35 semi-structured street-interviews at the Oldenzaalsestraat are foreseen, as well as a semi-structured interview with the Municipality of Enschede (client), next to an unstructured interview with the supervisors of this GP. Afterwards, the requirements will be set and categorized using the MoSCoW-method [43]. It gives a framework to prioritize requirements in the following categories, found in table 1 as shown below.

Must Have	Non-negotiable must-have requirements for the project. These are vital features for the project and cause significant value loss if left out.
Should Have	Important but not vital requirements. If added, these features add significant value to the project.
Could Have	Requirements wished to be added, but not necessary to the core function of the project and does not have a very big impact when added to the project.
Won't Have	Features that will not be implemented in the project considering the current timeframe, but might be of relevance or value in future work.

Table 1, *Overview of MoSCoW technique usage theory*

3.7 Scenario-based design

According to Benyon and Macaulay [44], when making design decisions it should be avoided that these decisions are made too early in the process. It is said that a scenario-based design approach can help with that, by making the design situation very concrete and therefore, easier to reason about.

An important aspect is that when using this approach, at first the effects of a design on the users should be carefully thought about. The exact sequences of actions comes second.

Scenarios are storylines that describe the actions of people that are using a certain technological solution. There are many different types of scenarios as can be seen in figure 5, ranging from idea-generating informal user stories which describe (real or imagined) user experiences, to formal use cases delivering an exact specification which can be used in the implementation of the solution. Inbetween, the conceptual scenarios can be found which can be of use in the prototyping of concepts. [44]

In this thesis, scenario based design is used in both the ideation and specification phases, in order to define the envisioned solution.

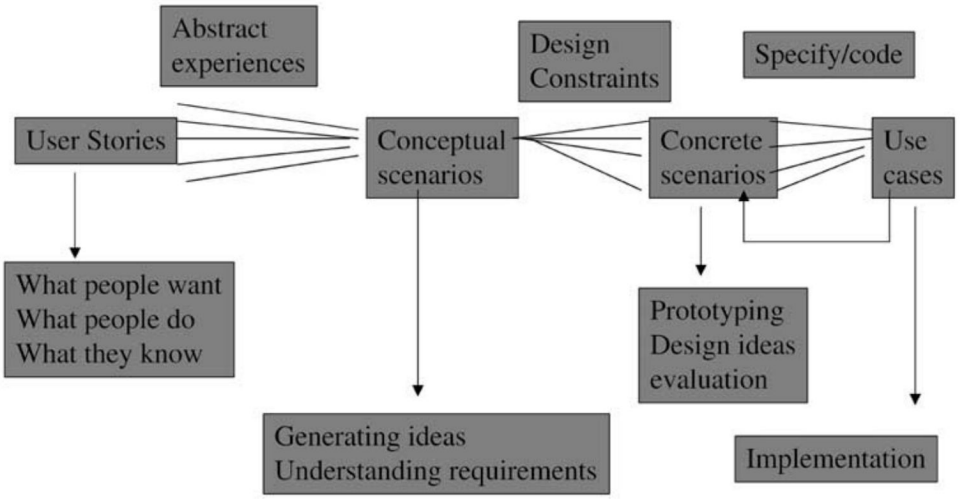

Figure 5, *Scenario types and their uses [44]*

3.7.1 PACT Analysis

Benyon and Macaulay [44] mention that in order to control the scenarios to prevent them from becoming messy, a framework is needed. They use the PACT to do so. This is an analysis performed before writing the scenario which describes People, Activities, Context and Technologies, which are the main aspects that should be present in the scenario. It is a user-centered design tool, which is used in writing a full user-centered scenario.

3.8 Evaluation Method

After realization, the solution will be evaluated in order to review whether it meets the requirements as set during the specification phase. This evaluation will be performed while adhering to the constraints imposed by COVID-19.

The evaluation consists of two phases. At first, a stakeholder evaluation will be performed in order to evaluate the experiences of the stakeholders with the prototype. Afterwards, a functional evaluation will be performed in which the designer evaluates whether the specification requirements have been met.

3.8.1 Stakeholder evaluation

As the development of the Hi-Fi prototype focuses on realizing a technically accurate digital representation of the "Groene Linie" installation, the stakeholder evaluation mainly focuses on the technical accuracy of the content as shown in the prototype.

Since the stakeholder "Municipality of Enschede" involves various representatives in later stages of this project, the evaluation will be decomposed into several semi-structured interviews, each fitting the profession of the different representatives. The Hi-Fi prototype is then evaluated with each representative individually, with a focus on prototype aspects that are relevant to their profession. The semi-structured interview approach (see section 3.5.1) is chosen in order to leave room for general feedback while still being able to ask the stakeholder about specific aspects of the prototype.

Due to constraints imposed by COVID-19, both evaluation with the visitors and residents and hands-on evaluation by the Municipality of Enschede representatives were not feasible. In order to overcome the latter, a digital evaluation will be performed. This will be done by preparing a video which shows the functionality of the Hi-Fi prototype, which is sent through e-mail to every Municipality of Enschede representative. The representatives watch the video before the interview takes place. Afterwards, the interviews will be conducted individually through phone calls. In these interviews, there is at first room for the representative to give general feedback and opinions. Thereafter, the interviewer can ask specific questions about the Hi-Fi prototype which directly relate to the profession of the interviewee.

3.8.2 Functional evaluation

After the stakeholder evaluation, a functional evaluation will be performed in which the designer evaluates whether the project "must have" and "should have" requirements as have been set in section 5.3 have been met. The requirements will be categorized as "requirement fully met", "requirement partially met" or "requirement not met". Argumentation is present where necessary.

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Chapter 4 - Ideation

In this chapter, the ideation process meant for developing ideas that can possibly be used in the envisioned solution provided by this graduation project will be discussed. Starting off with a stakeholder analysis, in which stakeholders will be identified and categorized based on their power and interest in the project, after which the conducted street interviews will be discussed. Then, several brainstorm sessions have taken place to generate ideas on possible solutions. Afterwards, several project meetings with Richard Bults & Kasia Zalewska took place, where a decision was made which of the concepts should be explored further. Lastly, an interview has been conducted with Annemiek van den Heuvel to set the preliminary requirements for the solution.

4.1 Stakeholder Identification & Analysis

For this project, multiple stakeholders were identified:

- University of Twente
- Municipality of Enschede
- Visitors & Residents
- Business-owners in the direct surroundings of the "Groene Linie"

Each stakeholder has their own level of power and interest in the project, analyzed as can be seen in figure 6 in section 4.1.1. Since the stakeholders are larger entities, their representatives are listed in table 2, as well as their role in the project. This analysis can later on in the project be used to decide on the importance of requirements made by these stakeholders.

Stakeholder	**Representative**	**Category**	**Participation**
University of Twente	Richard Bults & Kasia Zalewska	Decision-maker	Keep satisfied
Municipality of Enschede	Annemiek van den Heuvel	Decision-maker	Manage closely
Visitors & Residents	-	User	Manage closely
Business-owners in direct surroundings	-	User	Keep informed

Table 2, *Stakeholder Identification & Analysis*

4.1.1 Power Interest Matrix

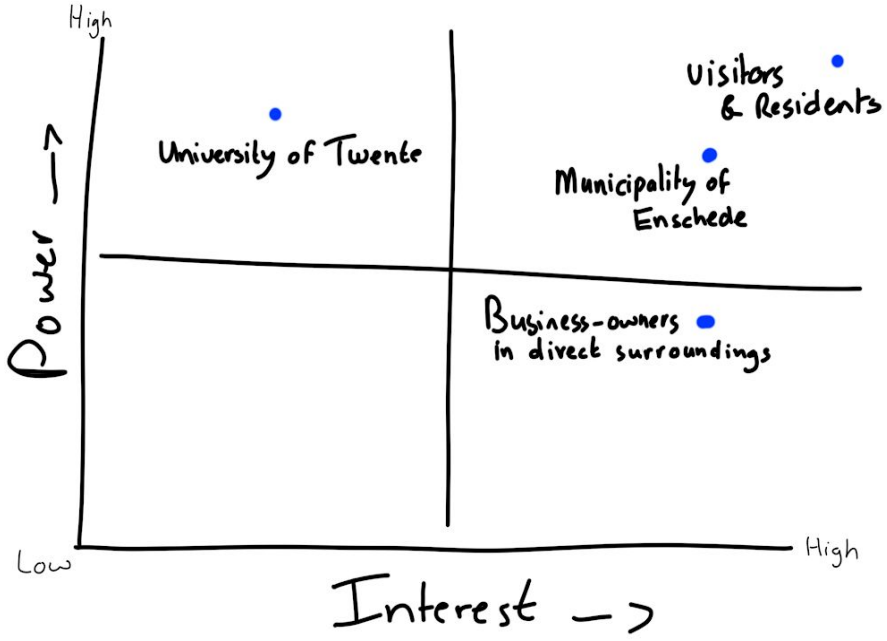

Figure 6, *Stakeholder Analysis*

4.1.1.1 University of Twente

The University of Twente represented by Richard Bults and Kasia Zalewska is a decision maker in this project. The power of this stakeholder is relatively high, as the University will not be the end user nor be involved in the final development of the solution. However, they do have legislation power. It is therefore important to keep them informed and satisfied about the project.

4.1.1.2 Municipality of Enschede

The municipality of Enschede is another decision-maker in this project, represented by Annemiek van den Heuvel. The municipality of Enschede is the client in this project and therefore has high power over the direction the project takes. Also, the municipality must be able to apply the solution in a real-life context, so their requirements are very important. Interest is very high as the municipality wants to promote the “Groene Linie” and wants to do it through the envisioned solution of this project. Therefore, this stakeholder should be managed closely.

4.1.1.3 Visitors & Residents

The visitors and residents of Enschede are the final users of the solution. Their power is very high as their experience is the decisive factor in whether the solution is successful or not. Their interest is also the highest, as they are the end users requiring more information about the "Groene Linie".

4.1.1.4 Business-owners

Business owners in the direct surroundings of the “Groene Linie” might be potential users, but not primarily. They should be kept informed about the influence of this project to their direct surroundings (for example physical objects being placed or an increase in visitors to their surroundings) to make sure that no major issues arise, as the solution might influence the direct surroundings of their business: the environment might have to be altered and/or there will be more people holding up in the area around their business. Therefore, their interest in the project itself is high, but as they do not have a direct influence on the success of the project, their power is low.

4.2 Street interviews

During the ideation phase, several interviews have been conducted. At first, 35 street interviews were conducted to better understand how visitors and residents of the Oldenzaalsestraat should be informed about the "Groene Linie". These interviews were conducted at the Oldenzaalsestraat in Enschede, on the 10th and 11th of December 2019. The sample consisted of 63% male and 37% female subjects aged between 15 and 65. 29% of the subjects live in a range of 500 meters around the Oldenzaalsestraat, the other 71% of the subjects live further away. The interview questions can be found in Appendix A. The most important insights given by the street interviews are listed here:

- The information needs are mainly on practical implications such as traffic information and rerouting, duration of the project but also why the project is being executed. Need for detailed information is limited, as only technology-interested interviewees seemed to be interested in technical specifications.
- Interviewees living near the Oldenzaalsestraat are more interested in contextual information and in-depth project information, where interviewees living further away show more interest in practical information.

- Interviewees living near the Oldenzaalsestraat are not in need of further improvement on the current information provisioning. Interviewees living further away are less satisfied about the information provisioning.
- Younger interviewees prefer to receive their information through digital media, mainly Facebook, Instagram and websites, where older interviewees prefer old-school media such as newspapers or flyers.
- Younger interviewees show a higher interest for practical information, where older interviewees show a higher interest for contextual information.
- There is limited interest in VR and AR as an information medium, but interviewees were generally willing to try it out.

4.3 Brainstorm sessions

Before and after the street interviews, brainstorm sessions have taken place. The first session was a group session organised in Enschede. Two of the participants were living outside of Enschede, three others were living inside Enschede. All participants were between 20 and 40 years old. Three participants were female, two others male. The brainstorm session was held in Dutch and took half an hour.

During this session, the initial question to start the brainstorm was about the kind of information about the “Groene Linie” the participants would be interested in, after they had been shortly introduced to the project by reading section 1.1 of this thesis. The results were that information on why the project is there and on what influence it has on the individual were important to the participants. Some of the participants were also interested in how the installation works; they would like more technical details. From that, two levels of information could be seen: the first contains superficial information on what the project is about and why it is here, the second contains more technical details about the exact workings of the installation. An important side note is that one of the participants mentioned that he would probably not have interested himself in this installation if he had not gotten the information given to him before the session. Therefore, the group agreed that most of them would have only read about the installation if they were already interested in the subject or when accessibility was really low effort: presented to them in a concise and attractive manner.

The next question was on the practical level: How could we present both levels of information to the public without boring each individual user with information he/she is not interested in? Two options were seen: 1) the user either needs to be able to directly choose the information and 2) the information should be automatically adapted by the system to fit the needs of the user.

The last point of discussion was about technologies or solutions that could be used in order to realise the above mentioned ideas. One of the main ideas was to set up an online community for the

people that are more into the subject, as a part of an internet site on which superficial information about the water management projects also was to be found for those just wanting a quick read. Another idea was to actively involve the more interested people through Do It Yourself-projects. Also, traditional media like social media and (online) marketing campaigns were named, with the addition that a second level of information could be reached through some kind of link. Next to that, a dedicated app or website was mentioned which would show certain kinds of information depending on (demographic) information the user enters before using the app.

A second, individual brainstorm was performed in order to combine the insights provided by the group brainstorm, street interviews and preliminary requirements as set in section 4.4, into preliminary concepts. The results of this individual brainstorm can be found in section 4.5.

4.4 Preliminary Requirements

As a result of reviewing the street interview results, brainstorm sessions and discussions with the Municipality of Enschede and the University of Twente, the following requirements have been set, using the MoSCoW method as described in section 3.6. Afterwards, a distinction between functional and non-functional requirements has been made, where functional requirements describe what the system does, and non-functional requirements describe how the system does this.

Must Have		
Requirement	Functional	Non-functional
The solution must visualize the "Groene Linie"	x	
The solution must enrich the reality with relevant audio-visual content	x	
The solution must be interactive		x
The solution must be attractive to use		x
The solution must be usable over a longer period of time		x
The solution must be easily accessible		x
The solution must provide an explanation about why specific water management projects are executed	x	
The solution must provide an explanation about the general workings of a specific water management project	x	
The solution must be weather-proof		x

Table 3, *The Must Have requirements, using the MoSCoW method*

Should Have		
Requirement	Functional	Non-functional
The solution should provide messages in a positively formulated manner		x
The solution should provide information through both analog and digital channels		x
The solution should take visual design aspects into account		x
The solution should inform on multiple levels of information (superficial -> in-depth) about the “Groene Linie” installation	x	
The information density should not be too high		x
The information should be communicated, framed and provided such that it corresponds with the personal environment, expertise, personal and professional background of the user		x

Table 4, *The Should Have requirements, using the MoSCoW method*

Could Have		
Requirement	Functional	Non-functional
The solution could have in-depth information on technical specifications & statistics of the “Groene Linie” installation	x	
The solution could have a social aspect focused on community building (forum, social interaction)		x
The solution could be focused on building a relationship with the user (using the solution over a longer period of time)		x
The solution could be available off-site		x
The solution could be usable for people in wheelchairs		x
The solution could be usable for people with hearing problems		x
The solution could be available in multiple languages (Dutch, English, German) due to diverse population and close distance of Enschede to the German border		x

Table 5, *The Could Have requirements, using the MoSCoW method*

4.5 Preliminary concepts

After converging several ideas that have been formed during the brainstorm sessions and interviews, the following ideas were developed.

4.5.1 Online community platform

A digital, online water management community platform containing an overview and detailed information of all water management projects in Enschede and their practical implications on everyday life, as shown in figure 7. (Development of) future plans for projects that still need to be constructed will be shown as well as information on (possible) disturbance caused by the construction works related to these projects, including traffic information if necessary. Technical specifications will be provided next to contextual information about why the project exists, why it is executed in that specific area etcetera. This makes the platform a central place which directly connects to the

information needs of the users as described in section 4.2. The users are able to select themselves which kind of information they want to read and the platform gives an option to show relevant projects, generated out of earlier page visits and ZIP code of the user when he/she decides to enter it.

To show which impact the projects have on water management in Enschede, statistics can be shown on the platform, to convince users of the importance of these projects. For example, the volume of rainwater handled by each project or the millimeters of flooding avoided by the totality of projects. As the municipality in the case of the "Groene Linie" often makes a reference of the rainwater buffering capacity to a certain amount of Grolsch bottles, it would be a good addition to also use this reference on the platform.

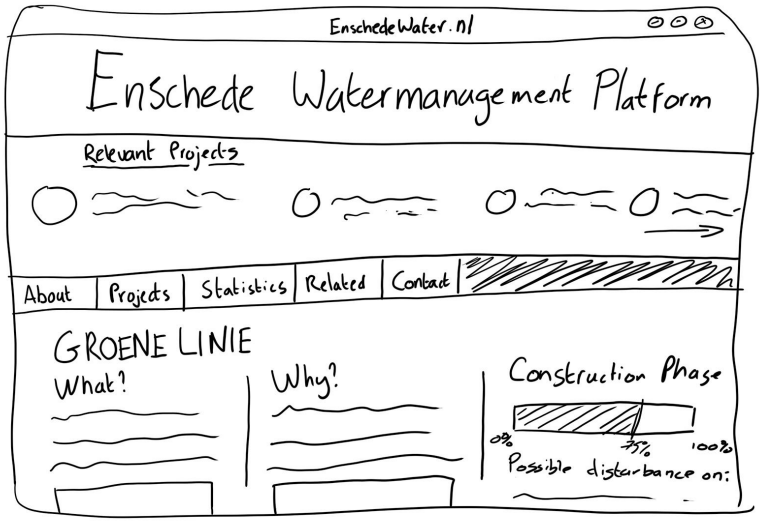

Figure 7, *Online Community platform sketch showing various kinds of information*

4.5.2 360 degree video narrative

In this application, a 360 degree video will be shown through a web-app, available on both mobile phone, tablet and PC, in which the "Groene Linie" project gets explained in detail, as well as practical information including building progress and detour information. On mobile phones or other mobile digital devices containing a positioning sensor, the ability of showing 360 degree video will be controllable through touch or mouse input. However, the video is also usable in VR setups where the user can control the movement of the camera simply by moving his/her head around. So, the installation can be used in both professional setups (in for example a promotional activity) as well as on a (mobile) device, at any location.

To add interactivity and user control over the information, the video is interactive and therefore user-controllable, as shown in figure 8. This gives the user the ability to shape the storyline of the video in such a way that it fits his/her interest. It might enlarge the attention span as the video now gets closer to the users background knowledge, educational level and interests. This alternative

can be used in similar settings as the above mentioned solution. It is a hybrid solution as the application administrator still has the possibility to force the provision of certain aspects of information, but in other aspects gives the user the choice to skip or watch specific parts of information. This is convenient as in this case there is no fixed narrative: the user can change the sequence of scenes and/or focus points of the video to suit their information needs, but the administrator still has the possibility to show certain information he/she *wants* to give to the user, for example to cover up the gap between the information that the administrator *wants* to give, but the users are not aware of that information even being available, for example certain reasoning behind the design decisions or construction plannings.

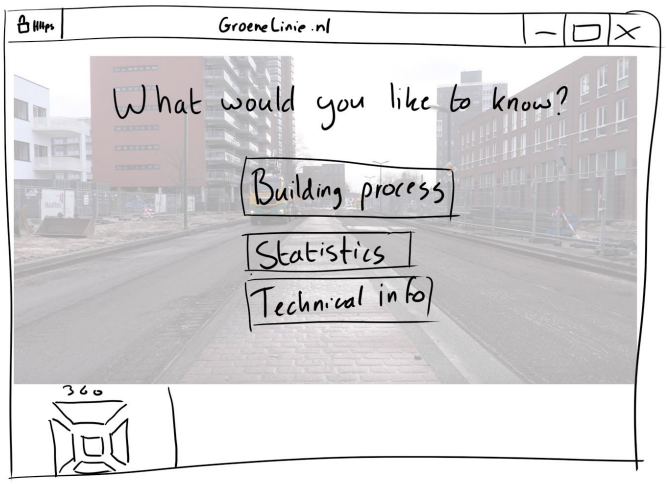

Figure 8, *360 degree video web app in a browser, showing a paused video at a user decision moment. 360 degree viewing controls on the bottom left.*

4.5.3 360 degree photorealistic information experience

This solution provides the user with a 360 degree virtual reality world in which he/she can virtually walk around. The solution is available in VR setups, but also through browsers on (mobile) devices. The user sees a photorealistic environment of the "Groene Linie" around him. Pop ups at certain spots along the "Groene Linie" show Points Of Interest (POIs), as shown in figure 9. Users can virtually walk to these POIs through the VR controls and after arriving at that POI, read more information, watch a video or photos on certain aspects of the project or see a hologram of the underground installation. In this case, the user has full control over the information he/she reads: there is no fixed narrative as the user can walk around to POIs that seem interesting to him.

Figure 9, *360 degree video environment in which the user navigates through the blue controls. Some orange Points of Interest are shown.*

4.5.3.1 360 degree virtual reality experience

Instead of using a 360 degree photorealistic environment, a 3D modelled, virtual version of the environment could be used. This adds the possibility to add information on aspects that are not (necessarily) visible through photos and/or in real life, such as information on what happens underneath the ground or during construction works that have already been finished.

4.5.4 Timeline walkway

(A part of) the walking path along the Oldenzaalsestraat will be used as a timeline, showing background information on the rainwater management problem, the idea generation, (preparations for) construction works, practical implications, encountered problems and reasons behind certain construction aspects, through time. This emphasizes the size of the project “Groene Linie” and gives the possibility to show inside-information that is not generally known to the public. Information is provided on screens/information signs along the route, using multimedia techniques (text, photo, video, animation). These information screens/signs contain an AR feature in which a user can scan a code provided on these screens/poles on their mobile phone, after which AR models of the explained subject pops up, which gives the possibility to use digital multimedia alternatives such as 3D models or holograms. This can also add an extra layer of information for the highly-interested. See figure 10 for reference.

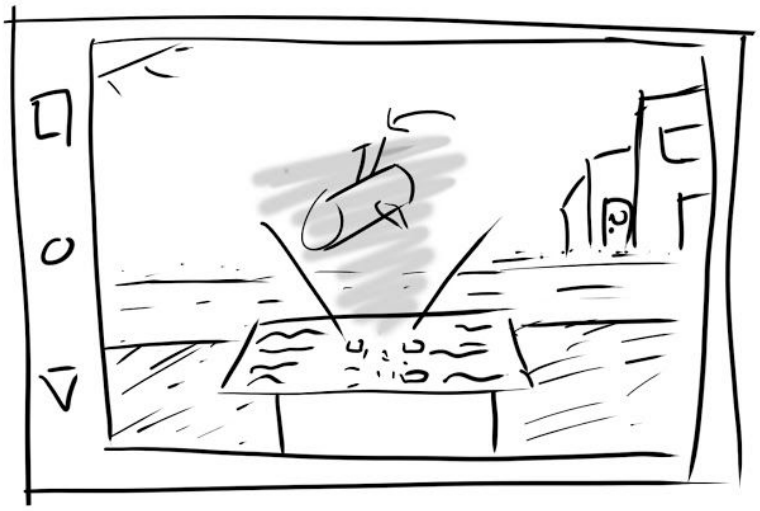

Figure 10, *Mobile phone app showing an AR hologram after scanning a QR code*

4.5.5 Water management walking route

The city centre of Enschede suffered from flooding in the past. In this concept, the outer border of the biggest flooding from the past gets marked throughout the whole city centre by special LED-lighted tiles, to show the size of the problem. This immediately creates exposure as all visitors of the city centre walk by these tiles and become aware of the general topic when viewing them, creating general awareness. A walking route along this border will be set up. Each LED tile marks an information point: an ID number is shown on each LED tile, as shown in figure 11. This number can be entered in the dedicated mobile phone app, after which it shows one of the different projects (that have already been implemented or are currently in development) around water management in Enschede and/or statistics on capacities/amount of rainwater handled, similar to section 4.5.1.

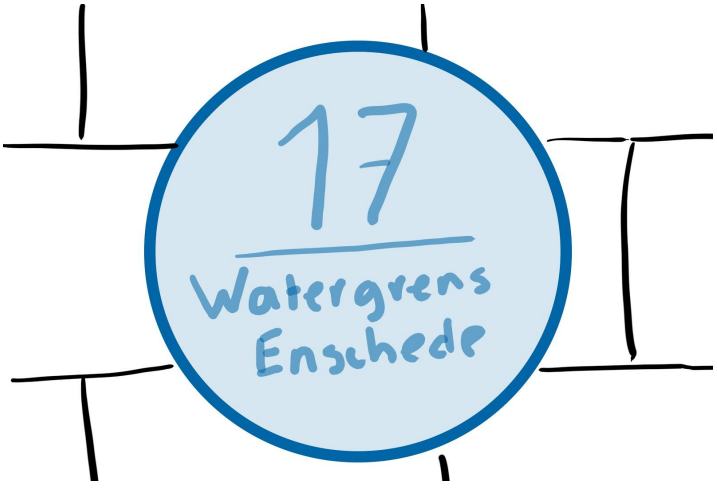

Figure 11, *LED-Illuminated tile showing the ID number to be entered in the app*

4.5.6 Data physicalization

Throughout the city centre at spots which would be most influenced by flooding, transparent poles containing water in them would be placed, which shows how high the water would have been on a certain day or time at that specific spot if Enschede did not work on any rainwater management projects. The user can select the day/time, and if the installation is on a remote location or at one non-specific spot, select the location. Depending on this information, the water level in the pole will be changed. It gives a very direct feeling of the problem to the user as he/she can relate it to the surroundings of the installation. On top of this, the user might also have the ability to select a certain rainwater management project, after which the installation changes its water level to show the impact of that certain rainwater management project on the currently selected situation.

4.5.6.1 Oil/water visualization

Instead of changing the water level, the installation might also use the property of water and oil not being able to mix. Using oil in different colors and densities might give an even better feeling of the impact of several water management projects, as the user can now compare the total amount of millimeters of flooding against the impact (prevented amount of millimeters flooding) of the selected water management project(s). See figure 12 for reference.

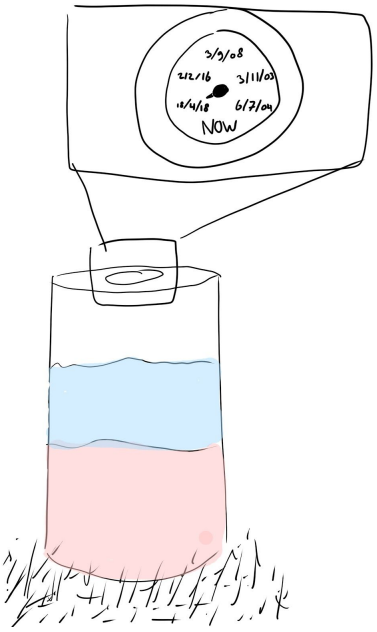

Figure 12, *Oil/Water visualization with an option to change the date. Could also be location or project.*

4.6 Project focus

After evaluating the generated concepts together with the University of Twente, represented by Richard Bults and Kasia Zalewska, a revised total concept was made through converging multiple preliminary concepts. This total concept, the “Twentse Waterroute”, is a cycling tour in and around Enschede, visiting multiple water management projects. At these water management projects, a dedicated app provides more information about these projects in an interactive approach. More details can be found in Appendix B.

In this project it has been chosen to follow a scenario-based design procedure. Theory on scenario-based design can be found in section 3.7. The scenario for the full concept Twentse Waterroute can be found in Appendix C. Considering the timeframe and scope of this project, it has been decided to focus on a certain, smaller aspect of this full concept. Therefore, the full concept has been moved to the appendices. In discussion with the municipality of Enschede, it has been decided that the 3D camera overlay solution as provided in this scenario is most fitting to the situation at the “Groene Linie”: it could give a tangible insight into the workings of the underground installation, both on- and off-site. In this decision, it has also been taken into account that it is not possible anymore to realize 360 degree video of the construction site in time as the construction works will finish very soon at the time of writing.

In order to write a focused design scenario for this solution, at first, a PACT analysis will be executed in section 4.7. For theory around Scenario & PACT Analysis, see section 3.7.1. Afterwards, the 3D camera overlay-application focused scenario can be found in section 4.8.

4.7 PACT Analysis

In table 6 as shown on the next page, a PACT analysis for a 3D camera overlay application is described, which gives an insight on potential users, activities, context and possible use of technologies. It will help in writing the 3D Camera Overlay Application Scenario as can be found in section 4.8.

People	Mainly young families with kids aged between 7 and 15 years old.
Activity	Using the “Twentse Waterroute” app to get to know more about the “Groene Linie” rainwater management project.
Context	Whilst on the biking route “Twentse Waterroute” through the city of Enschede, passing by important rainwater management projects of the city of Enschede.
Technology	An iOS or Android smartphone with the Twentse Waterroute app installed.

Table 6, *The PACT Analysis for the 3D Camera Overlay Application Scenario*

4.8 3D Camera Overlay Application Scenario

In this section, following the scenario-based design approach, a scenario focused on the 3D Camera Overlay Application can be found. It describes the envisioned solution from an end user point of view.

The context of this scenario can be found in Appendix C

(...) Thanks to the voice instructions within the app, Kevin successfully guides them to the 4th POI “Groene Linie”, of which a big part is built under the ground. As they arrive at the pole with the sign and blue waves on top (see figure 13) which they recognize from the previous POI, Kevin starts to read the information sign and immediately notices a small section on the bottom right side.

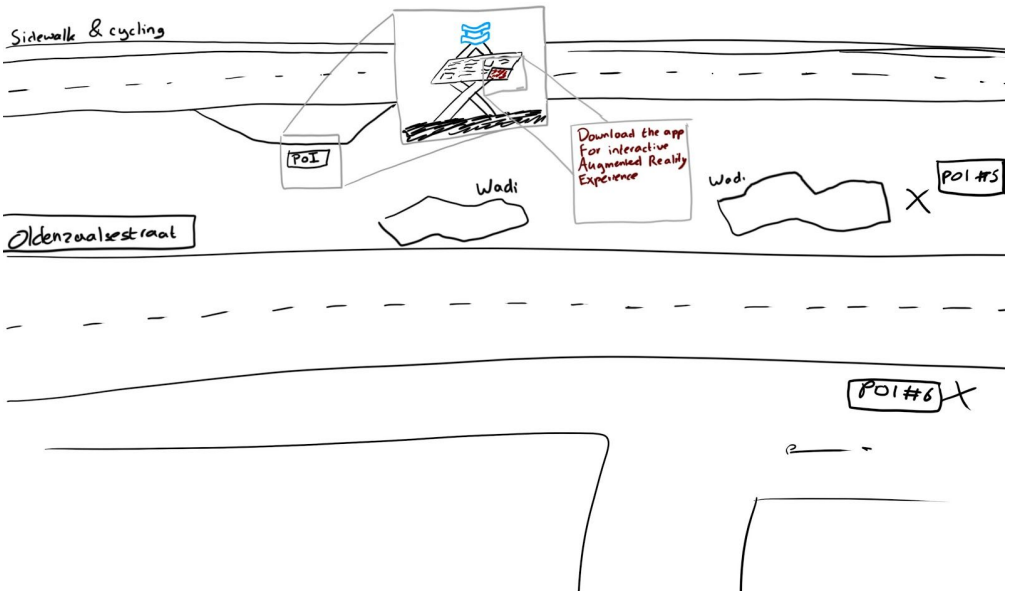

Figure 13, *Oldenzaalsestraat schematic layout*

It stands out because of its bright red color. Kevin reads the caption: “Download the Twentse Waterroute app for an interactive Augmented Reality experience on your mobile phone” and sees a picture of someone holding his mobile phone in the direction of the Oldenzaalsestraat underneath it. In the picture, the phone screen is showing the Oldenzaalsestraat from the phone camera perspective, with a 3D model of a giant tube projected in it, right underneath the street. Underneath the picture, Kevin notices a QR code and two logos: one of the Google Play Store and one of the iOS App Store. He knows that he has already got the Twentse Waterroute on his phone, so he decides to open the app to try it out. After he gets the phone out of his pocket, Kevin notices a small window popping up on the lock screen of the phone, asking to open the app to enable the Augmented Reality Experience. Kevin unlocks the phone and opens the app. When he does so, the app opens a camera view. A small screen pops up on the top side of the screen, asking to hold the phone horizontally. After Kevin has turned the phone horizontally, another message pops up, asking him to point the camera to the blue cross that is placed on the ground next to the information pole. Also, a picture of the cross is shown as a reference. Kevin finds the blue cross next to the pole not hard to find as it has the size of approximately 1 by 1 meter and is painted clearly on a big grey tile, with some other red shapes painted around it. He points the camera at the blue cross, after which the tile on the phone screen changes to a video through which Kevin is suddenly able to see the sewer system and gigantic buffer tube lying under the ground, as shown in figure 14.

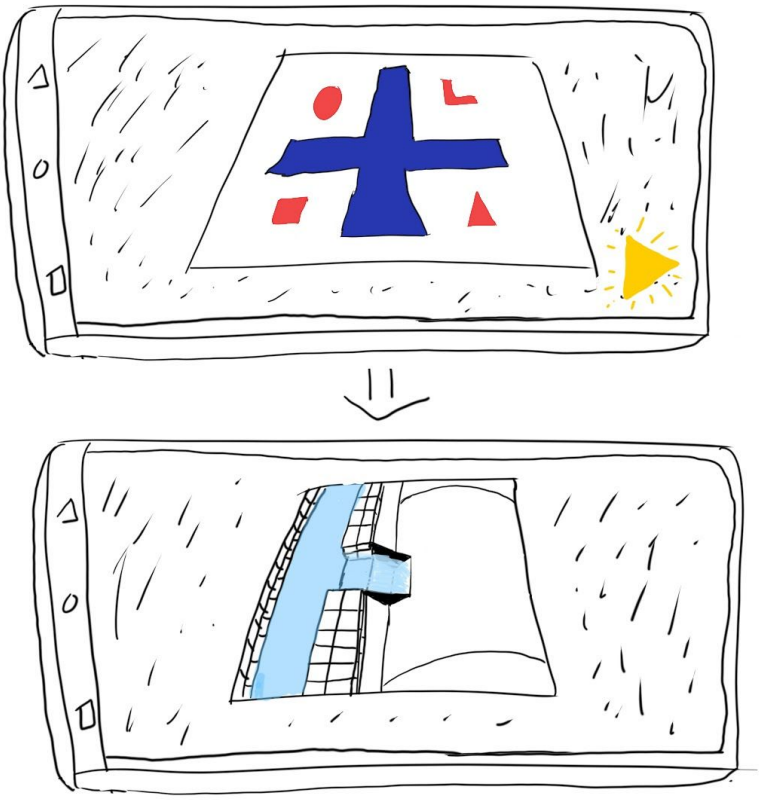

Figure 14, *Concrete anchor next to POI & projection of underground installation*

The application uses the blue cross and the smaller, red shapes painted around it as a marker on the ground to project a 3D animation of the underground installation into the camera view of the phone. After a few seconds the app shows a small window on th e top of the screen, with a text asking Kevin to walk around the tile a bit but to keep the phone pointed at the blue cross. Kevin does so and now notices that he is able to watch the projection from every side! After a few seconds, a "play" button on the bottom right side of the screen starts flashing. Kevin touches it, after which a voice-over starts playing. His parents join him in watching the model and listen to the voice-over, but Tim complains that he can't hear the voice-over very well because of the traffic noise behind them. Kevin therefore activates the subtitles by clicking a small knob on the bottom right side of the screen, which shows a square with lines in it, as shown in figure 15.

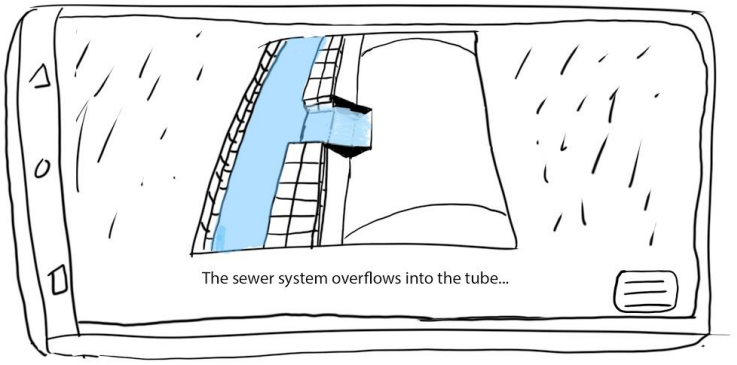

Figure 15, *Subtitles of the voice-over*

The voice-over gives an explanation of the technical workings of the “Groene Linie” installation by showing a heavy-rain scenario: it explains how the installation does its work during heavy rainfall. The explanations via the voice-over are supported by the 3D model: as the voice-over tells about the heavy rainfall causing the sewage system to overflow into the giant rainwater buffer-tube. Kevin notices that the projected model also shows a rising water level, shown by a blue color filling up the modeled tube. Afterwards, the voice-over tells them to move to the next POI, where they will be told more about what happens when the rainwater buffer is full. A map opens up, guiding the family to the next POI nearby one of the wadis, as shown in figure 16.

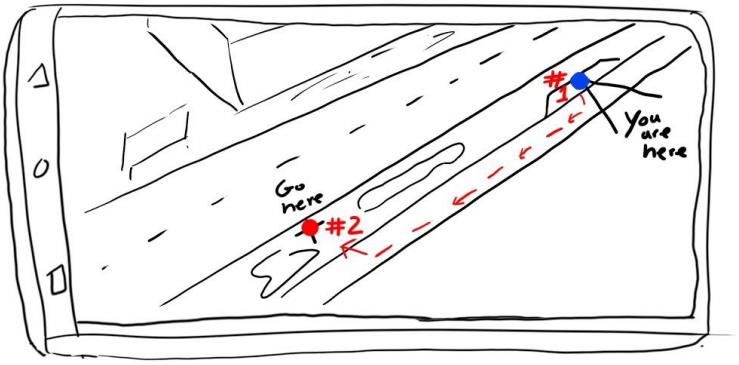

Figure 16, *Map & GPS Guidance*

While Kevin guides the family to the next POI, he notices that a blue dot represents their location on the digital map. This makes it easy to see where they need to go. Upon arrival at the next POI which is right next to a wadi, he sees another tile, quite similar to the one at the first POI. It is located on the bottom of the wadi. Kevin remembers from the first POI that something will happen if he points the phone at the tile again. Indeed, when he unlocks the phone a message pops up, asking him to do so. Kevin points the phone at the tile and sees the same thing happening as at the first POI,

but now, the animation is different. He touches the play-button and afterwards, the voice-over starts explaining what happens if the tube buffer is full: the water in the tube buffer overflows into the wadis. As the voice-over explains it to him, he sees on the phone screen that the water level in the wadi rises and starts to fill up the wadi! (See figure 17 for reference.) After the voice-over ends, a message pops up, asking the family to go to the next POI to continue the story, after which the map view pops up again, showing the route to the next POI which is near one of the valves controlling the water level in the buffer. (...)

The remainder of this scenario can be found in Appendix C

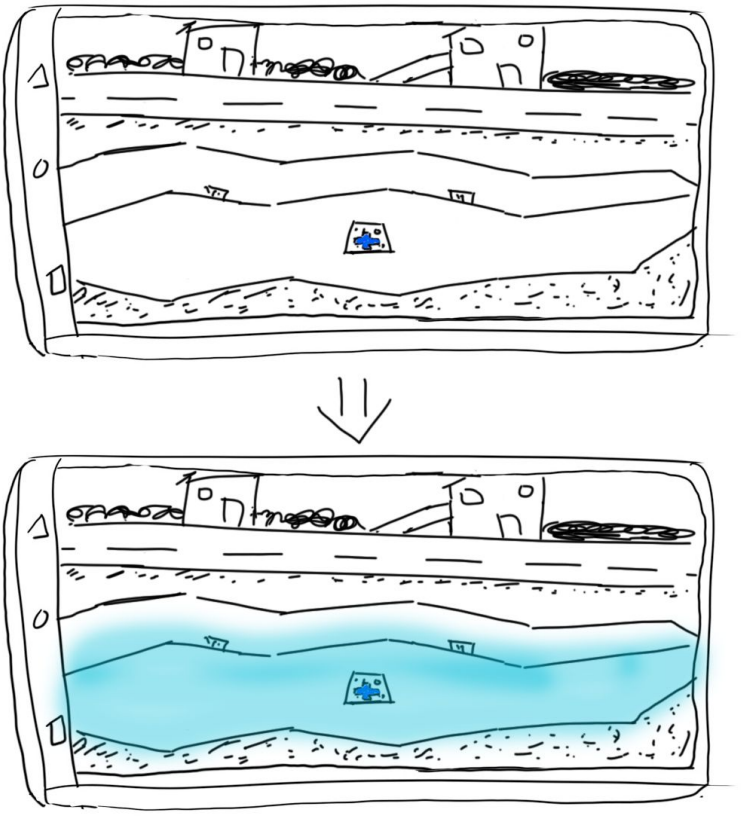

Figure 17, *The water level in the wadi virtually rises*

4.9 Application of Street Interview Findings in Full Concept

Following the full Twentse Waterroute concept as described in Appendix C, the implementation of the user needs found through the street interviews can be found in this section: results in regular text, implementation in italics.

- The information needs are mainly on practical implications such as traffic information and rerouting, duration of the project but also why the project is being executed. Need for detailed information is limited, as only technology-interested interviewees seemed to be interested in technical specifications.
  At POIs (both at the "Groene Linie" or at another project) where construction works have been planned or are already taking place, the user is able to view and share the planning so that he knows when and where possible detours and/or other discomfort will take place. Also, the user can automatically add this to his calendar through the installation functionality. General information about why the projects are/have been executed is available on the analog information signs at every POI. Detailed information will be available through the app but will not be present on the information signs.

- Interviewees living near the Oldenzaalsestraat are more interested in contextual information and in-depth project information, where interviewees living further away show more interest in practical information.
  Both categories and levels of information are available, through the app or on the information signs.

- Younger interviewees prefer to receive their information through digital channels, mainly Facebook, Instagram and websites, where older interviewees prefer analog channels such as newspapers or flyers.
  The Twentse waterroute in its analog version (route signs, information signs at POIs) does not require any digital assistance and provides a basic level of information. The digital version of the route is an addition to the analog version: the route itself is available through the app, but in order to use the more immersive experience of the app, the user needs to scan the physical information signs at the POIs.

- Younger interviewees show a higher interest for practical information, where older interviewees show a higher interest for contextual information.
  As older interviewees also showed a higher level of interest for analog information provisioning, the contextual information will be provided on the analog information signs. Practical information will be shown through the app or on a digital screen at a POI in construction.

- There is limited interest in VR and AR as an information channel, but interviewees were generally willing to try it out.
  VR and AR might be used occasionally to allow users to experience it, but is not the only functionality of the app. As it will be used on mobile phones along the route, professional VR/AR setups are not present and therefore, the application of VR/AR in the app will be a more simplistic version.

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Chapter 5 - Specification

This chapter contains the specification phase of this project, in which the envisioned solution will be specified through stakeholder involvement and requirement elicitation. A use scenario provides an exact walkthrough of the application, after which a low fidelity (LoFi) prototype will be developed in order to give the stakeholders a tangible prototype to set their requirements to. Then, the full storyboard and narration of the "Groene Linie" workings can be found as well which will provide the basis for the visual 3D overlay and the voice-over/textual narration of the application. Then, the final requirements will be set, to be used in the realization phase.

Because of the limited availability of time, it is not possible to realize the full Twentse Waterroute application as described in section 4.8. Therefore, in this project, an even more focused approach had to be chosen. As the Municipality of Enschede primarily wanted to focus on raising awareness around the "Groene Linie" installation as mentioned in section 1.1, it has been chosen to focus on a dedicated 3D overlay solution for the "Groene Linie" as will be described in section 5.1.

5.1 Use Scenario

5.1.1 Introduction

On a Friday evening, after work, Floor (39) is waiting for the bus home at the Oldenzaalsestraat in Enschede. Normally she does her commute by bike as she lives just in the northern part of Enschede, but it was raining this morning. Floor is in a good mood since the rain has gone away and the weekend has arrived in which she can spend time with her husband Tim (41) and her two children Kevin (13) and Rose (15).

As the bus is delayed, she has some time to kill. Next to the bus stop, in between the sidewalk and bicycle path, she notices a sign of about one meter by 60 centimeters, at about knee height. It has some text and illustrations on it. She has already seen it before during her commutes, but her curiosity never reached the point at which she bothered to stop to read it.

As she now has time to spare during the waiting, she takes a minute to read the sign out of curiosity. The sign gives information about the “Groene Linie” water management project which she already has heard of before but doesn't know the details of. At the top right part of the sign, she notices a section with a different, notable background color where she reads that this sign is marking a Point Of Interest along an interactive "Groene Linie" walking route at the Oldenzaalsestraat in Enschede and that and that there's a dedicated, native mobile app available through the Apple App

Store and Google Play store, which is called “Groene Linie AR Experience”. She doesn't install the app on her phone right now, as the bus will arrive shortly.

The following Saturday morning the weather is nice and due to her good mood, Floor decides that she wants to do something active and outdoors, together with her husband and children. While discussing what they want to do, Floor remembers the sign she saw yesterday near the bus stop at the Oldenzaalsestraat. She immediately tells Tim about it, but while going outside for a walk sounds like a good idea to him, he isn't convinced that it would be that much fun for the children because he thinks the "Groene Linie" might be boring to them.

5.1.2 Mobile Application

However, the fact that Floor called it an interactive walking tour, does get Tim more curious, but he doesn’t know exactly what this means yet. After he tells Floor that he’d like to know more about the route, she remembers that there was an app available. She decides to download it, so she gets her Android phone out of her pocket, opens the Play Store and searches for “Groene Linie”. The top item in the search results is the app “Groene Linie AR Experience”. She recognizes the name and taps the “download & install” button. After opening the app, she sees the first screen as shown in figure 18. It shows a picture of the Oldenzaalsestraat. Below the image there is some text, informing Tim and Floor that the route would lead them along various Points of Interest along the "Groene Linie" at the Oldenzaalsestraat in Enschede. They should start the route at the first POI and route guidance is available in the app, through another page containing a movable map and GPS guidance.

Figure 18, *Home screen & general information in the mobile application*

After opening the map page and allowing location access for this app through a pop-up requesting permission, they see that it shows a map of Enschede with all Points of Interest drawn on it: a total of 3 red dots at certain spots on the map, as can be seen in figure 19. After going back to the main screen, they also read that the route will take them through the workings of the "Groene Linie" installation through a heavy-rainfall scenario which will be visualized and explained through an overlay on the camera view of the phone and through a voice-over. The picture below shows someone holding up her phone towards the street, with on the phone screen a 3D model of some tubes with water flowing through them, projected into the street view! As this approach seems fun to Tim, he thinks that the children might like it and lets the family decide to try it out.

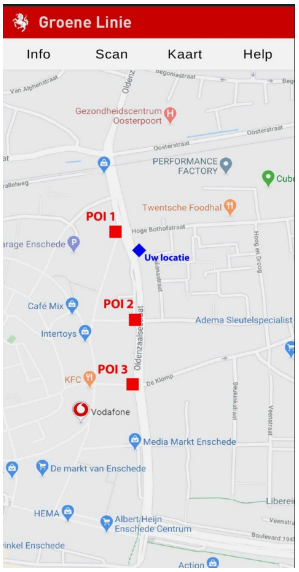

Figure 19, *Oldenzaalsestraat schematic layout with the POIs visible as red dots and the users current location as a blue dot.*

5.1.3 Arriving at the first Point of Interest

As the family arrives at the Oldenzaalsestraat, they don't immediately know where to go. Tim opens the app on his mobile phone as he remembers the map view which showed the Points of Interest. He notices that they just have to cross the street to arrive at the first POI. Tim successfully guides them to the 1st POI "Groene Linie". As they arrive Floor notices the sign which marks the POI, which is similar to the one she had seen at the bus stop before. Tim also recognizes it as there was a picture of it in the app. Tim starts to read the information sign and immediately notices a small section on the top right side. It stands out because of its bright red background color. He reads the caption: "Download the Groene Linie route app for an interactive 3D experience on your mobile phone" and sees a picture of someone holding his mobile phone in the direction of the

Oldenzaalsestraat underneath the text. In the picture, the phone screen is showing the Oldenzaalsestraat from the phone camera perspective, with a 3D model projected in it. Underneath the picture, Tim notices a QR code and two logos: one of the Google Play Store and one of the iOS App Store. He knows that he has already got the “Groene Linie” app installed on his phone, so he decides to open the app to try it out. After he gets the phone out of his pocket, Tim notices a small window popping up on the lock screen of the phone. As the app has detected him being at the first POI through the GPS location sensor, the message asks Tim to open the app to enable the "Groene Linie" 3D Experience.

5.1.4 Using the Augmented Reality functionality

Tim unlocks the phone and opens the app, after which he hands the phone to his son as Tim thinks this is the fun part for the children. After Kevin opens the app, a camera view appears. A small screen pops up on the screen, asking him to point the camera to the blue cross that is placed on the ground next to the information pole. Also, a picture of the cross is shown as a reference. Kevin finds the blue cross next to the pole not hard to find as it has the size of approximately 0.5 by 0.5 meter and is painted clearly on a big grey surface, with a few other red shapes painted around it as can be seen in figure 20. He points the camera at the blue cross, after which the tile suddenly disappears and shows a 3D model of the sewer system and gigantic buffer tube lying underground pop up, as shown in figure 21 below.

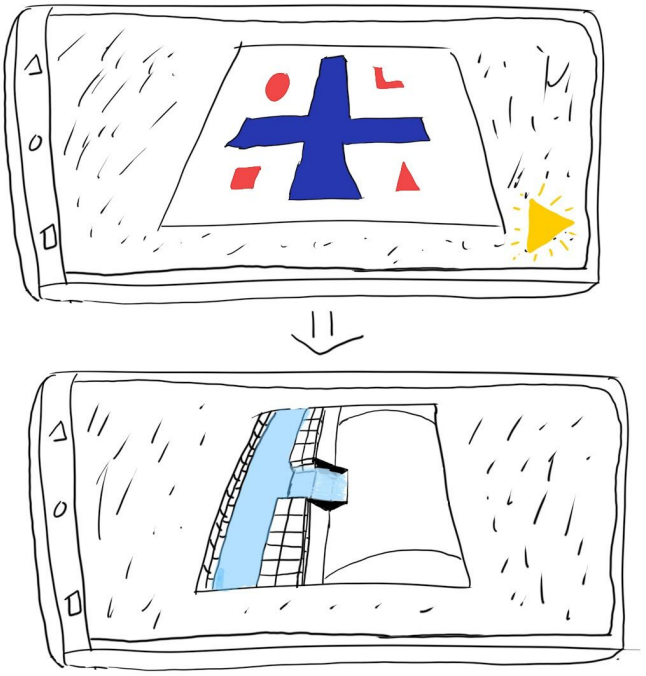

Figure 21, *Concrete anchor next to POI & projection of underground installation*

The application uses the blue cross and the smaller, red shapes painted around it as a marker on the ground after which the vuforia engine in the app projects a 3D animated model of the underground installation into the camera view of the phone as can be seen in figure 22. After a few seconds the app shows a small window on the top of the screen, with a text asking Kevin to walk around the grey surface a bit but to keep the phone pointed at the blue cross. Kevin does so and now notices that he is able to watch the projection from every side!

Figure 22, *Scanning view of the "Groene Linie" application*

5.1.5 Playing the animated 3D model

After a few seconds, a "play" button on the bottom right side of the screen appears. Kevin touches it, after which a voice-over starts playing. His parents join him in watching the model and listen to the voice-over, but Tim complains that he can't hear the voice-over very well because of the traffic noise behind them. Kevin therefore activates the subtitles by clicking a small knob on the bottom right side of the screen, which shows a square with lines in it, as shown in figure 23 below.

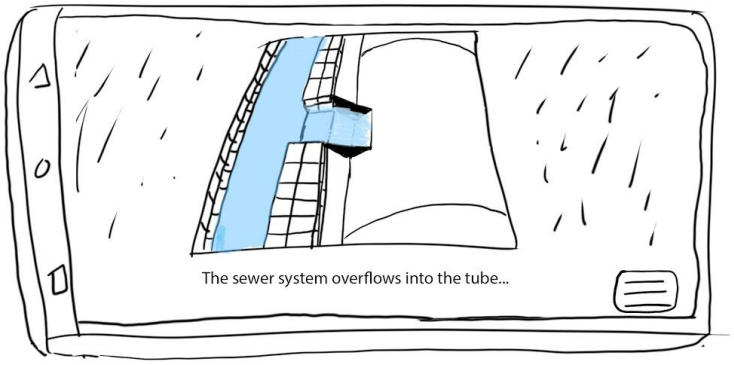

Figure 23, *Subtitles of the voice-over*

The voice-over gives an explanation of the technical workings of the "Groene Linie" installation by showing a heavy-rain scenario: it explains how the installation does its work during heavy rainfall. The explanations of the voice-over are supported by the 3D model: as the voice-over tells about the heavy rainfall causing the sewage system to overflow into the giant rainwater buffer-tube, Kevin notices that the animated 3D model also shows a rising water level, shown by a flowing, blue water filling up the modeled tube.

5.1.6 Navigating to the next POI through app guidance

After the animation finishes, the voice-over tells the family to move to the next POI, where they will be told more about what happens when the rainwater buffer is full. A map opens up as shown in figure 24 below, guiding the family to the next POI nearby one of the wadis. While Kevin guides the family to the next POI, he notices that a blue dot represents their location on the digital map and a red dot represents the location of the next POI.

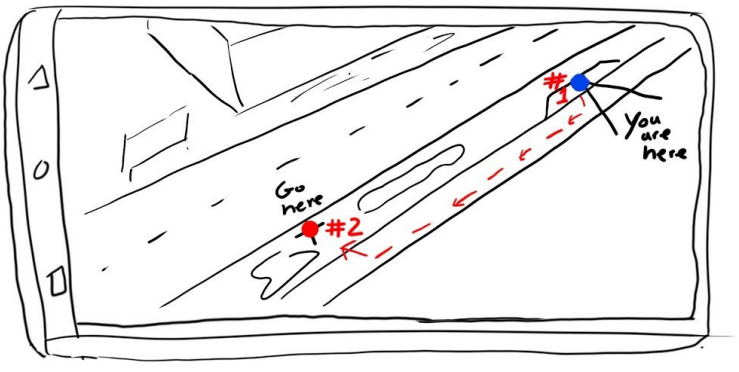

Figure 24, *Map & GPS Guidance*

5.1.7 Arrival at the second POI

Upon arrival at the next POI which is right next to a wadi, he sees another grey surface, quite similar to the one at the first POI. It is located in front of the wadi. Kevin remembers from the first POI that something will happen if he points the phone at the tile again. Indeed, when he unlocks the phone a message pops up, asking him to do so. Kevin points the phone at the tile and sees the same thing happening as at the first POI, but now, the animation is different as the vuforia engine recognizes a different marker. He touches the play-button and a voice-over starts explaining what happens if the rainwater buffer is full: the water in the tube buffer overflows into the wadis. As the voice-over explains it to him, he sees on the phone screen that the water level in the wadi rises and starts to fill up the wadi, as shown in figure 25. After the voice-over ends, a message pops up, informing the family to go to the next POI to continue the tour, after which the map view pops up again, showing the route to the next POI represented as the red dot on the map, in relation to their current location represented as the blue dot. The next POI is near one of the valves controlling the outflow from the buffer to the sewer system. (...)

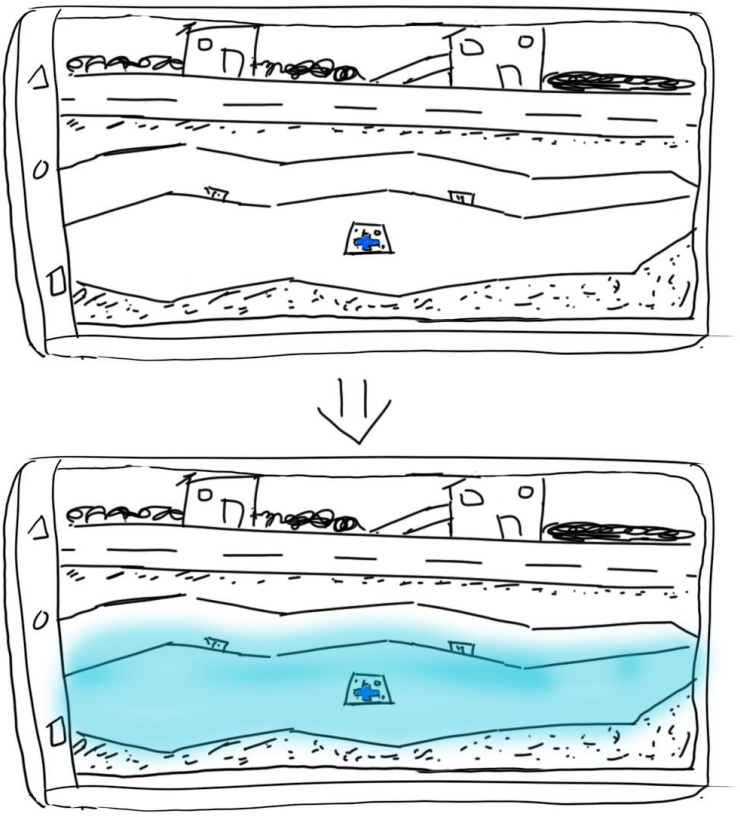

Figure 25, *The water level in the wadi virtually rises*

5.2 Low-Fi Prototype

In order to give the stakeholders a tangible prototype to set their requirements to, a low fidelity prototype has been developed which illustrates the basic use of the mobile application with a focus on the 3D overlay functionality, as can be seen in figure 26.

In order to realize this low-fi prototype, it has been chosen to use the Unity platform (version 2019.2.19f1 on Windows 10) as it has an integration with both Android and iOS Build Support which will prove useful in exporting the mobile application for installation on mobile devices, as well as an integration with the Vuforia Augmented Reality Engine which makes the use of AR within the (Unity-developed) mobile application possible. Next to that, custom made 3D models of the "Groene Linie" are made in the Blender application (version 12.8 on Windows) as Blender allows for easy exporting of 3D models to Unity, for both static and animated 3D objects. These 3D models are used in the Augmented Reality projections.

The app contains four screens:

- General information about the "Groene Linie" route
- Map view which shows the position of the Points of Interest, allowing for navigation
- AR Scanning section
- Help section

Figure 26, *A screenshot of the Low-Fi prototype.*

These sections are manually accessible through a menu, but sometimes the app switches automatically to another screen. This happens when an Augmented Reality animation has finished after which the user is asked to go to the next POI. The app then switches to the map view automatically to show the user where to go next. It also happens when the user arrives at a POI, which will be detected using the

GPS sensor. When this happens, the app automatically switches to the AR Scanning section to nudge the user towards scanning the anchor, available at that location.

5.3 Project Requirements

Must Have		
Requirement	Functional	Non-functional
The "Groene Linie AR Experience" application must visualize the "Groene Linie"	x	
The "Groene Linie AR Experience" application must enrich the reality by using a 3D model overlay on the camera view of a mobile phone	x	
The "Groene Linie AR Experience" application must be able to interact with the user through touch input		x
The "Groene Linie AR Experience" application must be attractive to use through the use of high quality visuals and design while not negatively impacting smooth application performance.		x
The "Groene Linie AR Experience" application must be easy to download and install		x
The "Groene Linie AR Experience" application must be available on Android (release 6.0 and newer)		x
The "Groene Linie AR Experience" application must have a clear menu structure	x	
The "Groene Linie AR Experience" application must provide an explanation about why specific water management projects are executed	x	
The "Groene Linie AR Experience" application must provide an explanation about the general workings of the "Groene Linie" rainwater management project	x	

Any physical objects that need to be placed in order for the "Groene Linie" AR Experience application must be weather-proof		x
The "Groene Linie AR Experience" application must be in line with the GDPR[3]	x	
Any physical object that needs to be placed in order for the "Groene Linie AR Experience" application to work must be usable for people in wheelchairs and therefore not be placed too high.		x
The "Groene Linie AR Experience" application must be usable for persons with hearing problems through a clear and easy subtitle enabling function.		x
The "Groene Linie AR Experience" application must be in line with governmental regulations around accessibility for governmental publications[4]		x
The "Groene Linie AR Experience" application must have any voice-over and/or subtitles available in Dutch		x
Placement of physical objects the public in living environment must be in line with safety and street scene regulations		x

Table 7, *The Must Have requirements, using the MoSCoW method*

[3] General Data Protection Regulation: "the Data Protection Law Enforcement Directive and other rules concerning the protection of personal data" [45]
[4] See "Digitoegankelijk": https://www.digitoegankelijk.nl/onderwerpen/themas/eenvoudige-uitleg

Should Have		
Requirement	Functional	Non-functional
In order to increase the attention span, the "Groene Linie AR Experience" application should provide messages in a positively formulated manner through the use of bright colors		x
The "Groene Linie AR Experience" application should be an addition to the analog information provision about the "Groene Linie" and provide its information through digital channels		x
The "Groene Linie AR Experience" application should inform on multiple levels of information (superficial -> in-depth)	x	
The "Groene Linie AR Experience" application should take the limited span of immediate memory into account		x
The "Groene Linie AR Experience" application should be available on iOS (release 9.0 and newer) mobile operating systems		x
The "Groene Linie AR Experience" application should be usable over at least 3 years		x
The target group should be young families with children between 7-15 years old.		x
The "Groene Linie AR Experience" application should have in-depth information on technical specifications & statistics of the "Groene Linie" Water Management project.		x

Table 8, *The Should Have requirements, using the MoSCoW method*

Won't Have		
Requirement	Functional	Non-functional
The "Groene Linie AR Experience" application is available in multiple languages (Dutch, English, German) due to diverse population and close distance of Enschede to the German border		x
The "Groene Linie AR Experience" will explain details about flora and fauna at the Oldenzaalsestraat		x

Table 9, *The Won't Have requirements, using the MoSCoW method*

5.4 Full storyboard & narration

To specify which details should be shown and explained in which way, a visual storyboard and textual narration script have been developed in collaboration with expert municipality-employees working on the "Groene Linie" project. The storyboard will provide a visual guideline for which 3D overlays should be shown in the envisioned solution, whereas the textual narration script (blue text) located under the corresponding illustrations in this section) will serve as a guideline for the explanatory voice-over and subtitling, which is played while that specific 3D overlay is being shown. The entire storyboard is divided in 3 parts, one part for each POI, as the to-be-explained aspects of the "Groene Linie" differ per POI.

These POIs all have their own physical location on the Oldenzaalsestraat, which users will visit sequentially through in-app route guidance. When the user physically arrives at one of the POIs, he/she is able to start a sequence of animated 3D overlays that is connected to the POI at his/her current location. These sequences provide explanations of the "Groene Linie" installation functionality through several animated 3D overlays on the camera view of the phone, while an explanatory voice-over is being played. Every POI shows a different functionality and therefore different sequence of overlays.

The first POI is situated at "De Heurne" in Enschede, where the app will provide a general explanation of the installation. This location has been chosen as it is near the beginning of the "Groene Linie" installation.

The second POI is situated near “de Wilhelminakerk”, which is the approximate physical location of a well that is connected to the installation, where water flows from the sewer system to the "Groene Linie". At this POI, this exact process will be explained.

The third and final POI is situated at “De Klomp”, where water flows out of the "Groene Linie", back into the sewer system. At this POI, this process will be explained.

The storyline in the envisioned solution has been developed in Dutch as this corresponds to the project “Must Have” requirements in section 5.3.

5.4.1 POI 1 - “De Heurne” - Starting point, general explanation

In this section, the storyboard and voice-over text for the animation sequence shown at the first POI, located near “De Heurne” is presented. At this POI, a general overview and explanation of the “Groene Linie” installation is present. The figures and text are presented in chronological order, similar to how they will be presented in the envisioned solution.

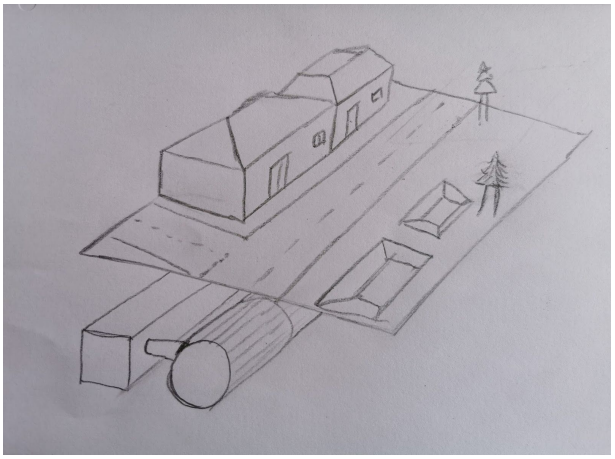

Figure 27, *Simplified overview of the “Groene Linie” installation and its structure underneath the Oldenzaalsestraat*

[Start projection of figure 27*]* Welkom op de Groene Linie. Je staat naast een immens grote regenwaterberging, van wel 700 meter lang! Deze is hier onder de grond gebouwd om er voor te zorgen dat de straten niet overstromen wanneer het veel regent. Zijn je voeten nog droog? Mooi! Laat de nattigheid maar komen, dan zullen we zien of we dat zo kunnen houden.

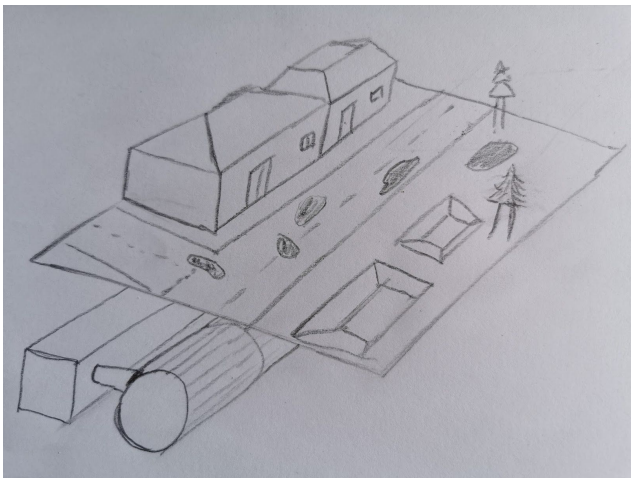

Figure 28, *Simplified overview of the "Groene Linie" installation including rain on the streets.*

[Start projection of figure 28*]* Oh jee, het is een stortbui! Als de straat maar niet overstroomt..

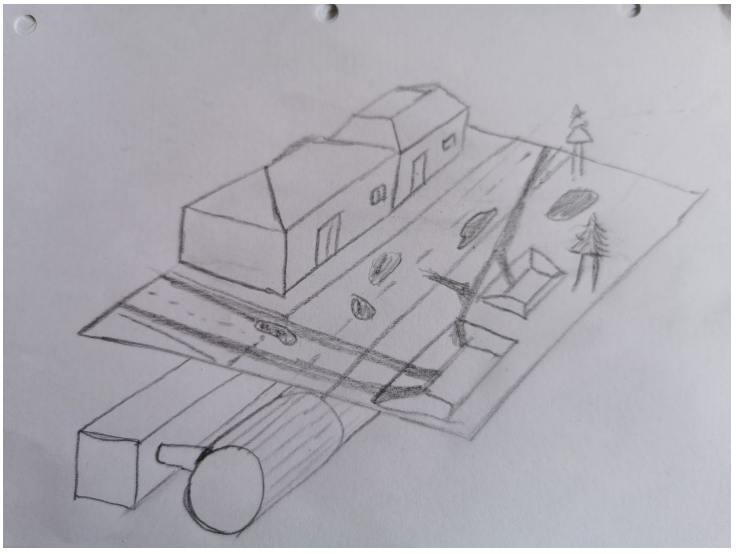

Figure 29, *Simplified overview of the "Groene Linie" installation with rainwater flowing from nearby houses and streets, into the wadi.*

[Start projection of figure 29*]* Omdat de omliggende wijken hoger liggen dan de Oldenzaalsestraat, stroomt het regenwater vanuit die wijken ook hier naar toe! Daardoor kan het riool te vol raken.

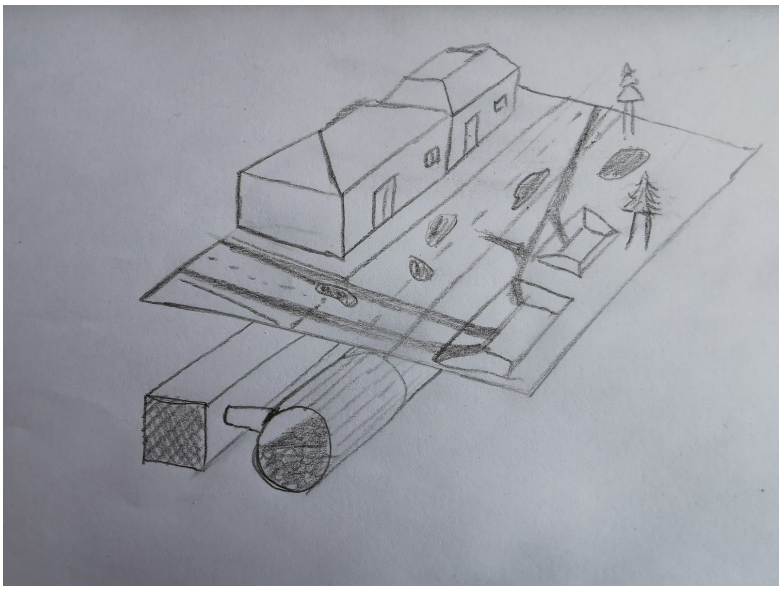

Figure 30, *Simplified overview of the "Groene Linie" installation with rainwater flowing from nearby houses and streets, into the wadi and from there, into the buffering tube.*

[Start projection of figure 30*]* Kijk maar in het bruine riool onder de straat: deze zit helemaal vol met water! Wanneer dat gebeurt, kan hier onder de Oldenzaalsestraat het volle riool overstromen in de ronde, grijze bergingsbuis. Kijk maar, deze stroomt nu vol! Deze buis kan gevuld worden met wel 3.5 miljoen liter water! Dat is hetzelfde als 350.000 emmers of 29.000 badkuipen vol water!

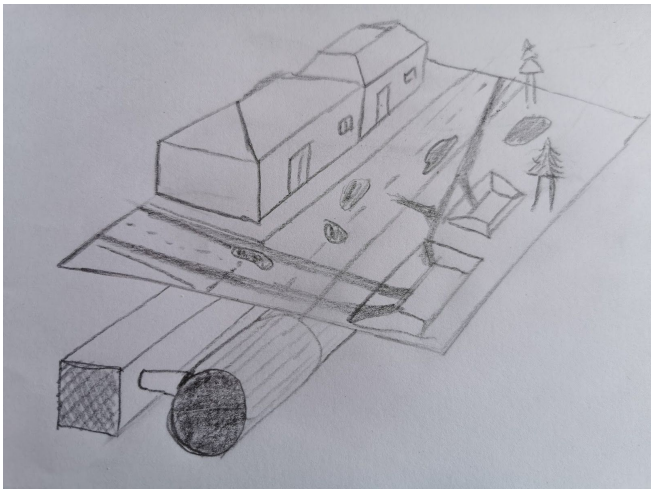

Figure 31, *Simplified overview of the "Groene Linie" installation with rainwater flowing from nearby houses and streets, into the wadi.*

[Start projection of figure 31*]* Ook kan de regen die valt rond de Oldenzaalsestraat via de wadi's in de bergingsbuis stromen. Kijk maar: het water stroomt eerst naar de grote "vijvers" aan de

zijden van de Oldenzaalsestraat. Dat zijn de wadi's. Vanuit die wadi's stroomt het water in de bergingsbuis onder de Oldenzaalsestraat.

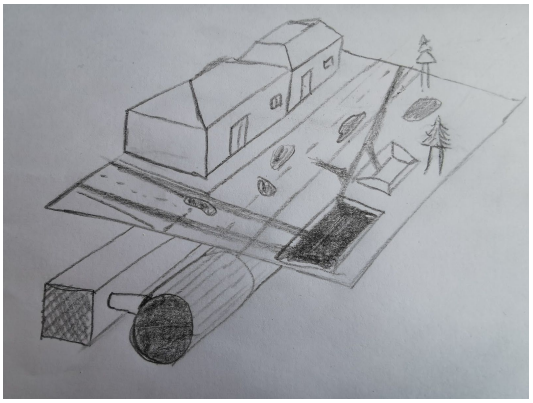

Figure 32, *Simplified overview of the "Groene Linie" installation with rainwater flowing from nearby houses and streets, into the wadi which is filled up.*

[Start projection of figure 32*]* Maar wat als deze buis ook vol raakt? Dan nemen de wadi's de taak van de buis over. Doordat het water niet meer in de buis kan stromen, blijft het water in de wadi's staan. Alle wadi's samen kunnen óók met 3.5 miljoen liter water gevuld worden. Daardoor kunnen we hier in totaal 7 miljoen liter water opslaan. Dat zijn 3 gevulde olympische zwembaden bij elkaar opgeteld!

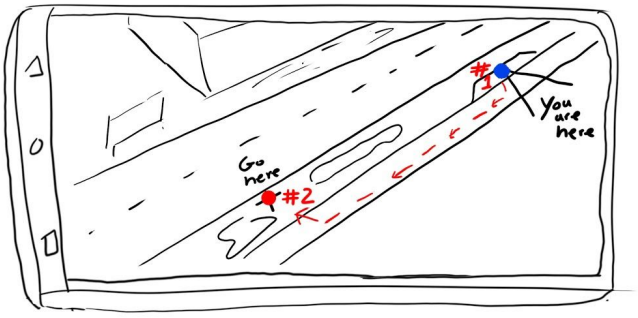

Figure 33, *Map view with the next POI represented as a red dot and the current location of the user, represented as a blue dot*

[Start projection of figure 33*]* Hoe dat allemaal precies werkt, vertel ik je zo. Eerst wil ik je vragen om een stukje verder te lopen naar het volgende informatiepunt, vlakbij de kerk aan de Wilhelminastraat. Kijk op de kaart om te zien waar je het informatiepunt kan vinden. Tot zo!

5.4.2 POI 2 - “Wilhelminakerk” - Overflow well, Wadi

In this section, the storyboard and voice-over text for the animation sequence shown at the second POI, located near “De Wilhelminakerk” is presented. At this POI, the functionality of the overflow well will be explained. The figures and text are presented in chronological order, similar to how they will be presented in the envisioned solution.

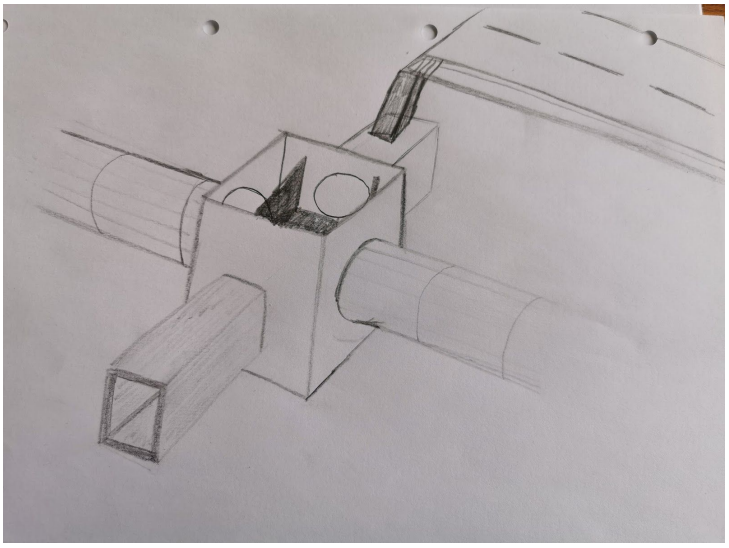

Figure 34, *A projection of the overflow well, where water from the sewer system (square) flows over into the buffer tube (round).*

[Start projection of figure 34*]* Zo, fijn dat je er bent. Ik hoop dat je je paraplu bij je hebt! Doordat het regenwater via de putten langs de straten in het riool stroomt, kan bij zo veel regenval als nu het riool vol raken. En natuurlijk willen we dat niet, omdat de straten dan overstromen! Gelukkig kan de Groene Linie ons helpen om dat te voorkomen.

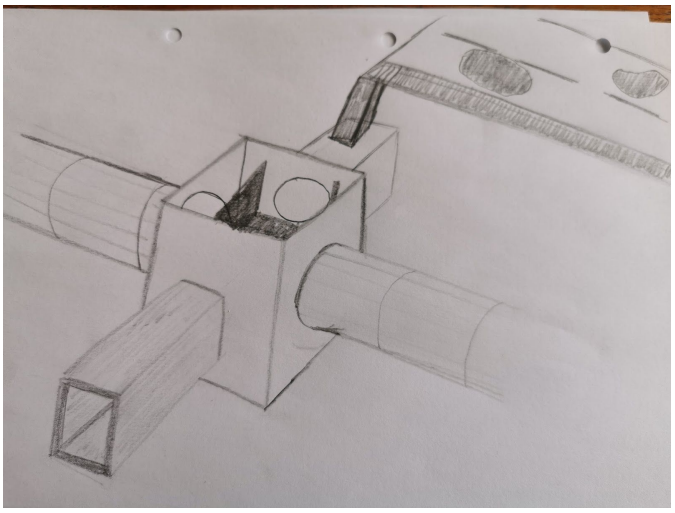

Figure 35, *A projection of the overflow well, with rainwater flowing from the streets into the sewer system (square).*

[Start projection of figure figure 35*]* Het bruine riool is aangesloten op de grote, grijze bergingsbuis, op deze plek onder de Oldenzaalsestraat. Wanneer het riool vol is, loopt het hier in een speciale put over in de bergingsbuis. Dit kan, doordat in deze put het riool aan de bovenzijde is opengemaakt.

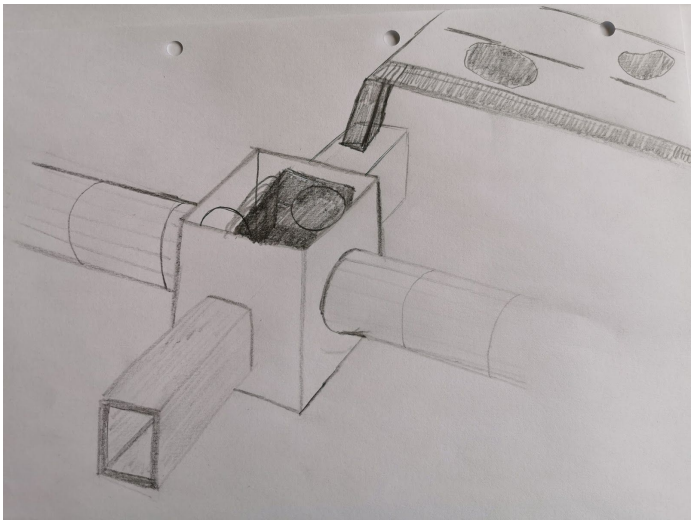

Figure 36, *View of the underground overflow well, showing water flowing over the u-shaped sewer cistern, into the bigger buffering tube.*

[Start projection of figure 36*]* Als het waterniveau in het riool te hoog wordt, kan het door deze opening overstromen in de put, die is aangesloten op de bergingsbuis . Dit zorgt ervoor dat het regenwater op de straat nog steeds weg kan stromen en dus niet voor een overstroming zorgt!

Wist je dat de bergingsbuis wel 2,4 meter breed is? Dat is nog breder dan een personenauto!

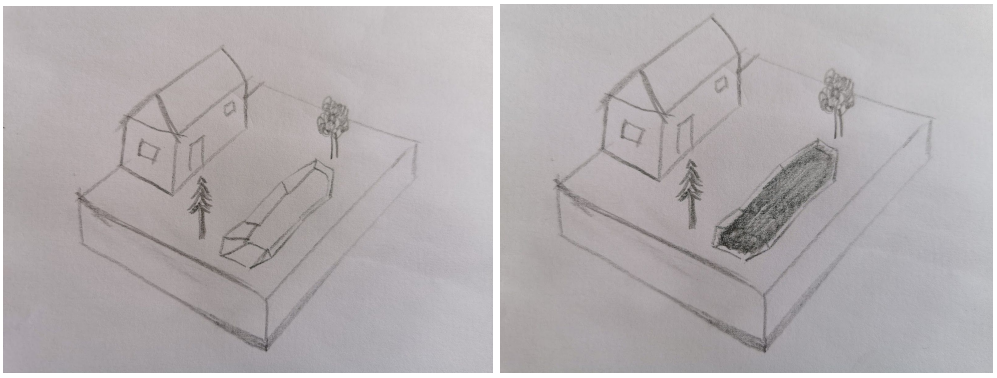

Figure 37, *One of the wadis fills with rainwater.*

[Start projection of figure 37*]* Zoals je al weet, kan de 700 meter lange bergingsbuis ook vol raken. Ook daarvoor hebben we een oplossing! Wanneer dit gebeurt kan het water vanuit de bergingsbuis overstromen in de wadi's. Dit gebeurt, omdat de wadi's hoger liggen dan de bergingsbuis. Kijk maar eens naar deze wadi. Hij stroomt helemaal vol met regenwater!

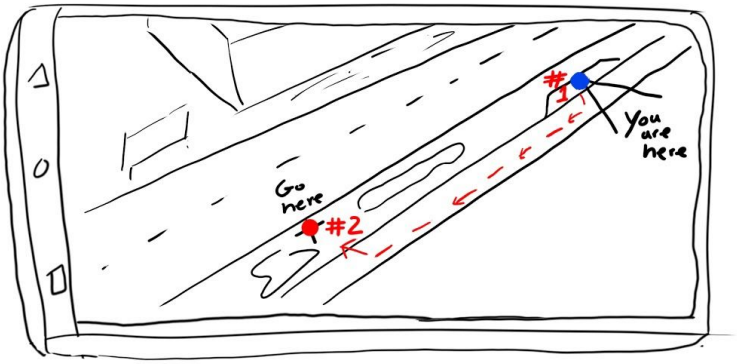

Figure 38, *Map view with the next POI represented as a red dot and the current location of the user, represented as a blue dot*

[Start projection of figure 38*]* Maar wat als de regen stopt? Blijft dan al dat water in de wadi staan? Ik leg het je uit bij het laatste informatiepunt. Zie ik je daar?

5.4.3 POI 3 - “De Klomp” - Outflow well

In this section, the storyboard and voice-over text for the animation sequence shown at the third and last POI, located near “De Klomp” is presented. At this POI, the functionality of the overflow well will be explained. The figures and text are presented in chronological order, similar to how they will be presented in the envisioned solution.

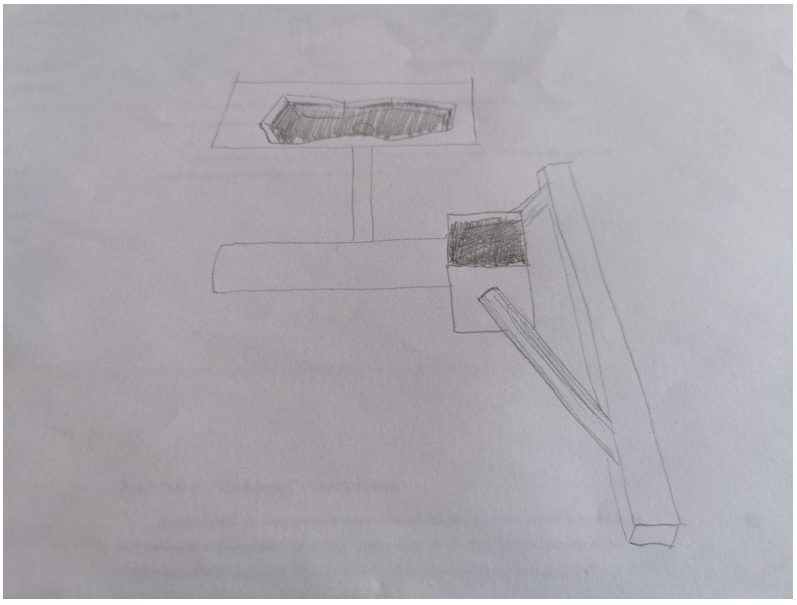

Figure 39, *Simplified view of a filled wadi and buffer tube, the remote-controlled hydraulic outflow well and outflow to the sewer system (square).*

[Start projection of figure 39*]* Hoi, wat leuk om je weer te zien! De regen is gestopt, dus ruim je paraplu maar weer op. Houd ‘m wel bij de hand, want het kan maar zo weer gaan regenen! Hetzelfde geldt voor de Groene Linie: we moeten snel weer klaar zijn om een volgende regenbui op te kunnen vangen. Om dat voor elkaar te krijgen, moeten we natuurlijk de volle wadi's en bergingsbuis weer leeg laten lopen.

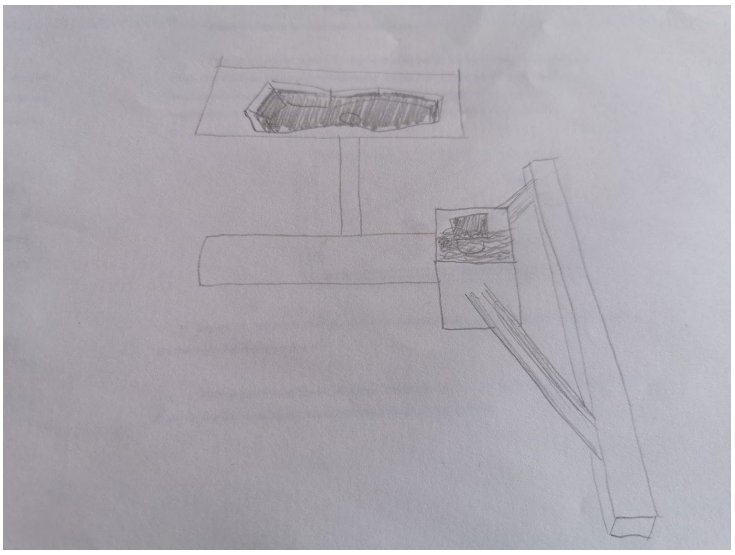

Figure 40, *Simplified view of the remote-controlled hydraulic outflow well, showing opening of the valve resulting in rainwater outflow.*

[Start projection of figure 40*]* Wanneer het riool weer wat meer regenwater kan gaan verwerken, gaan er hier in een speciale put onder de grond een aantal kleppen open. Kijk maar naar de linker binnenzijde van de put!

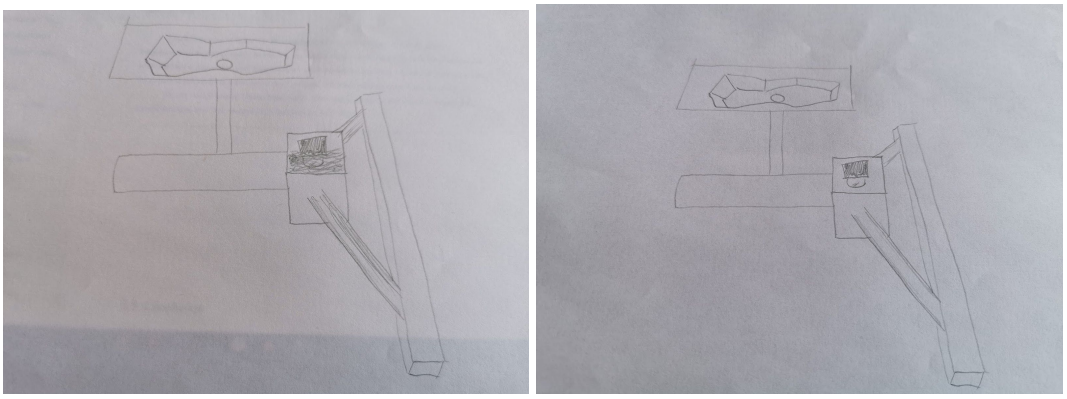

Figure 41, *Simplified view of the remote-controlled hydraulic outflow well, showing sinking rainwater level.*

[Start projection of figure 41*]* Doordat het bruine riool hier lager ligt dan de grijze bergingsbuis en de groene wadi's daarboven, stroomt het water vanuit de wadi's in de bergingsbuis om daarna te verdwijnen in het riool. Kijk maar: als eerst stroomt de wadi leeg, waarna het waterpeil in de bergingsbuis ook daalt! In totaal kan er wel 7 miljoen liter water uit de Groene Linie stromen!

Zo, nu weet je hoe de Groene Linie werkt. Wat vond je ervan? Vertel vooral je vrienden & familie hoe leuk was! Wie weet zie ik je dan nog een keer. Dag!

5.5. Conclusion

In this chapter, the full storyboard and voice-over script have been established, as well as a simple layout for a mobile application, which will serve as the framework capable of playing the 3D animated objects and voice-over.

These components have been designed in line with the project requirements as specified in section 5.3. The specified envisioned solution is successful in digitally visualizing specifications & statistics of the “Groene Linie” and its necessity. This is done through a simplified 3D model Augmented Reality camera overlay of a mobile phone, giving a user the possibility to interact with the application through touch input. However, as the used 3D models should not negatively impact smooth application performance, the quality of the 3D models cannot be too high, as these require more powerful hardware resources which are not available on every mobile phone.

The visual anchor used by the application as proposed in the scenario is suitable for use by people in wheelchairs, as it can be placed on the ground. However, this anchor is not weather-proof as it can be covered by snow or leaves. As currently no physical objects may be placed in the public living environment around the “Groene Linie” yet, an alternative, temporary solution is proposed in section 6.2.1.

The entire storyboard has been developed in Dutch and is written in a positive manner to increase attention span, while taking the target group into account in the writing style. Subtitles are present and can be easily activated in the specified application so that it is usable for people with hearing problems.

Developing this mobile application for recent versions of Android and iOS should allow the app to be used over multiple upcoming years, as well as easy downloading of the app through respectively the Google Play Store and Apple App Store. The menu structure can be very simple as only four pages are required (Info, Camera View, Map & Help).

This specification will serve as the basis for realizing the envisioned solution towards a High Fidelity prototype in the next chapter.

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Chapter 6 - Realization

In this chapter, the envisioned solution as described in the specification chapter will be realized. As the first step, the envisioned solution has been decomposed into smaller aspects: 3D Modeling, 3D Overlay, Voice-Over and Mobile App. These components were then realised one by one, after which an integration of them resulted in a high fidelity prototype.

6.1 Decomposition of envisioned solution

6.1.1 3D modeling

The 3D models will be the basis for the 3D camera overlays: these models will be projected into the camera view of the phone and will show an animation, clarifying the functionality of the “Groene Linie” installation.

6.1.1.1 Required models

As can be seen in section 5.4, the full storyboard has been divided into three POIs. Each POI requires its own 3D model(s). See table 10 on the next page for the required models per POI.

POI 1 - De Heurne	● Simplified system structure overview model ○ Puddles of water on the streets ○ Sewer filling up with water ○ Rainwater flowing from streets to wadi ○ Buffering tube filling up with water ○ Wadi filling up with water
POI 2 - Wilhelminakerk	● Overflow well ○ Water on the streets flowing into the sewer system ○ Water level in U-tube of sewer system rising ○ Water overflowing the U-tube into the well ○ Well and buffering tube filling up ● Wadi filling up with water
POI 3 - De Klomp	● Outflow well ○ Hydraulic valve opening ○ Water level in wadi sinking ○ Water level in buffering tube sinking

Table 10, *Required 3D models per Point of Interest*

6.1.1.2 3D modeling tool

For the development of the 3D models, Blender version 2.82 on Windows 10 [46] has been chosen, as this is an open source 3D modeling software also used in earlier stages of the Creative Technology bachelor studies. At first, the free online version of Trimble Sketchup [47] has been tried as well. The interface is more simple than the Blender interface and exporting 3D models is possible, but Sketchup did not allow for animated models which is a disadvantage. Also, Blender is highly compatible with Unity [48] as it creates 3D models that can be easily imported into Unity, which is the envisioned platform to build the mobile app on. As animations made in Blender can be recognised and made available for playback by the Unity engine, Blender was also used to develop the animations of the models.

6.1.2 Mobile app

In order to make a functioning mobile app, the Unity Platform version 2019.2.19f1 [48] tool has been chosen as this engine has been used in the Creative Technology program as well and allows for easy exporting to Android and iOS app installation packages. Also, app development is relatively easy to perform in Unity, as it provides a drag & drop interface and only requires advanced knowledge about programming when implementing non-standard, advanced features. It also greatly integrates with both Blender, used for the 3D model development as well as the Vuforia engine [48], [49], as described in the next section.

As iOS only allows for Apple App Store approved applications to be installed on mobile phones running iOS, it is not fairly easy to test the mobile app as developed in Unity on this platform. Google's Android does allow for external packages to be installed, so testing the mobile app on this platform is fairly easy. Therefore, focus lies on developing the application for Android users as a must-have requirement, whereas developing the app for iOS platforms is a should-have requirement.

6.1.3 3D Overlay

In order to be able to place a 3D model as an overview over a mobile phone live camera view, a framework is needed. It has been decided to use the Vuforia Augmented Reality tool [49]. Vuforia offers a great integration with the Unity engine, which makes it easier to use Vuforia camera in a mobile application, as Unity allows for relatively easy mobile app development (see section 6.1.2). This integration gives us an easy way to place the 3D overlay into a fully working mobile application framework.

Vuforia, when activated in the mobile app, searches for a pre-defined visual anchor (see section 6.1.3.1 in the camera view of the mobile phone. When it recognises the visual anchor, it places the 3D object in the camera view of the phone, relative to this anchor (see figure 42). This allows that, when the user moves the camera around the anchor, the 3D model can be viewed from each angle, as long as the anchor is still clearly visible and recognizable by Vuforia.

Figure 42, *3D model projected in camera view relative to paper anchor*

It has also been tested to just use the Unity mobile application to show the 3D model, in combination with the user being able to move this model around by touch input, but this gave less of an immersive experience. Also, it did not allow for precise projection of the 3D models relative to a certain anchor (for example, the tile as described in section 5.1), which is required for exact placement of the 3D models in real world space.

6.1.3.1 Visual anchor

One aspect to keep in mind during development of the app using Vuforia is that it needs a pre-defined anchor to place the objects in 3D space. Therefore, it is necessary to place a dedicated, distinguishable anchor at each POI of the "Groene Linie" for the app to recognize which 3D model(s) should be shown. This anchor can be any image or object, as long as it offers enough contrast points for the Vuforia engine to clearly recognize it. The anchors used for the Hi-Fi prototype is described in section 6.2.1.

6.1.4 Voice-over

The voice-over which explains the projected 3D models further, has been developed in cooperation with Mariëlle Schrijver-Booijink, as she works as a copywriter for the Municipality and

has experience with writing texts fitting to the target group. For the prototypes in this bachelor project the voice-over will be done by a student and primarily used as a test to set the timing of the animations and subtitling right, whereas in the final product a professional voice-over artist will be hired to increase the level of professionalism and to be able to choose a voice that is fitting to the target group.

Subtitles will also be available in the app, which can be activated during playback of the animation, as shown in section 5.1. This is necessary, following the project requirements.

6.2 Realisation of components

In this chapter, practical issues during realisation of the various components can be found, as well as how these issues were addressed in this project. The components were realized in an iterative manner, where the client was able to provide feedback throughout development of the components.

6.2.1 Placement of physical anchor at the Oldenzaalsestraat

After discussion with the client, the Municipality of Enschede, it unfortunately is currently not possible to place a physical object dedicated to this solution along the “Groene Linie”. This causes a problem in having a physical object as an anchor in order for the Vuforia engine to work. It might be tried to use physical objects that are already in place as anchors, but these should be clearly recognizable in order to be recognised and understood as an anchor by Vuforia and the user, as well as that these objects should not change over time (growing plants, tile covered by leaves etc.) to remain recognizable. In order to not let this slow down app development, it has been decided that stickers can be temporarily used as anchors. These stickers, one of them displayed in figure 43, can temporarily be placed along the “Groene Linie”, but can also be used in development of the solution. They have been developed in Adobe Illustrator, using the standard Image Target images as provided by Vuforia, with a title and “Gemeente Enschede” logo underneath it.

Figure 43, *Layout of a sticker, used as an anchor to project the 3D models.*

6.2.2 Processing power of mobile phones

It has to be taken into account that high quality 3D models can take quite some processing power and memory to render, especially on older mobile phones. To keep the app usable for a broad audience, high quality visuals and animations can only be used if these do not greatly impact application performance.

Following this requirement, it has been chosen to create and use low-poly 3D models and simple shading, materials & lighting, On top of that, particle systems cannot be used. Therefore, instead of showing raindrops falling down in the first scene, puddles of rainwater appear on the streets in the model.

6.2.3 Mesh textures in Unity

The 3D application Blender allows for easy use of images as mesh textures. This way, advanced texturing is made possible: random components like grass, gravel and tiling become easier to design but mainly, easier to render. This is done through UV unwrapping, which is a technique to place a 2D image (texture) on a 3D object.

However, when importing the 3D models into Unity, these image textures were not recognised by Unity. As a workaround solution has not been found, it has been decided to use a simpler coloring and shading method in development of this prototype.

6.2.4 Plane visibility in Unity

When using planes as meshes in the Blender application, these are visible from both the top and bottom side. However, after importing the 3D models into Unity, the planes were only visible from the top side. This made that, when the user looked at a 3D model from the bottom side, it became (partially) invisible. After research, this problem has been solved through solidifying every plane in the models. This is done in the Blender application through adding a 'solidify' modifier in the modifier panel.

6.2.5. Improving recognizability of the anchor stickers

In an early version of the stickers (see figure 43 for reference), the entire sticker was used as the visual anchor for the Vuforia application. As the bottom part showing the "Gemeente Enschede" logo and green POI title was the same or very similar to the bottom part of the other anchor stickers, sometimes the Vuforia application therefore recognised the images as the anchor of a different POI or even multiple POIs. This resulted in the wrong sequence of 3D models being shown or even multiple sequences of 3D models being shown in the application. This issue has been solved in the final sticker version by only using the top image of the stickers as the anchor for the application. The bottom part showing the "Gemeente Enschede" logo and the POI number + title is still visible to the user.

6.3 Integration of components

In this chapter, practical issues during implementation of the various components can be found, as well as how these issues were addressed in this project.

6.3.1 Animation playback in Unity

The animations of the 3D models have been made and timed in the Blender application. These models had to be imported into Unity to make them visible in the mobile application. Next to that, the animation sequences from the Blender file had to be imported into Unity separately in order to make the 3D models "playable" in the mobile application.

In early iterations this was a problem, as every object property that changed over time in the animation was displayed as a separate animation. This caused Unity to recognize every single movement in an animated 3D model as a separate animation as well. Unity was not able to play these animations at the same time, which caused problems in realistic playback and the timing of the animations.

This has been overcome through changing the process of importing the 3D models from Blender into Unity. The final process consisted out of exporting the 3D models in Blender, not as ".blend"-files, but as ".fbx"-files, while changing the following properties in the "animation settings" section of the export panel:

- Key all bones -> False
- NLA Strips -> False
- All Actions -> False

This caused the entire animation to export as only one sequence, which could easily be imported and played in the Unity application and therefore, functioned well in the mobile application as well.

6.3.2 Animation synchronization

Another problem regarding the animations was that Unity by default played the animations at the highest achievable framerate. Therefore, the speed of the animations changed over time and device: on mobile phones with less processing power the animations were played slower than on mobile phones with more processing power.

The main problem with this was that this caused an out-of-sync voice-over: what was explained in the voice-over did not match what was viewed in the 3D models anymore. This was solved by setting a fixed animation frame rate in the Unity application, to 24 frames per second. Then, this same frame rate had to be used in the Blender application in setting the timing of the animations. This resulted in a reliable, corresponding playback rate to which the voice-overs could be easily timed as well.

6.3.3 Vuforia C++ scripts resetting

A few functions regarding the visibility of objects in the mobile application (such as the aim-camera overlay or "play animation"-buttons), determined by whether and which anchor was recognised by the Vuforia engine, had to be programmed into the scripts of the Vuforia engine. However, every time the Unity Developer environment was restarted, these scripts were reset to their original versions. This problem has not been overcome, but practically solved through saving a copy of the edited scripts and reloading that script every time the Unity environment has restarted.

In a later update of the Vuforia engine (v9.0), the abovementioned functionality became basic functionality of the Vuforia app inside Unity, so the programming and self-created scripts became obsolete.

6.4 Simplification

In an early stage of the project, the goal was to show the “Groene Linie” installation as realistically as possible. During further development of the storyboard, it has been decided to simplify some of the aspects, of which the outflow well is one of these aspects. The structure of this well is quite complex as can be seen in figure 44, whereas a simplified view (see figure 45) would still provide a clear explanation of the function of that well to the general public.

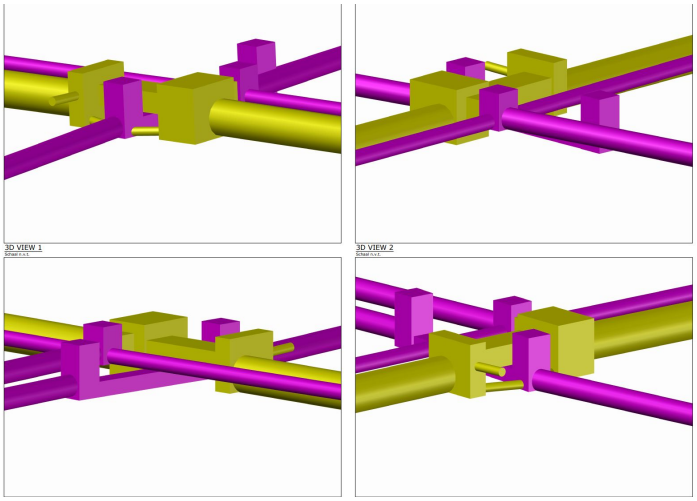

Figure 44, *Complex 3D view of the outflow well. Source: Municipality of Enschede*

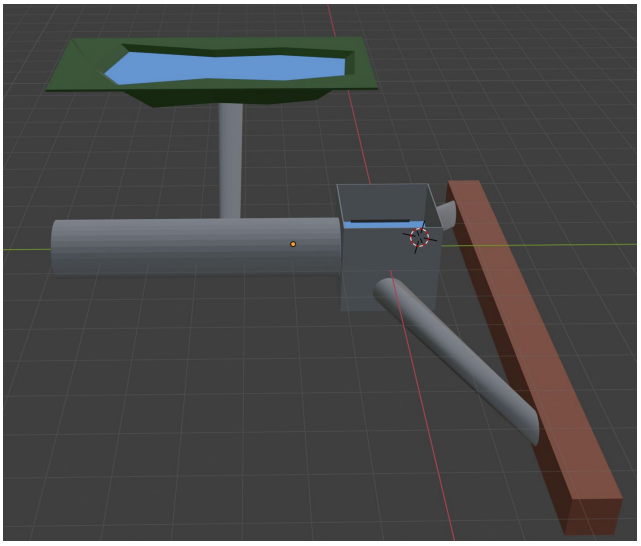

Figure 45, *Simplified model of the outflow well*

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Chapter 7 - Evaluation

In this chapter, the high fidelity prototype as it has been specified and realised in the previous chapters will be evaluated against the requirements as set in section 5.3. The goal is to evaluate whether the final prototype was a success, together with the Municipality of Enschede as the client in this project. Also, general feedback and input for further development towards an end product will be provided.

The goal of the Municipality of Enschede is to increase public awareness of the “Groene Linie” installation through emphasizing the importance and necessity of such large infrastructure projects, by explaining their inner workings and technical specifications. As the results of the street interviews show (see section 4.1), there is some interest amongst visitors and inhabitants in contextual information and technical specifications about large infrastructure projects. This overlap between the Municipality’s and inhabitants’s interests caused a focus shift towards developing a solution that shows the inner workings and technical specifications of the “Groene Linie” installation. In order to develop a Hi-Fi prototype that is technically accurate to the real-life situation, technical insights and knowledge about the “Groene Linie” installation were very much needed. This process required collaboration with Koen Wagelaar, City Engineer at the Municipality of Enschede, as he was able to provide detailed information and technical drawings of the “Groene Linie” installation.

As a result of the direction the development took towards a technically accurate prototype, the evaluation focuses on the technical accuracy of the content as shown in the prototype. Due to constraints imposed by COVID-19, evaluation with the visitors and residents was not feasible anymore.

7.1 Evaluation setup

The evaluation took place together with the client, the Municipality of Enschede. As the Municipality of Enschede involved various people in this project, each with their own profession, the evaluation has been performed through three semi-structured interviews which match the professions of the stakeholders. See table 11 for an overview of all involved stakeholders from within the Municipality of Enschede, their professions and focus of the matching evaluation.

Stakeholder	Profession	Evaluation focus
Annemiek van den Heuvel	Project manager	Visual quality & coherence
Koen Wagelaar	City Engineer	Technical accuracy
Mariëlle Schrijver	Marketing expert	Voice-over & texts

Table 11, *Stakeholders within the Municipality of Enschede*

Before evaluation, a video showing the full functionality of the Hi-Fi prototype was prepared. This video was sent to all stakeholders as mentioned in table 11. Afterwards, each evaluation was performed through individual phone calls, each of them following a semi-structured interview approach. This semi-structured interview approach, as mentioned in section 3.5.1 and 3.8, provided the possibility for each client to first provide open feedback, of which the results can be found in section 7.2. Afterwards, the interviewer asked for specific questions related to the profession of the stakeholder, in order to increase focus on details relevant to the profession of that specific stakeholder.

7.2 General feedback

In this section, general feedback that is not specifically related to any project requirement will be presented, as well as profession-related feedback. The feedback has been divided in two sections, describing respectively the positive feedback points and to-be-improved feedback points.

7.2.1 Positive feedback

1. Generally, the Hi-Fi prototype was perceived very positively: the Municipality of Enschede would love to see a further developed implementation of this concept later this year.
2. The prototype successfully translates a highly technical process to a storyline that is comprehensible for a wide public.
3. The Municipality of Enschede sees potential for the “Groene Linie” application to be developed towards an application that also includes other rainwater management projects in Enschede, similar to the full “Twentse Waterroute” concept (see Appendix C). As the Municipality of Enschede wishes to increase exposure for all water management projects that are being/have been executed in Enschede, the “Twentse Waterroute” solution shows potential. Also, there already is a biking route available along water-related points of interest in Enschede, which could be implemented in this concept.

4. The model in its current, simplified and easy-to-understand form is still accurate to the real world situation.
5. The voice-over is written and performed very positively.
6. The brown color of the sewer system and the grey color of the buffer tube are perceived as accurate.

7.2.2 To Be Improved

1. The Municipality of Enschede would like to see an implementation of the biodiversity-aspect of the "Groene Linie" in the application.
2. The Municipality of Enschede would like to have some text or voice-over at the end of the current storyline, describing the future perspective of the "Groene Linie". The goal is to change wastewater treatment in Enschede from the currently implemented all mixed sewer system to a distinction between a wastewater sewer and clean rainwater sewer system.
3. In communication from the Municipality of Enschede towards the citizens, the term “Groene Linie” has been replaced to “Groene, droge en mooie Oldenzaalsestraat” or “waterberging”. This should be changed in the voice over.
4. Although the "Groene Linie" installation can handle a lot of rainfall, it is not guaranteed that the streets won’t flood anymore. Therefore, the voice-over should be describing the situation in terms of “Wij pakken de wateroverlast aan (we tackle water management problems)” or “De kans op wateroverlast veel kleiner maken” (lowering the chance of flooding).
5. The visualization of houses along the Oldenzaalsestraat is not corresponding to the real-life situation.
6. The voice-over should not describe the WADI’s (Dutch: Water Afvoer Drainage Infiltratie) as “vijvers" (EN: ponds). Instead, “verdiepte groenstroken langs de Oldenzaalsestraat” (EN: Deepened green strips along the Oldenzaalsestraat) could be used.
7. In reality, the sewer system is round instead of square.

7.3 Requirements evaluation

After the stakeholder evaluation, the project requirements as set in section 5.3 were evaluated and categorized by the designer as follows:

- *Requirement fully met*
- *Requirement partially met*
- *Requirement not met*

The results of this categorization can be found in table 12 and table 13 below. Where needed, argumentation is provided as blue, italic text underneath the corresponding requirement.

Must Have			
Requirement	Fully met	Partially met	Not met
The "Groene Linie AR Experience" application must visualize the "Groene Linie"	X		
The "Groene Linie AR Experience" application must enrich the reality by using a 3D model overlay on the camera view of a mobile phone	X		
The "Groene Linie AR Experience" application must be able to interact with the user through touch input	X		
The "Groene Linie AR Experience" application must be attractive to use through the use of high quality visuals and design while not negatively impacting smooth performance. *The "Groene Linie AR Experience" in its current form does take design principles as mentioned in section 2.2 into account, but due to rendering limitations, the 3D models used in the product are low-poly, lower quality design. This is to make sure that the app performs smoothly, also on older mobile devices, as a smooth experience was deemed more important than high quality visuals.*		X	
The "Groene Linie AR Experience" application must be easy to download and install		X	

The final version of the app can be easily exported as app packages that can be uploaded to both the Google Play Store and Apple App Store, through which downloading and installing the app is made very easy for end users. The prototypes were not installable through both app stores yet, as they would first have to be verified by Google and Apple.			
The "Groene Linie AR Experience" application must be available on Android (release 6.0 and newer) *The "Groene Linie AR Experience" app in its current form is executable on Android releases 4.4 (KitKat) and higher.*	X		
The "Groene Linie AR Experience" application must have a clear menu structure	X		
The "Groene Linie AR Experience" application must provide an explanation about why specific water management projects are executed	X		
The "Groene Linie AR Experience" application must provide an explanation about the general workings of the "Groene Linie" rainwater management project	X		
Any physical objects that need to be placed in order for the "Groene Linie AR Experience" application must be weather-proof *Because of reasons as explained in section 6.1.2, in the current project stage, no physical objects can be placed at the Oldenzaalsestraat.*			X
The "Groene Linie AR Experience" application must be in line with the GDPR[5] *The GDPR should consistently be taken into account in further development towards a final product version of the application. In the Hi-Fi prototype, it has been tried to prevent data gathering as*			X

[5] General Data Protection Regulation: "the Data Protection Law Enforcement Directive and other rules concerning the protection of personal data" [45]

much as possible (f.e., no e-mail address requested), but it has not been proven that the Hi-Fi prototype is fully in line with the GDPR.			
Any physical object that needs to be placed in order for the "Groene Linie AR Experience" application to work must be usable for people in wheelchairs and therefore not be placed too high. *Because of reasons as explained in section 6.1.2, at the moment, no physical objects can be placed at the Oldenzaalsestraat. However, temporary stickers can be used as a hybrid solution, so that the application can still function well. These stickers can be placed anywhere, so in the application's current form, this requirement can still be taken into account.*		X	
The "Groene Linie AR Experience" application must be usable for persons with hearing problems through a clear and easy subtitle enabling function. *Sample subtitling has been implemented in the prototype, but is not coherent to the actual voice-over text yet.*		X	
The "Groene Linie AR Experience" application must be in line with governmental regulations around accessibility for governmental publications[6] *Just like the GDPR, for prototype versions of the "Groene Linie AR Experience" application it was not necessary yet for it to be in line with the governmental regulations, but it should be taken into account in the final product version of the application.*		X	
The "Groene Linie AR Experience" application must have any voice-over and/or subtitles available in Dutch	X		
Placement of physical objects the public in living environment must be in line with safety and street scene regulations *No physical objects have to be placed at the Oldenzaalsestraat in order for the prototype to function well. The temporary stickers as mentioned in section 6.2.1 are seen as an exception.*	X		

Table 12, *Evaluation of the Must Have requirements*

[6] See "Digitoegankelijk": https://www.digitoegankelijk.nl/onderwerpen/themas/eenvoudige-uitleg

Should Have			
Requirement	Fully met	Partially met	Not met
In order to increase the attention span, the "Groene Linie AR Experience" application should provide messages in a positively formulated manner through the use of bright colors	X		
The "Groene Linie AR Experience" application should be an addition to the analog information provision about the "Groene Linie" and provide its information through digital channels	X		
The "Groene Linie AR Experience" application should inform on multiple levels of information (superficial -> in-depth) *The provided information does include some detailed information, but in its current form, the "Groene Linie AR Experience" Application does not allow the user to opt-in for in-depth information yet.*		X	
The "Groene Linie AR Experience" application should take the limited span of immediate memory into account *Repetition of information is present in the prototype. Also, the information density has been kept low.*	X		
The "Groene Linie AR Experience" application should be available on iOS (release 9.0 and newer) mobile operating systems *Unity allows for exporting the application to Apple platforms, but this has not been tested thoroughly.*		X	
The "Groene Linie AR Experience" application should be usable over at least 3 years	X		
The target group should be young families with children between 7-15 years old.	X		

The "Groene Linie AR Experience" application should have in-depth information on technical specifications & statistics of the "Groene Linie" Water Management project. *The provided information does include some detailed information, but in its current form, the "Groene Linie AR Experience" Application does not allow the user to opt-in for in-depth information yet.*		X	

Table 13, *Evaluation of the Should Have requirements*

7.4 Conclusion

In this chapter, the technical accuracy, visual contents, texts and voice-over of the Hi-Fi prototype, as well as the project requirements as set in section 5.3 have been evaluated together with multiple stakeholders from within the Municipality of Enschede. Also, general feedback provided by these stakeholders has been included which generally showed a very positive attitude towards the app contents and technical accuracy, accompanied by a number of improvement suggestions, mainly focused on the voice-over and 3D models. The requirements evaluation by the designer showed that not all requirements have been met, as described in section 7.3, although these requirements can be taken into account in further development of a final product. In general, the Municipality of Enschede was very satisfied with the Hi-Fi prototype as it has been presented. The client sees a lot of potential to develop the application towards a final product.

Chapter 8 - Conclusion

This chapter will provide a conclusion on whether the project goals have been achieved and whether the research questions as stated in section 1.3 can be answered. Also, some recommendations for future work will be provided in section 8.2.

8.1 Conclusion

The goal of this project was to create a solution that could increase public awareness around the "Groene Linie" project in Enschede, the Netherlands. The Municipality of Enschede wanted that the part of this state of the art rainwater buffering installation that was built underground would remain “visible” after the construction works would be finished. Finally, as previously used awareness raising methods were not measured, it was a requirement that the envisioned solution of this project would have a measurable positive effect on public awareness. This given, the following research question and subquestions were stated:

RQ1: What is the most effective way to raise public awareness amongst inhabitants of Enschede about realized large scale rainwater management projects?

Sub RQ1: What are the principles in raising awareness to create a higher level of interest?

Sub RQ2: How to measure the effect of applied principles?

The solution provided in this project was a mobile application which informed its user about the necessity of the "Groene Linie" installation and its inner workings, at three Points of Interest along the Oldenzaalsestraat in Enschede. Through a camera view overlay, animated 3D models of the underground parts of the installation become visible to the application user. These models are projected into the camera view of the user’s phone, along with a (subtitled) voice-over which explains what is shown in the 3D models.

This solution was chosen because it overlaps the wishes of the Municipality and the inhabitants’s interests as presented in chapter 7. This approach was chosen as it would make sure that the solution would fit the needs of the visitors & residents as a stakeholder as researched through several interviews sessions as described in chapter 4, as well as the wish of the Municipality of Enschede as a stakeholder, wishing to emphasize the importance and necessity of such large

infrastructure projects through explaining their inner workings and technical specifications. As can be seen in the requirements evaluation, final development of the application is also done while taking principles of effective communication and visual design influences as described in chapter 2 into account,which contributes to the solution being as effective as possible in the project context.

In order to develop this solution in such a way that its contents are technically accurate to the real-life situation, this process required close collaboration with the Municipality of Enschede in development of the storyline, storyboard and final prototype and therefore caused a focus shift in the time scope of this project towards developing a technically accurate prototype. Due to constraints imposed by COVID-19, evaluation with the visitors and residents was eventually not feasible anymore. For the same reason, a hands-on evaluation together with the Municipality of Enschede was also not possible anymore. Therefore, the Hi-Fi prototype has been evaluated digitally together with multiple representatives of the Municipality of Enschede, each through a semi-structured interview focused on gathering general feedback and impressions, as well as details about Hi-Fi prototype aspects that were in overlap with the profession of the individual representatives. This evaluation resulted in a very positive response on the Hi-Fi prototype. Although some improvements, mainly focused on the voice-over text and some small adaptations in the 3D models have to be made as can be found in section 7.2.2, the Municipality of Enschede has a very positive attitude towards the technical accuracy of the final prototype, as well as towards the way in which it translates the highly technical inner workings of the “Groene Linie” installation to a storyline that is comprehensible for a wide audience. The requirements evaluation by the designer (section 7.3) showed that not all requirements as set in section 5.3 have been met, although these requirements can be taken into account in further development of a final product. To conclude, the client sees the Hi-Fi prototype as very successful and wishes to further develop it into a final product.

8.2 Recommendations & Future Work

The Municipality of Enschede has a very positive attitude towards further development of the prototype, but in order to develop the prototype further into a publicly available end product, some further considerations have to be made, based on aspects mentioned in the evaluation of this project, as can be found in chapter 7.

As described in the introduction of chapter 7, due to constraints imposed by COVID-19 and a shifted project focus, visitors & residents were not included in the evaluation of the Hi-Fi prototype. However, they have been classified as an important stakeholder in section 4.1. Therefore, to make sure that the solution is also fitting to their needs, further user testing needs to be performed.

In order to fit the end solution into current communication of the Municipality of Enschede towards the citizens of Enschede, some of the voice-over text has to be adapted. Suggestions for these adaptations can be found in section 7.2.2.3 through 7.3.3.6.

Also, a substitute for the temporary sticker anchors should be found, which should be in line with usability and accessibility regulations, as well as street scene regulations as set by the Dutch government.[7] Next to that, the application should also be tested and made available on iOS platforms.

The 3D modeling and animations were considered simplified but correct towards the actual "Groene Linie" installation workings, but to increase accuracy even further, the 3D modeling of the sewer system could be changed in line with section 7.2.2.7. To increase the quality of user experience, the location of these projected 3D models could be matched with their actual location at the Oldenzaalsestraat, as this is not yet the case in the final prototype of this project.

Further extension of the product could involve an option for more in-depth information provision, as well as an implementation of the biodiversity-aspect and/or the future perspective of the "Groene Linie" (see section 7.2.2.1 and 7.2.2.2). Also, the product could be extended based on the full Twentse Waterroute concept (see Appendix B), which would mean including other water management projects in/around Enschede into the application.

[7] See “Digitoegankelijk”: https://www.digitoegankelijk.nl/onderwerpen/themas/eenvoudige-uitleg

Appendices

Appendix A - Street Interview outline

1. Woont u binnen een straal van 500 meter van de Oldenzaalsestraat, in Enschede, of daarbuiten?
    - Hoe vaak komt u in de Oldenzaalsestraat?
    - Ondervindt u hinder van de werkzaamheden op de Oldenzaalsestraat?
        - Geen - Matig - Gemiddeld - Veel - Zeer veel
    - Hoe kunnen we deze overlast voor u verminderen?

2. Krijgt u voldoende informatie aangereikt over het project "Groene Linie"?
    - Zo ja, via welk kanaal?
    - Heeft u een voorkeur voor een van deze kanalen?
    - Bent u tevreden over deze informatie?
        - Hoe kunnen we dit verbeteren?

3. Zoekt u zelf naar meer informatie over werkzaamheden die uitgevoerd worden in Enschede?
    - Zo ja, via welk kanaal?
    - Bent u tevreden over deze informatie?
        - Hoe kunnen we dit verbeteren?

4. Op een schaal van 1 - 5 waarbij 1 = niet geïnteresseerd, 5 = zeer geïnteresseerd, in hoeverre zou u geïnteresseerd zijn in informatie over het project "Groene Linie"?

    - Algemene informatie (wat gebeurt hier?)
    - Contextueel (waarom wordt dit project uitgevoerd?)
    - Positieve en negatieve invloeden op u en uw omgeving
    - Technische informatie
    - Bouwproces
    - Anders?

5. Op een schaal van 1 - 5 waarbij 1 = niet geïnteresseerd, 5 = zeer geïnteresseerd, hoe zou u geïnformeerd willen worden?

- Facebook
- Instagram
- LinkedIn
- Video
- Augmented Reality
- Virtual Reality
- DIY-projecten
- Kunst
- Anders?

Op de volgende demografische vragen is het niet verplicht een antwoord te geven.

6. In welke leeftijdscategorie valt u?
   15-20, 20-25, 25-30, 30-40, 40-50, 50-60, 60-65, 65+

7. Mag ik uw geslacht noteren?

8. Gaat u ermee akkoord dat ik uw antwoorden gebruik in mijn onderzoek?

Appendix B - Revised Concept - Interactive water management route

To increase awareness of water management projects in general, an interactive water management route throughout Enschede will be set up, which leads the visitor along several water management projects throughout Enschede. This route is due to its length, preferably done by bike. It is marked by poles along the route, but the user can also find the route in a dedicated mobile application. This application also contains supporting functions which can be used while the user is on route.

Every Point Of Interest along the route (every water management project) is marked by an Information-point pole . This pole contains an information board on which the user can find general information about the installation: what is it, what does it do and why is it here?

To add interactivity and a deeper level of information, some additions will be done to these general information boards. Here, the mobile application comes to use. Possible uses are:

- At suitable locations the user is able to view a 360 degree video of buildings/inner workings of an installation which are not generally accessible to the public. The user can move his mobile phone in order to look around in the video. A tour guide or voice-over might explain more about the contents of the installation/building. The video can also be interactive to suit multiple information needs; would the user for example like to know more about technical details, statistics or context?
- At specific locations, a big part of the installation is built underground, which makes it invisible to the visitors. To overcome this issue and to be able to explain the installation better, the user can use his mobile phone to view a 3d model of the underground installation in his direct surroundings, by pointing the camera of the mobile phone towards the ground at that specific location.
- At locations where functional explanation can be supported by a visual element, the user can use the app to scan a marker on the information board, after which the user sees a 3d model on his phone screen in his current surroundings (AR projection). The user is able to look at the model from different angles by turning his phone in another direction. It can be an animated/narrated functioning model of the installation to show detailed working of the installation.
- Using the app, the user can scan a QR code after which a narrative video or animation is shown on the phone screen. The video is user controllable: at certain parts in the video, the user can select on which topic he/she would like to receive more information. Depending on that choice, the storyline continues.

At locations where there are still construction works going on or future construction works have been planned, the POI consists of a digital screen instead of a physical board. It shows a timeline, containing pictures and information about the project in different stages, from the description of the problem, to the end solution as it is planned. There will also be a section which addresses possible disturbance or detours caused by the construction works, with an option to add this information to one's agenda through a calendar invite link. In order to do this, the user has to enter his email address.

Appendix C - Concept Scenario - Twentse Waterroute (Full version)

On a Friday evening, after work, Floor (39) is waiting for the bus home at the Oldenzaalsestraat in Enschede. Normally she does her commute by bike as she lives just in the northern part of Enschede, but it was raining this morning. Floor is in a good mood since the rain has gone away and the weekend has arrived in which she can spend time with her husband Tim (41) and her two children Kevin (13) and Rose (15).

As the bus is delayed, she has some time to kill. Next to the bus stop, in between the sidewalk and bicycle path, she notices a pole of about two meters high with a light box in the shape of two blue waves on top. On the pole, there is a rectangular sign with some text and illustrations on it. She has already seen it before during her commutes, but her curiosity never reached the point at which she bothered to stop to read it.

As she now has time to spare during the waiting, she takes a minute to read the sign out of curiosity. The sign gives information about the “Groene Linie” water management project which she already has heard of before but doesn't know the details of. At the top part of the sign, she reads that this sign is marking a Point Of Interest along an interactive water management cycling route in Enschede and that there's a mobile app available through the Apple App Store and Google Play store, which is called “Twentse Waterroute”. She doesn't install the app on her phone right now, as the bus will arrive shortly.

The following Saturday morning the weather is nice and due to her good mood, Floor decides that she wants to do something active and outdoors, together with her husband and children. While discussing what they want to do, Floor remembers the sign she saw yesterday near the bus stop at the Oldenzaalsestraat. She immediately tells Tim about it, but while a cycling tour sounds like a good idea to him, he isn't convinced that it would be that much fun for the children because he thinks that they are not interested in the information about the water management projects in Enschede.

However, the fact that Floor called it an interactive cycling tour, does get Tim more curious, but he doesn’t know exactly what this means yet. After he tells Floor that he’d like to know more about the route, she remembers that there was an app available. She decides to download it, so she gets her Android phone out of her pocket, opens the Play Store and searches for “fietstocht Twente water”. The top item in the search results is the app “Twentse Waterroute”. She recognizes the name and taps the “download & install” button. After opening the app, the first screen she sees shows a map of Enschede with a route drawn on it, containing a total of 26 blue dots at certain spots on the route. Below the image there is some text, informing Tim and Floor that the route would lead them along various water management projects in Enschede marked on the map by these blue dots, called Points of Interest (POIs). They can start the route at any POI and route guidance is available in the app,

through another page containing a movable map and GPS guidance. They also read that at every water management project there is an information point with some interactive aspect, like interactive data physicalizations, Augmented Reality or 360 degree videos, which lets them think that the children might like it and lets them decide to try it out for a few POIs.

As they can start the route at any point, Floor, Tim and their children arrive at the 3rd POI which is closest to their home. Floor recognizes the sign indicating the POI, which is similar to the one she has seen near the bus stop at the Oldenzaalsestraat. Tim also recognizes it as he has seen a picture of it in the Twentse Waterroute app. They stop at the pole and read the sign which contains general information about the what's and the why's of the water treatment plant Roombeek, which is the water management project at that location. Floor notices an image on the sign captioned "360 degree experience - scan me using the Twentse Waterroute app". She opens the app on her phone, opens the menu by tapping the red icon with three white horizontal bars underneath each other on the top left of the screen. The menu shows three options: Home, Route and Scan. She taps "scan", after which the menu closes and a screen appears which immediately opens the camera view. She points the camera at the image on the sign. After she does so, a screen pops up in the app in which a video starts playing. She notices that the video starts on the location where she is standing right now. It shows a tour guide on the screen who explains that he will give the viewers a virtual tour through the building next to them, which is normally closed to the general public. Tim starts watching the video with her, but complains that he can't hear the tour guide very well because of the traffic noise behind them. Floor therefore activates the subtitles by clicking a small knob on the right bottom side of the video player, which shows a square with dots and lines on the bottom of it. The tour guide then takes them into the building and once they are in, he tells them to move the phone around a bit. Tim and Floor notice that when the phone is moved in a certain direction, the video turns with them, showing the 360 degree environment of the "water house" they just virtually entered. Meanwhile, the tour guide explains to them that if they look underneath them, they can see the pumps and if they look a bit to the left, they can see a big drain pipe which leads the clean water to the Roombeek. Thus, they move the phone in these directions and as they really like that they can look around this way, Tim shows it to his son and daughter. Kevin takes over the phone and moves it around as well. After looking around for a few seconds, the tour guide asks what they would like to know more about: the route of the water through the installation and its surroundings, the inner workings of the "water house", more technical information about the installation or information about costs & benefits. Then, a screen pops up on the phone, where these options are shown as knobs in a selection screen. Kevin selects the "route of the water" option, after which the video continues with the tour guide telling and showing them more about how the water enters and leaves the installation.

As the video ends, the family decides that the first POI was a success to them. The children are eager to go further. Floor hands her phone to her son after she has activated the route guidance in the Twentse Waterroute app, so that he can take the lead. She does so through selecting the Route tab in the menu, after which she clicks “continue route”. Thanks to the voice instructions within the app, Kevin successfully guides them to the 4th POI “Groene Linie”, of which a big part is built under the ground. As they arrive at the pole with the sign and blue waves on top which they recognize from the previous POI, Kevin notices a small window popping up on the phone, asking to point the camera to the blue cross that is placed on the ground next to the pole. After he taps on the message, the Twentse Waterroute app appears, which opens a screen showing the camera image of the phone. Kevin finds the blue cross next to the pole not hard to find as it has the size of approximately 1 by 1 meter and is painted clearly on grey concrete, with some other red shapes painted around it. He points the camera at the blue cross, after which he is suddenly able to see underground through the phone screen. It uses the blue cross and the smaller, red shapes painted around it as a marker on the ground to project a functional 3D model of the underground installation into the camera view of the phone, explaining the basic workings of the installation. After a few seconds the app shows a small window on the top of the screen, with a text asking Kevin to walk around a bit but to keep the phone pointed at the blue cross. Kevin does so and now notices that he is able to see the projection from every side! His parents join him in watching the model and listen to the voice-over, as they learn more about how the underground project actually works.

As the children become tired after cycling along another 10 POIs, Floor and Tim decide to head home. Their route back home leads them along one final POI, very close to where the family lives. It is a bit different. The project at this POI has not started yet. Also, there is a digital touchscreen instead of a physical sign. On the left side of the screen, a 3D model of the installation that is going to be built here is shown. A text underneath the model invites the family to watch the model from other sides by touching and swiping the model around. As Floor moves it around, she notices blue circles with white exclamation marks in them popping up around the model. She touches one of them which is near a small house in the model, after which a window appears, showing a video explaining the function of that house to the installation. Meanwhile, on the right side of the screen, Rose starts sliding a knob on the screen from left to right, along a timeline from around 3 years back until 4 years in the future. The screen shows pictures and information about the project in different stages, from the description of the problem of about 3 years ago, to the end solution as it is planned to be working in 4 years. Tim reads with her and notices a section which addresses possible disturbance or detours caused by the construction works. As he slides through the timeline again, he is glad to see that there will only be a slight detour for one week in the coming months. On the bottom right part of the screen he sees a calendar icon, captioned with “Send this information to my agenda!”. After clicking it, a

screen pops up in which Tim is asked to enter an email address. After he does so, he immediately receives an email on his mobile phone with an attachment, which he can directly import to his digital calendar. Afterwards, they arrive home, feeling satisfied after 15 kilometers of biking.

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