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The Citizen Test Process in Virtual Gothenburg Lab

Involvement in city development through the digital twin of Gothenburg

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

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A Master Thesis in the civil engineer program of Industrial Design

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Master's Thesis 2021
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Cover: An illustration of the experience of the Citizen Test Process.

Printed by Chalmers Digitaltryck
Gothenburg, Sweden 2021

Abstract

The need to understand and analyse changes in city development is increasing in order to develop sustainable cities. Autonomous vehicles will be more common in shared spaces in the near future which results in challenges in the meeting between autonomous vehicles and pedestrians. In order to test future traffic scenarios where autonomous vehicles are involved, digital twins can be used as a tool, and Gothenburg City is currently developing their own digital twin parallel with the test bed Virtual Gothenburg Lab. In order to include the human perspective in digital tests with autonomous vehicles, citizens can be involved as test subjects and with that also be a part of city development. Why, when and how they should be involved in tests in order to create value for customers and VGL have been investigated through interviews and surveys with citizens and possible future customers of VGL.

The analysis of the collected data resulted in findings that showed that customers want to test citizens' behaviour, emotions, understanding and opinions digitally in order to save resources and time to market. Digital tests are also a safer way of performing tests for the test subjects. The customers need the citizens to represent the human perspective, which requires an interest and willingness of participation from the citizens. Several criteria were found related to the tests and are important for customers and citizens to enter VGL. In order to fulfill the customer and citizen criteria of accessibility, time efficiency, effort, immersiveness, credible data and number of participants, an app and a VR simulator are suitable tools and were developed as a part of the *Citizen Test Process* that was delivered to VGL in this master thesis project.

Keywords: *city development, citizen involvement, digital twin, virtual reality, autonomous vehicles, testing of interaction.*

Acknowledgements

This report is the result of a master thesis project conducted at the Master of Industrial Design at Chalmers University of Technology. This project has been performed by Matilda Schulz and Victoria Sundbom during the spring of 2021 and included 30 education credits.

Inspiring and dedicated people have contributed to conceptional meetings, discussions and collaborations. We would like to thank Berge and our supervisor at the company Erik Uddgård who chose to bring us into to this project and guide us through our work. We are grateful for the inspiration, help and trust that we have been given.

We would also like to thank the rest of the VGL team for giving us your time in order for us to create the most suitable final solution for VGL. A great thanks to all the citizens participating in our interviews and prototype testings. Finally, we would like to thank our supervisor at Chalmers, Helena Strömberg who has helped us through our work with a great trust, guidance and valuable feedback.

Matilda Schulz and Victoria Sundbom, Gothenburg, May 2021

Contents

1
Introduction

More than 50 percent of the world's population lives in urban areas and this is expected to increase to 70 percent in 2050 [1]. Growing cities can create new possibilities for economic growth but also contribute to increased social inequality and the urbanisation around the world needs to be managed in a socially sustainable way. Sustainable city development includes sustainable planning of buildings, infrastructure, public areas and transport, etc. This requires new technology and cooperation between several sectors within a city. In order to make the cities more sustainable for the future, an inclusive and innovative city planning is needed. This is the foundation in the eleventh goal [2] of the United Nations Sustainable Development Goals which is to

> *"Make cities and human settlements inclusive, safe, resilient and sustainable."*

A new technology used within city development is digital twins which are virtual 3D models, copies of the real world. It includes information about buildings, streets, trees and everything that exists in the real world. Making use of digital twins can optimize companies' processes or products within everything from smart cities to high-tech sport and manufacturing, without risks [3]. Gothenburg, among other cities, is growing which contributes to the challenges of coordination [4]. The importance of communication is increasing in order to make informed decision and to be able to describe, understand, plan and control the city and analyse the development. Therefore, Gothenburg is now developing their own digital twin called Virtual Gothenburg (VG). With all information in the digital twin, future scenarios regarding for example extreme weather conditions and new city areas could be created, simulated and tested in order to evaluate different solutions [5].

Digital twins require new tools and methods for how to use them in city development. A test bed, called Virtual Gothenburg Lab (VGL) [5], see figure 1.1, is currently under development where tools and methods for performing tests and working in VG will be created. Five pilot projects are used to develop the test bed design. A test bed [6] is defined as a physical or virtual environment where companies, researchers and other organisations can collaborate in development, tests and implementation of new products, services or processes.

Through VGL, there is an opportunity to involve citizens in city development in order to create an inclusive city where new measures are accepted and understood

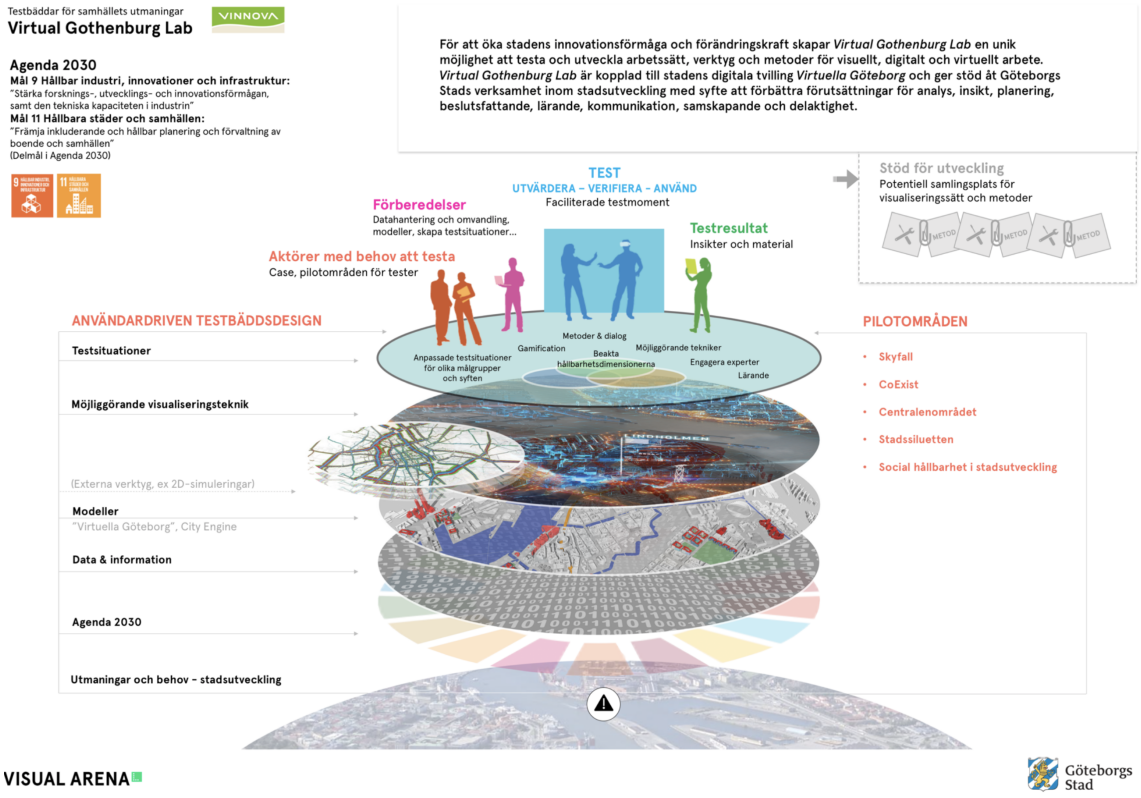


Figure 1.1: Visualization of the test bed design [5].

by the citizens [7]. VGL, therefore, has the potential of becoming a platform that contributes to a participating and sustainable planning. In turn, the global goal [2] that is based on involvement could be reached for Gothenburg. The goal states

> *"By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries."*

Within city development, autonomous vehicles (AVs) are becoming increasingly common elements of city life in shared spaces [5]. CoExist2 is a pilot project within VGL used to develop the test bed design to support future traffic situations with AVs in shared spaces. It could for example be a situation where an autonomous pod meet a human in a shared space where no traffic rules apply. In order to increase the value for customers, when they enter VGL, citizen involvement could be an additional component to increase the acceptance of customers products [20]. The idea of involving citizens in tests and by that create a link between customers and citizens was therefore formed and became the basis for this master thesis.

A previous European project, called CoEXist1 [8], conducted a study on how to prepare for the implementation of AVs with the mission to increase the capacity of road authorities and urban mobility stakeholders. During that project, digital tools were used in order to simulate different traffic situation where AVs and pedestrians

interacted in shared spaces. In these simulations, pedestrians were represented by digital avatars with a pre-programmed behaviour based on how citizens act towards conventional cars today. Qualitative factors, such as the attitudes towards automation, were not investigated in the project [9] and the interaction between people and AVs is still a topic that is not investigated enough.

VGL can potentially be used as a collaborative platform to investigate this interaction and contribute to a more solid understanding of the potential impact of automation for companies, public authorities, researchers, and citizens. We saw an opportunity to involve citizens as test subjects in order to contribute with the human perspective in tests.

Therefore, the aim of the master thesis was to

> *Investigate why, when and how citizens could be involved during tests of simulated autonomous vehicles in VGL to create value for customers of VGL, the citizens and the VGL platform itself.*

The goal was to

> *Design a process for involving citizens in VGL that will be delivered to VGL.*

Three problem areas constituted the basis of this project, together with the research question, see figure 1.2.

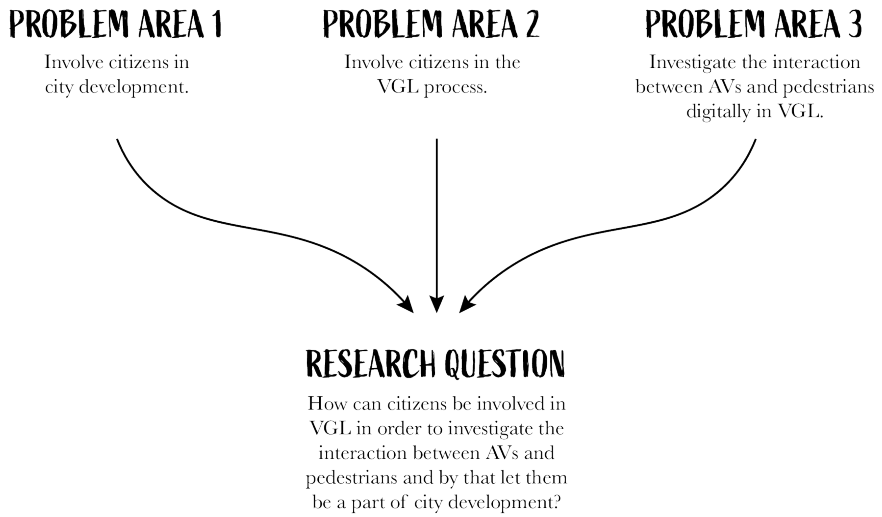


Figure 1.2: Problem areas and research question.

2
Project context

This project is a part of the development of the digital twin of Gothenburg through the test bed Virtual Gothenburg Lab. The pilot project CoExist2 is the basis for the project where a private car company in Gothenburg is the owner of the pilot, in collaboration with a stakeholder in the public sector. In this chapter, an explanation of involved stakeholders, Virtual Gothenburg and Virtual Gothenburg Lab are presented in order to understand the context of the project.

2.1 Stakeholders

Customers, owners and citizens are three different stakeholder groups involved in this project with different roles in VGL. The customers are divided into three subgroups, private companies, public authorities and researchers, with a need to test an idea or a concept. They work within different areas of city development and have different reasons to enter VGL. It could for example be companies who develop autonomous vehicles, public authorities who implement new traffic solutions or researchers and other academic people who do research within the field. Visual Arena and Gothenburg City are the test bed developers and owners of VGL and will be the link between customers and citizens in the future. This project will deliver a tool to VGL which future customers can use when entering VGL. When citizens are mentioned, it includes everyone who lives in Gothenburg. Their role in VGL was not defined when this project started, therefore we will investigate why, when and how citizens could be involved during tests of simulated autonomous vehicles in VGL. Autonomous vehicles were chosen as an example that could be tested since that is the case used in the CoExist2 pilot.

2.2 Virtual Gothenburg

Virtual Gothenburg (VG), is the digital twin of Gothenburg City [4]. The aim of this twin is to make city planning easier and more efficient in order to build a better city for the citizens. VG creates an opportunity to simulate and visualise different traffic scenarios and make informed decisions from the result before implementing the solution in the real world. VG is built up by parametric modelling and visualised in Unreal Engine. This makes it possible to change the parameters of buildings, streets, vehicles, people or weather among more in the digital world. VG is owned by Stadsbyggnadskontoret but involves other departments that works

with city planning. A prototype, with parts of VG included, will be used in this project as a way of visualising the test scenario.

2.3 Virtual Gothenburg Lab

In order to make the digital twin as useful as possible, Virtual Gothenburg Lab (VGL) [5] has been created. The system of VGL is visualised in figure 2.1. The project is run by Visual Arena and Göteborgs Stad and are funded by Vinnova. The test bed is going to be open for customer who want to test ideas or concept that they want to implement in the city. The idea is that any customer with a need to test something in the digital twin can come to VGL with their data. The people in VGL will use the data and help the customer to connect to VG and test the idea or concept. The results will be evaluated and handed back. After that, the customer can continue to work in VG on their own or go through VGL. However, whether VGL will remain as a separate service/company after the research project is finished is not yet determined.

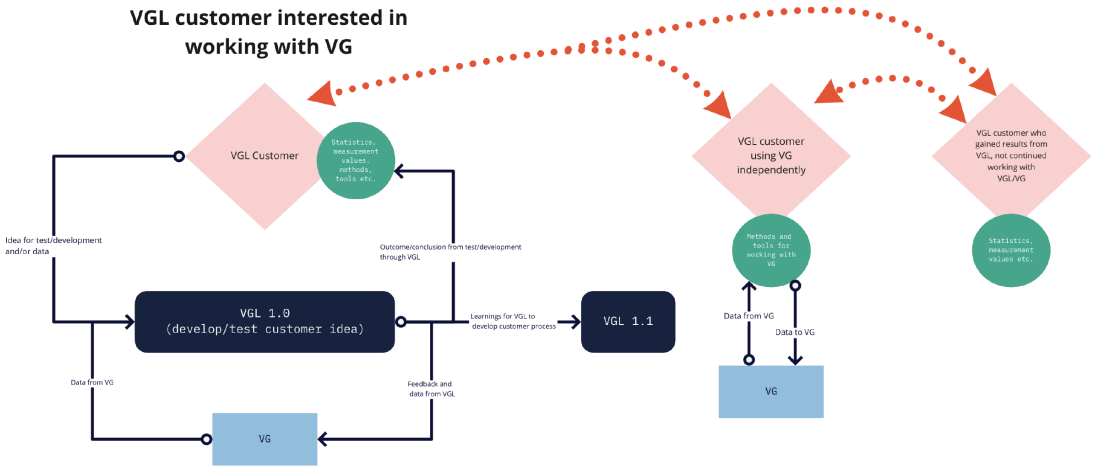


Figure 2.1: Visualization of the VGL system (from ongoing work in VGL).

In VGL, a total of five pilots [5] are included. Two of the pilots, Centralenområdet och Stadens siluett [10], have already been completed and will be used as inspiration for this project in the development of the process delivered to VGL. The other pilots will be run in parallel, and the result will be shared between the pilots along the way. Even though this project is within the CoExist2 pilot, general findings and part of the solution might be applicable for other pilots like Jämlik Stad for example, which focuses on social sustainability and citizen involvement.

3
Autonomous vehicles

This chapter presents autonomous vehicles (AVs) and how they are tested today in order to understand the complexity of the interaction between these vehicles and pedestrians.

3.1 Levels of automation

There are five different levels of automation [11] for autonomous vehicles. This project has focused on the two highest levels. Therefore, when autonomous vehicles are mentioned in this report, it includes vehicles that are highly or fully automated. The highly automated level requires the driver to be available for occasional control of the vehicle but the transition time is sufficiently comfortable. Vehicles at this level give the driver an opportunity to cede full control of all safety functions under certain environmental of traffic situations. In addition, a vehicle can today demand only a navigation and destination input from the driver and not expect the driver to be in control at any time. That is the definition of a fully self-driving level of automation. All critical safety functions are performed by the vehicle, including monitoring roadway conditions during the entire trip. Both occupied and unoccupied vehicles, such as the autonomous robot HUGO, see figure 3.1, that is owned by Berge, are included on this level.

Figure 3.1: The autonomous last mile delivery service robot HUGO [12].

HUGO can for example deliver food or packages and lower the cost for companies

[12], while autonomous cars can increase the road safety and give the driver time to relax instead of focusing on the road [13]. In order to understand the environment, AVs use sensors to detect pedestrians, other road users and signs [14]. In order for the vehicles to be safe, these sensors need to work in all weather conditions which still is a challenge. Most AVs will use machine learning or artificial intelligence to process the data from the sensors and use the information to make decisions. In the future, these vehicles will have a better and safer driving performance than human drivers. However, today there is no agreed basis for ensuring that this machine learning is safe and no agreement on how this should be trained, tested and validated.

A conclusion of this section was that there is a complexity regarding the human factor. When the driver is no longer in control of the vehicle, the communication between the driver and pedestrian is lost. Therefore, it has to be replaced by new ways of communication between the vehicle and pedestrian.

3.2 AVs in digital twins

Having the ability to use simulations in traffic planning, design and engineering has become an important tool since it is important to test AVs before implementation, as a safety measure [15]. In order for vehicle manufacturers to test their AVs in a safe and risk-free environment, United Kingdom (UK) is one of the countries that uses a digital twin to simulate different traffic situations. They use the twin to test their software in order to see how their vehicles will perform in the real world.

Public administration in the UK [15] also uses the digital twin to perform tests in order to forecast the changes in sustainable transportation. Both private vehicle manufactures and public administrations can test and analyse a lot of scenarios in a short period of time with varying amount of AVs on the roads, which would be hard to do on the real roads. In 2018, Connected Autonomous Vehicles (CAVs) pilots were run in the digital twin in UK with the aim to develop transportation services and strategies for the citizens. So far, the twin is used to test the technology, and citizens are not involved in the simulations.

The pilots in the UK show the usage of a digital twin in order to perform safe tests where different environmental factors easily can be changed. However, the tests are more focused on vehicle performance and does not include the interaction with humans. The benefits with digital tests found in the use of other twins will be used as a motivation for performing tests in VG through VGL. Investigating the human perspective and how people interact with vehicles in a greater extent, is an area of development.

3.3 How is the interaction investigated today

Since the aim with this project was to investigate why, when and how citizens could be involved during digital tests, there was a need to understand how the interac-

tion is investigated today. With this information, problems and disadvantages with the methods were used as potential areas of improvement. Tests can be performed physically at a certain location or in digital VR environments as a safer alternative.

One way of performing physical interaction tests is through AstaZero [16]. It is the world's first full-scale independent test environment for future road safety. At AstaZero, different stakeholders are able to test functions and advanced safety systems for traffic situations. Tests of driver behavior, vehicle dynamics, functional reliability and communication technology, can be conducted. AstaZero focus on the vehicle-driver interaction and urban environments are not tested.

Even though AstaZero is an important test bed when it comes to road safety, it still has limitations and drawbacks. To perform tests at AstaZero, it requires a lot of resources such as money and time from the companies, authorities and researchers. Compared to digital tests, the ones who want to test their vehicles at AstaZero need to manufacture the vehicle before testing, which in turn makes it harder to make any changes late in the process. AstaZero is an evidence of that it is important to test different traffic situation before implementing new vehicles on the roads but since the tests in urban environments are not possible, AstaZero is not suitable for tests of vehicle-pedestrians interaction. The drawbacks will be used as areas of potential improvements.

In order to test and develop AVs without risking expensive equipment, VR has played an important role [17]. Seen from a safety perspective in AVs, VR will play a major role in the development. Recent accidents where AVs were involved implied that the safety in AVs has not yet reached an acceptable level. The development of safety in AVs could be performed partly in a VR environment where users can interact with the environment without being exposed to any dangerous situations. Through VR, tests can be performed that in the real world would be expensive, risky or impossible. VR can be used as a tool in test beds to investigate the interaction between AVs and humans without exposing the humans to a physical risk in the real world. Also, it is possible to control the environment and analyse the behaviour of the user in different situations.

A project in Canada [18] presents a VR-based simulator to test the interaction between AVs and pedestrians. Since it is hard to study the interaction in a real world where there is a mixed traffic condition and the situation is hard to control, they used the VR simulator to test different scenarios and highlight the potential of using VR as a tool for exploring the interaction between AVs and humans. Similar studies were found in the UK [19] where a project group used a VR simulator to test different traffic situations and examine pedestrian's trust in AVs. The result showed that pedestrian trust were influenced by factors such as AV driving behaviour and the type of crosswalk. This implies that VR can be used as a tool for analysing the interaction between AVs and pedestrians.

3.4 Conclusions from AV theory

AVs need to be tested prior to implementation in order to work collaboratively with pedestrians. It is not only the vehicles that need to be tested but also the interaction with other cars and pedestrians. This project has focused on the pedestrian's behaviours and not the drivers since the driver will potentially have a secondary or a non-existent role in the vehicles that will be tested by customers to VGL. When involving humans in real world tests there is always a safety risk for the participants. This safety risk could be minimized by performing tests in a VR simulator. Previous studies have shown that VR has the potential to be a suitable tool for performing digital tests where AVs interact with pedestrians. This will be brought into the next phase of the project.

4

Involve citizens in development processes

Cities around the world are trying to increase the involvement of citizens in city development in order to create an inclusive city and increase the acceptance and understanding of new measures and initiatives [20]. Projects where citizens have been a part of the development process are presented in this chapter along with existing services for involving citizens in city development. This is presented in order to understand what is done today and important factors when involving citizens.

4.1 How citizens are involved today

Different initiatives, projects and services in Gothenburg among others are trying to involve citizens in city development and have a dialogue about the development. Citizen dialogue [21] are defined as information and communication technologies with citizens to encourage participation in political and civic processes. Since one of the problem areas in this master thesis was to involve citizens in city development, an investigation of how this is done today was conducted in order to inspire the work and find problems in the existing solutions. One project, two services and a study were found that cover different areas within city development that use different methods for involving citizens.

Landvetter Södra [22] is an example of a city development project close to Gothenburg where the project managers want to involve citizens but are not sure on how to manage different interests. They have a survey [23] where they ask about interests and personal information but state that they do not know how they are going to use this information yet. According to IVL [20], involving citizens will increase the understanding and acceptance for new measures and solutions but there is also a risk that it will lower the trust if the citizens feel that their inputs are never used.

Since Landvetter Södra do not present a clear aim with their survey, citizens might feel that their inputs are not used in the decision making an planning of their city. Similar problems can be found in Min Stad [24] which is an interactive online map where anyone can share their dreams, needs and ideas related to city development. It is a platform owned by Göteborgs Stad where citizens can publish suggestions and have discussions about different problems in Gothenburg. Gothenburg city encourage citizens to be creative and they state that they will use every feedback, critique

and idea as an inspiration in the development work of Gothenburg city. However, they also state that they do not have the time and resources to give feedback to the proposals so the citizens will never know if their idea was used.

SKL, Sveriges Kommuner och Landsting (2011a) [25], present a dialog ladder with different levels of involvement. The levels are, from bottom to top, information, consultation, dialog, influence and co-decision. While Landvetter Södra and Min Stad tries to involve citizens on the dialog level by asking questions and creating a discussion, a visiting centre called Älvrummet [26] is more of an educating service that involves citizens on the information level. Älvrummet has a physical 3D model of central Gothenburg that shows current and planned buildings, bridges and streets and citizen can participate in presentations, events, guided tours etc.

A recent study from Dublin [27], published in January 2021, presents how a digital twin can be used to visualise future projects in the city to get feedback from the citizens on an influencing level. They used a digital 3D model to visualise the current city and the planned future city. When the citizens had looked at different images, they could go to an online survey and give feedback on the proposed buildings. This feedback could then be used to provide useful insights to urban planners. Since a 3D model provides a low barrier for the citizens to enter, they will more easily be engaged in city planning decisions and people with a low interest in technology can also participate. As Landvetter Södra [22], they believe that by involving citizens, the city will be developed in the best possible way. Depending on how much influence the citizens should have, different levels on the dialog ladder are appropriate and will be considered in this project.

4.2 Important factors when involving users

Involving users in the design process is a central part of a user centered design approach. By involving users, the final solution has a higher chance of being successful and accepted by the users [28]. When involving users in the ideation phase of the design process, there are several factors that need to be taken into consideration in order to get a trustworthy result. Pettersson [29] presents an approach for eliciting rich user experiences and talks about important factors when designing for future experiences. The approach is supposed to be used in the early phases of the design process such as during analysis, ideation and evaluation.

One of the steps in the approach is *Contextualise* which means that the context is of high importance when testing a concept with users in order to get a credible result. This is a challenge when designing for future situations, but to only study the present context will not be enough. When performing tests for a future situation in a context that does not exist today, the context need to be created in order to transfer the users to the future situation. In order to enable the contextualisation, Pettersson presents three suggestions that is important to have in mind when planning a test. The first one is to provide participants with probes or tasks before the

study. The second one is to consider the scenario that are presented during the test and the third one is to carefully design the test environment so that the participant can get a sense of the future scenario.

In order to find all use and user situation needs, different methods are necessary [30]. Interviews are used to find the subjective needs while observations are used to identify needs that emerge in the use situation. Empirical data are for example collected from interviews, observations and surveys. Through observation, a user is studied in a real context or a lab. The aim with observations is to gain an understanding of the use situation without affecting the users behaviour. Observation is used to find out what humans actually do, not just what they state that they would do. In comparison to observations, interviews and surveys are question based methods that are used to collect information about how the user thinks and argues. The primary aim with surveys is to collect data from a large number of people.

4.3 Conclusion of Citizen Involvement Theory

Involving citizens in city development has the chance to create a better city with high acceptance of different solutions. Thus, it is important to have a clear aim with the involvement and be transparent on how the information from the citizens are being used in order to avoid mistrust. How an opinion from a citizen is transferred into an actual change need to be considered. Real power, transparency and whether an illusion of involvement is given to the citizens has to be discussed, in this thesis too. When the level of involvement has been decided, an important factor to consider when developing for the future is the context. In order for the users to transfer to a future situation, they need to be provided with the right material and context. One example of this is the project in Dublin where different options were visualized for the citizens before they gave their feedback. This is something that needs to be considered in the final solution of this project.

5

Process

The work process for this thesis was based on the design thinking approach HCD [31] which is a human centered design methodology that uses methods of deep understanding, brainstorming, prototyping and testing to address problems of end users. It is an iterating approach that includes three phases, *Hear, Create and Deliver* that are visualized in figure 5.1 and presented in this chapter in order to follow the development of the final solution of the *Citizens Test process*.

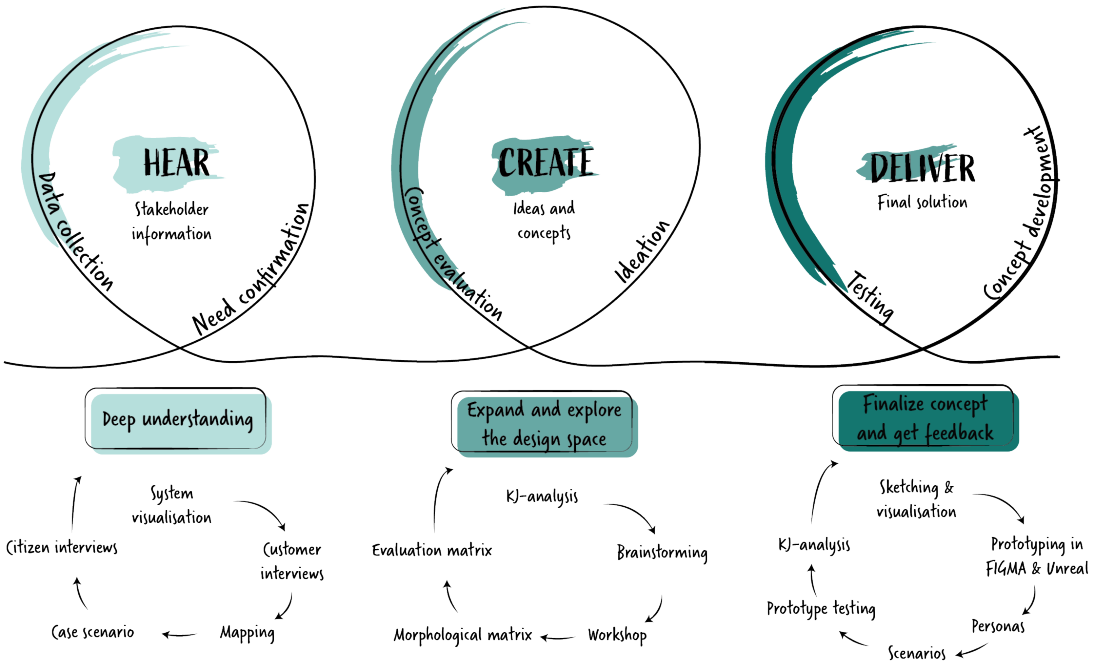


Figure 5.1: Visualisation of the work process.

5.1 Hear

During the *Hear* phase, data about the problem areas presented in the introduction and customer and citizen needs were collected through a study of a previous project and empirical methods. The result from one stakeholder was used in the meetings with the next one and mapped in order for it to be analysed. The *Hear* phase was divided into problem confirmation with stakeholders, need identification from customers and citizens, mapping of data for the analysis and a case found from a customer that could support the creation phase.

5.1.1 Starting point of the *Citizen Test Process*

An illustration of the system of VGL and the test bed design was given from VGL, see figure 2.1 and 1.1. It was determined that customers and owners were already a part of the system, and the purpose was to find why, how and when to involve the citizens. Assumptions regarding involved parties in the future organisation of VGL was done since the structure was not yet completely defined.

The CoEXist1 [8] project was studied in order to find a specific need of involving the citizens. From the study, the idea of involving them as test subjects was created and a confirmation of that idea was then necessary. This was done through interviews with the owners of VGL. Since the system of VGL is not yet completely defined, representatives for this group were chosen so that interviews could be conducted. With the new idea of involving citizens as test subjects in VGL, the system of VGL was examined in detail and visualised in order to understand the structure of VGL and how the citizens could potentially be involved as test subjects. This system was through the entire project used as a foundation for the final solution of the *Citizen Test Process* delivered to VGL. Questions in this stage were

- How can citizens be involved in tests as test subjects?
- What do customers want to test with citizens?
- How can citizens be reached?
- How much data does the customer need to have when they come to VGL?
- What data can be brought back to the customers in order to create value?

5.1.2 Need identification customers

In this stage, it was only assumed that the customers wanted to perform tests with citizens. In order to confirm the assumed customer need, semi-structured interviews [32] were performed. The interviews were semi-structured in order to create additional depth to the questions by offering dialogue exchange. In addition to the confirmation of the need, the aim was also to identify the individual customer needs, from the different customer subgroups, in order to develop a solution that fulfilled their needs. Interviews were conducted with two representatives from the public sector, two researchers and two representatives from the private sector in order to cover all customer groups, see figure 5.2.

Interview subject	Customer type	Industry	Specific area	Involved in VGL
1	Private company	Vehicle manufacturer	Autonomous vehicles	YES
2	Private company	Design consultancy	Autonomous pods	YES
3	Public authority	Urban development (short term)	Traffic situation changes	YES
4	Public authority	Urban development (long term)	Urban planning	YES
5	Research company	Automobility	Autonomous vehicles	YES
6	Researcher	Automobility	Autonomous pods	NO

Figure 5.2: Table of involved potential customers.

Questions asked during interviews were related to the following areas and outputs from each interview gave inputs to the next interview. The areas were

How interaction tests are performed today.
What interactions and traffic situations are tested today.
How customers involve their users in tests today.
Customers opinions on performing digital tests.
What interaction tests would be relevant to perform with citizens.
Potential of testing interaction in digital twins.

5.1.3 Mapping

The collected data from interviews were mapped into one customer mapping in order to find relations between different needs and possible future use cases. The mappings were made digitally as a first step of the analysis phase and as a way to structure all collected data. Questions in this stage were

- How can private companies use the test bed of VGL in their work when citizens are involved?
- How can public authorities use the test bed of VGL as a tool to develop traffic implementations in a more efficient way?
- What could the owners and the entire project of VGL gain from the development of a process where citizens are involved as test subjects?

Based on the system of VGL and findings from the customers, a first draft of the

Citizen test process was developed. The visualization of the test process opened up for new questions which were used during the development of ideas and concepts applicable to the process.

5.1.4 A case to support the creation phase

In order to support the creation phase and the communication with citizens, possible test situations were formed based on customer findings. These were used to create a scenario that was presented in the interviews with the citizens.

5.1.5 Need identification with citizens

In parallel to the interviews with the customers, a survey with the citizens was conducted in order to investigate if citizens wanted to participate as test subjects. The survey consisted of ten questions and was published on Facebook, both privately and in city development communities. It involved questions regarding interest in city development, autonomous vehicles and interest of involvement in digital tests with AVs. The survey was used as a first step to involve the citizens in the development of the *Citizen Test Process* and to confirm the idea of involving them in tests. The 75 answers was then used to map the engagement from this stakeholder group. The result from the survey justified, together with the findings from customers and owners, the decision to develop a solution where citizens are involved as test subjects.

Interviews with the different segments of citizens were then conducted in order to collect deeper information about how citizens want to be involved as test subjects. The participants were found in the survey and each segment, based on age, was divided into groups, see figure 5.3, in order to find the need from all citizens. Interviews were conducted digitally and in order to facilitate the dialog, a maximum of two citizens participated in each interview session. The questions asked during the interviews were based on the three areas of motivation, result from tests and channels to reach citizens found in the survey. In order to open the space of ideas, brainstorming [30] on each area was used in the interviews.

Interview session	Amount of participants	Age segment	Interest in city development
1	2	18-30	Medium
2	2	18-30	High
3	1	31-50	High
4	1	31-50	High
5	1	50+	High
6	1	50+	High

Figure 5.3: Interviews with citizens.

5.2 Create

The *Create* phase was conducted through exploration of the opportunities found in the previous phase. A planning activity was conducted in order to find the best method of analysis to use for the collected data. The data and the mappings were then analysed through KJ-analysis [30], in order to define the value for the citizens, involved customers and the owners of VGL. The phase of ideation was then started followed by a concept evaluation.

The test bed design of VGL consists of a before, during and after phase and this thesis has mainly been developing concepts in the during phase. The part of the *Citizen Test Process* where citizens are involved is an additional component to the test bed design in the during phase and concepts on how to perform tests and involve citizens were developed for that phase only. How customers will enter VGL and receive results from the tests conducted was not included in this thesis since VGL will develop a general approach for that. This approach will be independent of the test situation and if citizens are involved or not. However, specific details when preparing tests needed to be defined even if they are in the before phase, since the preparations and test design will differ when involving citizens.

5.2.1 KJ-analyses

In order to analyse the collected data, two KJ-analyses [30] were conducted, one of the data collected from the interviews with the customers and one of the data from the citizens. The KJ-analyses resulted in two function lists, one for the customers and one for the citizens that were used during the ideation. It also resulted in three

test related criteria for the customers and three entry level criteria for the citizens that were used during the evaluation of the concepts and the final solution of the *Citizen Test Process*. The customer criteria related to test results and the citizen criteria related to the design of the test.

5.2.2 Ideation

The ideation was performed through brainstorming [30] with the aim to explore different digital tools to perform interaction tests with. It was also investigated how to design the test in order to collect data about the different levels of interaction found in the interviews with the customers. In order to find suitable digital tools, experts in technologies for interaction were involved in a workshop in this phase to fill the knowledge gap. From this, a decision was made to focus primarily on the most suitable tool before secondary details. The recommended digital tools were then used in a morphological matrix [30] together with the lists of functions in order to open up the space of ideas. Only functions related to when citizens are involved in tests were included since the other functions are not included in the during phase of the VGL test bed design. When each function in the list had been ideated on, the morphological matrix included several part solutions that were combined and experimented with through sketches and digital visualisations. The morphological matrix resulted in eight concepts where each digital tool were included in, at least, one detailed concept.

5.2.3 Concept evaluation

The concepts were compared in a concept evaluation matrix where we gave different points in relation to different stakeholder criteria. The concepts received one to three point for each criteria found from the citizens and the customers. This scale was created in order to compare the different digital tools against each other. The points were then compiled into a total score for each concept. Since the digital tool was the main focus, all concepts with the same tool were compared with each other and the concept from each digital tool group with the highest score was brought into the concept development phase. The concept evaluation, therefore, excluded three of the concepts in this phase.

5.3 Deliver

During the *Deliver* phase, the concepts were analysed and developed further. Through sketches and prototypes, feedback was received that was iterated on into a prototype that was tested with the citizens. Personas and scenarios were created in order to communicate the final solution.

5.3.1 Concept development

The remaining five concepts were analysed in relation to the fulfillment of each criteria found from the citizens and the customers data analysis. Connections between immersiveness and credible data of behaviours and emotions were found and immersiveness was therefore defined as the most important customer criteria. Since one of the problem areas in the project was to involve citizens, the accessibility criteria was of high importance in order for people to participate in the tests. The concept that fulfilled the immersiveness criteria had a low score of accessibility and therefore needed a complement. A combination of the concept with the highest score of accessibility and highest score of immersiveness was then created.

5.3.2 Final solution and prototyping

When the decision of combining concepts was made, details regarding each part were developed.

Due to the time limit of the project and the available resources, the decision of developing the phone concept in the combined concept was made. In this phase, representatives from VGL were brought in for discussion of details which resulted in the decision of developing an app. Since the aim with the phone in the combination concept was to reach out to citizens and make the tests more accessible, findings from the citizens were used to brainstorm ideas and define the details. Sketches and prototypes of the app were made in FIGMA in order to enable quick changes and easy communication with the VGL team. The idea was discussed with a developer from Berge. Since the VR function was going to be the most complex part in the app, the developer wanted to start prototyping in Unreal Engine as soon as the idea of the app was presented for him. The interface of the VR environment was made by the developer with inputs from user journeys.

5.3.3 Personas and Scenarios

In order to maintain a clear communication of the final solution and to follow the user-centered design approach, three personas [30] of citizens and three of possible future customers of VGL were created with associated scenarios [30].

The scenarios represented when citizens and customers might use the solution in the future. The personas for the citizens and their scenarios were based on findings and the different functions in the app. The personas for the customers and their scenarios were created with the different areas of interaction to test as a basis. With inspiration from the personas, a user test was developed with a scenario as an introduction, see appendix A.3. The scenario gave the foundation for the entire test and how the user would experience all the functions in the prototype was discussed. The test was then used in the next phase of testing the prototype with citizens.

5.3.4 Testing the prototype

The *Citizen Test Process* and the app were presented for two people that work at Gothenburg City and representatives of VGL, as a further evaluation. This was conducted in order to get their perspective and feedback on the final solution. Their opinions were used in order to validate if the solution was relevant and to define necessary future work.

The app was then tested with citizens in order to validate the functions. The user test was designed as a user journey in three different steps. An introduction of the app, the usage of the app and questions related to the app, see figure 5.4.

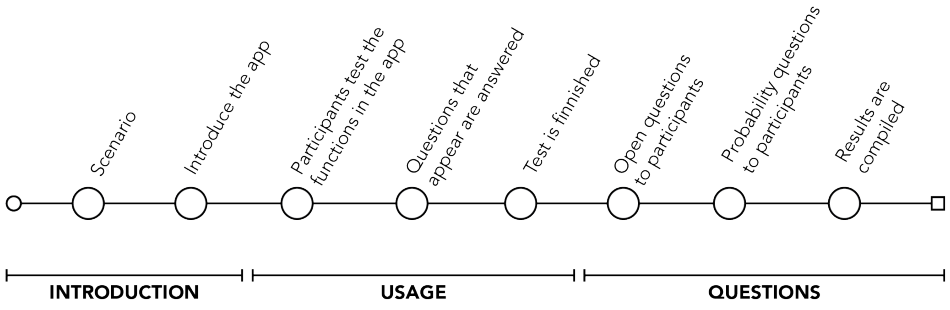


Figure 5.4: Prototype test process.

The purpose of the test was to evaluate the probability that citizens would use the app and also to investigate the function in the app that would be used the most. Strengths and weaknesses also needed to be identified in order to make the last changes of the app. Test subjects were chosen with a diversity in age segments. Six test subjects were in the age between 18-30 years where three had a great interest in city development, and three were not so interested. Two test subject were in the age of 30-50 years. One had a great interest, and one had no interest in city development. The final four test subject were older than 50 years of age and they all had a medium interest in city development. See the participants in figure 5.5.

In the beginning of the test, a scenario was presented to each test subject that ended with them entering the app. The participants then had the freedom to use the app in their own way and test the functions of the app. If a participant did not find all functions, they received help. One part of the prototype was made in FIGMA and located on a iOS device and the other part was made in Unity Engine and located on an android in order for the programs to work as efficient as possible during the test. Therefore, a switch between two phones was made when the test subject wanted to enter the VR function and the digital twin.

The test subjects were encouraged to speak out loud and everything they said and the choices they made, were documented in a protocol. Afterwards, they were asked

Test subject	Age	Level of interest in city development
1	24	Small
2	26	Large
3	44	Large
4	22	Small
5	21	Small
6	23	Large
7	30	Small
8	59	Medium
9	57	Medium
10	20	Large
11	53	Medium
12	58	Medium

Figure 5.5: Table of test subjects

questions regarding strengths and weaknesses with the app and probability of usage. Since the app was not published, this was the most suitable way to collect data about the app. The questions were related to each function in the app. For more specific information about the test, see appendix A.3.

5.3.5 Analysis of tests

When all of the tests had been conducted, the result was analysed in two ways. The answers from the probability questions were summarized in statistics and used as an evaluation of the prototype. The questions about strengths, weaknesses and purpose with the usage were compiled trough a KJ-analysis and the result was presented as areas of improvement. The interviews conducted with two people from Gothenburg City was only used, as earlier mentioned, as a checkpoint to see if the solution was still relevant for a future implementation.
The master thesis final delivery to VGL was a process for digital tests between

AVs and pedestrians. For VGL, the *Citizen Test Process* can be used in the ongoing pilots within the development of VGL but also as an applicable function in the future service of VGL. The *Citizen Test Process* has the potential of bringing customers and citizens together to collaboratively develop the city.

6
Hear

In this chapter, all findings from potential customers of VGL and citizens are presented, including a first draft of the *Citizen Test Process*. The criteria found during interviews with customers and citizens are also presented. The criteria are important to understand in order to follow the development of the final solution.

6.1 Need confirmation

By examining the system of VGL, see figure 2.1, it was found to be possible to involve citizens in tests but also an opportunity to involve them after the tests when the results are presented as can be seen in figure 6.1. It was assumed that the value of VGL for customers could increase by involving citizens in tests in order to receive the citizen's perspective in the interactions with AVs. The interviews with potential customers of VGL confirmed the assumption and the need for performing tests with citizens. There are different aspects that the customers want to test with the citizens and those findings are presented below.

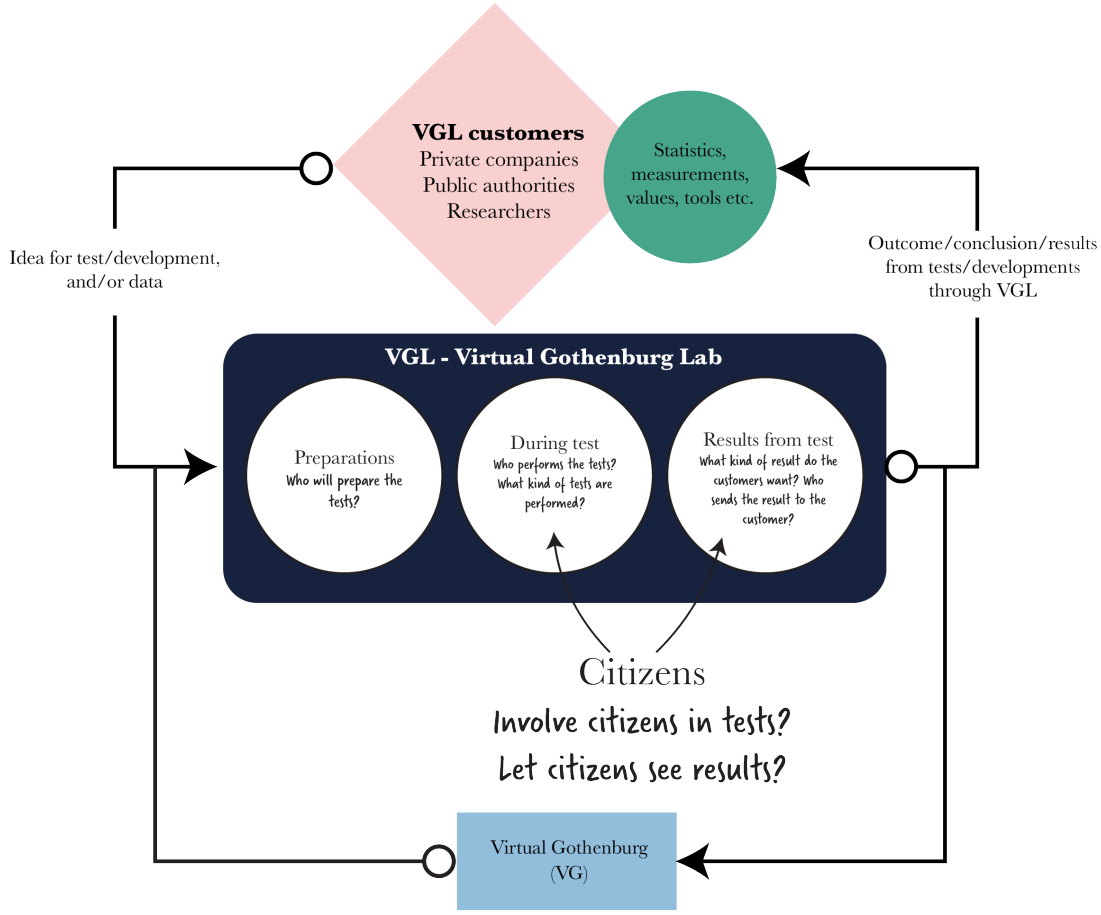


Figure 6.1: Visualisation of the VGL system and where citizens could potentially be involve.

6.2 Customer needs

The interviews with the customers not only confirmed the identified need but also gave insight and information about what they want to test, what data they want from the citizens and important factors regarding the tests. The findings related to

test situations will be defined as *Customer criteria* and were used in the ideation phase as requirements of the final solution.

6.2.1 Need of digital tests

Today interaction between vehicles and pedestrians are tested in limited and controlled environments due to several reasons. The interviews conducted with both private and public customers as well as researchers in the academia showed that companies and organisations need to seek permission from Transportstyrelsen [33] (a Swedish state administrative authority of transport) in order to perform these tests out on the streets. According to the customers this is something that creates limitations in their work and is time consuming. As described in chapter 3, physical tests require a great number of financial resources which was another reason that strengthens the need for digital tests as a complementary approach.

The interviews also showed that physical tests consume a great number of tools and materials. A smaller private company such as Berge do not have the same capacity of building a test environment as bigger companies. Testing their product, the robot HUGO, which is an autonomous vehicle on level four, in a digital world would give them the opportunity to simulate several Hugo robots at the same time without having to build the same amount physically.

In addition to environmental limitations and resources, time to market was expressed in the interviews as two beneficial aspects in digital tests. Today, new traffic solutions in the city are implemented directly from the concept stage and are not evaluated with citizens trough a prototype before they reach the market. One of the public authorities mentioned in their interview that they evaluate their projects from the feedback that they receive from the citizens after an implementation in the city. An opportunity of testing their solutions digitally beforehand will probably decrease necessary changes needed after implementation.

The safety aspect was also brought up as a favorable factor with digital tests. Compared to tests in the real world, the test subject is not exposed to the same physical risk when participating in digital tests. Many of the customers expressed this as an important factor when testing their vehicles.

6.2.2 Need of involving citizens

Since AVs are not implemented in shared spaces in Gothenburg today, data has not been collected on how people interact with them on the streets. Therefore, it is not possible to use pre-programmed avatars as pedestrians in simulations when investigating the interaction. In the pilot Centralenområdet it was possible to apply an existing behaviour on the avatars since that data existed. The aim was to visualise how people change their behaviour when crossings or rain covers are moved or scaled, which can be predicted and thereby programmed. When investing how people will interact with AVs in different tests, the behaviour can not be predicted.

Customers need a human behaviour that corresponds to a real behaviour in the interaction with AVs. Therefore, citizens need to be involved as pedestrians in the tests. It is also not possible to ask a pre-programmed avatar about their behaviors or emotions which motivates the involvement once again.

6.2.3 Levels of interaction

The interaction between pedestrians and machines, in this case AVs, is a complex test to conduct. The result is dependent on reactions and behaviours that emerge in new situations when pedestrians meet AVs. These reactions can not be pre-programmed with digital avatars when testing new vehicles or traffic situations, if the customer wants information about a specific reaction. The KJ-analysis of the customer needs resulted in four different aspects of interest to test, see figure 6.2. These aspects were defined as levels of interaction and they need to be possible to test for customer to VGL.

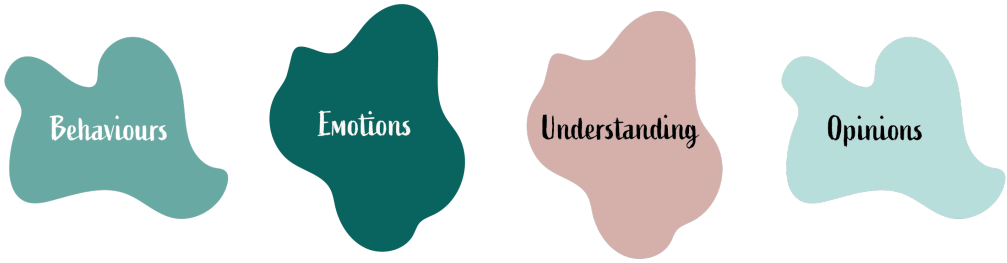


Figure 6.2: Levels of interaction.

The four levels can be used to guide the customers how to design the test when they enter the *Citizen Test Process*, depending on the result that they want to receive.

Behaviour
The stakeholder analysis showed that possible future customers to VGL want to test how pedestrians behave around their vehicles in open and shared spaces where the only rule is to show respect between the two parties. A public authority expressed that they want to test how citizens' behaviour will change when introducing AVs in the city centre and how different traffic solutions will affect the behaviour. Questions that customers wanted to investigate were related to

- How do people behave around autonomous vehicles?
- Which path do they choose?
- Will pedestrians go in front of the vehicle or let it pass?
- What type of behaviour can arise when introducing autonomous vehicles?
- How does it work to drive around corners for the HUGO robot?
- Which type of traffic flows will arise?

These questions could potentially be answered in VGL and facilitate the development and introduction of AVs on city roads.

Emotions
The need to investigate how pedestrians feel in traffic situations with AVs is another finding from the stakeholder analysis. Creating a comfortable user experience for pedestrians when vehicle manufacturers are introducing their products on the market is of importance for them. A researcher expressed that he wants to test how citizens feel when meeting an AV on the street. Therefore, they want to conduct tests in order to find out

- If pedestrians find it scary to cross the street if an autonomous vehicle is approaching?
- Do pedestrians trust the autonomous vehicles?
- How are people affected emotionally by the autonomous vehicles?
- Do pedestrians feel respect for the vehicle?
- How do pedestrians feel if the driver of an autonomous vehicle is reading a paper?

Feelings and emotions are connected to the experience that pedestrians will have when moving in shared spaces. It is important to create good experience in order for people to feel safe, in control and comfortable. It is also of importance to investigate if pedestrians will or will not show respect for the vehicle and the consequences of that. Companies want to find a balance where pedestrians feel comfortable around AVs while at the same time having respect for the vehicle in order for the AVs to be able to drive among people.

Understanding
How pedestrians understand the intention of the AVs is of importance when they are about to interplay in shared spaces. Future customers from the private sector stated that they want to test communication, purpose, cognitive ergonomics and usability. Researchers also stated the need of developing ISO-standards for AVs through digital tests. A private company expressed that they want to test how citizens understand the intention of the autonomous vehicle. Potential questions that could be asked on this level are

- How do pedestrians understand what the autonomous vehicles are communicating with them?
- Do they understand the purpose with the vehicle?
- What does the vehicle convey, and what do pedestrians understand?

Testing the understanding could result in a safe, comfortable and effective interaction between AVs and pedestrians. It is one way to work with risk reduction between humans and machines.

Opinions
Gathering data on what people think about AVs is another area of interest for future

customers of VGL. It is not important for vehicle manufacturers to receive opinions about every decision in their product development, but some aspects are helpful to gain in order to create a good user experience. Questions that companies expressed that they want to ask are

- What colour, shape and size should HUGO have?
- How many autonomous vehicles are you comfortable meeting?
- What do pedestrians feel about HUGO driving slowly or wobbly?
- What do pedestrians think of a specific sound from an autonomous vehicle?

6.2.4 Customer criteria

The interviews with customers showed a need of credible result from tests of citizens' behaviour, emotions, understanding and opinions in order for them to make informed decisions. Many customers believed that it was hard to conduct digital tests where results about behaviours and emotions represented reality and one customer said

> *"The feeling of how something is moving is hard to create digitally but if the tool is developed correctly, it is probably possible to get a real sense of how something is moving."*

Interviews with technical experts showed a need of high immersiveness in order to create reliable results on behaviour and emotions. They also stated that it can be conducted by the design of the context. This was confirmed by the theory of designing for future experiences where the context is a critical factor. The analysis of the data showed that immersiveness is more important when behaviour and emotions are being tested since these levels of interaction need to be tested in the moment and can not be asked if a trustworthy result is needed. This result confirms the theory about user tests where the theory says that behaviour needs to be observed and not asked in order to get the true behaviour and not the experienced behaviour. Understanding and opinions can on the other hand be asked and still create a reliable result.

The result also showed that a high number of participants are desired. A high number of involved participants will contribute to a more accurate conclusion from the results. One customer said that

> *"We plan to understand and capture more perspectives and not only those who make themselves heard"*

and when AVs are implemented in shared spaces it will affect everyone that uses the streets. It is therefore important to perform tests with different users within different segments in order to develop solutions that will satisfy as many people as possible. No matter of culture, interests of AVs, knowledge about the technology

or involvement in city development, people will share the streets with AVs in the future. The customers want to involve different segments of people in order to avoid a design of a product that is developed for a specific citizen segment.

With the findings about the need of credible result, high immersiveness and high number of participants to create credible results and draw more accurate conclusions, three *Customer criteria* were defined and are presented below. These criteria will be applied on the concepts implemented in the *Citizen Test Process.*

- Credible results
- High immersiveness
- High amount of data

These criteria where used in the evaluation of the concepts as well as the development of the final solution.

6.2.5 Need for collecting data from tests

In order to use the results from the tests, it is important that the data about behaviours, emotions, understandings and opinions is collected in a suitable way. Interviews with customers also showed that it is important to compile the data and visualise it in an understandable format, in order for the customers to interpret the result. Specific questions that arose during interviews with VGL and the customers regarding data from tests with AVs were:

- How to collect data about a behaviour, an emotion, an understanding and an opinion from a digital test?
- How to quantify the data from these levels?

Finding from the theory showed that interviews, surveys and observations can be used to collect empirical data. The way questions are asked and observations are performed will affect how measurable the result will be. The different methods for collecting data were used in the morphological matrix in order to create concepts with different suitable methods.

6.2.6 Test situations for the creation phase

From the questions that arose with the customers regarding what to investigate, a scenario was created and used in the interviews with citizens. We wanted to create a scenario that involved all levels of interaction in order to represent all possible traffic situations. Shared spaces were used since the CoExist2 pilot was investigating that area. HUGO was involved to represent the company, since this master thesis is conducted at Berge who is the owner of HUGO.

HUGO is driving around on a crowded shared space area where no traffic rules exist. The challenge for HUGO is to make his way to his final location within time and

with respect towards the people sharing the street with him.

The HUGO team want to test the appropriate speed, flow and aggressiveness of the robot with the citizens and how they will behave, feel, understand and think about the robot. That is why they need to involve citizens in the test, in order for the citizens to act themselves. With this information, the HUGO team could then optimize the robot to work in synergy with the citizens in the city. Therefore, this case has to be possible to conduct in a future solution and were used when explaining the process to the citizens as well as in the ideation phase.

6.3 First draft of the test process

Based on the test bed design of VGL and findings from the customers, a first draft of the test process where citizens are involved was developed. The visualization of the test process, see figure 6.3, opened up for new questions which were used during the development of ideas and concepts applicable to the process. The test process was divided into three phases, before, during and after citizen involvement.

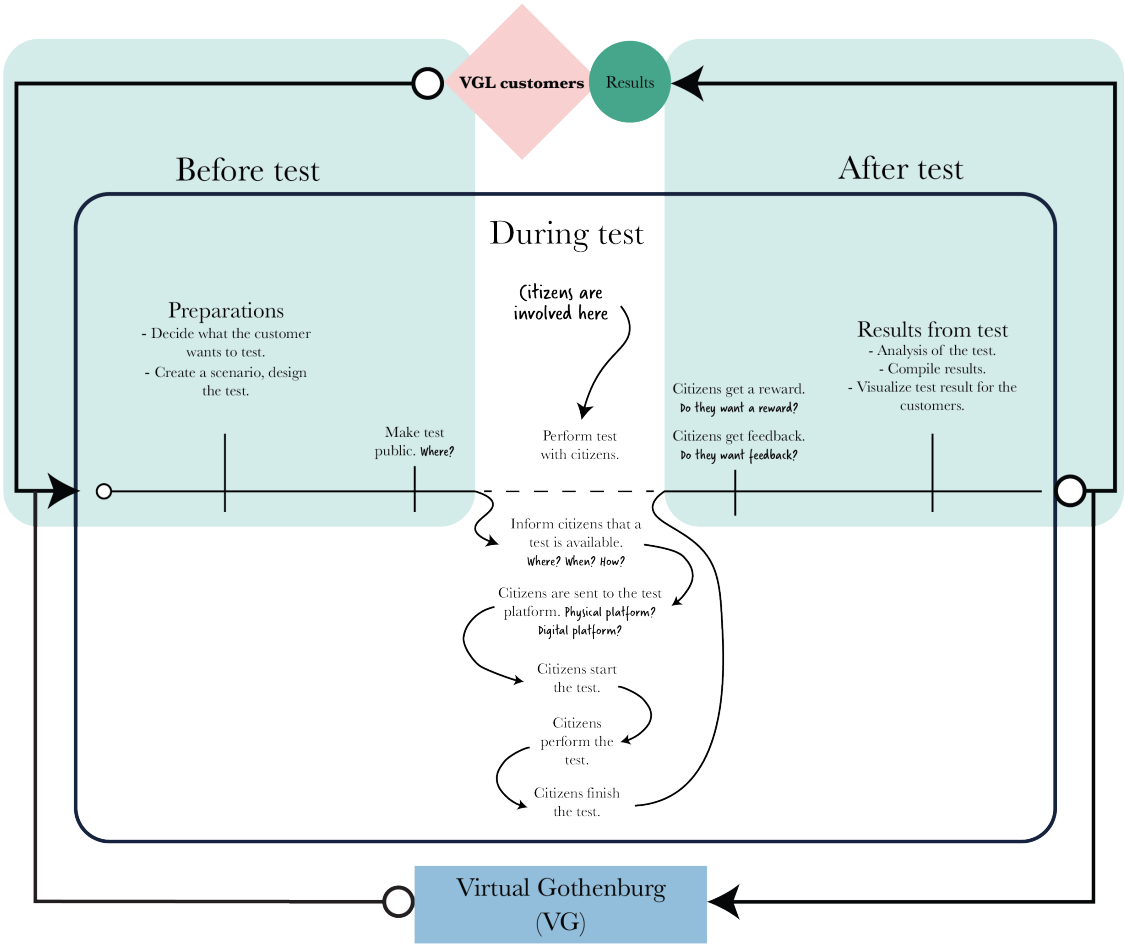


Figure 6.3: Visualization of the VGL test process when citizens are involved

6.3.1 Before

Independent of what customers want to test or if citizens are involved, customers will enter VGL with their scenarios. If they want to involve the citizens, details in the preparations and design of tests will differ from other tests. Citizens will then be involved in the during phase.

6.3.2 During

Citizens are involved in the test process as test subjects if the customers need information about a behaviour, emotion, understanding or opinion regarding the scenario they want to test. Questions that arose in this phase were

- How can we make the test available for citizens?
- How can citizens participate in the test? Digitally or in a studio?
- Do citizens want feedback on their results?
- Do citizens want a reward for participating?

6.3.3 After

When the test is finished and the citizens are no longer involved, the results will be analysed and visualised for the customers. They can use the result to make changes, implement the tested concept and come back to VGL to test a new idea.

6.4 Citizen's needs

Since the citizens need to be involved in the interaction test, their needs were investigated and are presented below.

6.4.1 Citizens motivations to participate

Of those who answered the survey, almost 50 percent had a large or quiet large interest in city development, and 45 percent had a little interest as can be seen in figure 6.4. These result showed that there is an interest in city development from citizens which implies that a solution with citizen involvement would be appropriate. Today, there are no collaborative platform where all stakeholders within city development are gathered and the citizens can be involved. The survey showed that a large amount of the participants stayed updated about city development through the news and by talking to each other. This was confirmed in the interviews where some of the participants also listed different discussion forums as platforms to stay updated on. Results from the interviews showed that the participants want to continue to take part of city development.

Almost 50 percent answered that they only have a small or no interest in AVs. 86 percent were still interested in participating in a digital tests with AVs, where 34

percent needed more information before they joined, as can be seen in figure 6.4. This finding was confirmed in the interviews where 50 percent of the participants expressed that a clear aim with participation was crucial in order for them to conduct a test or not. It was also important for them to see the duration of each test since that information was important to know prior to participating. They expressed that they were more likely to participate in several short tests than one large, seen from a time perspective. They also said that they wanted to know how their test result were supposed to be used. This finding confirms the theory about being transparent with the purpose of citizen involvement. Even though some hesitated to join because they did not have enough information, the majority still wanted to take part of the results from the tests. In the following sections, reasons for participating is presented.

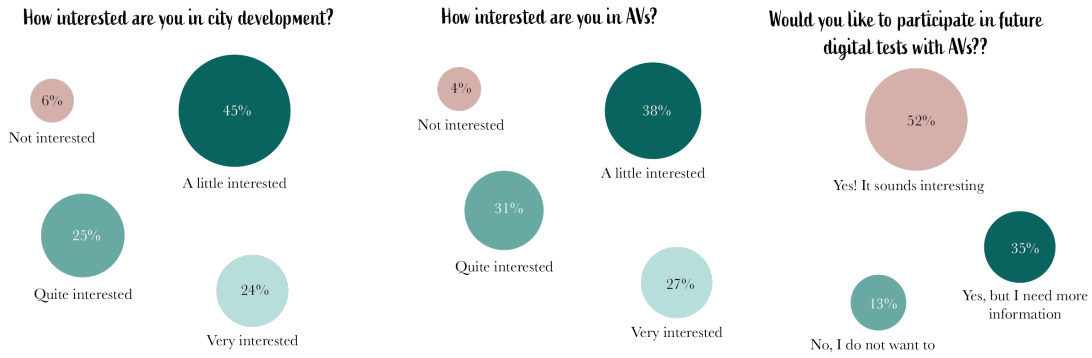


Figure 6.4: Statistics from the survey, appendix A.1

Entry level
The KJ-analysis of the interviews conducted with different segments showed three main criteria necessary for the citizens, in order for them to participate in a digital test. These are defined as *Citizens criteria* and are explained below.

One of the criteria was *accessibility*. Results from the interviews showed that digital tests need to be easy to access through a suitable device in order for citizens to even start a test. Many participants said that they wanted to participate if the tests were accessible from home any time of the day.

Another criteria related to the entry level was the *time efficiency* of the tests. The result from the interviews showed that if the participants were able to perform a test at home they were more willing to participate than if they needed to travel somewhere. The willingness was affected by how time efficient it was to participate regarding the total period of time that they needed to perform the test, including traveling.

The final criteria regarding entry level found in the results from the interviews were the *degree of effort* needed during a test. The participants were more willing to participate if the test could be performed in the sofa while watching TV compared

to if they needed a quiet room or to walk around during the test.

The findings regarding entry level are related to specific design of the tests in the test process and have been used in the concept evaluation as well as the development of the final solution.

Individual interest
One of the reasons for citizens to participate in the digital interaction tests was their own interest in city development and AVs. This result was clearly shown in the survey where 30 percent answered personal interest to the question "why do you want to participate in digital interaction tests?". When the question was discussed in the interviews, there was a slightly difference in the answers between people who had an interest in the topic and the ones who did not. Almost all participants with a personal interest said that they did not need any reward or other motivation to participate in a test since the opportunity to participate were enough motivation for them. It was only the youngest segment which had an interest that still needed a reward to be motivated enough to participate.

The survey also showed that many participants want to perform the tests since they get the chance to be a part of city development and the future. 24 percent of the participants said that this was their reason for participating and some added that it made them feel important.

Another result from the survey explaining why citizens want to participate was because they like to be the first person testing something. Almost 10 percent of the participants gave that as a reason for participating. These people might have an interest in the topic as well but are interesting in anything new and want to be first with the technology, so called early adopters.

Rewards
The survey showed that some of the participants would consider participating in the digital tests if they were given a reward afterwards. This result was confirmed by the youngest segment in the interviews, as mentioned. Regardless of interest in the topic, they needed something else to motivate them. It was mostly small everyday rewards such as free coffee, a cinema ticket or gift cards that they mentioned as suitable rewards but money was also brought up as an example. The two other segment groups did not need any reward as long as their level of effort in the tests was low and it was not to time consuming. When they were asked the question "Is their any difference in what you need in order to participate in a test at home or in a studio?", everyone said that they wanted some kind of reward if they needed to leave their home for the test since it was time consuming and not as easy to access.

6.4.2 Results from test

When citizens perform tests, feedback on theirs and others' results are something that they want to have presented when the test is finished, out of curiosity. Another

main result that participants want to see is for what purpose the test has been conducted. The need of feeling like a better person that contribute to society was important from all ages. How they want the information presented varied but the need and wish for direct and concrete results where the same for all ages. They want to know how their participation contributed to the development for different customers.

The interviews showed that receiving results from digital tests is a desirable function for the citizens in order for them to follow the conducted test but also to create an interest to return to similar tests. Alternatives on how to receive these results came up during brainstorming sessions in the interviews. These were used in the concept development as inspiration.

6.4.3 Channels to reach customer

The citizens expressed different ways for how they wanted to be reached. These ways were all located on a phone. The citizens said that they used their phones to a greater extent than their computer. To reach the citizens, some part of the solution should therefore be connected to a phone.

6.5 Customer and citizen criteria

In order to perform digital tests with citizens, a digital tool is required. Findings from expert interviews and research regarding digital tools showed that VR, AR, computers and phones are suitable tools to test the interaction between AVs and pedestrians digitally.

Virtual Reality (VR), is a simulated experience of a real or unreal world. In VR it is possible to build up an environment with images and sounds and generate other sensations to simulate a physical presence for the user in the virtual environment. The user can look and move around in the virtual environment and interact with items. VR represents a credible replication of an environment, a sensation for the participant to be in a future context. In Augmented Reality (AR), the user views the augmented world from an outside perspective, inter-playing with it through a device. AR is related to a concept called mediated reality which means that a part of the reality is changed by a computer. It can be explained as adding layers of objects on the real world that can be viewed through a smartphone for example. The user will be aware of the actual reality to a greater extent in AR compared to VR. In this context, a computer is related to a desktop device that are individually owned by the users. A phone refers to a smartphone where it is possible to download apps and play games.

The tool used to test the interaction contributes to fulfill different criteria for customers and citizens. The tool will affect the *citizens criteria* accessibility, time efficiency and effort for the test subject. It will also affect the *customer criteria* and

contribute to different levels of immersiveness which is important for the experience for the citizens and will affect the credibility of the results for the customers. The tool used will also affect the number of participants, which was important for the customers. In order to use these criteria in the concept evaluation, each criteria are divided into a scale from one to three that are explained in Appendix A.2.

6.6 List of functions

The KJ-analysis of the data from the different stakeholders resulted in two lists of functions, one for the customers and one for the citizens. The main function of the *Citizen Test Process* for the customers was to perform interaction tests between simulated AVs and pedestrians. The function that was related to the during phase of the *Citizen Test Process* concerned collection of data of behaviour, emotions, understanding and opinions and was used in the ideation phase. The list of functions also includes functions related to the before and after phase. These were not used in the concept development since it was the during phase that was developed. Functions related to the before phase of the *Citizen Test Process*, included the design of the test and selection of participants. Functions related to the after phase concerned the results from the tests. The customer's list of function is presented below.

Perform tests with customers' own products.
Involve citizens in the tests.
Choose what level of interaction to test.
Define traffic situations to test in.
Choose a target group to test with.
Choose amount of participants.
Collect data of behaviour, emotions, understanding and opinions during tests.
View results from other companies.
Receive results from tests.
Visualize data from the interaction.

The main function of the *Citizen Test Process* for the citizens was to participate in city development through digital tests. It was necessary for the operating system to be independent in order to suite all smartphones. Desirable functions in the process for the citizen were to

Receive a reward
Understand the aim with participating
Choose a test to participate in.
Choose when to perform the test.
See other results.
Feedback from tests.

7
Create and deliver

Applicable concepts on the *Citizen Test Process* have been developed through ideation and matrices and they are presented in this chapter. The concepts were compared with each other and combined in order to find the most suitable solution for the process of VGL. The first shell of the process given in the beginning of the project was used as a basis when ideating on concepts possible to implement. The design of the process developed through this master thesis was adjusted depending on the details of the concepts developed from a morphological matrix. The development of a final solution to VGL is presented in this chapter.

7.1 The Citizen Test Process

At this stage it was not defined whether one or several digital tools would be necessary in order to fulfill the customer and citizens criteria when testing the interaction between AVs and pedestrians. The solution was open for using different digital tools in order to fulfill different customer needs. The result of the findings was in this phase applied to the test bed design, the process developed through this project was from that defined as *The Citizen Test Process*, see figure 7.1. This was the first edition of the process that was going to be delivered as a final solution to VGL.

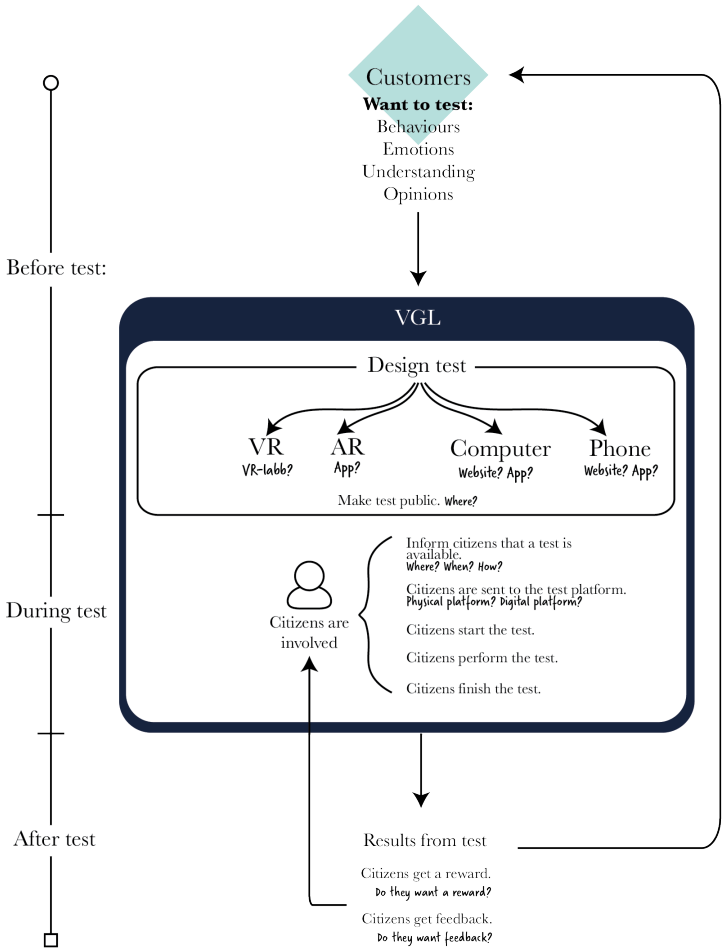


Figure 7.1: Early sketch of the *Citizen Test Process*.

The findings showed that customers want to test either a behaviour, emotion, understanding or opinion. The findings also showed that these levels of interaction could be tested through different digital tools. A morphological matrix, with the tools as a basis, was therefore used to open up the space of ideas for the concepts applicable on the process.

7.2 Morphological matrix

The functions in the left column of the matrix in figure 7.2 were used as a merge of the two function lists for the citizens and the customers. The part solutions of each function are presented horizontally. Some functions were defined as general in the test process and could be applied in every concept. Therefore, they were not ideated on in the morphological matrix presented below since that would have created the same outcome in every concept combination.

Main function: Perform digital interaction tests in 

Part functions

Collect data from tests	Questionnaire	Observation	Interview	Workshop	Focus group	
Recieve a reward	Money	Small everyday rewards	Bonus points	Discounts	VIP invitations to events	
Understand the aim	Text brief	Movie brief	Face-to-face brief	Video call brief	Sound brief	
Place to perform tests	Home	On the go	Studio			
Choose a test to participate in	Customized suitable test	View all possible test	Only one test available	Premium level test		
Choose when to perform the test	Always available	Limited hours	Does not require additional people	When your group is ready	Time slots	
See others results	Website	App	Demos	Cinema	Show room	News
Feedback from citizens	Phone call	Statistics in App	Email	Website		

Figure 7.2: The morphological matrix.

7.3 Concept Presentation

From the matrix, eight concepts with different combinations of the functions were developed. The eight concepts are presented in detail in this section and are all applicable on and adjusted for the *Citizen Test Process*.

7.3.1 Collaborative VR

A group of citizens will collaboratively perform an interaction test in a VR studio together, see figure 7.3. During and after the test they will discuss with each other the scenarios and their experiences. They will have a pre-decided task to perform which will be created by the VGL team together with their customers. Before the test the participants will watch an introduction video that explains the aim with the test and the task. In order to participate, citizens need to book a test, and the reward will be the experience in itself. This would be an event where the citizens pay to participate.

Figure 7.3: The concept of Collaborative VR.

When applying this concept to the *Citizen Test Process*, a booking system of physical tests in a studio would be necessary. Depending on the number of participants that the VGL team and the owner of the test have chosen, there would be a need to match the desirable number of participants with willing citizens. This concept would also require staff and equipment for the studio.

7.3.2 Computer game with friends

A focus group with people who know each other would, in this concept, perform a test together on their own computers at home, see figure 7.4. Each participant would have a personal account where he or she can book a test and receive feedback. When the group is gathered at a certain time, a brief regarding the aim of the test and the task would be shown in a video. Observations and questionnaires would be used in order to collect data from the tests.

Figure 7.4: The concept of Computer game with friends.

Requirements of the process would be a digital booking system, a developed system that mediates feedback from the tests back to the participants and pre constructed briefs of each test. However, all equipment necessary would be personally owned devices. The data from the tests would be complied into statistics from the questionnaires, but there would be a need to perform observations in order to evaluate some of the levels of interaction tested.

7.3.3 Computer game with strangers

This concept is similar to the computer game with friends concept. The difference would be that the participants in the focus group would be unknown to each other, see figure 7.5. The participants would book tests through their personal account and watch brief videos of the test in the same way from home.

Figure 7.5: The concept of Computer game with strangers.

For the process, it would mean that VGL need to collect all participants necessary for a certain test separately instead of as a group. It could mean that it becomes harder to find participants that want to perform tests with strangers but it would

also open up for everyone to join. Finding a complete group of participants, even if they know each other, could be difficult too.

7.3.4 AR on the go

In this concept, citizens would have a personal account connected to an app on their phone, see figure 7.6. The person using AR on the go would see all available tests on a map of the city. When a citizen starts a test, a brief of the aim and the task of the test would be presented in writing. Every test that is performed would give the participant bonus points as a reward of participation. The points would be saved on the personal account and could be used to open up premium levels. Data would be collected from citizens answers of questionnaires.

Figure 7.6: The concept of AR on the go.

For the *Citizen Test Process*, it would be necessary to develop an app with heavy technology. Regular updates, of the simulated scenarios that a customer want to test, would be necessary in the app. Every level of interaction would be tested digitally regardless of certain locations. No physical meetings with citizens be conducted in the process. Data from tests would be collected through questionnaires and complied in statistics and from that sent back to customers and citizens as feedback.

7.3.5 Individual computer game

The participants in this individual computer game could create their own personal account in order to conduct interaction tests with their personal avatar, see figure 7.7. The tests could be performed at home and at any time. When a test is started, a short text of the aim of the test and the task would be presented for the player. When playing, the participant would be observed and asked questions in order to gather data and statistics from the separate tests. The result would be connected to the individual avatar and account.

Figure 7.7: The concept of Individual computer.

Performing tests at home with individual devices would have no physical demand on the *Citizen Test Process*. Developing a computer game on the other hand would have a high demand of digital technology and knowledge. Developers would have to be involved, and it would require resources in time, staff and money in order to develop and keep this concept updated. No booking system would be necessary. Data from tests could be sent back to customers and citizens through statistics. However, the observations of the players would have to be performed by someone, either by VGL or by the customers themselves.

7.3.6 Phone VR

Citizens would perform the tests on their own phone and/or with VR glasses, see figure 7.8. Before the test starts, participants would get instructions about the test in writing. During the tests, their movements and reactions would be observed when they perform different tasks. The tests would be available at anytime, and the participant would collect bonus points for participation in different tests. They could, in this concept, also be used to enter premium test levels for example, but was not further developed in this stage.

Figure 7.8: The concept of Phone VR.

In the concept, VR tests would be performed through an app or a website. The platform used would require different development and financial resources for the developers in VGL. That choice was not made in this stage since it needed further discussion with experts.

The data collection and analysis would be complex in this concept since observations instead of questionnaires would be included. Calculations of statistics to send back to the customers and citizens would therefore not be possible. Individual observations of behaviours through recorded movies would be necessary. Once again, no physical equipment or meetings would be a part of the *Citizen Test Process* since the smartphones and the VR glasses would be owned by the citizens.

7.3.7 Phone game

In this concept, citizens would perform tests through their own phone and play an avatar in a phone game, see figure 7.9. Before the test starts, the participant can read about the test. During the game, questions would appear in different situations asking about behavior, emotions, understandings and opinions. The way the participant moves their character would need to be tracked and observed by VGL or customers in order to compile and analyse data. These tests would be available at anytime, not require at booking system and the citizens could view all

the published tests on a map in their phone. The participants would collect bonus points as a reward that can be used to cash out everyday things in selected stores.

Figure 7.9: The concept of Phone game.

7.3.8 Individual VR

Citizens would individually perform interaction tests in a VR studio where the VGL team and customers have designed the test, see figure 7.10. All the tools and equipment needed would be given to the participant on arrival, and the test leader would introduce the test. During the test, the participant would be observed and asked to speak out loud when performing different tasks. The VGL team would ask questions during the test and measure different reactions regarding for example time and distance. In order to participate in these tests, citizens need to book a test and as a reward for participating, they would get a free coffee or a cinema ticket.

Figure 7.10: The concept of Individual VR.

For the *Citizen Test Process*, it would mean that a physical VR studio has to be designed and built with associated equipment. It would require staff on site during opening hours. The studio would also have to be open after working hours in order

for citizens to be able to participate. A booking system would be necessary to reach the citizens and the data collected would be constrained towards the amount of possible test participants in the studio. The data would have to be compiled by VGL in order to enable analysis for the customers.

7.4 Concept evaluation

The criteria of accessibility, time efficiency, effort, immersiveness, credible data of behaviours/emotions/understanding/opinions and number of participants were used to weight the concepts against each other. Each criteria could receive one to three points which is explained in A.2. The final score for each concept is presented in the end of figure 7.11.

Concepts → / Criteria ↓	Collaborative VR	Computer game with friends	Computer game with strangers	AR on The Go	Individual computer game	Phone VR	Phone game	Individual VR
Accessibility	1	1	1	2	2	3	3	1
Time efficient	1	2	2	2	2	2	3	1
Effort	1	2	2	2	2	2	3	1
Immersiveness	3	2	2	2	2	2	1	3
Number of participants	1	2	2	2	2	3	3	1
Credible result of behaviuor	3	2	2	2	2	2	1	3
Credible result of emotions	3	2	2	2	2	2	1	3
Credible result of understanding	3	3	3	3	3	3	3	3
Credible result of opinions	3	3	3	3	3	3	3	3
TOTAL	**19**	**19**	**19**	**20**	**20**	**22**	**21**	**19**

Figure 7.11: The concept evaluation matrix.

The final score of each concept differed marginally. Since details in the concepts were not prioritized in this step, the concepts with the same digital tool were compared against each other. Due to this, three concepts were excluded. Since the details in Collaborative and Individual VR are both applicable for VR in a studio and the two concepts scored the same in the evaluation matrix, these concepts were brought into the next phase as a merged concept called VR in a studio. The five concepts that remained can be seen in figure 7.12.

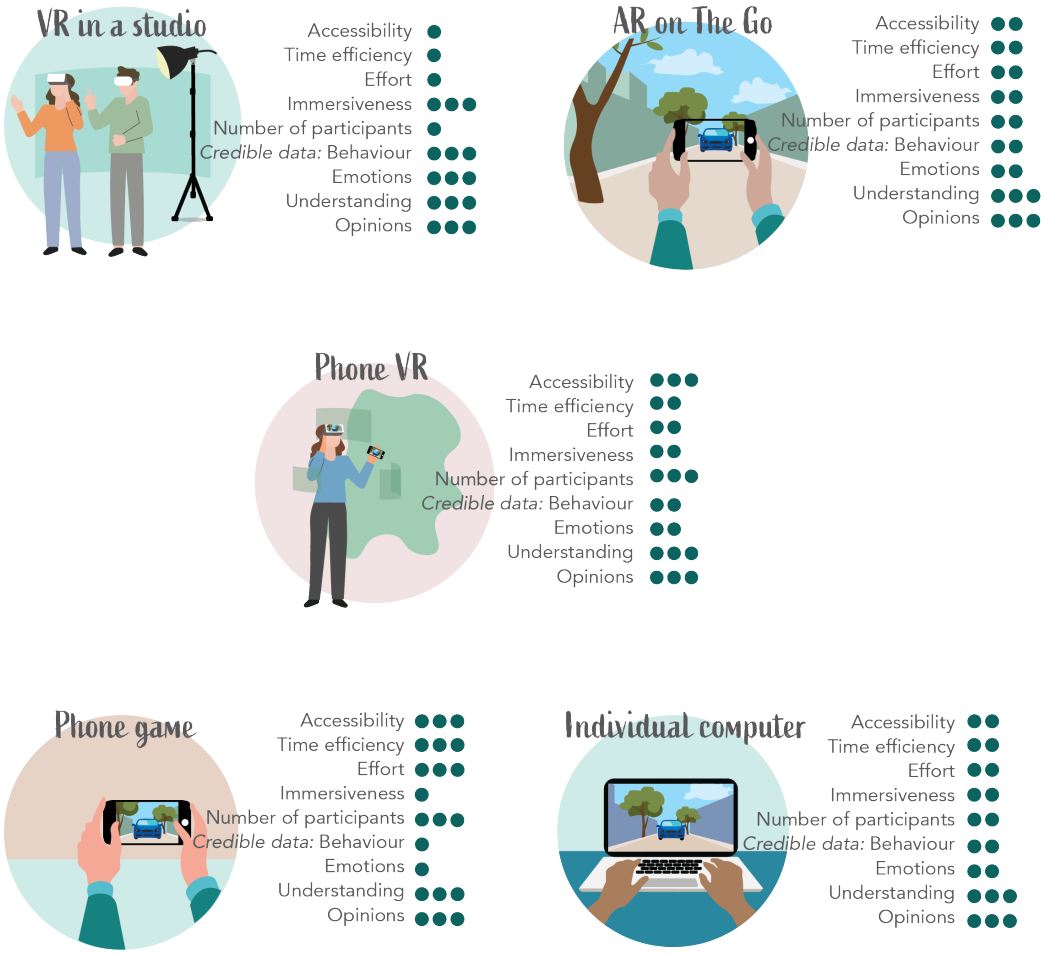


Figure 7.12: The five remaining concepts with scores from the concept evaluation matrix.

7.4.1 Concept combination

The five concepts fulfilled different criteria, but none of the concepts fulfilled all of them. In order to meet all the needs found from the citizens and the customers, a combination concept was created for the *Citizen Test Process* in VGL. In order for customers of VGL to be able to test all possible interactions with credible results, the technology of VR in a studio was the only option. A parallel could be seen

between credible results and high immersiveness which would be received in a VR studio where several factors in the environment could be controlled. The context that can be created in VR will transfer the test subject to a future situation to a grater extent than trough AR, a computer or a phone. In AR, the test subject views the augmented world from an outside perspective, inter-playing with it through a device. Therefore, the test subject will be aware of the actual reality to a greater extent in AR compared to VR. However, since AR inter-play with the real world, the level of immersiveness is higher compared to a game on a phone. When playing a game on a phone or a computer, the test subjects are outside the simulated world interacting with an avatar. In games, the real world is represented by a digital world where the test subject is controlling an avatar, and the movement is therefore not physically represented by the person playing. This will lower the level of immersiveness but the size of the screen will also contribute to the level of immersiveness and therefore, the computer game scored higher on immersiveness. The phone VR will create a higher level of immersiveness than a phone game since the test subject is moving while performing tests. However, the screen is small, and the environment can not be controlled to the same extent as in a VR studio and therefore the phone VR got a medium score on immersiveness. Therefore, VR in a studio was a clear concept to keep on developing since testing citizen's behaviours and emotions require high immersiveness in order to create credible results for the customers. Since testing understanding and opinions do not require the same extent of immersiveness to create credible results, these tests could be performed in any of the five concepts.

As can be seen in figure 7.11, VR in a studio scored low on citizen criteria and the customer criteria of *amount of participants* and therefore needed a complement in order to become a powerful final solution. Phone VR and Phone game, as can be seen in figure 7.11, scored high on citizen criteria as well as *amount of participants*. Therefore, these two were merged and further developed into a combination concept together with the VR concept. Together, these concepts fulfilled each criteria completely and became a basis for the final solution of the *Citizen Test Process*.

7.4.2 Development of the concept combination

When suitable digital tools were decided, development of the details became relevant. Due to the time limit and available resources for prototyping, developing the phone concept was prioritized. Questions that arose in this phase regarding the functions of the phone concept were

Should it be an app or a website?
How will the citizens be informed about new tests?
How do we communicate the aim with the tests?
How do citizens perform tests?
How do we communicate the result of the tests?

From interviews with citizens it was clear that creating a relationship in the solu-

tion was important in order to create customer loyalty. Therefore, in collaboration with experts, the decision of moving forward with an app was made. An app also facilitated the function of using the phone VR. Questions that arose regarding the development of the *Citizen Test Process*, see figure 7.13, were

How will citizens find out that a new test is available?
How will citizens book VR tests in a studio?
How can citizens connect to the digital twin through an app?
How can results of tests be sent back as feedback to the citizens and the customers?

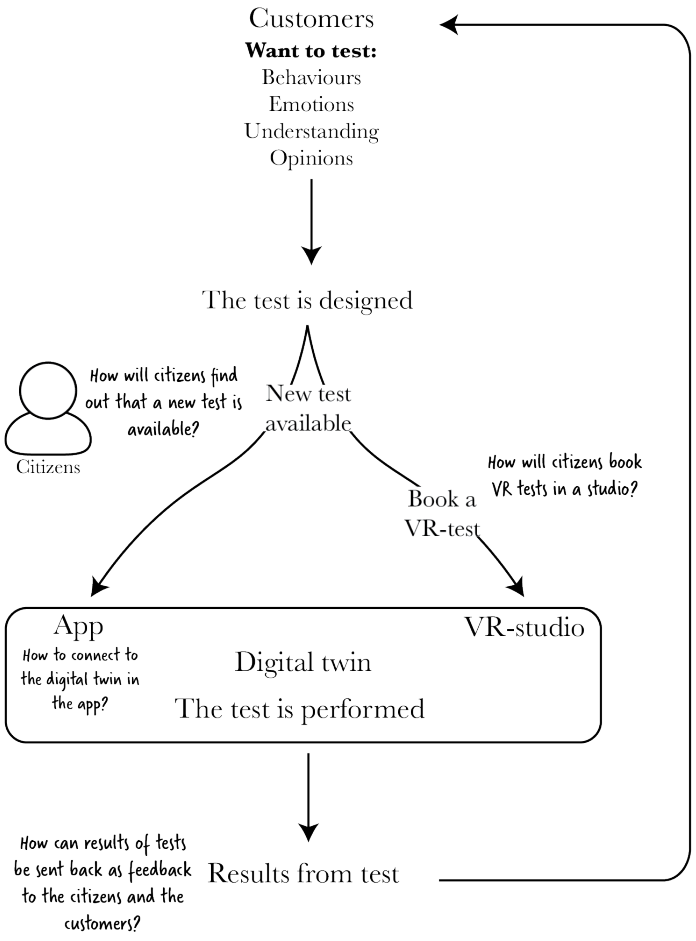


Figure 7.13: The *Citizen Test Process* when the concept combination had been chosen.

These questions were used as a basis in the development of the app that is presented below. The questions needed to be answered in order to make the *Citizen Test Process* complete.

7.4.3 Development of the interactive app

When developing the app, it was important to reflect on and implement the findings from the survey and the interviews with the citizens since they are the intended users of the app. The findings were therefore discussed in order to match them with the functions in the app. Since it was determined at this stage that the app was going to have a VR function where citizens can experience future Gothenburg and perform tests, the app was defined as an interactive app. The connection between the digital twin, the interaction tests and the app then started to be formed. From brainstorming and digital user journeys different ideas on how to enter the digital twin was developed. The examples developed were a list of available tests, search fields, maps and links through articles about city development.

The main reason for prototyping the app was to communicate the functions. Therefore, the interface will not be the final one since usability testing will be necessary and the design will be affected by the owner's brand. The aim with the project and the development of the *Citizen Test Process* was to involve citizens in city development. Since the customers wanted a wide range of different citizen segments the decision of using as many relevant entrances as possible was made. All of the ideas mentioned above were therefore brought into the final design of the app. It was also important to once again reflect on the scope of the project and the goal of focusing mainly on the functions in the process. The designs of these entrances to the digital twin were therefore created rapidly and with less focus on usability and digital experience.

Since the survey, see figure 6.4, showed that citizens want to receive more information about tests before participating, how to stay transparent with the purpose and task of the tests were ideated on. The findings also showed that citizens are interested in follow different city development projects. These two findings gave ideas about a news/information site in the app. To create a logic order of the functions in the app, the news site was placed before the VR function since citizens want the information first. Links to different tests were placed at the end of a connected city development article in order to follow that logic order of information in this specific function too.

The interface of the app was designed from similarities in other social media apps in order to create recognition for the users. The interface was not developed through different concepts since the main focus was on the functions. A final function designed in the news site was a summary of short movies/events from the VR studio. Since the citizens stated that they wanted more information before entering a test, it was relevant to show information and happenings from the tests in the VR studio as well. The aim was to create a communication path in order to introduce more participants to the physical interaction tests as well.

In this phase two main functions had been developed in correlation to the citizens needs, a new app and a VR environment. In the interviews, reward of participation was also discussed. The finding shows that a reward was a small part of the

experience if the solution was accessible and was therefore excluded from the final solution. However, if the solution is not that accessible, as in the VR studio, some of the citizens need a reward as a motivation to participate. How a reward will be a part of the VR studio is not decided in this thesis since the details of the VR studio are not defined. This needs to be further investigated.

The next function that was developed was the booking system of the VR studio tests. The interface was created through digital prototypes. In order to fulfill the need of more information before entering a test, information about time, location, amount of participants and purpose with the test was included. The interface can be seen in chapter eight, but since the function was the primary factor in this development, the interface can be changed before a potential implementation.

Finally, the findings showed that citizens and customers want to receive feedback from the tests. That is one of the important factors in this process in order to create a more inclusive city development. A function where citizens can see information about the result of their conducted tests was therefore developed. A page where users can read about specific results from the tests that they have been involved in were therefore created. How the information from the app is sent back to the customers was not decided since the entire service of VGL was still not developed.

8
Final solution

The final solution of the *Citizen Test Process*, see figure 8.2 includes interaction tests in a VR studio and in an app which is illustrated in figure 8.1. By following the process, customers can test different cases or scenarios with citizens with the help of VGL in the digital twin of Gothenburg.

Figure 8.1: Visualisation of the experience of the *Citizen Test Process*.

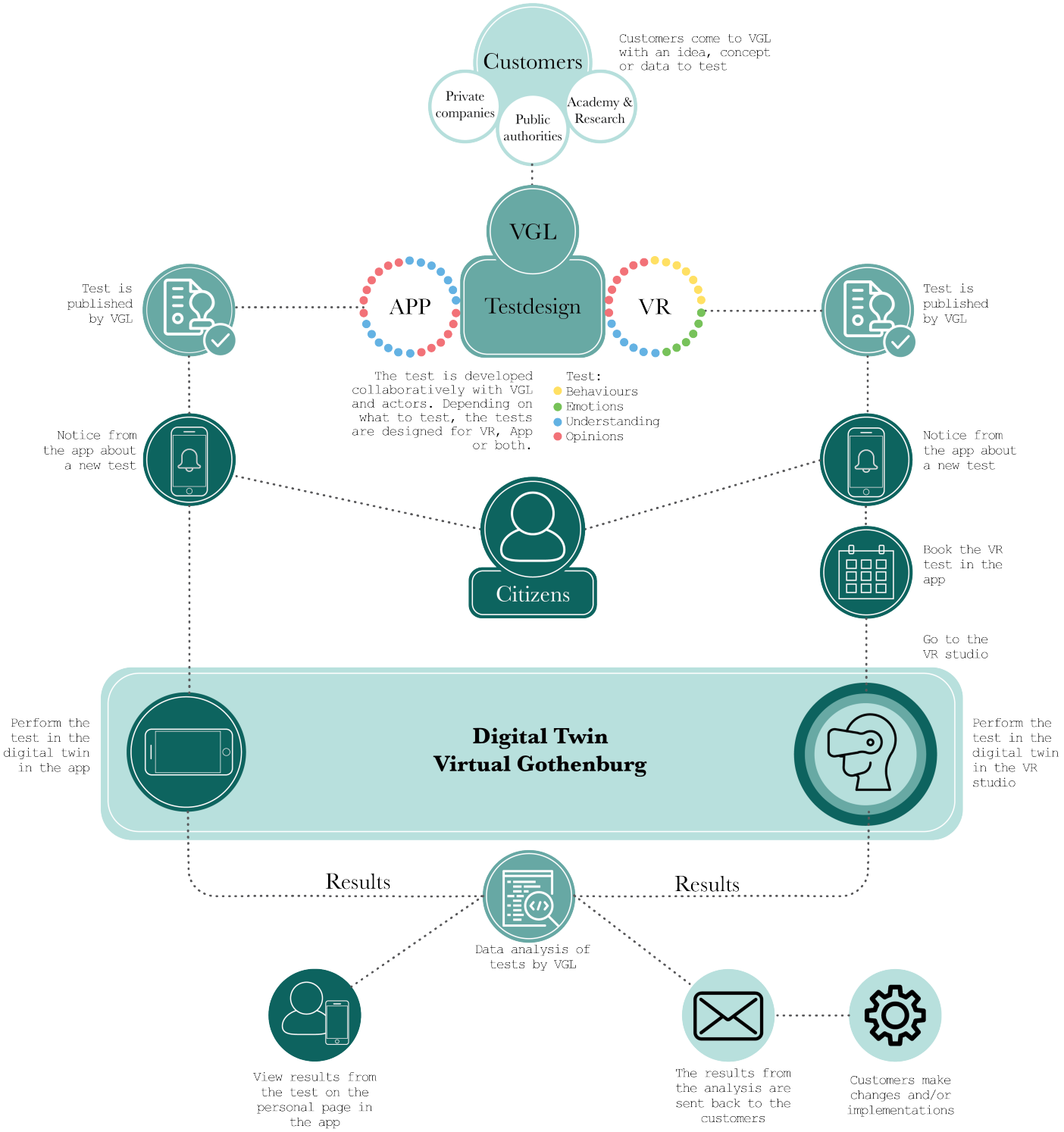


Figure 8.2: The final edition of the *Citizen Test Process*.

8.1 Citizen Test Process

In the *Citizen Test Process*, customers and the VGL team will design the test. Depending on what type of interaction that the customers want to test, the test is designed either for the VR-studio or the app. If the customer wants to test citizen behaviour or emotion towards the autonomous vehicle, the test is designed for the VR studio since these levels of interaction needs high immersiveness in order to get credible results. However, if the customer wants to test citizen understandings or opinions, the test can be designed for both VR and the app since these levels of interaction require lower levels of immersiveness.

When the test is designed and available for the citizens, they will access information about the test in the app. Depending on the design, citizens can either book a test for the VR studio or continue to the test in the app. If the test is designed for VR, citizen will get a confirmation that they have booked the test. When it is time to participate, citizens will go to the VR studio where they will get an introduction of the test and given all necessary equipment. They perform the interaction test and get observed and asked questions connected to the scenario during the test.

If the test is designed for the app, citizens will see all available tests on a map and will be able to choose what test to participate in. When choosing a test, citizens will enter the digital twin through their phone and participate. The tests in the app are question based and depending on the test, the participant will either watch a video or see pictures before they answer the questions. When the citizen has answered a question, he or she will remain in the digital twin and are able to walk and look around and interact with other tests and the future city.

After the tests, results will be sent back to the customer when it has been analysed and compiled by VGL. They can use the results in the development of their products. The customers of VGL can use this process single or multiple times as an iterating part of their development process and implementation. The citizens will be able to see the results from the tests in the app.

Through this process, citizens will be a part of the VGL system and thus in city development which was two of the problem areas in this project. Through the process, customers will have the possibility to investigate the interaction between autonomous vehicles and pedestrians who fulfill the third problem area. The representatives of VGL expressed that this process also could be applicable in other city development areas where AVs are not included. The transferable parts of the *Citizen Test Process* are the app, the VR studio, the different levels of interaction that could be tested and the involvement of citizens. One example could be that Gothenburg City want to allow citizens to experience a future building and contribute to the development of the appearance and location.

8.2 VR simulator in studio

The VR studio will be a physical place located in Gothenburg containing all necessary equipment for enabling tests of the levels of interaction. It will also require staff onsite during opening hours. The studio will be open after working hours in order for citizens to be able to participate.

8.3 Interactive VGL app

To make the *Citizen Test Process* more accessible for the citizens, the app was created as a part of the process. In this section, the different functions in the app are presented.

8.3.1 News page

When opening the app, the user will enter a news page, see figure 8.3. The user can scroll between different news and articles connected to projects in Gothenburg city.

Figure 8.3: The interface of the news page in the app.

The citizen analysis showed that the majority of participants wanted to read about ongoing projects and be updated on current city development. Therefore, this page was added as a part of the app. Since some of the participants expressed an uncertainty in participating in tests, this page can introduce them to VGL and lower the barriers for participation. In order to make the tests more accessible for citizens that do not want to interact with the digital twin, tests that are connected to a

specific article on the news page will be available in the end of the article. This will make it easier for the citizens to participate in tests where they are interested in the topic since they choose to read the article. However, participating and answering questions will always be optional.

One additional function in the app is located on the top of the page, where short videos from the tests that has been performed in the VR studio are being published in order to introduce citizens to how the tests are performed. This aims to create an interest and hopefully lead to a higher number of participants.

8.3.2 Map of accessible tests

In this function users can see all available tests connected to a certain location in the city, see figure 8.4 . When the test is designed, the customers choose, together with the VGL team, a suitable location for the test. The purpose of placing the tests on specific locations is to create experiences that could be of relevance in the future.

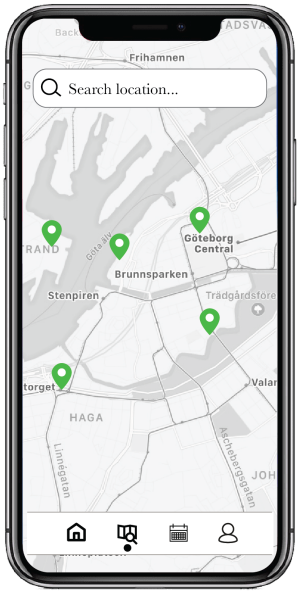


Figure 8.4: The interface of the map with available tests in the app.

Users can also choose to enter the digital twin on a free location, that does not have a test connected to it. The aim is to create relevant usage and accessibility for citizens with different interests. The map allows the user to search for tests that they have heard about, scroll among all tests available, search for a certain location or click directly on the location that they are interested in. When a test or a location has been chosen, the user is redirected to Virtual Gothenburg through VR.

8.3.3 Virtual Gothenburg through VR

The user enters the VR function in street view of the chosen location. Available tests will be visualised through green spots which can be seen in figure 8.5. The user can choose to walk around freely in the digital world or click on a test. The VR environment allows the user to rotate their view by tilting the phone and the user can through that experience the city in a way that is close to reality. It is possible to change between how many years ahead, that the user want to experience the future of Gothenburg city in order to see when projects are supposed to be implemented.

Figure 8.5: Screenshots from the VR function in the app.

If a test is chosen, a pop up window will open with an explanation of the duration, task and purpose of the test in order for the citizens to choose whether to participate or not. If citizens want to participate, a video or image will be visible with a related question as can be seen in figure 8.6. When the test is complete and the users have sent their answers, the pop up window will disappear and the users will be back at the same location as before.

Figure 8.6: Screenshots of a tests in the VR function in the app.

There is no limit of the amount of tests that can be conducted. Users can always enter the digital twin and participate in current tests. The citizens criteria of accessibility is by that fulfilled.

8.3.4 Booking a VR studio test

One of the functions in the app is to book tests that are designed for the VR studio, see figure 8.7. On the calendar page, users can find all available tests and see which tests they have booked or not. By clicking on one of the tests, users can get more information, including aims and goals which was found to be important for the citizens in the citizen analysis. If the user wants to see the tests in a calendar view he or she can toggle between list view and calendar view.

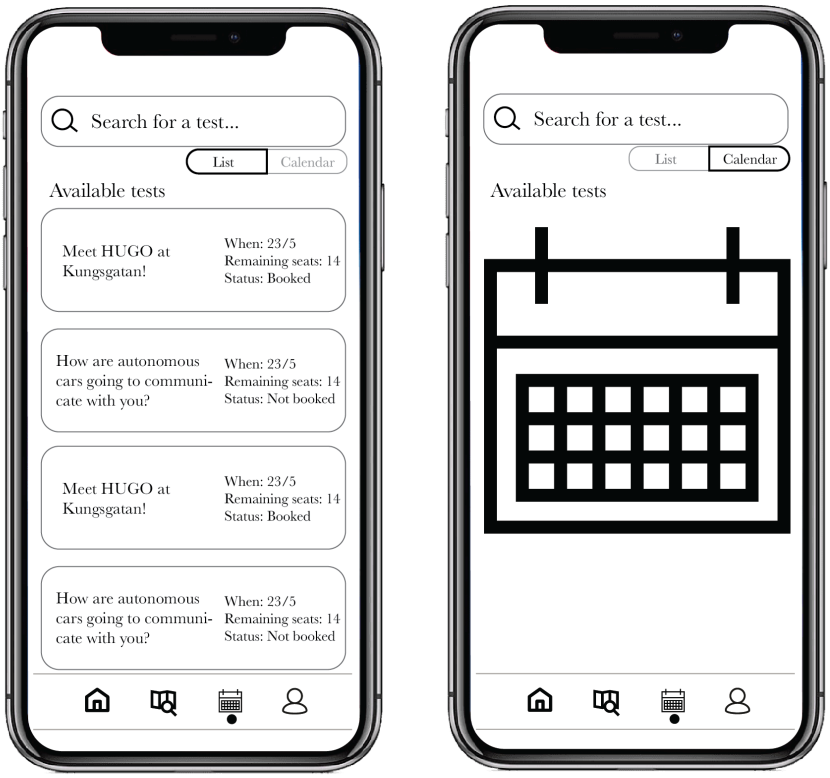


Figure 8.7: The interface of the booking system of VR tests in the app.

8.3.5 Personal page

Since almost every participant in this project expressed that they wanted to take part of the results from their tests and see how their participation contributes to valuable data for the customers, a personal page, see figure 8.8, are included in the app. The personal page includes information about tests that the user has booked and also results from tests that have been finished. The user can click on each test result and read more about how many participants that were involved and what the data have been used for.

Figure 8.8: The interface of the personal page in the app.

8.4 Personas to describe the use of the process

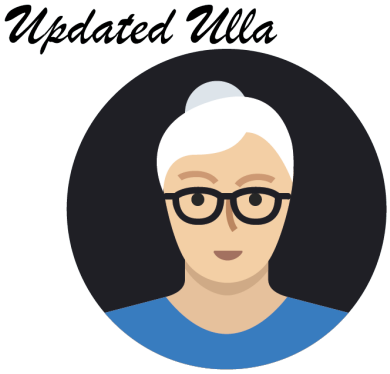
During the customer analysis, different customers were found. The citizen analysis also showed different interests in being involved in city development. In order to communicate possible future customers of VGL and users of the app, personas and scenarios were used as a method and they are presented below.

8.4.1 Citizen personas

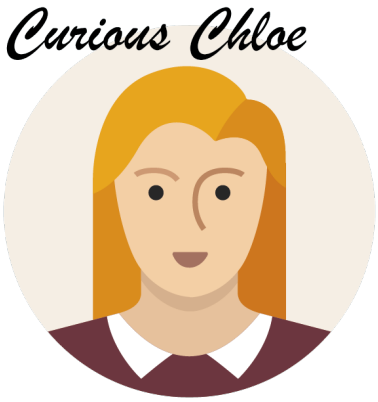
The three different personas created with the aim to communicate the final solution in detail, are presented in this section. They are called Participating Pete, Updated Ulla and Curious Chloe.

Pete loves technology and is an early adopter to everything within that field. He bikes to work every day. When Pete comes home from work, he often participates in Facebook discussions about city development and new technology.

Ulla loves to be a part of new things and spend time reading about new developments in the city. Ulla is very keen on expressing her opinions and contributing to city development.



Chloe likes to see future plans for Gothenburg and is easily inspired by new ideas. Chloe enjoys walking around and understand the city she lives in so that she can, efficiently, find her way to different locations, restaurants and relatives.



8.4.2 Customer personas and scenarios

Private companies, public authorities and researchers are possible future customers to VGL. Scenarios where they come to VGL to perform tests are presented below. The citizen personas are used to illustrate typical users in the scenarios.

Private company - All levels of interaction The HUGO team at Berge are currently developing an automated last-mile-delivery robot and wants to know how it feels to walk around at Kungstorget when several HUGOs are driving around at the same time. They want to study the behaviour of people when they meet HUGO and also understand their feelings about HUGO and his driving logic. They also want to test how people understand the intentions of HUGO and get inputs about his size and shape. Therefore, they reach out to the VGL team since they want to test this in the test bed of VGL. They want to perform the test with citizens in order to get real human insights of the meeting with HUGO. The VGL team helps them to design a test for both the VR studio and the app since the HUGO team wants to test all levels of interactions.

When the test is designed, the VGL team makes the test public in the VGL app and citizens get a notification. Several citizens start to perform the test in the app where they view a short movie of a situation when HUGO is driving on Kungsgatan. When the movie ends, they first answer some questions about what they think that HUGO was communicating in the movie and then they vote on what colour they think suits HUGO the best. Many citizens, where Participating Pete is one of them, also book the test in the app since this is a situation that they feel will affect them in their everyday life. Participating Pete performs the test in the VR studio at the time he has booked. The staff helps him with the equipment. When the test is finished, Pete opens the app and his personal page in order to see the result from

the test that was performed. The staff takes care of all the equipment afterwards and prepares for the next test subject. When the number of test subjects is enough for the customers, the VGL team closes the test and starts to analyse the data. When they have compiled the results, they send it back to the HUGO team who can use the results in their development process. Participating Pete and the other participants can find the result on their personal page.

Public authority - Opinions A public authority in Gothenburg is developing the bridge to Hisingen and wants citizen's opinions on the shared walkway on the bridge. They need this information in order to make informed decisions based on what the citizens think and want. Therefore, the test bed in VGL is of interest to them since it is an easy channel to reach out to a great number of citizens. They choose to design this situation for the app together with the VGL team. The test is made public in the app and an article about the project is also published. Updated Ulla, among other citizens, starts to read about the new bridge to Hisingen. She has just poured a cup of coffee when she is asked if she wants to give her opinions about the shared walkway and bike path on the bridge, which she accepts without hesitation. When she has given her opinions, she keeps on reading other articles to stay updated. When the number of test subjects is enough for the customers, the VGL team closes the test and starts to analyse the data. When they have compiled the result, they send it back to the public authority. This data can now be used in order to create an inclusive city that is developed with and for the citizens.

Research institute - Understanding A research institute is currently working on a project on where to find out what ISO standard that should be developed for the communication behaviour of autonomous vehicles. They want to test different ways that the vehicles communicate with the citizens in order to develop a solution that is accepted and understood by the citizens when implemented, that is why the researchers choose to contact VGL. Since they want to investigate citizen's understanding, the test is designed for the app. The test is made public and notices about the new test are sent out to the citizens. Curious Chloe is one of those who receives this notification when she is using the VR function. She was currently experiencing the new building at Masthugget in the VR function, when this test captures her interest. During the test Chloe looks at pictures and is asked about how she interprets different communication behaviours of an autonomous car. She is also encouraged to put on her headphones to listen to different audio signals and interpret them to. When Chloe is done, she continues to walk around in the future of Gothenburg and explores new streets and buildings that are planned to be ready in 2050. The VGL team compiles all the data and sends it back to the research institute.

9
Testing and evaluation

In order to evaluate the solution, the process and the app were presented to experts within Gothenburg City. User tests of the app were also conducted with citizens, and the result is presented in this chapter.

9.1 Validation with experts

The final solution was presented to experts in Gothenburg City and people involved in VGL in order to validate it. They asked if we had investigated the possibilities for applying the process in other areas since they saw a future value in the solution and that it was applicable to city development projects such as new buildings and social green areas. They thought that the phone was a suitable device to reach citizens in order to increase participation in city development. They also said that involving citizens as test subjects is an interesting perspective on how to involve them in city development. They wondered how much time and money that could be saved compared to physical tests in the real world which is something that needs to be further investigated. The *Citizen Test Process* will be used as an inspiration in the following pilots in VGL and the VR function in the phone has potential to be used as an inspiration in other projects in Gothenburg City.

9.2 Validation with citizens

In order to validate the functions of the app, the prototype was tested with citizens. For more information about the design of the test and the questions related to the app, see Appendix A.3. The compiled result showed that the probability of downloading the app, reading the news, usage of VR-environment and performing tests in phone-VR was relatively high compared to performing physical VR-tests in the studio as was expected. The probability results of each question are presented in Appendix A.5 and the average score can be seen in figure 9.1.

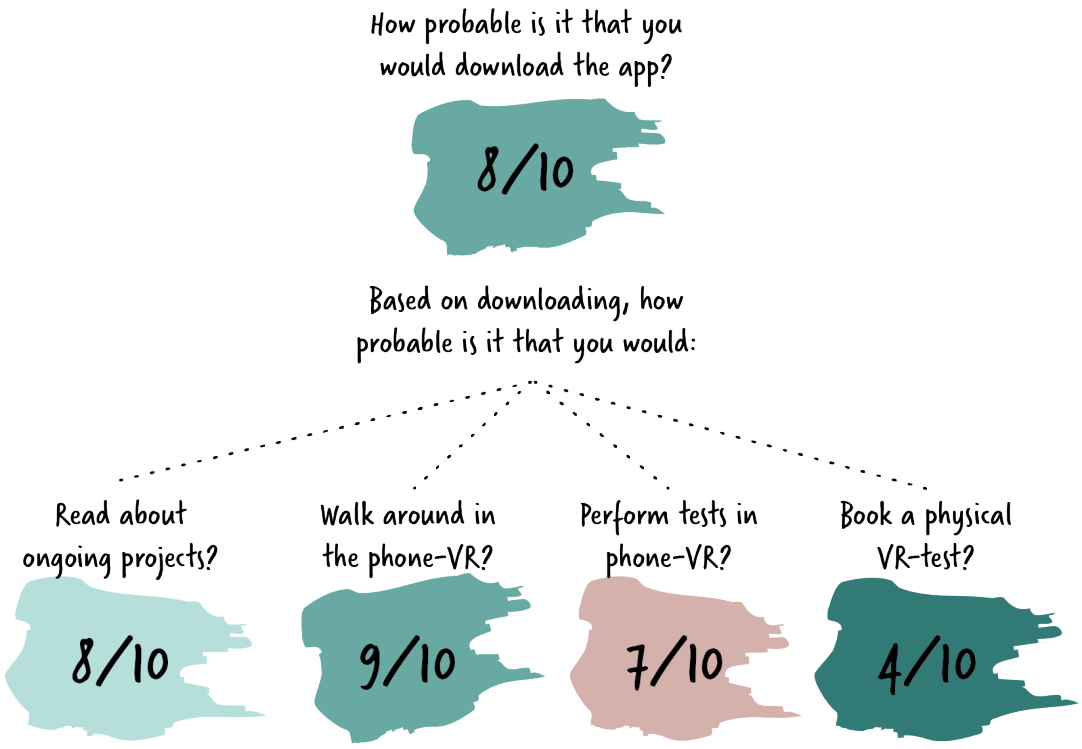


Figure 9.1: Average scores on probability questions from prototype test.

The open questions regarding the purpose of usage and strengths and weaknesses with the app, confirmed the statistics shown above. Individual answers can be found in Appendix A.4. Many of the participants were impressed by the VR functions and commented things like

> *"Wow, it is cool that you can walk around and see the future of Gothenburg" and "Oh wow, I can look around here"*

These reactions implied that the VR function in the app can create immersiveness. Another comment was

> *"It is interesting to be a part of the development and to see how everything is planned. I liked the VR function, it is better to experience and see the changes and future plans than read long articles about it."*

which showed that the app can encourage individual interests, keep citizens updated about development projects and create a new way to experience cities. These comments, together with the test result, implied that there is an interest in being updated on what is going on in the city and that the VR function creates extra value for people who want to be involved in city development. The fact that citizens think that it is better to experience future Gothenburg through VR, instead of reading articles, strengthens the statistics regarding use of the function. From these comments, we can assume that the app will have a potential of being downloaded

by people with an interest in city development. The comments primarily strengthen the VR function that is the main function in this app which therefore validates the idea of citizen involvement through VR.

9.3 Final changes in the app

From the notes taken during the tests, comments on changes in the app were brought up. Specific answers can be seen in Appendix A.4.

An introduction to the functions of the VR environment was one aspect that some of the test subjects felt that they missed. Using VR was something that several of the test subjects had never done before, so an introduction to all of the buttons should be a part of the final solution. The prototype was designed so that the user enters the digital twin in street view. Due to that, some of the test subjects found it hard to understand their location. They went back and forth from the 2D map, which had a bird's eye view, and the 3D city in order to understand where they were. Therefore, a zoom function in the 3D environment should be implemented in the final solution of the application.

The prototype represented the future of Centralenområdet in Gothenburg City. The test subjects commented that they found it hard to locate themselves in the future Centralenområdet and said that they wanted to be able to change between the future city and the actual appearance of today. An original version of today's city will also be available in the VR environment and the users should be able to switch between the future city and today's city rapidly.

Targeted information was another aspect that came up during the tests. Several of the test subjects commented that they mainly wanted to see projects, news and information that are related to where they live or their interests. However, some said that they even wanted to see another city in the VR environment so a function that gives the user an opportunity to choose what type of information that they want to see in the app is of high relevance.

10
Discussion

This chapter includes a discussion of how the aim and criteria found are fulfilled, what is delivered to VGL and how the final solution will affect city development and citizen involvement. The methods used in this project are also discussed together with recommended future work for the implementation of the *Citizen Test Process*.

10.1 The purpose with the *Citizen Test Process*

This project has contributed with knowledge about why citizens should be involved in digital tests, how they can be involved and when customers want to perform tests with citizens. By that, the research question of how citizens can be involved in VGL in order for customers to investigate the interaction between AVs and pedestrians, and by that be a part of city development have been answered. The *Citizen Test Process* contributes with an additional function in VGL that can be used for citizen dialogue and as a collaborative platform for city development work.

Through this project, why citizens should be involved in VGL was investigated, and two reasons were found. Reasons for customers to come to VGL and perform tests with citizens were to reduce costs and time to market in their development processes, and also to create a safer test environment for participants compared to today. Another reason to involve citizens in VGL is to involve them in city development. Through the citizen involvement in VGL, Gothenburg City has the potential to fulfill one of the United Nations Global Goals [1] of a sustainable and inclusive city. Through interviews with customers, when to involve citizens was investigated. Customers want to involve citizens when they want to test the four levels of interaction found in this project. The investigation of how citizens should be involved showed that the most suitable way, found from the interviews, where as test subjects through an interactive app and a VR studio.

In addition to creating value for the customers of VGL, the final solution also creates value for citizens and encourages individual interest of city development in a new way than today's services. The app contributes to a new way to experience city development projects through VR in a more interactive way for citizens who want to know more and follow development. It also makes it possible for citizens to be a part of the development and influence decision processes. Several services already include citizens involvement today. However, through the *Citizen Test Process* the involvement will be even more transparent with clear purposes for citizens involve-

ment. Tests will not be performed in order to justify decisions that are already made or used in processes where other factors, and not the citizens, affect the outcome [34]. Previous criticism has been that citizen involvement is more about information and consultation [35], the two lowest levels of the dialog ladder [25] presented in chapter 4. Since citizens will be involved on a participating level through the *Citizen Test Process*, the risk of an illusion of power and mistrust between citizens and customers can be reduced.

Through the app developed for the *Citizens Test Process*, the criteria of accessibility, time efficiency and effort have been reached. The app creates an accessible and interactive platform for city development that does not exists on the market today. Citizens will not have to travel to a physical place like Älvrummet [26] which has the potential to increase the number of participants. The tests in the app could be performed efficiently since the tests will be shorter than 15 minutes.

Theoretically the *Citizen Test Process* has a great potential to develop VGL as a collaborative platform, however the process still has to be implemented and evaluated in order to see the final impact. The prototype of the app tested the functions but did not test any level of interaction. The *Citizen Test Process* has not been tested with real cases where citizens are involved as test subjects. No tests were performed in the VR studio either and data has therefore not been delivered to customers. The credibility of the data has therefore not been evaluated. The digital tools need to be tested with real cases before implementation in order to evaluate if reality corresponds to the findings of this thesis.

10.2 Contributions to VGL

This project has contributed with inputs and a proposal of the test bed design where citizens are involved. This was presented and compiled for VGL, and they can use the *Citizen Test Process* in further development of the test bed as a source of inspiration. Reasons for customers to enter VGL have been found which VGL can learn from and use to develop the test bed. For the pilot CoExist2, a tool for how to test autonomous vehicles with citizens in shared spaces has been delivered. The app and VR studio are not limited to tests with AVs and have a potential to be used in the future service of VGL.

10.3 Credibility in digital tests

It will always be an uncertainty if digital and physical tests could ensure a result that is representative to a situation in the real world. However, since the human perspective is a part of the tests performed in the *Citizen Test Process*, customers will receive a higher reliability of data for the levels of interaction, in comparison to simulations with digital avatars. Therefore, the solution fulfills the enlightened criteria, and customers could perform tests with citizens to investigate the interac-

tion between AVs and pedestrians. The process could also be used as a method for dialog between decision makers and citizens.

The test subjects are not exposed to the same risk as in a real situation and can therefore experience less respect for a vehicle in a simulation compared to when they meet a vehicle out on the street in the real world. This could affect the result from the test negatively but still give valuable information to the customer. Different ways of conducting digital tests will fulfill the criteria of credible results of different levels of interaction. However, a remaining challenge is that the test subject will always be aware of that he or she is performing a test and will due to that be partly biased. This is the case for all user tests no matter if it is a digital or a physical test which could be a motivation for digital tests in comparison to the physical ones performed today.

Digital tests do not need to replace physical tests and instead be used earlier in the development process for the customers. It will be up to them to decide the balance between digital and physical tests depending on specific scenarios and resources. Some tests might even be easier to perform physically due to the required resources to design and publish a digital test. An assumption is that the *Citizen Test Process* will be used in an early phase of the development as a laboratory tool. Different customers will probably have various interests in testing the different levels of interactions which in turn will affect the citizens involvement in different sectors.

10.4 Accessibility and social sustainability

A risk with involving citizens as participants in city development is that some segments do not have time, interest or the possibility to participate in the dialogue [20]. A risk with not receiving participants from all segments is that the result from the tests will affect the development of the customer's products. The city might then be customized based on people with an interest in technology and city development. A factor that affects the variation of participants is the choice of technology. While the solution will facilitate the involvement in many cases, it might also exclude some segments that do not have access to a smartphone.

An ethical question is whether everyone should be able to participate in all tests or if the some tests should be connected to where people live and work. For example, is it right to let people who lives at location A influence the development of location B if that person never spends time there? By letting people who live in a specific area be the only ones influencing the outcome, the area will be developed for them and thus increase the acceptance and understanding of new implementations. However, shared spaces in the city centre will be used by everyone and tests related to the area should be open for everyone in order to develop an inclusive city.

10.5 Methods used

During the project, it has been a challenge whether to design a solution with the purpose to create an interest for city development for those who are not interested or give the ones that are interested a new platform for participation. The survey showed a high interest in city development among the participants, and the decision to mainly focus on that segment was therefore made. Further work could involve investigating how to adjust the app in order to attract those who are not interested in city development in order to achieve a more inclusive city where all segments are represented. The high interest might be due to the choice of publishing the survey partly in city development groups on Facebook. Since the interest of city development was relatively high among the participants, the solution has been biased and developed for that segment. However, this does not need to be a negative outcome since it is the people who are interested in city development that will use an app like this in the end.

The number of citizens participating in the interviews was quite low, therefore, we did not manage to see a saturation within the segments. It was hard to draw a conclusion if the segments differed from each other and the assumption was that they will be reached through different channels. However, the choice of using the specific finding for each segment was still made, and citizen personas were created based on these segments. Three personas were created, but it might be necessary to investigate whether a higher number of personas could be relevant in order to represent all segments in Gothenburg.

The brainstorming sessions in the interviews with citizens were a challenge since they were performed digitally. It was hard to encourage open discussions and the creativity since they needed to talk one by one. The digital barrier might have affected their will of expressing themselves. The concept evaluation might have been affected by this since the citizen criteria found in the interviews were used as a basis in the evaluation. This could have been avoided through physical sessions. This was not a challenge when conducting interviews with customers since their sessions were question based and did not include brainstorming.

The prototype required a switch between two phones which might have affected the experience of the app. However, this did not change the usage of the separate functions, and the usability was not a part of the test but instead a necessary part of further work. The VR prototype was not completely developed, and the experience of future Gothenburg was of relatively low quality which might have affected the impression of the function. The evaluation of the function might have received a lower score on the probability question of usage among the participants. The weaknesses of the VR function that was brought up by the participants, might have been the result of the low usability. Recommended further work was based on the weaknesses and could also have been a result of the low quality of the app. A redesign of the VR function might be necessary in order to evaluate whether the last changes and further work with the app is relevant.

10.6 Future work

If/when implementing the final solution in VGL there will be a need of overcoming obstacles when introducing the solution into the real context. A bridge between a 2D visualized process and an implementation in the Virtual Gothenburg Lab has to be created. Further marketing through suitable channels for both customers and citizens will be necessary in order for the solution to be used. The final solution of the app was only tested with citizens when they already had the app in a phone. In order to evaluate the need of the app from the citizens, it has to be launched through a developed marketing plan. The evaluation showed a high interest of the app, however, it still has to be evaluated if the test subjects involved will do what they said. UX/UI development and usability tests with the app also has to be conducted. The function of switching between years in the digital twin was not possible to test and a development of that function has to be conducted in the future.

Some of the interviews enlightened other areas of usage for the *Citizen Test Process* and not only in the autonomous vehicle industry. The process allows customers to test their ideas and products with citizens and it links customers and citizens as a method for dialogue. Since there are no limitations to the test scenarios and the process is not reliant on a specific digital twin, the process could be applied on other cities, digital twins and industries. How the app and the VR simulator could be financed has not been investigated and are a part of future work for this thesis as well as for the VGL project.

11
Conclusion

This master thesis project has shown that customers want to test citizens' behaviour, emotions, understanding and opinions digitally in order to save resources and time to market. Digital tests are also found to be a safer way of performing tests for the test subjects. In order to conduct these tests, the customers need the citizens to represent the human perspective. This requires an interest and willingness of participation from the citizens. One way to connect customers and citizens is through a digital tool. In order to fulfill the customer and citizen criteria of accessibility, time efficiency, effort, immersiveness, credible data and amount of participants, an app and a VR simulator are suitable tools and were developed as a part of the *Citizen Test Process*.

The app opens up the opportunity for citizens to read about, experience and be involved in future projects of Gothenburg. The number of participants, because of the high accessibility of an app, also creates value for the companies involved in VGL. For the owners of VGL, the master thesis has opened up the question of citizens involvement in VGL and contributed with a ground to be inspired by and develop further.

Through the *Citizen Test Process*, the goal of involving citizens in VGL has been fulfilled. The test process creates a link between customers and citizens through an app that is available for everyone. This contributes to a social sustainability and inclusive city where citizens are a part of the development. Regardless of knowledge in technology, the app results in a low barrier for participation which strengthens the potential of a high number of participants. All tests in the app are available with the purpose of allowing citizens to influence decisions. This will result in a high transparency towards citizens and not create an illusion of power. The *Citizen Test Process* is one way to involve citizens in city development and by that fulfilling one of the United Nations Global Goals. This solution fulfills the customer and citizen criteria and could through an implementation have a great potential of increasing the citizen dialogue in urban development.

Bibliography

[1] UNDP. *Hållbara städer och samhällen.* [Online] Globalamålen. [Updated: 2021-02-23; read: 2021-05-13] Available: https://www.globalamalen.se/om-globala-malen/mal-11-hallbara-stader-och-samhallen/

[2] United Nation. *Goal 11: Make cities inclusive, safe, resilient and sustainable.* [Online] United Nation website. [Read: 2021-05-13] https://www.un.org/sustainabledevelopment/cities/

[3] Markku, B. *Kan digitala tvillingar förändra vår värld?* [Online]. Göteborgs Stad. [Updated: 2021-03-09; read: 2021-05-13] Available: https://www.infrastrukturnyheter.se/20210309/24348/kan-digitala-tvillingar-forandra-var-varld

[4] Göteborgs Stad. *Digital tvilling*[Online]. Göteborgs Stads offeciella webbplats för stadsutveckling. [Updated: 2019-10-18; read: 2021-03-13]. Available: https://stadsutveckling.goteborg.se/digitaltvilling/

[5] Visual Arena. *Testbäddar för samhällets utmaningar - genomförandeprojekt 2019*. Projektbeskrivningsmall för ansökan i Vinnovas riktade utlysning 2019. [2019].

[6] Vinnova. *Testbädd Sverige* [Online]. Vinnovas website [Updated: 2021-02-10; read: 2021-05-10] Available: https://www.vinnova.se/m/testbadd-sverige/

[7] Rupprecht Consult, Forschung, Beratung GmbH. *D1.2 automation-ready Framework*. h2020-coexist. [2020]. https://www.h2020-coexist.eu/wp-content/uploads/2020/05/D1.2_Automation-Ready-Framework.pdf

[8] CoEXist. *What is CoEXist?* [Online]. [Updated: 2021; read: 2021-02-13]. Available: https://www.h2020-coexist.eu/what-is-coexist/

[9] Olstam J., Johansson F., Liu C., Pereira I., Fléchon C., van den Bosch F., Anvar A., Miles J., Sonnleitner J., Tiberi P. and Paliotto A. *D4.3 Technical report on the application of the tools for assessing traffic impacts of automated vehicles*. h2020-coexist. [2020]. https://www.h2020-coexist.eu/wp-content/uploads/2020/05/D4.3_Technical-report-on-the-application-of-the-tool-for-assessing-traffic-final.pdf

[10] Lindholmen Science Park. *Digital samverkansmiljö som stödjer stadsutveckling* [Online]. Visual Arena. [Updated: 2021-02-24; read: 2021-03-02]. Available: https://visualarena.lindholmen.se/nyheter/digital-samverkansmiljo-som-stodjer-stadsutveckling

[11] Strand N., Nilsson J., Karlsson M., & Nilsson L. (Elsevier B.V.). *Semi-automated versus highly automated driving in critical situations caused*

by automation failures. [2014]. Available: https://www.sciencedirect.com/science/article/pii/S1369847814000436#bb0045

[12] HUGO. *A friendly delivery robot* [Online]. [Updated: 2021; read: 2021-05-02]. Available: https://hugodelivery.com

[13] Doll G., Kellner M., Wiemuth C., Ebel E., Heineke K. *Private autonomous vehicles: The other side of the robo-taxi story*. [Online]. [Updated: 2020-12-01; read: 2021-05-02]. Available: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/private-autonomous-vehicles-the-other-side-of-the-robo-taxi-story

[14] The Conversation. *Autonomous cars: five reasons why they are not on our roads* [Online]. [Updated: 2021; read: 2021-05-17]. Available: https://theconversation.com/autonomous-cars-five-reasons-they-still-arent-on-our-roads-143316

[15] Transportation as a Service (TaaS) Magazine. *Digital Twins: Testing Autonomous Vehicles in a Virtual World* [Online]. [Updated: 2018; read: 2021-04-02]. Available: https://www.publishing.ninja/V4/page/8409/358/270/1

[16] AstaZero. *Parabola Wordpress* [Online]. [Updated: 2021-03-09; read: 2021-03-09]. Available: https://www.astazero.com/

[17] Nascimento A., Queiroz A., Vismari L.,Bailenson J., Cugnasca P., Camargo J., de Almeida Jr J. and J. *The Role of Virtual Reality in Autonomous Vehicles' Safety*. Stanford. [2019]. Available: https://vhil.stanford.edu/mm/2019/12/nascimento-aivr19-role.pdf

[18] Mahadevan K., Sanoubari E., Somanath S., Young J. Sharlin E. *AV-Pedestrian Interaction Design Using a Pedestrian Mixed Traffic Simulator*. [2019]. Available: https://ilab.ucalgary.ca/static/publications/dis-2019-mahadevan.pdf

[19] Jayaraman S., Creech C., Tilbury1 D., Yang J., Pradhan A., Tsui K. Robert Jr L. *Pedestrian Trust in Automated Vehicles: Role of Traffic Signal and AV Driving Behavior* [Online]. Frontiers Media SA. [Updated: 2019; read: 2021-04-01]. Available: https://www.frontiersin.org/articles/10.3389/frobt.2019.00117/full

[20] Karlsson A., Roth S. / Buhr K. *Dialog för hållbar stadsutveckling*. IVL Svenska Miljöinstitutet. [2015]. Available: https://www.ivl.se/download/18.34244ba71728fcb3f3f9d2/1591705612031/C149.pdf

[21] Torres L., Pina V., Acerete B. / Royo S. *E-Government and Accountability in EU Local Governments*. Handbook of Research on Strategies for Local E-Government Adoption and Implementation: Comparative Studies. University of Zaragoza, Spain. [2019]. DOI: 10.4018/978-1-60566-282-4.ch010

[22] Landvetter Södra Utveckling. *Dialog och Samarbeten* [Online]. Landvetter Södra Utveckling.[Updated: 2020-04; read: 2021-03-09]. Available: https://landvettersodra.se/dialog-och-samarbeten/

[23] Landvetter Södra Utveckling. *Dina ideer* [Online]. Landvetter Södra Utveckling.[Read: 2021-03-09]. Available: https://landvettersodra.se/dina-ideer/

[24] Invest in Gothenburg. *Min Stad* [Online]. Göteborg Stad. [Read: 2021-03-09]. Available: https://www.investingothenburg.com/find-testbeds/min-stad-my-city

[25] Langlet L. *Medborgardialog som del i styrprocessen*. Sveriges Kommuner och landsting.[2013]. Available: https://centerforborgerdialog.dk/wp-content/uploads/2017/10/medborgardialog-i-styrningen-skl.pdf

[26] Älvrummet. *En titt på framtidens innerstad* [Online]. Göteborgs Stad. [Read: 2021-03-24]. Available: https://alvrummet.se/om-alvrummet/

[27] White G., Zink A., Codecà L. Clarke S. (2021). *A digital twin smart city for citizen feedback* [Online]. ResearchGate.[Updated: 2021; read: 2021-03-26]. Available: https://www.researchgate.net/publication/348382801_A_digital_twin_smart_city_for_citizen_feedback

[28] Saskatchewan. *User-Centred Design and Why it is Important* [Online].[Updated: 2019; read: 2021-03-12]. Available: https://www.saskatchewan.ca/government/vision/5ion/5ual-identity-and-protocol/digital-standards-and-framework/usability-and-accessibility/user-centered-design

[29] Pettersson I. *Eliciting User Experience Information in Early Design Phases*. [2018]. Available: https://research.chalmers.se/publication/504907/file/504907_Fulltext.pdf

[30] Bligård L-O. *ACD3 -processen: Utdrag från andra upplagan av Utvecklingsprocessen ur ett människa-maskinperspektiv*. Göteborg: Chalmers Tekniska Högskola. [2015]. Available: DOI: 10.13140/RG.2.1.1954.4400

[31] Gordon P., Fuge M. Agogino A. (ASME). *Examining Design for Development Online: An HCD Analysis of OpenIDEO Using HCD/UCD Metrics*. [2015]. Available: https://asmedigitalcollection.asme.org/IMECE/proceedings/IMECE2014/46606/V011T14A017/260883?casa_token=UZ3fBriBuB0AAAAA:9eqGeMnBqfsoZBWj-nJHwiy5QJwaj_4UvhWz1n4G0x1EFgWwY6DisJ_gEM_chiPAugSztUo

[32] Husband G. *Ethical Data Collection and Recognizing the Impact of Semi-Structured Interviews on Research Respondents*. Faculty of social science. [2020]. 10(8), 206.

[33] Transportstyrelsen. *Automatiserade fordon* [Online]. Transportstyrelsen.[Updated: 2021; read: 2021-04-01]. Available: https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/forsoksverksamhet/sjalvkorande-fordon/

[34] Tahvilzadeh N. *Det våras för medborgardialoger*. Publikation för Demokratiutredningen 2014. [2015]. Available: https://demokratiutredningen.files.wordpress.com/2015/04/tahvilzadeh-det-vc3a5ras-fc3b6r-medborgardialoger.pdf

[35] Enquist K. *Medborgardeltagande i PBL – tre problem och möjliga lösningar*. Hållbara Städer – tankar från kursen Stadens utmaning. Sveriges Lantbruksuniversitet. Rapport 2013:11. [2013]. Available: https://pub.epsilon.slu.se/10234/1/jansson_m_130413.pdf

A

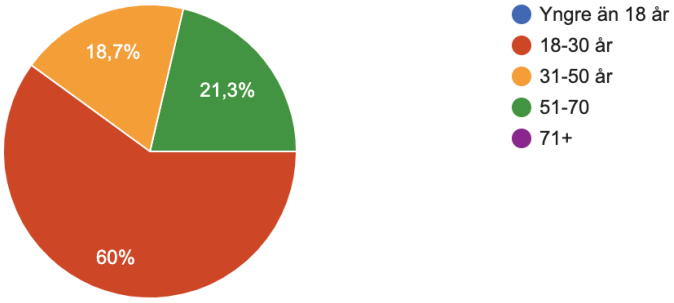
Appendix

A.1 Citizen survey

Total respondants: 75

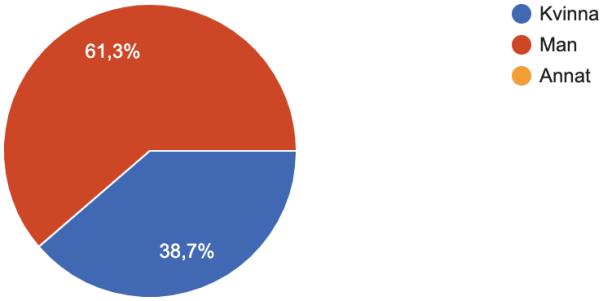
Hur gammal är du?

75 svar



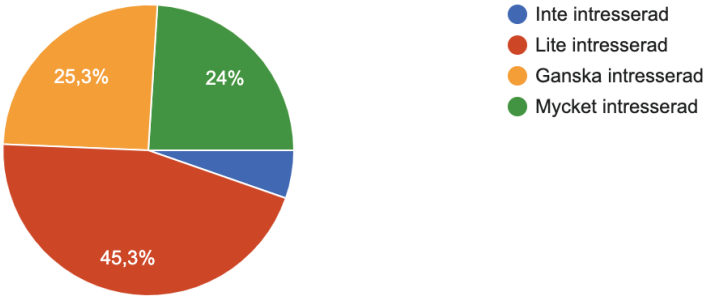
Kön?

75 svar



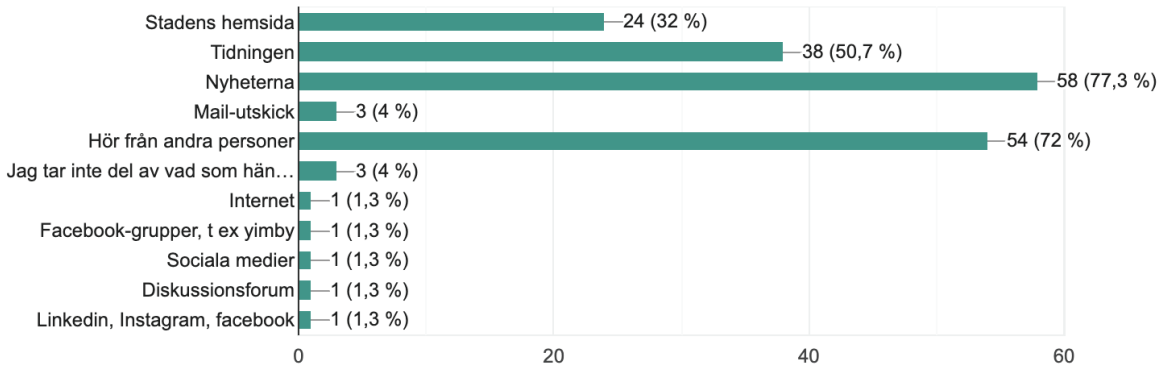
Hur intresserad är du av stadsutveckling?

75 svar



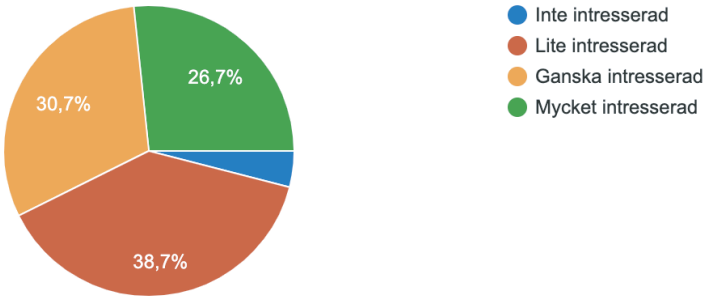
Hur tar du del av vad som händer i din stad idag?

75 svar



Hur intresserad är du av självkörande fordon?

75 svar



Följande frågor handlar om digitala tester av självkörande fordon i stadstrafik. Med självkörande fordon menas i detta fall bilar och bussar som transporterar människor samt "sista-milen-leveranser" så som roboten HUGO (se bild nedan).

Om det i framtiden skulle utföras digitala tester av självkörande fordon i din stad, skulle du vilja delta?

75 svar

Varför vill du/vill du inte delta?

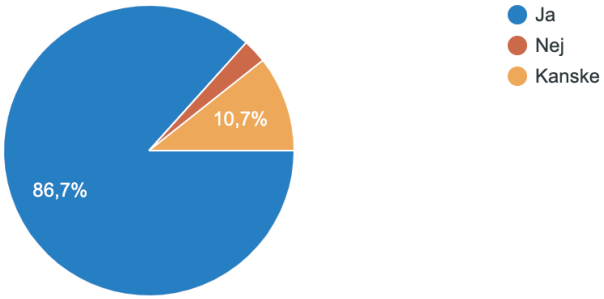
75 svar

Intressant
Låter läskigt. Vill att andra testar för att säkerställa att det är säkert.
Gillar att prova på nya saker först
Skulle inte våga
Hade behövt mer info
Kul att vara del av att utveckla framtidens teknik
Kul att få testa innovativa lösningar
Sett liknande fordon i England och det verkar kul
Jag tror att självkörande bilar i stadsmiljö är ett måste och det skulle vara roligt att ta det av den utvecklingen.
.
Är kul med nya saker
Jag har själv inte körkort av medicinska skäl och vill verkligen att utvecklingen ska gå framåt som jag också kanske kan färdas med annat än vara kollektivtrafik. Säkerhetsaspekten gör att jag hade velat ha lite mer information innan
jag tycker att det är intressant med tester
Spännande att få ta del av samhällsutvecklingen och ny teknik
Är inte så mycket intresserad!
För lågt intresse.
Intresserad och jobbar med innovation inom energi
Säkerhetsrisk
Spännande utveckling
Utveckling får inte stanna
Inte tid
Tar för mycket tid
För att det är häftigt
Kul!
Kul att testa flöden och kapacitet
För att påverka hur de kan komma att bete sig, så att skaderiskerna för människor minimeras.
Jag har alltid varit intresserad av tekniska framsteg och innovation.
Intressant framtid!
Jag välkomnar alla förslag som konkurrerar ut bränsledrivna fordon
Intressant men vill ha mer info
Intressant att få ta del av utvecklingen/ny teknik ”före” allmänheten
Vill vara med och utveckla
Jag jobbar för närvarande med en (liten) del i utvecklingen av självkörande fordon. Det hade varit kul att följa och fortsätta vara en del av det.
Får man belöning så
Intresserad av tekniken och vill se hur långt den utvecklats
Jag tror att självkörande fordon är framtiden då det gör trafiken mycket mer effektiv. Men jag tycker att idén av självkörande fordon är lite srämmande så vill därför ha mer information så att jag vet att det är säkert.
Otroligt spännande och rolig teknik att ta del av.
Intressant, se något nytt

Spännande
Nytänkande och spännande
För att bidra till utvecklingen av fordon som är säkrare än människokörda.
Spännande
Känns riskabelt
Vet för lite
Vill ha mer information innan, annars låter det intressant
Dels av eget intresse men också att övertyga andra om säkerheten bakom autonoma fordon.
Jag känner att det ska krävas en stor motivation för att gå med på ett test. Jag möter bilar varje dag, robotar finns överallt. Tycker inte det är så häftigt längre helt enkelt. Bra, spännande, utvecklande absolut, men wow-faktorn har försvunnit för mig
Lite nyfiken på vad det betyder för framtidens utveckling
Kanske intressant men lite tveksam.
Inte intresserad
Så länge det är betalt är jag gärna med!
Kul att vara med och testa nya innovativa lösningar!
Känns innovativt
Tid finns inte
Kanske
Jo fler som testar, desto bättre.
Självkörande bilar som just ”last-mile” är kanske den mest intressanta delen av autonomi. Jag tror att självkörande bilar säljs in som något bättre än det är vanligtvis men om de används i kombination med kollektivtraffik kan vi skapa ett robust system. Att se hur detta utvecklas är väldigt intressant.
Jag tror det är framtiden. Och spännande att se hur det funkar. Det får dock inte ta för mycket tid
Vill få information om hur man som person isåfall skulle delta
Vill ta del av framtiden, vara med i utvecklingen.
Tidskrävande
kul att testa nya grejer + kul att känna att man bidrar/hjälper till
Jag är tekniknörd :-)
Tror det är jättebra med självkörande fordon som kan gå på ställen med löpande och regelbunden trafik.
Vill gärna var en del i vår framtida utveckling.
Intressant när ny teknik utvecklas
Det beror på hur studien är uppbyggd och vad som krävs av mig. Sen om det passar med livspusslet.
Spännande att se hur självkörande fordon hade funkat i praktiken
Låter som framtidens lösning, automation har varit en del av människansutveckling
För att få fram ett bekvämare och säkrare sätt att framföra fordon, där den mänskliga faktorn inte finns med.
Alltid spännande med ny teknik trots att jag älskar att köra bil så faller självkörande fordon in i mitt intresse
Kul att få va först och testa tekniken

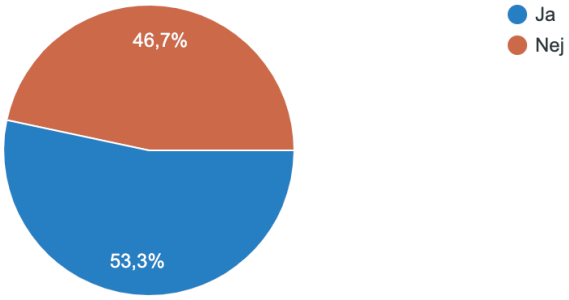
Om tester av självkörande fordon skulle utföras i din stad, skulle du vilja ta del av resultatet?

75 svar



Bor du i Göteborg?

75 svar



A.2 Scale of Criteria

Accessibility

Accessibility is a citizen criteria and is divided into these levels

1 - Low accessibility
2 - Medium accessibility
3 - High accessibility

Low accessibility means that a test demands a certain time and place and low flexibility for the test person.

Medium accessibility means that the test person either can access the test whenever he or she wants but needs to move to a specific place or that the test person can perform the test at home but needs to wait until a certain time.

High accessibility means that the test is accessible whenever the test person wants and can be performed from home.

Time efficiency

Time efficiency is a citizen criteria and is divided into these levels

1 - Low efficiency
2 - Medium efficiency
3 - High efficiency

Low efficiency means that the test takes more than 30 minutes to perform a test.

Medium efficiency means that it takes between 15-30 minutes to perform a test.

High efficiency means that it takes less than 15 minutes to perform a test.

Effort

Time efficiency is citizen criteria and is divided into these levels.

1 - High effort
2 - Medium effort
3 - Low effort

High effort means that the test is demanding and requires high attention from the test person.

Medium effort means that the test is not that demanding but requires the test person to only focus on the test.

Low effort means that the test is not demanding at all and that the test person can perform multiple tasks at the same time as performing the test.

Immersiveness

Immersiveness is a customer criteria and is divided into these levels \\

1 - Low Immersiveness
2 - Medium Immersiveness
3 - High Immersiveness

Low immersiveness means that the test person will experience the test with a high mental distance. The surroundings around the person can interfere and affect the overall experience and the reactions from the test person. The participant will on this level not represent themselves in the test.

Medium immersiveness describes an overall experience that is close to what people would experience in a real world situation. The test person will represent themselves in the test but still be aware of the real world surroundings.

High immersiveness means that the test person is mentally completely in the test environment with no outside factors interfering. That will contribute to an experience that is as near to a real world experience that you can have digitally. However, the awareness of being in a test for people is the one factor that is hard to erase and it will affect the level of immersiveness negatively.

Credible data

Credible data refers to the credibility of result for each level of interaction and is a customer criteria. It is divided into these levels

1 - Low credibility
2 - Medium credibility
3 - High credibility

Low credibility means that the result from the test regarding the different levels of interaction have low reliability.

Medium credibility means that the result from the test regarding the different levels of interaction have medium reliability.

High credibility means that the result from the test regarding the different levels of interaction have high reliability.

Number of participants

Number of participants is a customer criteria divided into these levels

1 - Low number
2 - Medium number
3 - High number

Low number of participants means that fewer than 10 participants will participate.
Medium number of participants means that between 10 and 1000 participants will participate.
High number of participants means that more than 1000 participants will participate.

A.3 Prototype test process

SCENARIO

Du sitter på en fika med din kompis och hon/han tipsar om att det håller på att utvecklas en självkörande robot som kallas för HUGO. Ryktet går att roboten eventuellt kommer kunna leverera take-away i framtiden. Det här väcker direkt ditt intresse eftersom du ofta beställer hem mat och funderar hur detta kommer att fungera! Din kompis menar att man kan uppleva/se hur det kommer se ut med Hugo robotar som kör runt i ett framtida Göteborg i en app som heter VGL.

Din kompis hjälper dig att ladda ner appen och skapa ett inlogg så att du får en personlig sida.

Du öppnar appen med förväntningen att få ser hur den här självkörande roboten kommer se ut när den kör runt med matleveranser inne i centrala Göteborg bland alla människor.

Du kommer in på startsidan där du direkt ser en hel del olika artiklar om pågående projekt i Göteborg Stad.

TESTET

Testpersonen får nu klicka runt fritt och han/hon observeras kring de val som tas.

Vi svarar på frågor som kommer upp eftersom UX inte är i fokus. Styr testpersonen till VR miljön/digitala tvillingen.

Testpersonen får klicka runt tills vi ser en mättnad. Protokoll på alla steg som tas. Personen får prata högt.

Testpersonen går in på sin personliga sida och kan se resultat och statistik från det test som är genomfört.

Testet avslutas. Leder över till frågor för testpersonen. Eventuellt ytterligare förklaring av appens funktioner. Visa/hjälp testpersonen så att hon/han har upplevt alla funktioner.

FRÅGOR TILL TESTPERSONEN

Vad hade du använt VGL appen till mest? I vilket/vilka syften?
Vad tyckte du va bra med appen? Styrkor
Är det någonting du tycker är onödigt? Vad tycker du är sämre med appen?

Hur sannolikt på en skala mellan 1-10 är det att du...
Ladda ner appen?
Gå in och läsa om pågående/kommande projekt?
Gå in i appen och gå runt i framtida Göteborg i VR miljön för att se hur det kommer se ut?
Gå in i VR miljön och utföra tester som olika företag har lagt upp och vill ha hjälp med?
Boka in dig på ett fysiskt VR test på plats i VR studion?

A.4 Open answers from the prototype test

Answers from the prototype test

	What would you use the app for?	What was good with the app?	What was bad/less good with the app?
1	View future projects. Read first and then use the phone VR.	Articles, VR-function, stories and the map.	Need an introduction to the VR-environment, how to walk around and all the buttons. Didn't realise that the green button was the test.
2	To be up to date with everything that is planned in the city	Easy to understand. Not too much information.	Hard to understand where at centralstationen I was looking. Want to switch between now and the future view.
3	Experience Hugo. Read about new projects.	Walk around in VR- Look at new buildings.	-
4	See what is planned in the city. Have a say in the development.	There is nothing like this on the market. It is fun to participate in city development.	Be more clear to be easier to use for everyone.
5	To vote.	Easy to use. Not too much information.	-
6	Participate in phoneVR-tests if I get some reward. Walk around in the city.	Simple and clear.	Adjust to what I am interested in.Is the calender needed to be in the bottom bar? too much focus.
7	View future city plans. How everything is going to be connected in Gothenburg city.	Easy to understand	Targeted information.
8	Interesting to be involved in the development of the city. To see future changes of the city.	That you can see the city centre and how everything is going to look. It is nice to have the VR function where you can look at the changes instead of reading long articles.	That you can not meet a tram, people or a HUGO when they are moving around in the city. The app also needs to keep up with the development in order for me to keep on using the app.
9	Out of curiosity. Stay updated.	Recognition with other apps. The simplicity and flow of the app, logical.	-
10	For the VR function, to look around and see how everything is going to look like.	VR	-
11	Fun to see what is going on in the city. The function itself. Maybe seeing another city would be fun.	You become curious to keep on using the app and click around.	-
12	Out of curiosity. If something special happens.	You can see what happens in the city and follow the development.	-

A.5 Probability answers from the prototype test

	Download the app	Read about ongoing projects	Walk around in the phone-VR	Perform tests in phone-VR	Book a slot time for a physical VR-test
Person 1	10	8	10	10	5
Person 2	8	10	10	8	4
Person 3	10	10	10	8	4
Person 4	10	9	9	8	6
Person 5	8	6	8	7	3
Person 6	10	10	10	4	1
Person 7	6	10	3	3	3
Person 8	8	4	10	9	9
Person 9	10	10	10	10	3
Person 10	3	3	8	5	2
Person 11	7	9	10	5	5
Person 12	5	8	8	6	7
Avrage-rounded	**8**	**8**	**9**	**7**	**4**

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