Welcome to my Bubble

Designing the interaction between pedestrians, autonomous vehicles and the city at a cross walk

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Msc. Integrated Product Design

Master Thesis

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Preface

The automotive industry has always kind of interested me personally, but I never imagined I could work in the industry. Throughout my masters I was able to further explore my interests in the industry and slowly I saw what possibilities an industrial designer can bring to the table. Especially with the radical changes that are coming now, with the automation of our vehicles. Cars are not just a question of how fast they can go, but how we experience our time spent in it. Even crazier, how we interact with it as an independent traffic participant. This project was truly one dear to my heart as I was able to create it completely from scratch allowing me to follow this new professional passion for the mobility world. It was truly an insightful project that has given me new knowledge beyond what I expected. I was able to talk with three inspiring researchers who were willing to share their knowledge with me about the smart city and autonomous vehicle – pedestrian interaction. For this, many thanks for Martijn de Waal, Usman Haque and J. Pablo Nuñez Velasco.

Like I said, I was able to create this project from scratch, but that would not have been possible without my mentor Iskander Smit, who has been very helpful and patient during my preparations. Thank you for the many inspiring meetings before and during the project. Your feedback always gave me new insights or motivation to keep going.
However, the project would have never been able to take off without my supervisor Euiyoung Kim. Your expertise on research and design methods have given me a new-found interest in design research.
I want to thank both my supervisors for their understanding during the project as things did not always go as planned. Our regular meetings, once even from Korea and a car, always brought up new insights and allowed me to ask questions and learn about many new things that I had not yet learned about in my masters programme.
It has been a long process that took place completely during the strange times we have found ourselves in during the Covid-19 pandemic. These unique circumstances presented with a new working space, the home, and meetings over video calls.

Lastly, but maybe most importantly, I need to give a huge thanks to my parents and friends who have supported me throughout all these years of studying. My parents for always standing by my side especially during the last days of this project has kept me going. And my dear friends (you know who you are), industrial design has given me a lot of knowledge and skills, but most important have been the people I have met during my studies and the friends I have made.

Enjoy the read!

Ragna

Executive Summary

In a future where most of our transit system consists of autonomous vehicle, the question is raised how we as humans interact and communicate with them, and they with us. This project explores these interactions in the current time to uncover how humans interact and negotiate in traffic. More specifically how pedestrians do so. From the analysis it came forward that such interactions are mainly based on implicit communications – messages sent through behavioural cues that are not necessarily meant as a message. This contradicts the belief that humans use mostly explicit communications such as eye contact and gestures to communicate with fellow traffic participants. The disappearance of the driver might thus not have as much of an impact of the effectivity with which we humans can communicate with autonomous vehicles. However, many research currently study how more explicit communication tools, such as external human machine interfaces (eHMI) on the vehicle can help the pedestrian in making their decision to cross. These studies do find that there is a slight benefit to these eHMI systems, however they are not as significant as one might hope. eHMI systems also present several concerns including their visibility from afar, ambiguity and one sided communication. Especially that last concern is one that is central in this project. The process follows the guidelines of the Vision in Product design process, which explores current day interactions and context to then formulate a vision for the future. Based on this future and the gained insights a design statement is formulated that contains the goal to be fulfilled by the final design. The goal defined in this project is as follows: designing a cross walk that prioritises pedestrian transit while maintaining an efficient interaction between autonomous vehicle and the pedestrian. The final design proposal presents a cross walk that uses animations that come to life through lights integrated in the floor tiles. The cross walk is unique in its design as it extends onto the side walk to allow pedestrians to consciously show their intention to cross towards the autonomous vehicle. The cross walk is able to register the pedestrian. Since the cross walk registers the pedestrian early on, it can send a signal to the autonomous vehicle to slow down to give the pedestrian the right of way. The pedestrian receives feedback that shows them how safe it is for them to cross through the use of these animations. A series of animations have been designed and evaluated and based on the results a final set of animations has been designed. These animations will communicate that is either safe or not safe for the pedestrian to cross. As such, the pedestrian is able to actively communicate with the autonomous vehicle and receives personal feedback, instead of being told what to do by the autonomous vehicle what to do. Bringing both their different communication bubbles together and translating them through the cross walk so both understand what the other will do.

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0. Introduction

In a future where our transit system exists mostly of autonomous vehicles, walks the pedestrian. A human among urban robots that speak a different language the pedestrian cannot seem to fully grasp.

An autonomous vehicle drives through a crowded area with many pedestrians. An urban robot among humans who speak such a different language it cannot seem to really understand.

When the human driver has disappeared from behind the wheel, the way humans will communicate with the vehicles might completely change. As the human driver changes to an algorithm, humans are likely not able to use the same communication means like before. This causes an issue for human road users who may have difficulty interacting with these newcomers to the road.

The autonomous vehicle encounters many humans on their way through the city. The human however is not fitted with electronics that allow them to communicate what they are going to do towards the autonomous vehicle and other urban robots around them. Without those electronics, the autonomous vehicle has a hard time understanding what these humans try to do by waving, looking and walking right in front of them.

Both these stakeholders will share their space in this proposed future, however they do not share the same communication bubble. Not yet that is.

With the disappearance of these direct communication lines between pedestrian and human driver, interactions on the street might become even more difficult. Both actors have a favoured way of communicating that the other actor does not instantly understand. Research into interactions between the autonomous vehicle and humans currently focuses mostly on the passenger experience of an autonomous vehicle. However when the autonomous vehicle becomes an independent part of our transit system, they will engage a lot more with humans on the outside too. This raises the question how these interaction will go, will the autonomous vehicle be able to successfully communicate their intent towards the pedestrian, or will the autonomous vehicle become so smart it can understand every move of a pedestrian?

Currently, developments in the autonomous vehicle world happen mostly by automotive companies who focus on developing the vehicles themselves. They do want to solve the possible communication issue, which leads to interfaces mounted on the vehicles to communicate intent to other road users. These systems however lack the ability to facilitate two way communication. Such systems share intentions and want the pedestrian to correctly respond to those, but they forget to take into account that usually traffic interactions are negotiations where the pedestrian also actively communicates towards drivers.

One such place where pedestrians and vehicles interact, is the cross walk. A space that now is designed with traffic lights and visual signage for humans, which are cues that are more difficult to understand efficiently. For the autonomous vehicle it would be enough to receive directly transmitted signals that clear up the situation, which would make visual signage in the infrastructure obsolete. However this causes a problem for humans who cannot receive these signals as directly, they need those signs to be physical. There is thus a gap between how infrastructure should be designed for each actor.

That is where this project comes in. The starting point is to bring the two communication styles, or bubbles, of the autonomous vehicle and pedestrian together so they can get a better understanding of each other's intentions. Instead of looking for solutions mounted on the vehicle, the goal in this project is to explore the possibility of using the smart city as a platform to bring the two actors together. This will create an environment that would be beneficial to both the autonomous vehicle and the pedestrians.

The assignment, as written in the project brief, is as follows:
Creating a new solution for an intersection used by fully autonomous vehicles and human bystanders to create mutual trust and understanding through two-way communication. Thus also exploring the possibilities of the smart city as the platform in enabling inclusive communications between AV and human.

For this project a couple of design boundaries have been set up to narrow down the final solution space. Some of these boundaries formed throughout the project but have be collected here.
The focus will be on Dutch society, or similar societies. These societies are often earlier adopters of new technology and it is likely that these countries will be the first to adopt to autonomously driven mobility services. This context is also culturally close to the designer, taking away some unknowns in an already complex project with many other factors influencing the outcomes.

The autonomous vehicle is seen as a fully autonomous vehicle that can drive without any interference of a human driver. The passengers can thus focus completely on other activities. This project will not take into account the interactions between the autonomous vehicle and its passengers, only on the interaction with pedestrians. The context for which will be designed will be imagined as one that is fully occupied by autonomous vehicles and not mixed traffic. It is possible that at first some areas will only be accessible for autonomous vehicles, which could thus be a testing ground for such innovations.

The targeted user will be pedestrians, although at first also cyclists were taken into the target group, the differences between these two groups proved to be quite big in regard to their needs in interaction and communication styles. Pedestrian are a slower part of the traffic system and therefore can form a bigger nuisance for autonomous vehicles to encounter. Secondly, a choice was made to, for now, focus on people with good vision. It is assumed that new technological advances will create solutions for people with vision loss that cover a wider array of issues at once to create more accessible cities. Such possible solutions could possibly later be integrated in the final design or similar innovations.

Lastly, it was chosen to design for a street where autonomous vehicles can drive at higher speeds (50[km/hr]). These larger roads pose more problems for pedestrians and autonomous vehicles to communicate. These are also often bigger and busier roads that pedestrians need to cross to move between different neighbourhoods.

Methods:
This project will not only explore the human needs for these new interactions with the autonomous vehicle and infrastructure, but will also explore the needs of the autonomous vehicle as a Thing. To do so, a novel design method will be used; Thing Centred Design. This method explores how a Thing experiences the world and how it engages with its users.

The overall project will be guided by the Vision in Product design (ViP) process. ViP fits well within this project as it aims to create a future context to design for based on a structured process. It is a human centred process that focuses on creating a product based on how it should interact with users. It divides the process in two phases based on three levels. It starts with the deconstruction of the existing product based on its product qualities, interaction and the context is was designed for/in. After that, a future context is created that will lead to a statement as to what direction the project will head into. It goes back through the same three levels by first defining the context to be designed for/in, then create an interaction vision that supports that direction and from that product qualities are defined that will enforce this interaction.

Additionally, two these two processes a number of expert interviews will be conducted to get more in depth knowledge about relevant subjects.

The interviews were conducted with the following experts:

Martijn de Waal: He is a lecturer in Play and Civic Media at the Amsterdam University of Applied Sciences. He has focus on the design of public spaces in a networking society, dealing with questions like how is this public space a medium where citizens can meet each other, where they can relate to each other and the government, and share information. And all this done from an affective standpoint rather than a rational one which plays with feeling at home in your city. He coined the term Social Cities as a more holistic view on future cities than the term Smart Cities carries.

Usman Haque: He is a British architect with his own design firm Umbrellium. With the company he focuses on how to make cities work for everyone. They use technology to activate urban environments. A good example of this is their Starling Crossing, a dynamic cross walk that learns from usage patterns. He coins the term Engaged Cities where people are put first, and cities are not designed from a technological optimisation standpoint.

J. Pablo Nuñez Velasco: He is a PhD student working on the subject of how pedestrians and autonomous vehicles interact on crossing zones. He has done studies to validate the best way to design systems to communicate intend to pedestrians.

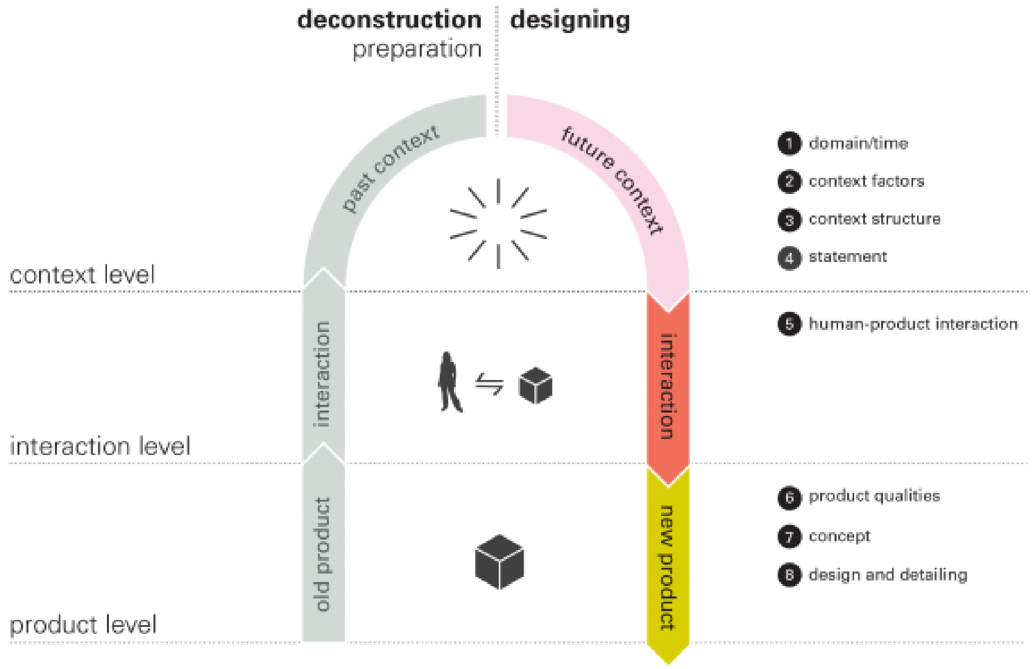


Figure 1 The ViP model in illustration, visualising the three levels and the steps that are part of the process

PART I

Explore

Performing analyses is a vital step in any design project. It helps to explore the context of the project, strengthens knowledge or leads to completely new insights. This project started with an extensive analysis to uncover these insights. The part is called explore because the outcomes are not predefined and insights can lead to redirecting a project, knowingly or unknowingly. I would like to invite you to explore with me throughout the next chapters about smart cities, interactions between traffic participants and new types of citizens. These subjects surprised me the most and gave me a new understanding of subjects that I had not expected.

Part I - Explore | Introduction

This first part you can find out all about the different topics related to the project that were explored throughout the project. The first three chapters describe the three main subjects that are stated in the assignment
"Creating a new solution for an intersection used by fully autonomous vehicles and human bystanders to create mutual trust and understanding through two-way communication. Thus also exploring the possibilities of the smart city as the platform in enabling inclusive communications between AV and human."

Chapter 1: The Intersection explores the different types of intersections and the products and interactions present there.

Chapter 2: The Autonomous Vehicle takes a look at how we got to the point where cars might actually become driverless and how we, humans, interact with them and that this might be different than expected.

Chapter 3: The Smart City tries to define what a smart city entails and brings in different perspectives from academia and design professionals.

The analysis is based on the deconstruction phase described by the ViP process, where the current product is analysed on three levels: product, interaction and context. These levels were used mainly in structuring the research but are not necessarily used in presenting the research outcomes for each topic, as for some topics not all levels were as relevant to discuss separately.
Additional subjects that are discussed in this part are gathered in the following chapters:
Chapter 4: Things explains what can be understood under the term Things, how their role in society might change and this chapter also includes the Thing Centred Design method Interview with Things to explore the deeper needs of the autonomous vehicle.

Chapter 5: Human Perception goes shortly into more detail about how humans are able to understand and process their world around them and how they are able to interact with them through their senses. (I am still working on this chapter, to find the content too)

The outcomes of the chapters are collected in one conclusion at the end of Part I specifying the most important takeaways for this project that were used as guidelines for the process and design. (this is still formulated in bullet points and under construction as it changes with the development of the final product to figure out what conclusions are more important for the final design.

Chapter

1

The Intersection

1.1 Introduction

The intersection (road); the place where two or more roads join or cross each other. (Dictionary, 2020)
This definition of an intersection is fairly straightforward, however when adding the notion of humans into the equation the definition may be broadened;
An intersection is the place where multiple traffic participants of conflicting directions come across one another which leads to a moment of interaction between them.
The addition of human factors to the definition makes an intersection more interesting to investigate from a designer's perspective on how the product serves the interaction. It also opens up the definition to cross walks, another important area of interaction between pedestrians and drivers. Even though at this point in the process the future context is still an unknown, it is noteworthy to understand how currently humans communicate in these situations. Analysing these current situations will help to understand how these interactions may change with the implementation of autonomous vehicles once these interactions are analysed (chapter 2.3), and therefore clarify what problem the solution should aim to solve.
In this section the intersection will be deconstructed, however to do so a difference will be made between two types of intersections: the signalised and unsignalised intersection. It would, however, be inaccurate to address these intersections as just one product. Each intersection is made up of multiple parts and products that invite different interactions. For the signalised intersection the main product that traffic participants interact with, or through, are the traffic lights. At unsignalised intersections different products and features appear that support communications between different participants. Although these two scenarios bring different types of products to the table, they serve a similar goal; to facilitate negotiations between road users. The deconstruction of the intersections focuses therefore on these products or features to analyse the interactions happening.

1.2 The Signalised Intersection

Signalised intersections are commonly found at larger crossroads in a city area. This means that there is larger flow of traffic participants per time unit that passes through it. Because of this larger flow it becomes more unclear who has the right of way and to oversee all participants one might encounter. Therefore, on these intersections traffic control systems are put into place, commonly known as traffic lights. One could call them the executive ruler of the intersection as they have the final word in who passes the intersection at what moment. Traffic control systems remove the human assessment of when they can cross and pass the intersection. Especially for turn lanes these systems help to reduce crashes between turning and forward moving road users.
This section will be focused on the traffic light system as the most apparent source of interaction present. It describes it on the three levels of ViP; product, interaction and context. It mainly provides background information into the current widely known traffic control system. Other features like signs and road surface signage or lane layout are not taken into the scope as they serve mainly as a support for traffic flow directing for the traffic lights or for wayfinding rather than as a tool for negotiating right of way for traffic participants. In some cases a distinction will be made between traffic lights for drivers and those for pedestrians and/or cyclists.

1.2.1 Product

Looking at the traffic lights in the streets now, they are designed for function only. Their simple shapes, structural form and sturdy materials assure them being able to withstand many years of wear and tear from the weather, and possibly vandalism. The main function of the traffic lights is of course guiding road users safely past intersections, therefore it is not as important for them to be aesthetically pleasing. They must be highly visible and always clear in their workings. Their visibility is important from afar so road users can take appropriate actions in time. However, in their functionality they appear dull and cold, yet safeguarding. The lack of any decorative additions in the design makes them dull, and the colours cold, but with the absence of decorations, it becomes clear that the traffic light is there to do its job. Much like a uniform from the police or firemen, there to fulfil its duty.

1.2.2 Interaction

The way traffic lights communicate is completely focused on visual signage; using coloured lights to guide drivers. Traffic lights for pedestrians often also have audible cues for road users with a visual impairment. A ticking or beeping sound is used to indicate the change of light.
The interaction with a traffic light as a driver is predominantly one sided from traffic light towards the driver. The traffic light orders the driver to stop and wait before entering the intersection. A driver can choose to obey it or not, thereby breaking the law. On itself the traffic light has little power as it does not have the capability to stop or arrest a non-compliant driver. It needs law enforcement to execute the law when broken. However, for many people knowing there are consequences -

the law and the possible unsafe situation it may create, is enough reason to abide by the directive of the traffic light. This one sided way of communication and the possibility of a ticket, makes the traffic light authoritative.
A cyclist or pedestrian often has the option to push a button to notify the traffic control system that they want to cross. They thus have an influence on how the system's pattern works. In this regard they may feel that the traffic light is less authoritative than drivers.
On the other hand, once the light turns green, it gives road users the possibility to enter the intersection and continue their travels. It ensures them safe and effective crossing of other roads. It does this for all road users, pedestrians and cyclist included. All the road users get the chance to cross the intersection safely, even if it requires them to wait a little while. Traffic lights are optimised to create an efficient traffic flow, so a busy lane may get more time to pass or more often a green light than other lanes entering the intersection. Nonetheless, amidst it all the one pedestrian that wants to cross will also get their moment to do so. In this context it makes the traffic lights also equitable/reasonable.

1.2.3 Context

History

The traffic light, similar to how we know it now, was introduced in the early 1900s to accommodate the increasing number of traffic participants. In 1914 the first electric traffic light became operational in Cleveland, Ohio, designed by James Hoge (History, 2019). Its main function was to control pedestrians, cyclists and horse drawn carriages. In 1922 the system was updated and automated by William Potts. This was the first time that the traffic control systems did not need manual operation anymore. Soon after this update, a button was added that allowed road users to exert control over the system like pedestrians can do nowadays (IsGeschiedenis, 2020).

In the year 1928, on one of the busiest intersections of the Hague, the first automated traffic light of the Netherlands was put in place. Its design is different from the current ones, but the communication style is similar. With three coloured lights layered in circles around one another, it could communicate stop, go, and caution. Many larger cities got their own traffic lights soon after that. The design in the Hague came from the company Heemaf, the one in Eindhoven, quite logically, from the local company Philips and Amsterdam got a system from the foreign Siemens. Some years later the Netherlands would also adapt to a more internationally generalised design (Hermsen, 2008). Since then not too much has changed in the design of the traffic light as we know it now. With the introduction of the traffic lights, the job of traffic operator changed and disappeared from the streets in western societies. One could argue that this is the first step in cities becoming 'smarter' in terms of technological optimisation of processes.

Figure 2 First automated traffic light in the Hague, NL. From Het Nationaal Foto Archief

Developments

Fast forward to 2020, the traffic light is a common part of our infrastructure and the general look of the traffic light has not changed for decades [figure 3,4].
Throughout the years only minor changes have been made to the appearance of the traffic light, like the shape of the lights or the addition of the backboard to increase visibility against a light sky. It is sensible not many big changes have been made, since people have known these signs all their lives and are integrated internationally with only small differences. There has also been little motivation to change them as the automotive industry and hence the infrastructure have not seen impactful changes over the past decades. Changing a system like the traffic lights thus seemed redundant. However this change seems to lie ahead of us with the shift towards new mobility systems like self-driving vehicles.

No, the design has not seen many changes, but to say there have been none at all would be like looking at it with blinders on. The traffic light is part of a bigger system, the traffic control system, which has seen it adaptions.
A quick message to my parents confirms my hunch, they also have not seen much change in the design of the traffic light the past decades, however immediately mentioned that the system did change.
Over the past decades sensing technology has been added to the road's surface which notifies the control system about waiting cars. Similar technology has been added to many cyclist traffic lights, although many also still have a button like pedestrian traffic lights. With this sensing ability traffic lights have become a bit smarter, however compared to recent developments, these traffic lights with basic sensing technologies have become "dumb" again.

Newer systems are going beyond the pre-programmed timer patterns and adapt the pattern based on where cars are waiting. This can eliminate the waiting for 'ghost' cars as the system skips empty lanes and prioritises lanes with waiting vehicles. Often these systems are found in areas with irregular traffic flows. In busier areas traffic flows are more constant and therefore work best with a timed system (How Stuff Works, 2020).

Another update in the field of traffic lights is the countdown timer to reduce jaywalking/cycling at pedestrian or cyclist crossings. Such a feedback system seems to have a positive outcome as the amount of people ignoring a red light and the number of crashes have gone down in places with countdown timers (Huitema, van Houten, Manal, 2014; Sobota, Klos, Karon, 2017; Keegan, O'Mahony, 2003). These countdown timers are slowly making their way into the Dutch infrastructure, also for cars. In Rotterdam the first couple of traffic lights have gotten an additional countdown timer to notify drivers how long they have to wait (Ramaker, 2018).

In Deventer, a city in the east of the Netherlands, all the traffic lights have been replaced by “smart” traffic lights in early 2020 (Klaassen, 2020) These traffic lights are (inter) connected to each other and other services and sensors. They can sense cars passing and waiting and prioritise traffic based on the data. Their connection to apps will make it possible to inform road users about a green wave speed or waiting times for a red light. Through this connection the system will also know if specific type of traffic is approaching and make them a priority on the intersection. Such as a truck that will not have to slow down (saving emissions) and cyclists who do not have to wait in bad weather (Talking Traffic, 2020a; Rutgers, 2018). This connected traffic light system is part of the Talking Traffic initiative by the Dutch government and industry companies, aiming to innovate the infrastructure to make traffic flows more efficient and optimal for its users. The initiative is also seen as the first preparation of the infrastructure for the introduction of autonomous vehicles, which requires and enables infrastructure to vehicle communications (and vice versa) (Talking Traffic, 2020b).

Figure 3 An old Traffic light in the 1950s From Het Nationaal Foto Archief

1.2.4 Conclusion

Our traffic system has not seen many changes throughout the past decades, however new technologies allow objects to communicate with each other and connect to other services and systems through internet connections. This enables a smarter system that responds to real time data which can improve the traffic flow. Projects like Talking Traffic and the Audi example show that there is a drive to implement such systems to benefit from smoother traffic flows, both more short term and long term. The implementation of such systems will also change the way we interact with the traffic control systems as they are more responsive to the real time situation instead of basing it on generalised patterns. This way also pedestrians and cyclists might have to wait less to get their right of way in a system which generally prioritises motorised vehicles over them.


Figure 4 Traffic lights in Netherlands in the 1970s From Het Nationaal Foto Archief

1.3 The Unsignalised Intersection

Not every intersection needs the traffic light system to control traffic flows. When an intersection has a smaller traffic flow per unit of time, is physically smaller, and easier to comprehend and oversee, there is no need to invest in adding the system. On these intersections the law guides how road users should behave on the intersection. At these intersections humans depend on more personal communications like gestures. Gestures can be understood as body language (like eye contact, waving and head movement), yielding (vehicle or VRU) and light signals (indicators or flashing the headlights). These gestures are used to communicate an intent of one road user towards the other(s). As the project focuses on interactions between vehicles and other road users, this section focuses on the interaction drivers have with VRU, and not on interactions between drivers. Discussed are the eye contact and its influence on communications between traffic participants. This interaction is of particular interest in this project as it is one of the main communication tools that will disappear with the implementation of autonomous vehicles which is expected to have an impact on our ability to communicate. Furthermore, vehicle yielding and turn indicator lights are shortly discussed as the other main tools of communications at unsignalised intersections.

1.3.1 Eye Contact

The research into eye contact and gaze is performed mostly at cross walks or designated crossing points. This is due the fact that here the pedestrian has the right of way but this is not always granted by drivers and therefore negotiations need to take place. When a pedestrian would want to cross at a random location without right of way these negotiations do not take place as it becomes the pedestrian's own responsibility to find the right time to cross (Dey & Terken, 2016).
The role of eye contact in traffic has been researched quite extensively, especially with the rising question of how the autonomous vehicle should behave and communicate with pedestrians. Researchers want to know how these interactions currently take place so they could be translated onto the behaviour of the autonomous vehicle (Dey & Terken, 2016; Schneeman & Gohl, 2016; Nathanael et al., 2019).

Most research finds that the eye contact or gaze has an influence on the driver's behaviour. A driver is more likely to comply to the rules of a cross walk, and thus stops or yields more often for a pedestrian when eye contact is made (Guéguen & Meineri & Eyssartier, 2015; Ren & Jiang & Wang, 2016). However, research by (Dey & Terken, 2017) found that there is no, or rarely any, explicit communication happening between pedestrian and driver when they meet at a cross walk. Explicit communication happens when the sender intents to send a message to the other. They found that implicit communication - where a message is sent through certain behaviour which is not per se intended as a message, is more significant in the negotiations of right of way between pedestrian and driver.
This contradiction can be explained by the methods used to research the interactions. Where the first used participants with a script to perform tasks, the latter used video recordings to examine real life situations. The use of eye contact could have an influence on how drivers respond to pedestrians, however it is rarely done in real life. Rather, pedestrians gaze at the approaching vehicles to estimate the gap. Approximately 90% of pedestrians show this behaviour (Rasouli & Kotseruba & Tsotsos, 2017). This behaviour fits with the idea of gap acceptance theory, where a pedestrian will estimate the distance between them and the vehicle in order to decide whether or not it is safe to cross the road. Is a vehicle too close, a pedestrian is more likely to wait for the vehicle to yield or come to a stop before crossing. This happens even at a designated cross walk where law states that the vehicle should stop. A negotiation between pedestrian and driver still needs to take place to determine who takes/gets the right of way. Based on the results of (Dey & Terken, 2017) this negotiation at first happens less or not at all through direct eye contact, rather through more behavioural moves. Examples are the yielding of a vehicle or a pedestrian stepping onto the road and taking the right of way. Nathanael et all. (2019) found that pedestrians show body cues (head and or body movements) when wanting to cross, however only for a third of the cases this was enough to resolve an unclear situation to cross. In 65% of the cases an eye-gaze – a glance in the direction of the vehicle, was observed which was enough to resolve 50% of these cases. Direct eye contact, however, was rarely made in these interactions. It can be difficult to make direct eye contact as the windshield often has glare issues that make the driver invisible to the pedestrian. A gaze in the direction of the driver could make more of them stop for the waiting pedestrians.
In practice it seems that the direct eye contact has less of an important role as might have previously thought which raises the question how interactions with AVs might go. This question is analysed in Chapter 2.3.

1.3.2 Vehicle Yielding

As found in the previous section, vehicle yielding or vehicle movement patterns play an important role in the pedestrian's decision to cross. Dey & Terken (2017) explains this as the pedestrian seeing the driver and vehicle as one entity, where the vehicle is the showcase of the intent of the driver. For a driver to yield there are several aspects that play a significant role, among these are some that the pedestrian has an influence on. A driver is more likely to yield for the pedestrian if they are waiting close to the curb, they step onto the street or if someone is still in the act of crossing (Schroeder & Rouphail, 2011). These factors suggest also more implicit communications rather than explicit ones as the main reason to yield.
Research by Schneemann & Gohl (2016) found that especially with higher speeds (50km/h) pedestrians fix their gaze on the vehicle rather than looking for the driver. Less so with lower speeds when pedestrians tend to gaze more at the driver. Possibly, because with lower speeds vehicles are less anticipatory (Schneemann & Gohl, 2016) therefore yielding

Figure 5 The zebra crossing seems to floating in a village in Iceland

occurs later and thus is looking at the vehicle less effective in the decision process of crossing. Yielding of a vehicle is an important indicator for pedestrians that the driver has seen them and is anticipating their crossing. However, yielding is not always accepted by the pedestrian and they will wait for the vehicle to come to a full stop before they start crossing.

1.3.3 Turn Indicator Light

At some unsignalised intersections there are also no cross walks present that grant the right of way to the pedestrian. Here they have to wait for vehicles and other road users to pass before they can cross the road. Communications on these intersections between road users happens more directly here and they are more dependent on gestures. Such a gesture is the extension of the arm by cyclists that indicates they are intending to make a turn. This sign can be used by pedestrians to see if their path will be clear to cross and by drivers to understand what direction a cyclist will be going. Drivers themselves cannot perform this gesture and it is outsourced to the turn indicator light on the vehicle. Similar to the extension of the arm, drivers can use the light to indicate which way they intend to go, allowing other road users to act accordingly to the situation

Figure 6 A classic turn indicator light that Flips up from the side of a classic VW Beetle

at hand. Although it is required by law to use the indicator light or extend the arm, it is often more seen as a courtesy from one to another rather than a tool to make traffic safer for everybody. Depending on the situation, sometimes additionally eye-contact or gestures are used to communicate. The same goes for the extended arm of a cyclist. An example of additional gestures could be as a courtesy to give someone right of way when they do not necessarily have the right, or to showcase anger when someone disobeys rules, or as thanks for a courtesy.

!.3.4 Conclusion

In the way the turn indicator has been a translation of the extended arm onto the vehicle, many researchers and autonomous vehicle developers are looking into ways to translate other gestures like eye contact onto the vehicle, to replace the lack of a human driver. An indicator light could be seen as a first type of eHMI (external human machine interface) on vehicles in the current world. These kind of tools can help to clarify the intentions of a driver, besides their driving behaviour as main indicator. While it was expected that eye contact would be found as an important tool of communication, it seems that this is more of a last resort for pedestrians to either demand their right of way or to ensure they have in fact been seen by the driver if they show unclear behaviour. For autonomous vehicles this could mean that less explicit ways of communication might be necessary for successfully resolving interactions with humans. This subject is elaborated on in Chapter 2.3.

1.4 Observations

The analysis performed focused more on a general definition of an intersection, however throughout the project the boundaries, as discussed in the introduction, were narrowed down. A more specific target group, being pedestrians, was chosen to focus the final design on. Throughout the analysis of the interactions with drivers currently, the research had focused mainly on pedestrians. However, to gain more insights specifically in how pedestrians behave on cross walks, some observations were done at actual cross walks. Cross walks are a type of intersection specifically for pedestrians, and it is here where they interact with vehicles – both currently and in an autonomous future.

The area where the observations were done is the Hoven in Delft. The roads here are slightly bigger distributor roads where the speed limit is 50km/hr. There are residential areas and shopping centres surrounding the streets and therefore they often have to be crossed by pedestrians going to the shops or home. The two roads that were observed also have the four main types of crossings we know in the Netherlands, being the traffic lights, zebra crossing, cross point indication but no right of way, a random crossing point decided by pedestrian. The latter is rarely seen though at these streets since there are plenty of spots to cross and the streets are rather busy with higher speed vehicles.

From the observations it becomes clear that methods like a traffic light often do not work well in the area. The traffic light is operated with a button which often is pushed, however more often than not does the person already cross before the lights turn green as no cars are approaching. The system however does not know this and the light for the cars does turn red, causing them to wait unnecessarily. Waiting times at traffic lights are often longer than people feel the need for. This is redundancy of the system that cannot measure if someone is still crossing or not and needs to give slower walkers also their time to cross. For a slower walker it can also mean that the lights have already turned red, and are about to turn green for the cars, which can cause dangerous situations if oncoming cars do not anticipate the person still on the road. A traffic light does guarantee a pedestrian will be able to cross a road, and therefore is valuable in busier areas.

At zebra crossings often the waiting times are way shorter since people decide themselves when they can move. However, negotiations between driver and pedestrian can be difficult. Drivers are not always clear in their intentions when they only stop quite late for the pedestrian, or keep rolling. Pedestrians show distrust by waiting longer than was necessary. Some pedestrians also increase their walking pace to cross faster to no longer inconvenience the driver. Albeit, crossing at a zebra is more time efficient, it can be quite nerve wrecking.

A crossing point where room is made for the pedestrian (a walkway through grass in the refuge) but without a right of way for the pedestrian has a similar efficiency of the zebra crossing, however, when it is busy pedestrians have a hard time crossing here as they have to wait for the cars to pass by. This situation is similar to when a pedestrian decides to cross at a random non-designated location. Since they do not have the right of way they have to find a gap that is acceptably large enough to cross. This often causes them to have to wait long, or start running in order to clear the road before a car would need to slow down.

Although the new design will not be a redesign of one of these crossings, some elements could be used to create it. The reassurance of a traffic light, guarding over a pedestrian's safety, the fluency of a non-right of way crossing combined with the right of way of a zebra to create a more efficient traffic flow in terms of shorter waiting times for all participants. Creating a more natural crossing experience while maintaining safety.

Figure 7 A cross walk controlled with traffic lights

Figure 8 A zebra crossing near a busy shopping centre

Figure 9 A marked crossing without the right of way

Figure 10 No cross walks in the vicinity, rogue crossing

1.5 Conclusion

Intersections exist in different configurations, and based on their size, traffic flow and clarity it could be operated by traffic lights. These take over the interaction that happens between different traffic participants, and is fairly authoritative yet reasonable. The traffic light as we know it has existed for some decades now and in design has not changed much, rather the system is undergoing some developments. In some Dutch cities the first steps are being taken to create connected traffic lights that can "talk" to one another to decide a more optimal pattern to prioritise certain road users. These connections are also slowly extending to services beyond the traffic controls. By sharing the patterns to traffic apps, road users will know when the lights will change for example. When these services make it into the vehicle more directly, the first steps in infrastructure2vehicle communication is created. An important step for the implementation of autonomous vehicles. Projects in this area indicate a drive to prepare the infrastructure to create more fluent traffic control systems and flows.

When such a traffic control system is not in place, humans have to negotiate who gets the right of way. Between road users mostly the indicator light or an arm extension is used to show an intent of direction, while at cross walks less of these explicit forms of communication are used. Between driver and pedestrian such explicit communications happen mainly when one of the participants shows behaviour that is unclear or unexpected. People then start to look for more direct lines of communication like eye contact. In a more common situation, pedestrians rarely look for eye contact, rather they look at the vehicle's movement pattern to estimate the gap and speed or possible yielding. Based on these implicit communications the pedestrian will decide if crossing is safe.

Both types of intersections generally prioritise motorised vehicles where the right of way for the pedestrian is more an exception to the rules than the main focus. Although pedestrians should get the right of way at zebra crossings, as stated by the law, crossing is often an action of high uncertainty still due to unclear and differentiating behaviours of human drivers. Often the pedestrian will wait until a car has clearly slow down, or has come to a full stop before starting to cross. A traffic light takes the uncertainty out of the equation however it currently can add quite some unnecessary waiting time for both the pedestrian/cyclist or driver. The traffic light also does not take into account that different pedestrians may need more or less time to clear the cross walk. At these cross walks there is thus often a higher level of uncertainty and unnecessary waiting that can happen for either actor in the situation.

Chapter

2

The Autonomous Vehicle

2.1 Introduction

The automotive industry has not seen a large disruption since the internal combustion engines and line production of Ford, which basically fuelled the industry in becoming so big. Nowadays, the autonomous vehicle is slowly but firmly making its way into our societies, disrupting how we look at mobility. Decades of research are culminating into concept vehicles that are becoming more realistic each year. We can already see higher levels of automation being featured in new car models like Tesla with AutoPilot or Volvo with auto parking modes. However, AVs have an affect beyond the technological developments. They bring changes that will ripple through to society, politics and urban design. Just to name a few.

The previous chapter looked into the traffic system with human drivers occupying the roads, however it is assumed in this project that at some point in time autonomous vehicles will be the main occupants of the roads. It is thus crucial in this project to understand what the autonomous vehicle is, how we interact with it and how it affects, or is affected by, its context. The three levels of ViP are used here to cover all bases of the analysis. The product level is analysed, however in this project the AV itself is seen as a black box of which the properties are a parameter that cannot be altered during this project. This is to keep a focus on solutions connected to the smart city, instead of design features that can differ for each automotive brand. The technology analysis is used to better understand how the AV perceives and understands its surroundings. These insights were used during the Thing Centred Design Method; Interview with Things (Chapter 4.3). In the section Interaction the question that was raised in the previous chapter (Chapter 1.3) on how humans will interact with AVs when eye contact plays a smaller role in communications than previously assumed (by research and the designer, me), will be analysed.

The context of the autonomous vehicle describes in short the history of how AVs are becoming part of our daily lives and discusses the (dis)advantages of them. The section also looks into how the AV will influence how we can design our urban areas in an era of self-driving vehicles.

2.2 Product

2.2.1 Design

There is not one distinct look for the automated vehicle. At this point, the closest we are to the self-driving car are automated vehicles like the Tesla which already can take over some operations of the driver. However, the driver still has to remain attentive and always ready to take over the control of the vehicle. When looking at these semi-autonomous vehicles, they look like any other vehicle currently on the market. They still have a very recognisable shape with hood and greenhouse often separated into two different volumes. Although, they may differ in design styling among brands, the vehicle fits within the range of vehicles of its own brand.
Self-driving cars might not be seen on the streets yet, in the world of research into autonomous vehicles, there are the pods. For example the one operative at RIVIUM business park in Rotterdam. It has been driving on its separated route for years, as part of a study into self-driving vehicles. A so-called pod is often a self-driving person transport, like a small taxi van. This pod has a more distinguished look from what we are used to see on the street nowadays. Its symmetry to enable bi-directional driving without having to turn and single volume greenhouse to provide more space inside, distinguishes it.
For more distinct vehicle styling, one can look at concept cars that have been developed in recent years that are meant to be either highly automated or fully autonomous. Styling wise, it seems that there is this idea that an autonomous vehicle should consist of a single volume body. By eliminating the dipping curve from hood to greenhouse roof and making it into a unibody, the front seat passenger's headspace increases. This enables the chairs to be rotated so that a small living room or office forms itself.
The autonomous vehicles become functional spaces rather than just a means of transport.

Figure 11 The Renault Symbioz, a vehicle that has become part of the living room

2.2.2 Technology

Line-of-sight Technologies

In conventional cars the driver's eyes are the main sensors to collect data about their surroundings. Mirrors are used to review what is happening besides and behind the vehicle without having to rotate the head or torso. In recent years some additional electronic sensors have been added to the car to support the driver in creating a more complete overview of the surroundings. Cameras on the rear of the car helps with parking, and cameras on the side reveal the blind spot of a car to the driver.

An autonomous vehicle has replaced human eyes with cameras that together create a 360 degree view of its surroundings. The cameras provide the vehicle with live representation of who and what is around it and where they might be moving. Although cameras have a similar function as the human eye, on their own they are not enough to provide the vehicle with all necessary information. Other surroundings-scanning sensors are needed to provide a more complete comprehension of the situation. With radar and Lidar the vehicle is able to more precisely pinpoint where each object is. Radar helps the vehicle to understand the speeds and distances of its surroundings. However, it is not able to distinguish between objects, which is where Lidar comes in to support camera images. With Lidar the vehicle is able to create a 3D representation of the near surroundings by measuring distances of every object to the vehicle. These sensors can sense other objects within its line of sight, meaning it can only see what is directly around it, but objects that are obscured by other objects cannot be detected (Burke, 2019). All these sensors together give the vehicle a complete oversight of its direct surroundings and how they are moving. However, they only work when the brain of the vehicle is able to process the data and combine them. AI is used in processing all this data in order to come to a decision and complete a task within a framework of regulations. (IHS Markit, 2020).

Some of the data is used as redundancy, a double check of the surroundings to ensure nothing and no one was missed so it can make the right decision. Image processing allows the vehicle to distinguish between different objects (infrastructure, vehicle or person). With advanced processing abilities, the software is also able to predict where pedestrians are going and if they have seen the vehicle while for example crossing the road.

Learning

More often do AV developers rely on machine learning too (IHS Markit, 2020). This way the vehicle can learn and train itself from its experiences on the road. This enables it to more quickly recognise similar situations and respond to them accordingly and quicker. For situations that happen more rarely machine learning across a fleet of vehicles can help to build behaviours within a fleet. It can help individual vehicles to act responsibly even if they have not encountered the situation itself. This is also closely related to the more advanced deep learning where a vehicle after coming across similar experiences can learn to recognise certain patterns without the input of a programmer.

The hardware exists and is proving to be ready for the autonomous vehicle revolution. However, the software behind it, which is what will in the end drive the vehicle, is still being optimised and improved. Companies like Waymo have been intensively testing and training their software both in physical situations on the road and in a virtual environment. (IHS Markit, 2020). This way the vehicles will be able to recognise more situations and has created certain behaviour patterns respective of the situation it finds itself in. Researchers like the Intelligent Vehicles Group at the TU Delft have been working on detection systems that are able to detect pedestrians and predict their behaviours and path based on their head movement and gait. (Intelligent Vehicles Group, 2019)

Vehicle to Vehicle Communication (V2V)

Sensors located directly on the AV can sense objects and surroundings in the line of sight of the vehicle. It enables the vehicle to make short-term decisions about its behaviour and manoeuvres necessary. However many objects are obscured from this direct line of sight, which can cause unforeseen situations, causing the AV to redirect its manoeuvre quickly. (Ali & Jiang & Patil & Li & Heath, 2018)

Vehicle to Vehicle communication can create a network of lines of sights. Other vehicles become part of the sensing range of one AV, giving each vehicle more data to base its decisions on and also anticipate more long term planning of its manoeuvres. Vehicles can also share their own movement data, allowing AV's behind it to anticipate. For example if a vehicle encounters a pedestrian crossing and has to brake, vehicles behind it can, based on this data, slow down to anticipate the braking instead of having to brake last minute too. This can improve general traffic flow and possible accidents.

The time to complete manoeuvres, like lane changes and left or right turns, can be reduced with the help of V2V communications. As all intentions of surrounding vehicles are known to the AV, it can decide quicker if it is safe to perform the manoeuvre and can thus behave more actively instead of waiting passively for other vehicles to show their intent.

Infrastructure to Vehicle Communication

An additional level of communications is the infrastructure. As discussed in Chapter 1.2 the first steps are taken to develop connected infrastructures that communicate among itself and vehicles. This could increase the indirect line-of-sight of AVs even more, as signals like a red light are not visually communicated but ahead of time via data connection. This allows AVs to anticipate other AV's behaviour but also situations up ahead. Traffic control systems also know ahead of time what the AVs approaching plan to do, which in turn can be optimised through a system overseeing it all.

2.3 Interaction

2.3.1 Interaction Research

In recent years it has become clear that fully autonomous vehicles will become part of our future, at least if it is up to automotive and mobility companies. While the AV is still in its early development stage technologically speaking, the need for clarity on the influence of the AV on our human lives arises. A lot of (design) research in the recent years that has been performed, revolves around the interaction of the driver/passengers with the vehicle; trusting the vehicle, how to gain control over a semi-autonomous vehicle, etc. Although this is an important factor in the acceptability of the AV, the passengers are just a small section of people interacting with the vehicle when it is driving around the city. For passengers the autonomous vehicle becomes a functional space in which they can occupy their time differently than focusing on traffic. However, for other road users, the vehicle becomes another participant in traffic with which they have to deal and communicate with. Arguably this communication will differ from how we communicate nowadays with the human drivers, as explicit communications will disappear. Research into this subject is rather slim and with a focus on how we could replace the VRU to driver communication when it becomes VRU to AV communication. One frequently researched method is the use of an eHMI (external human machine interface). This is a feature integrated into the exterior of the AV to communicate its intentions towards other human road users.

Throughout academic research, different types of eHMI have been researched in relation to their influence on pedestrian behaviour, to be more specific their willingness to cross and perceived feeling of safety in doing so. Often the reason to initiate the research is the disappearance of direct communication with the driver. The lack of eye-gaze or gestures might make it more difficult for VRU's to predict the behaviour of the vehicle. (Clerq & Dietrich & Nuñez Velasco & Winter & Happee, 2019; Deb & Strawderman & Carruth, 2018; Habibovic et al., 2018)

From the research of (Böckle et al., 2017; Clerq et al., 2019; Deb & Strawderman & Carruth, 2018; Habibovic et al., 2018; Mahadevan & Somanath & Sharlin, 2018) it appears that an eHMI on the vehicle improves the perceived feeling of safety in pedestrians when they are planning to cross the road. In the research of Clerq et al. (2019) this is true for yielding vehicles only. Pedestrians generally perceive the AV with the eHMI to be about as safe as a conventional car with a driver (Habibovic et al., 2018). Using eHMI helps to clarify the vehicles intent towards the pedestrians and makes it possible for them to decide earlier to cross instead of waiting for the vehicle to come to a full stop (Böckle et al. 2017).

Even though adding an eHMI to the vehicle has a positive influence on the crossing behaviour of pedestrians, it might not be as necessary to do so. According to (Rothenbücher & Li & Serkin & Mok & Ju, 2016) people are quite capable of handling a breach of expectations of the vehicle's behaviour, even when there is no eHMI present. For the majority of people additional communication cues might not be necessary as many people are capable and confident enough in reading the AV's behaviour and intent from its movement pattern. This could be explained by the experience people have in a similar situation where direct communication with the driver is not possible due to window glare or at night. This capability can also be backed up by (Dey & Terken, 2017) who found that pedestrians mainly use implicit ways of communication to predict a driver's intent. In the case of AVs, pedestrians thus can rely on these implicit communications through movement patterns of the vehicle. In an experiment by (Moore & Strack & Currano & Sirkin, 2019) they filmed unscripted interactions between pedestrians on a zebra crosswalk and a wizard of oz AV. In the video it can be seen that most pedestrians, who are just going about their day, do not even look at the vehicle and just cross when they see the vehicle stopped or is about to. Especially when the pedestrian is about to approach the curb they show very little interest in the vehicle. This indicates that if a car shows clear intentions through its movement, pedestrians feel safe to cross and actually barely even notice that the car is driverless.

In the research by (Mahedevan & Somanath & Sharlin, 2018) participants indicate that speed and stopping distance are still very important factors in their crossing behaviour, even in the presence of external (explicit) communication cues. The paper suggests that the vehicle's movement pattern should be the baseline in its communication (implicit communication) and that adding external cues (explicit communication) can reinforce the vehicle's intent towards the pedestrian.

These results indicate that adding an eHMI system is not necessarily required for effective interactions between pedestrian and AV, however it can improve the efficiency of the interaction. Pedestrians are more likely to cross earlier and also when the AV is still moving. This can improve traffic flow as vehicles do not need to come to a stop and can continue moving forward, although at a lower speed.

2.3.2 eHMI

Since eHMI is seen as one of the main potential solutions for communications problems between AVs, a closer look is taken at the subject, and especially the possible concerns that exist with the system. These concerns indicate that eHMI might not be the (only) way to go and that there is room to explore different solutions. To gain more in depth insights, an interview was conducted with PhD candidate J.P. Nuñez Velasco on the subject of VRU and AV interactions and the use of eHMI (Nuñez Velasco et al., 2019).

Types of eHMI

Throughout the academic research conducted on the subject of eHMI, different configurations of the system have been used. Most researchers have used text to convey messages, while some have used more visual imagery like smiley faces or images. Research shows that textual messages have a short learning curve, while the more visual cues require more time to be understood correctly (Clerq et all., 2019). Besides text, (Deb & Strawderman & Carruth, 2018) found that an image of a walking person is favoured over the smiley face, which is considered difficult to understand due to ambiguity of whose perspective it represents, vehicle or pedestrian (Clerq et all., 2019). Generally, visual cues are favoured over audible or physical cues in terms of displaying a vehicle's awareness and intent (Mahedevan & Somanath & Sharlin, 2018). However, also mentioned is that some road users might be excluded when using visual cues only, like people with visual impairment or due to colour blindness.

An exception within this academic field is the research by Mahedevan, Somanath, Sharlin (2018), who used cues other than eHMI on the vehicle, and also included infrastructure and mobile devices. They prove that the scope of eHMI solutions goes beyond the ones fixed on a vehicle itself. Although the other types of cues also presented concerns, there was a preference by the participants for a prototype that used both interfaces on the vehicle and the infrastructure. Other prototypes which used haptic or audio feedback through a mobile device were often found to be confusing as these cues are commonly used for receiving messages on a phone. Audio cues can also get lost in an environment where there is a lot of noise or other sounds, which reduced its preferability as a communication tool.

Discussion on eHMI

From the researches it becomes clear that eHMI does have a positive impact on the perceived safety and thereby willingness to cross when a pedestrian encounters an AV. However, these systems also bring forth some concerns with their implementation. Some of these concerns were also shared by J.P. Nuñez Velasco during an expert interview concerning the topic of eHMI and its influence on crossing behaviours, which came forward during several researches during his PhD on the matter (Nuñez Velasco et al., 2019).

One sided communication

Most of the research focuses on the loss of communications from the driver to the pedestrian and therefore new solutions need to be found to replace this. However, that only is one way of the communication. Drivers also pick up a lot of cues from pedestrians in their behaviour, which will also be a lot more difficult for the AV to understand. Pedestrians can thus also no longer communicate their intent to the vehicle through established communication behaviours (Chapter 1.3). eHMI only solves the communication from the vehicle to the pedestrian, however disregards the two way communication that happens currently with drivers. This takes away much of the control a pedestrian has in the situation. The loss of control is something humans do not appreciate when it comes to (new) technology (Voorst tot Voorst & Hoogerwerf, 2013). Pedestrians can only receive directives from the vehicle, but not respond or even initiate interactions.

Communication

Research into the use of eHMI is focused on interactions between one vehicle and one pedestrian, while it is more likely that there will be multiple pedestrians or AVs interacting with each other at once. With eHMI on each AV, multiple vehicles would be communicating towards the pedestrian(s), or one AV would be communicating towards multiple pedestrians which does not reassure that all of them will understand similarly and thus respond in the same manner. It all possibly leads to confusing situations.

Right of Way

When an AV approaches a zebra crossing and tells the pedestrians not to cross, even though they have the right of way here, they are much less likely to cross. The AV could take away the right of way of pedestrians. In doing so, the AV would be overruling the law, which seems like a highly undesirable situation.

Visibility

This concern is two part, one is about bad weather conditions which limits visibility ranges for everyone. The other part is a day to day situation for people with visual impairment. eHMI could really show its limitations here when only using visual cues. In bad weather conditions the interfaces might not be visible from a distance which limits the effect of the eHMI on earlier crossing behaviour. For people with visual impairment, the visual cues are more useless on a day to day basis. People with vision loss are very limited in understanding the directive of the AV without additional feedback or help. Those with low or impaired vision may have difficulty reading the interface either from a distance or at all, which also limits their ability or interact and understand the AVs directive.

Besides these visibility issues, research by Deb et al. (2016) found that about 70-80% of pedestrians actually looks at the oncoming vehicle when they are crossing, which means that about a quarter of the pedestrians would not even see the eHMI mounted on the vehicle.

Differentiation

As eHMI is something that is part of the exterior design of the vehicle, it will be designed by the automotive companies. Without regulations, these designs could differ a lot among different brands. This would create a chaotic and unclear situation when multiple vehicles are encountered, as with each brand a pedestrian would have to remember its unique signs or language. It will take the pedestrian time to decipher what the vehicle(s) means and the pedestrian(s) might not take the action as the AV expected them to, creating possible dangerous situations.

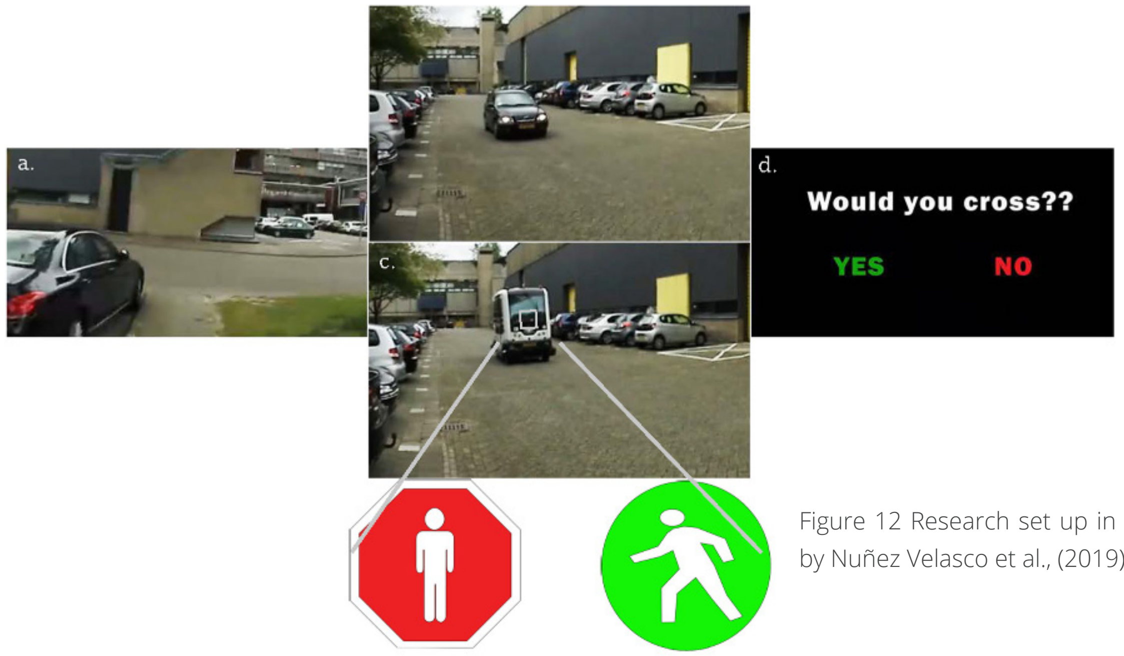


Figure 12 Research set up in VR by Nuñez Velasco et al., (2019)

2.3.3 Interaction in the real world

Experience

Currently, most people have had no experience with actual AVs yet, which makes it harder to trust the AV when encountered. The hands on experience is a key element in the acceptance of AVs (Merat & Madigan & Nordhoff, 2017). Now, VRUs are still are still cautious about AVs as they are not fully trusting the technology to detect them (Vissers, Klint, Schagen, Hagenzieker, 2016).
When we have become more accepting of AVs and their behaviour has become part of our instincts when manoeuvring outdoors, our behaviour could have completely changed.

Researchers use, for ethical (safety) reasons, VR environments (animated or video of cars or Wizard of Oz (human driver is concealed while driving a conventional car) applications to test their eHMI set-ups. These situations seem quite lifelike, but a significant difference remains. This makes it difficult to understand how responses would be in real life when vehicles or streets might look different, some first-hand AV experiences arise and there is an actual vehicle approaching and more real threats might arise.

Research into eHMI thus might have more near future implementations to aid a smoother transition into creating these behavioural instincts, by reassuring the vehicle's intention. With time humans will get more used to and gain experience with AVs and with this an understanding of how the vehicles behave. Probably this behaviour becomes more standardized as the AVs will be programmed to respond similarly in similar situations while human drivers can be unpredictable in similar situations due to their personality and driving style.

However, with the afore mentioned concerns, designing a system that is not fixed on a vehicle, rather is part of the urban design/ infrastructure could take away some of these limitations.

AV in real life

In a research performed by former TU Delft graduate student P.K. Rodriguez Cabezas (2017) on the interaction of the WEpod and VRUs, findings concluded that mainly pedestrians would like to have a designated spot to cross the roads when interacting with the pod. The lack of direct interactions with the driver of a traditional vehicle is something participants missed and should be made up for by signals provided by the pod.
Cyclist feel less safe on an unsignalised intersection when it is also used by a self-driving pod, while pedestrians do feel safe. Pedestrians seem to choose the dedicated crossing areas more when interacting with the WEpod due to not feeling as safe with it. Especially those who use cues when interacting with human drivers more than others (eg. they gesture or look for eye contact more often).

Participants who had previously interacted with the self-driving pod felt safer than those who did not. Thus in the future it makes sense that almost everyone has interacted with self-driving vehicles and thus already will have less concerns about sharing the roads with AVs.
These findings do contradict aforementioned conclusions about looking for direct contact with the driver, or the lack thereof in most traffic situations. This can be explained that the WEpod has a rather novel appearance which might be confusing to participants. They therefore want to negotiate their actions with a driver which happens in uncertain conventional traffic situations too. However, with the driver now really missing this negotiation cannot happen anymore. With more experience such negotiations might not be as necessary as when first encountering AVs. However, these points do indicate that some sort of facilitation for these negotiations will be necessary, especially in the transition towards AV mobility.

Figure 13 The self driving WePod driving in real mixed traffic

2.4 Context

2.4.1 History

The self-driving vehicle concept is not as recent as you might have thought. Already in 1925 Francis Houdina built a radio controlled car and drove it around Manhattan (Dormehl & Edelstein, 2019). The concept of the self-driving car made a comeback at the 1939 World Fair in a futurama made by Norman Bel Geddes. He presented a roadway with embedded circuits to proper the cars on the road. He believed that by 1960 human free driving would be realised. It took until 1957 to even build a real life demonstrator, using detector circuits in the road. GM's Firebird concept used similar embedded electronic guide systems on automated highways (Wikiwand, n.d.). Developments using this system continued throughout the 60's and 70's until in 1979 the Stanford Cart made its way through an obstacle filled room in about five hours. It was the first "vehicle" to use image processing as guidance (Futurama, n.d.; Jenn U, 2016). This sparked research into sensor/image based processing as a guiding system. In 1980 Ernst Dickmanns used a vision guided system on a van allowing it to drive on a highway without traffic. In 1995 his updated van drove 1600km throughout Europe, achieving about 95% of the ride to be "autonomous". The van was able to steer and pass other cars, and managed to drive 158km without any human interventions. In the same year Carnegie Mellon University's NavLab vehicle drove from coast to coast in America, also able to steer itself, but humans needed to control speed and braking (Dormehl & Edelstein, 2019; Wikiwand, n.d.).

Only four years later the first fully autonomous vehicle is introduced in the Netherlands at the Rivium Business Park, a people transport pod designed by 2GetThere. In 2001 they introduced the second generation with increased route length that also crosses car and pedestrian routes. In 2021 their third generation vehicle will operate in mixed traffic, and will be the first to do so in the Netherlands. The pod is one of the few fully autonomous vehicles that is commercially operational (2GetThere, n.d.).

In private cars the new millennium brought the first automation systems such as (adaptive) cruise control to support the driver in controlling speed and maintaining distance (in adaptive cruise control).

One of the most well-known autonomous vehicle development projects is Waymo by Google, since they shared their project with the public. Starting in 2009 Google started testing self-driving systems, also on public roads. Six years into the project their cars were involved in 14 minor accidents, allegedly all caused by human drivers (Dormehl & Edelstein, 2019). Waymo is still testing their systems in a taxi ride setting, which is already being commercially used in certain American city areas (Naughton, 2019). The vehicles are still remotely accessible by safety drivers if the system fails. However, Waymo is planning to remove these safety riders in a select amount of rides to test its fully autonomous functions (Matousek, 2019).

Come the 2010's more automotive and mobility companies, and not just research programmes, become more involved in making automation systems gearing towards fully autonomous vehicles. Systems like adaptive cruise control, lane assist and parking assist are more widely introduced into cars. Nissan, Toyota, BMW, Volvo, Daimler, VW, Audi, Ford, all have projects and collaborations running to develop autonomous vehicles.

Even though many automotive companies had started on concept cars with more automated systems, nobody brought as much attention to the subject as Tesla did with their AutoPilot system (Wikiwand, n.d.). In the past years the AutoPilot system has become more advanced and available with all models. It is one of the most advanced automation systems currently on the road.

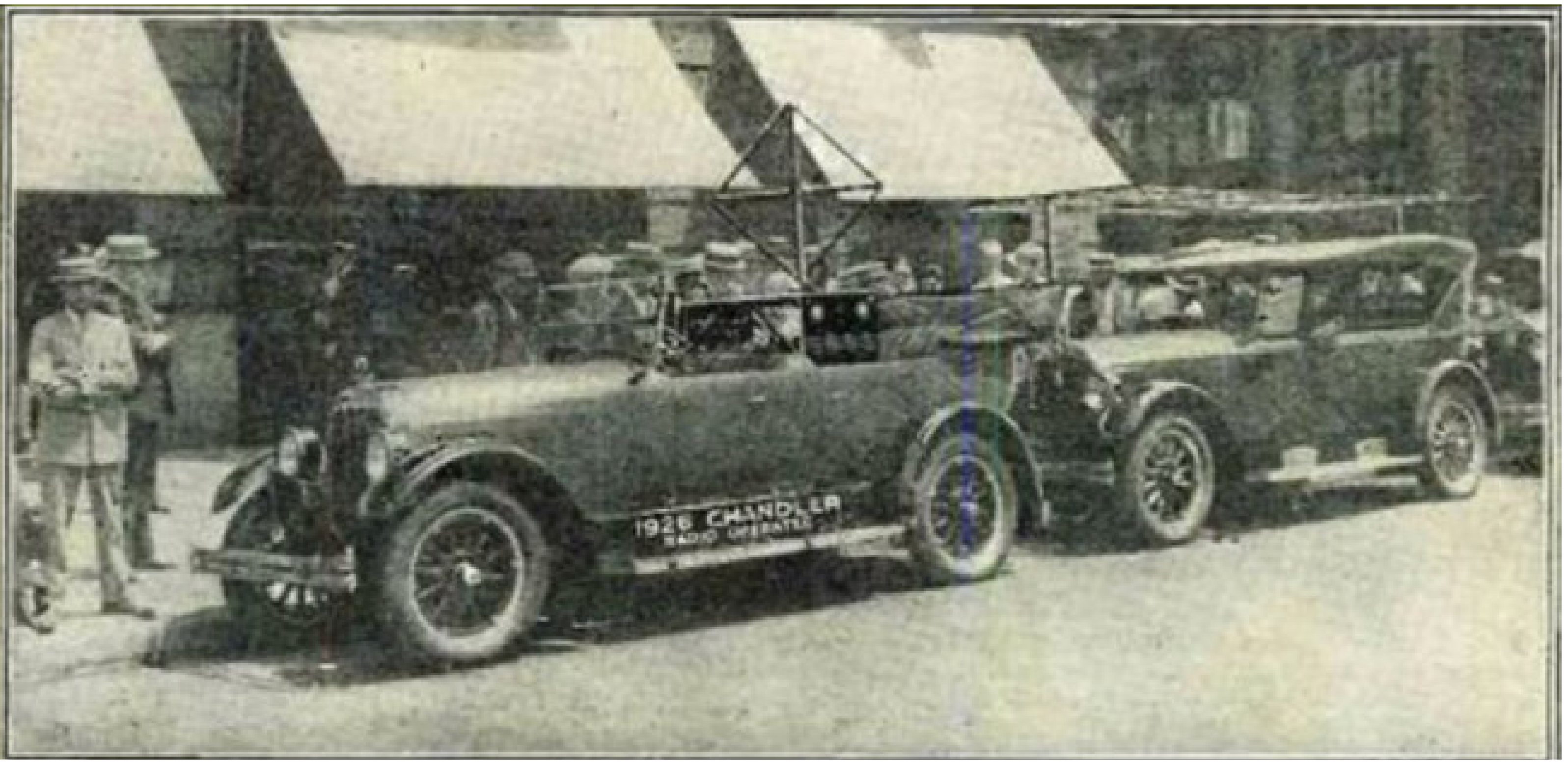


Figure 14 The 1925 American Wonder by Houdina, the first radio controlled car

Figure 15 The Rivium Parkshuttle at Rivium Businesspark by 2GetThere

2.4.2 (Dis)Advantages of the AV

With the AV development come both predicted benefits and disadvantages. On some of these subjects still no consensus has been found as they are difficult to model. This only shows how wide the impact of AVs can go, beyond technological advancements.

Congestion and Traffic Jams

This subject is often one of the first that comes up in discussions about AVs and is one of the main subjects that is unclear whether it will be a benefit or disadvantage. It is argued that there will be less congestions and traffic jams due to lesser amount of vehicles on the road and platooning. With platooning vehicles it could be possible to optimise traffic flows which will decrease the amount of traffic jams, or at least stand still jams (Half Fast Chicago, 2018). When AVs are operated in fleets and shared rather than privately owned less vehicles will be necessary to complete current mobility needs of citizens. (Bloomberg Philanthropies, 2017). So with fewer vehicles that drive predictably, congestion and traffic jams could decrease. However, with AV technology becoming cheaper, this means of transportation could become favourable over cycling or walking when covering shorter distances or public transport for longer distances. With a shift in needs like this more vehicles will be necessary to also complete these transports, increasing the number of vehicles again (Bloomberg Philanthropies, 2017).

Cities then have the option to encourage walking, cycling or other last mile mobility means, through walkable and bike friendly city design or making prices for other means of transport (last mile and public transport) more competitive to the AV.

Safety

This subject is two-fold; there is road accidents and cyber security.

Without human error behind the wheel, accidents are predicted to happen less (Half Fast Chicago, 2018). Many of the current accidents happen because people made wrong assumptions, were not attentive, had been drinking or were tired. About 90% of accidents result from human errors (Coates, 2020). Also pedestrians or cyclists at fault cause dangerous situations because they are not attentive, which also cause a big part of accidents involving VRU. The latter is harder to remove when we transition to driverless vehicles, however, these vehicles have a shorter response time and with predictive software are quicker to respond to inattentive VRU. The software driving the vehicle will also not get tired, break rules or get drunk which reduces more accidents. AVs also have their limits and will not be able to prevent all accidents, but it is thought that about 30% of accidents could be prevented by AVs (Coates, 2020). Then we get to the second part of the safety issue: cyber security. AVs are likely to communicate over broadband connections to share and receive data, this makes them a target for cyber-attacks. When a vehicle or fleet gets hacked this can cause dangerous situations when people with bad intentions take over control from the vehicle's pre-programmed algorithms. It can also lead to leaks of personal data of passengers which is a sensitive subject.

Functionality

Most commuters have to drive themselves or share a busy train coupe in rush hours. AVs would allow commuters to use this time for other activities like relaxing or already getting started on those pesky little work tasks. (Half Fast Chicago, 2018) How one would spend this time is up to them, but it could create more spare time in the day if the commute becomes part of the work day. AVs could even be designed to fit better with needs for these commuters. However, that is a completely different, but interesting, design project.

Besides this new way of spending time on the road, not owning your car anymore opens up other functionalities as well. One can request the exact type of vehicle they need for their goal. Going on a weekend away with the family; get a vehicle with more seats and luggage room, and after the weekend you need to catch up on some work; get a smaller one person vehicle for focus on your way to work. It is comparable to renting and sharing services nowadays, however more options will be available.

Accessibility

People who currently are not allowed to drive will be able to become equal users of the new mobility systems to those with a driver's license. The elderly, people with visual/hearing impairments or disabilities, neurodiverse or even children, can more easily use door to door mobility. That is, if in the design of the system and vehicles these groups are taken into account or put atop as the main target group. (NCMM, 2018)

Environmental

For this factor to become a benefit, it also is dependent on how the AV is introduced. If AVs would be privately owned vehicles like conventional cars, then the environmental impact is limited to the fact that new cars will be electric and thus have fewer emissions while driving. If the AVs are introduced as shared, fleet operated vehicles than they can have a positive impact on the environment. Like mentioned before, with shared fleets fewer vehicles will be necessary to fulfil the mobility needs. Even though these vehicles will be used more intensively, vehicles have long life spans. Usually longer than we currently keep a car. They will also be maintained more regularly, and possibly better with the help of AI that checks the vehicles processes and can notify when problems start to occur before they become too big.

Conclusion

When it comes down to it, there are still many unknowns about how much the autonomous vehicle will impact human lives. The aforementioned subjects can become benefits, but it all comes down to how we implement the AVs in our lives. In the words of Peter D. Norton:

> **“There is a naïve view that AVs are in themselves beneficial. They can be beneficial only if we deliberately make them so.”** *- Peter D. Norton, Associate Professor of History, Department of Engineering and Society, University of Virginia (citation from NCMM, 2018)*

2.5 Urban Design Implications

The arrival of the autonomous vehicle does not just disrupt how we drive our vehicles. It can disrupt how our cities will look like and how we use public transport. It could even mean the start of a de-urbanisation movement.
It remains unclear how the future infrastructure and urban design will be influenced exactly by the introduction of the autonomous vehicle. Many believe that with the introduction, less space in the city is occupied by vehicles which stand still for about 95% of the time, which opens up spaces like parking lots and garages to be re-designed for other purposes. (Duarte & Ratti, 2018; Milakis & Arem & Wee, 2017). What for these spaces will be used is up for each city to decide based on needs of its citizens and municipality. Some examples are parks or greenery, markets, community areas, meeting points for mobility services, or new building opportunities like houses, offices (or other business spaces) or public services (education, sports, community etc.).
Cities can open up more space for the pedestrians, cyclists, Things and other non-motorised vehicles. The autonomous vehicle will need less street space due to more efficient traffic flow operations, it can manoeuvre through narrower streets and needs fewer lanes (Jolma Architects, 2018). Some concepts also propose a mixed area where AV and other road users share the same space as co-citizen.

These factors add to the notion that urban design no longer has to be reigned by cars, but rather infrastructures could be redesigned revolving around the citizens and the cityness. As Urbanism Next describes it: "Using streets for transportation will remain a necessity even as transportation modes evolve, but shifting towards thinking of streets as places that host activities and where people spend time as opposed to just pass through will help create updated and engaging spaces for the benefit of a wider audience than cars alone." (Urbanism Next, n.d.).
Designing a city's infrastructure from a more human centred perspective instead of vehicle centred can create more walking/cycling friendly cities. Especially a city that promotes walking can lead to improved mental health among its citizens (Kroesen & de Vos, 2020). Promoting such behaviour can be done through various methods. It was mentioned shortly in Chapter 2.4 that one such possibility is by means of the infrastructural system design. There are many factors that can enhance a city's walkability, based on an analysis by the Institute for Transportation & Development Policies (ITDP, 2018). They indicated many factors on different focus levels. For crosswalks they indicated that waiting times should be reduced to 30-45 seconds on signalised crossings and that these should be levelled with intersecting traffic. Important too is that there are enough crossings in lively areas, about 1 every 150 meters should suffice.
It is thus beneficial for urban planners to create cities with a pedestrian centred perspective as it can reduce the need for more vehicles to fulfil transportation needs on shorter distances, improves mental health through active transport and can create a more lively city. Instead of creating, once more, cities built for vehicles.

Exploring now what might be possible in the future can help cities and automotive companies to strategize about urban planning, collaborations and necessary infrastructure redesigns. Instead of waiting for the AVs to hit the roads, governments can already work towards their introduction to create policies and designs that will allow their cities to gain the benefits of AVs.

"Expending the effort to plan and strategize before AVs hit the streets is critical. Cities can be purposeful about how its public right of way serves the public; but if they are not – the AV technologists will do it for them. The time for cities to plan and act is now." (Schlossberg & Riggs & Millard-Ball & Shay, 2018)

Figure 16 A shared space concept by Mercedes Daimler using projections

2.6 Conclusion

The main insights that will be most important to this project are the ones concerning the interactions between pedestrians and AVs. The lack of a driver is seen as a big issue for pedestrians, as it is predicted that this lack of human to human communication makes negotiating with the AV more difficult. However, research shows that humans are quite likely able to still negotiate effectively with the AV as most of the communication cues used to make a decision about crossing come from the implicit behaviours such as vehicle movement to yield. These signs can still be executed by an autonomous vehicle and will be much more consistent as AVs will adhere to the laws they have been programmed to follow. This means that once they recognise a pedestrian at a cross walk, they will start to yield for them, even if the pedestrian will not cross. Many pedestrians are still likely to wait for the AV to slow down, or come to a full stop before they will cross, as they would feel less secure about whether or not the AV has seen them, or will wait for them. A solution that has been the main topic in interaction design currently is the eHMI system. Through additional, explicit, external cues mounted on the AV should help the pedestrian to understand what the AV does or wants the pedestrian to do. Just within the research many different ways of how to design these eHMI systems already exist, which can lead to a wide variety of designs existing on the road. Meaning that pedestrians will have to learn and know each different system and understand all the different cues and perspectives these eHMI represents. Then there is also the question of visibility, where the eHMI can often only be seen when the AV is already close to the pedestrian at the cross walk. The vehicle should then already have slowed down so much, the pedestrian might already have decided to cross. Also for people with lower vision, or on days with low visibility due to bad weather conditions, these eHMI systems will be hard to read beforehand. EHMI systems can help the pedestrian in feeling more reassured about their decision to cross, however, the many concerns with eHMI reveal that there is much to improve on.

The AV also presents new opportunities to make our transit system more inclusive and create an urban environment that is focused more on active travel modes, like walking, rather than a vehicle focused infrastructure. The environment however, should keep the needs of AVs in mind. A comprehensive infrastructure will make it easier for the AV to roam the streets, and will therefore be safer to implement. Its need for less space opens up a lot of formerly occupied space to be redistributed to different functionalities. Creating an environment beneficial for both the pedestrian and AV will optimise benefits of both modes of travel.

Chapter

3

The Smart City

3.1 Definition

It has become clear to me that trying to define what exactly a smart city is, was wishful thinking. Over the past decades researchers, policymakers and companies have developed their own ideas and definitions about what entails a smart city.

There are however some elements that are being mentioned in many of the definitions. Research by Gil-Garcia et al (2015) formed a framework that describes the smart city not in one definition but in all the components based on a collection of definitions from academic research and practical tools. It distinguishes four main categories which are composed of two or three components with relevant elements. They propose that technology and data are a means to achieve developments in the other three categories, rather than technology being the end goal of the smart city.

A quote from A. Townsend's book 'Smart Cities' (p. 15) adds to this idea:
"The broad view is important, since cities must be viewed holistically. Simply installing some new technology, no matter how elegant or powerful, cannot solve a city's problems in isolation."

While some definitions focus mainly on the technological advancements of the city to become smart, more policy makers also define well-being of the citizens as the main output for their smart city.

3.1.1 Expert Interviews

Two more developed concepts of citizen centred cities are the social and engaged city. Though they carry different adjectives, their goals are quite similar in aiming to create more participatory cities for the citizens. The social city is a term coined by Martijn de Waal, and engaged city by Usman Haque. Both focus on the human or citizen side of cities when technology becomes more integrated in city fabrics. After two inspiring interviews with both of them these terms have given the Smart City a new, broader, perspective to work with. The main results of the interviews have been collected in table 7.3.Transcriptions are available in Appendix A.

From the interviews two main elements came forward that in different words were discussed by both interviewees when discussing the crucial parts of a smart city according to them. The two main ones are the technological developments and the rights management system. Both interviewees argue that the smart city would not be a desirable goal if it only focuses on implementing technological optimisations and solutions. As Usman Haque puts it, only implementing technological solutions with narrow parameters are likely to quickly become obsolete and thus the complete city would become a brittle system with little flexibility. Instead of only looking for these technological solutions, Martijn de Waal opts to also look at environments and how these can be used to attain certain goals. Especially when looking at urban design solutions, these might not just be found in technological solutions, but rather could also be created through reimagining how our environment looks.

Technology might play a supportive role but was not the main starting point in the design.

Element	Sub-Element	Quote	By
Beyond Technological Developments	Design Perspective	"So we should not stare blindly at just the technological solutions, but we can also look at how we reshape our environment so we do not have to solve it with technology only. [...]Designing more from a values perspective rather than just from the technology."	Martijn de Waal
	Design Perspective	"It's [AV technology improvements like pedestrian detection and trajectory analysis] all from the perspective of the vehicle. And I think that, for me, it's important to have it from the perspective of the city fabric itself. But also from the pedestrians."	Usman Haque
	Brittle Systems	"When a technological system is added into the city with only one purpose and way of functioning, this system can become obsolete quite easily."	Usman Haque
	Effects of Technology	"Mere optimisations do not make a city valuable. Rather it is the unpredictability and spontaneity of it. Like wrinkles, which create a messy city, is what make a city valuable."	Usman Haque
	Effect of Technology	It's [technological optimisation] not desirable because you'd have this effect of damaging the thing that makes the city actually attractive and valuable and dynamic and kind of capable of generating diversity"	Usman Haque
Rights Making	Rights Management	"The next step of the smart city is about rights management; who has, and under what circumstances, access."	Martijn de Waal
	Rights Management	"It is not so much about making the data public, it is more about translating the rules into algorithms in combination with access to those databases."	Martijn de Waal
	Rights Systems	"So once you start designing these systems you cannot evade thinking about all these kinds of rules concerning the system."	Martijn de Waal
	Flexibility	"If, as a government, you start developing these systems they should be transparent and accountable. That means that they should be flexible so you do not end up locked in with one provider."	Martijn de Waal
	Participatory Rights Management	"The smart city as a rights management system for local communities to lay down their rules, and set those in automated systems."	Martijn de Waal
	Participatory Rights Management	"So what is that decision making framework that enables, even in that present situation, people to govern their own systems."	Usman Haque
Participatory City Making		"Where I do have a strong inclination, it is just to kind of bring it back to changing the way we make decisions about cities. [...] If we can all feel that we are an active participant in creating that and have some sense of responsibility and agency for it."	Usman Haque
Measurability of Terms		"So you can't really assess whether you've actually got it or not, or achieved it [smart]." "you can actually measure in a lot of different ways engagement, you can assess whether you've got more or less engagement."	Usman Haque

Figure 17 Table containing the main insights from the expert interviews

Usman Haque uses the example of pedestrian recognition as one such technological solution to a problem that might also be solved differently. Martijn de Waal mentioned a similar issue for AVs, where we might have to solve some technological shortcomings of the AV by reshaping our environment. He mentioned the danger of this with a reference to the 50s when infrastructures were redesigned merely to support transport by cars. Streets that cut through neighbourhoods, creating physical barriers in cities. So there is a fine balance to be found between using technology to solve the problems and using the environment to do so. It depends highly on what perspective one takes in designing the solutions. From an automotive manufacturer the technological route is more logical as that is what they can directly influence, while (urban) designers can also take a more social perspective and design from the pedestrian's perspective.
This difference in approach to smart cities can also be found in the definitions provided in academic papers, where some see a smart city as a technologically optimised system whereas others discuss citizen well-being as the main element (Gil-Garcia et al., 2015).

The other main element discussed is the rights management of a smart city. This term is one that did not surface in academic research on smart city definitions and elements, however forms a crucial part of its existence. More functionalities of a city are likely to happen through the virtual layer of a city which is largely based on technological solutions. With such services there are certain rules attached to it on how it can be used. As an example, Martijn de Waal described a navigation app with additional layers for a taxi driver. To avoid busy traffic in front of schools, the navigation system will redirect the taxi driver from school areas when school starts of ends. This is a rule – not being allowed to drive near schools when there are many children, that than has been translated into an algorithm that dictates the navigation. Whenever a service or system is designed, especially when it is a public service used by multiple people, such rules and rights need to be set. Even if a system is designed from an ideological standpoint, one cannot avoid the necessity of creating the rights. There are different ways how these rights can be established, a government (or organisation) can create the rules, but also local communities could set up how they want the system to manage the rights. The last one comes into the territory of participatory city making where active citizenship allows citizens to have a voice in how their city is governed and made. This goes further than allowing citizens to take a look at a finalised plan and give their opinion, instead citizens should be included from the beginning of the process to really create a design fitting to local communities. The government might not even be the ones to design all of the systems for the city. Martijn de Waal says that the government can become the catalyst rather than the initiator that boosts the collective energy of communities or designers to create their own solutions. Adding the notion by Usman Haque on this subject, when citizens are more included in creating how their environment is made might give them a feeling of responsibility for it to also maintain their environment and possibly to keep participating.

When looking more specifically at urban design in a future city environment, algorithms that control traffic will likely become connected and smarter, but that also means that there are more rights and rules that need to be established to create a safe traffic system.
Another element that was found noteworthy to highlight is the measurability of the terms used to describe a future city. Usman Haque argues that the adjective 'smart' is one that carries less value than for example 'engaged' for the simple reason that the first cannot be measured. Since there is not a clear consensus on what smart actually means, especially when it comes to a city, it is hard to measure if a city is achieving that goal. While engagement can be measured more easily, as its semantics have a familiarity already.

3.1.1 Conclusion

These interviews have widened the scope of what a smart city can be beyond technological advancements or citizen well-being. Most importantly is the notion that simply implementing technological systems to solve problems will not lead to desirable cities. Rather it is the opportunity to look for other solutions, from a user and citizen perspective in designing a city for them. Although many definitions in academic papers still largely focus on technical advancements being the core of a smart city, a shift in perspective seems to be happening towards a more human centred city making process. People like Martijn de Waal and Usman Haque research and show how this perspective can be implemented. It surely presents a challenging but fascinating opportunity for designers to take part in.

3.1.2 The Three Paradigms of the Smart City

The Delft Design Lab Cities of Things sees that there are three paradigms of the smart city (Cities of Things Lab, n.d.).

- City as a dashboard
- City as intelligent infrastructure
- City of Things

The first paradigm, city as a dashboard, is seen as the first step in the development of smart cities. Sensors placed around the city feed processed data back to stakeholders like the citizens. An example could be the air quality in different areas of the city. These types of services are often meant to create awareness in citizens so they know what is going on in their city, and maybe alter their behaviour for healthier living. A government can use the data to create policies and regulations. In the example of air quality, governments can regulate which types of cars can enter a certain area in order to improve the local air quality. A fascinating development is the involvement of citizens in creating a network of sensors by placing them in cities which started in Barcelona (Conzález & Camprodon, 2020). Citizens are empowered to create their own data instead of big corporations, and give them solid data to showcase and reflect upon. When the city acts an intelligent infrastructure, the sensors are not just collecting and processing data, but there are also actuators in place that can respond accordingly to the data. These actuators can be smaller like adaptive lighting which responds to where people are walking or bigger like Umbrellium's Starling Crossing (Umbrellium, n.d.). An example of intelligent infrastructures that exists for some years now, are the traffic lights for cyclist that use rain sensors. In some Dutch cities like Rotterdam and Enschede cyclists will be prioritised over the motorised vehicles when it rains. (Enschede Fietsstad, 2017; Verkeersnet, 2016)

The last paradigm is the City of Things. In this type of smart city sensors and actuators have moved from being infrastructure to autonomous 'Things' * (more on this topic in section Things, chapter The Internet of Things and Things). Things will become social entities that live besides humans as citizens of the city alike. An often mentioned example in this paradigm is a last mile delivery pod driving on sidewalks by itself. Projects in this paradigm are still mostly conceptual, but steps are taken to test Things in real life.

Figure 18 Starling Crossing by Umbrellium, a dynamic and learning cross walk

3.1.3 New Citizenship

"The smart city can also be understood as an 'assemblage' – a group of actors both of human and non-human kind, that together shape actual urban practices" (Waal & Dignum, 2017, p. 264)

Smart cities will not only transform how the technological layer of a city will look like, but will also influence how citizens live in a city. How this will turn out depends on how the smart city is shaped. (Waal & Dignum, 2017) proposes three types of smart cities and how they might influence citizenship.

Control Room

The citizen is a consumer of services provided by the city. Usually these services are operated by governments or companies and have little transparency in how they exactly operate. Citizens only see the output, which might nudge them into certain "good" behaviour. They might take away privacy and autonomy while the collective imagination disappears in individualised consumer services.

Creative City

The economy is driven by technological innovation and entrepreneurship. It focuses on the entrepreneurial mindset of its citizens through hackathons and co-creation where the aim is to include citizen's opinions, however they hold no final say in the governance. What is worrying about these types of cities is the possible exclusion of non-creative citizens, or those with lower educations since higher education is stimulated and made increasingly important.

Smart Citizens

The city comprises of self-organising citizens using digital platforms for subjects they personally care about. Governments use digital services to streamline processes and to make them more accessible to all citizens. Most importantly about these cities is that citizens are more involved in how the city is shaped. They collect their own data and can collect independent solid data to support cases to argue for certain changes. An example is the FabLab Barcelona initiative that supports citizens to build their own sensors and in doing so gain insights into how and what data is collected, and the results. This makes the data directly transparent to the public. This type of city also has its issues, that this type of self-activation is more for certain groups (like higher educated) and not for all and requires more active participation.

The question that thus remains is how we ensure that these initiatives and smart cities are representative of all citizens.
Through being more connected, citizens can become closer to policymakers and city builders, giving them the opportunity to influence how the city is made (Scheerder, 2014) Smart cities can thus bring along a shift in what citizenship means, namely from being a consumer who simply lives and works in the city to a co-creator of the city (Waal & Dignum, 2017)
By being more engaged in the city making, citizens can create more of a place for themselves that adds to the cityness of their city.

People do not only live in the city but also for the city as they add up to new civic possibilities with their actions. Simply, cityness fathoms the pleasantness of urban lives and the responsiveness of urban construction, and illustrates the co-performance between them for sustained improvement. *(Lin, 2018)*

3.2 Conclusion

Based on the definitions provided by academic reviews, most of those definitions define a smart city as a City as a dashboard and some make remarks that would fit with the City as intelligent infrastructure. They had not foreseen how far the technology would develop in becoming autonomous and smart too. Smart cities also go far beyond technological innovations and can create a shift in how humans experience citizenship, and can become smart citizens.

Combining components mentioned in the framework by Gil-Garcia et al. (2015), the three paradigms and smart citizens, a general indication of how a smart city will be seen in this project is defined as the following:

A smart city can be made up of smart (integrated) technologies that through collaboration and learning can help improve city processes and public services (in the digital and physical city), improve the quality of life for its citizens and address social problems, and become more sustainable (ecological and economic), but will only reach its full potential through participatory governance and involved smart citizenship (of human and Thing alike).

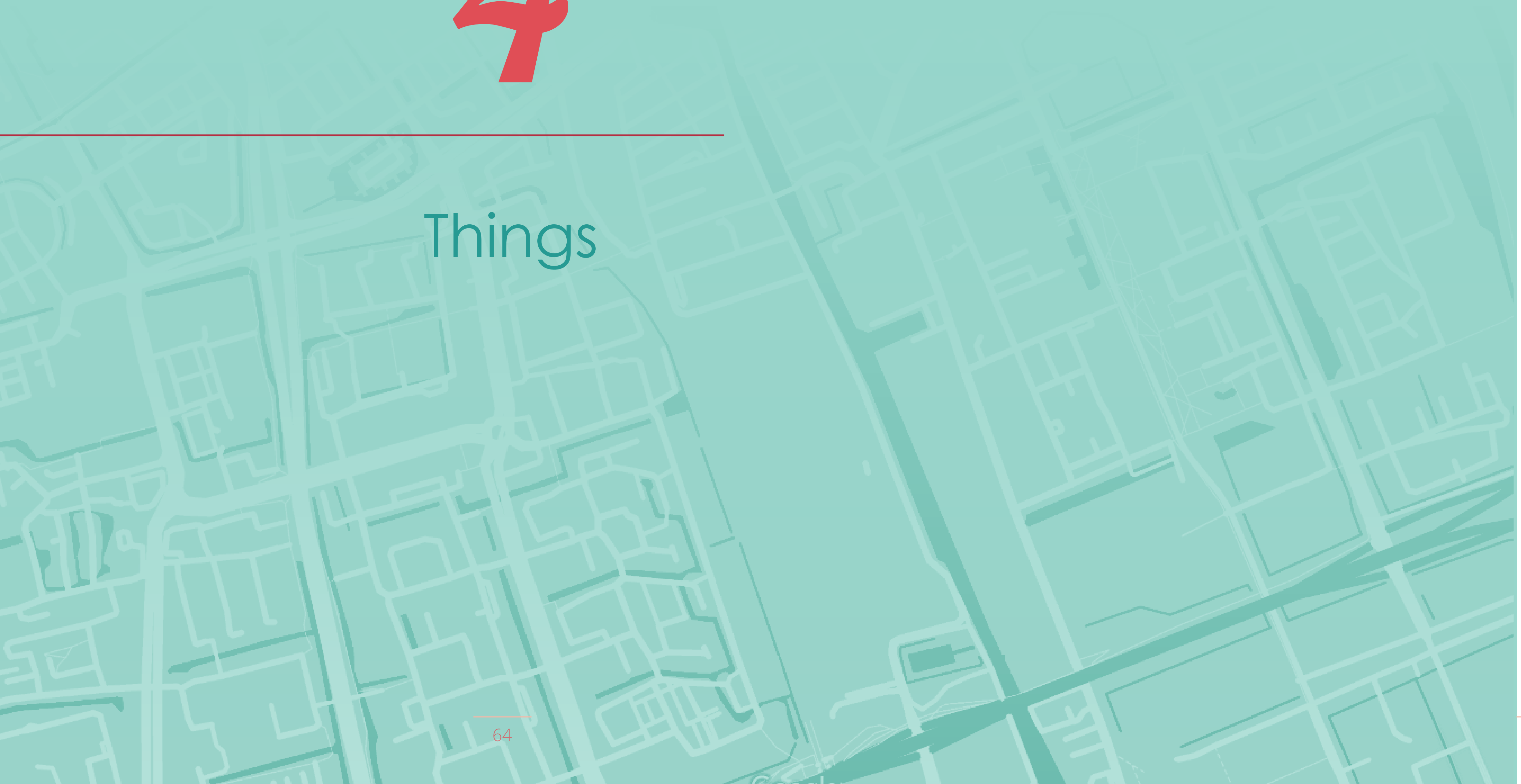
The most important takeaway from this chapter is the wide variety in the understanding of what a smart city actually is. However, for this project the key of a smart city is as described in the personally crafted definition above, is the supportive role technology should play as a means to establish a city where designs and solutions are focused on creating a positive city dwelling experience for the citizens. An important element in doing so is the rights management of systems that are to be designed.

The term smart city will continued to be used throughout this project to further the development of its definition into a more holistic approach taking into account the perspectives of social or engaged cities.

A city can only become truly smart through smart citizenship where technological innovations serve the rising and changing needs of its citizens. *– Ragna*

Chapter 4

Things



4.1 What is a 'Thing'

We are familiar with smart phones and smart wearables, devices connected to the internet that therefore gain additional functionality beyond it being a phone or watch. But, there is a new type of connected object on the horizon, the Thing. A Thing goes further than being connected, they are able to act upon the data they share.
Things can be described as:
"data-enabled artifacts with performing capabilities which are able to connect with existing networks of data, collect real time data, act pro-actively, and potentially behave socially."
(Lupetti & Smit & Cila, 2018)

Things as such can be as small as chips in a machine or medical aids, to our everyday water boiler and household appliances, to even a complete building as one system. However, their functionality as a Thing does not come from them as a singular object, but the combination of all these objects together. The network in which they operate is what we call the Internet of Things (IoT). Through internet connections these objects can share, receive and retrieve data from other Things and databases that they can use to act a certain way based on their algorithms. Through actuators and microprocessors these Things are able to effectively use the data, combine data and react upon the results (McGehee,2019). They can operate without the need for human interference. Some of these Things and IoT networks operate in the background without us humans noticing them, but these Things are also slowly making their way into the foreground where they actually start interact with humans. As such, we can engage with the Things and create bonds with them even. A step even further are Things that can autonomously move around, like an AV, which is basically a large Thing.

4.2 Things as Citizens

Things that are robots which can autonomously roam around cities, raise the question how they should act around humans. These so-called urban robots (Lupetti & Cila, 2019) will need not only need to be designed from a technological aspect but also from a social perspective in order for them to optimally make their way through the city alongside humans. With the integration of artificial intelligence (AI) in robots, their ability to make decisions becomes indistinguishable from human decision making. Such robots can have cognitive abilities and therefore reciprocate empathy. This then raises the question of their rights in public spaces (Lupetti & Bendor & Giaccardi, 2019). By making them citizens, they will have to abide by the law, but will also be protected by it for example against vandalism. Lupetti & Bendor & Giaccardi (2019) regard this citizenship not as simply a set of rights and responsibilities but rather proposes one based on the socio-relations that robots engage in with non-robots.

"Attributing citizenship to robots should not be based on the question of whether robots are "like us", or "help us", but are "part of us". (Lupetti & Bendor & Giaccardi, 2019).

Taking robot citizenship into account when designing such urban robots, allows designers to think more deeply about the relations they engage in based on what these robots can and maybe more importantly cannot do themselves. It opens a new way of how robots themselves and their interactions with non-robots can be designed.

"Attributing citizenship to robots should not be based on the question of whether robots are "like us", or "help us", but are "part of us". *(Lupetti & Bendor & Giaccardi, 2019).*

4.3 Thing Centred Design Method

4.3.1 Interview with Things

With Things becoming more apparent in our daily lives, roaming around autonomously and interacting with humans, there is something to say to also start to better understand the Thing's perspective of the world and the interactions they have with the world. This is the goal of a novel design method called Thing Centred Design. It presents different ways on how one can uncover the Thing's perspective, one such method is the interview with Things (Chang et al., 2017). As part of the initial research goal in this project was to uncover, besides the human needs of future interactions with AVs, the needs of the AV as well in order to create a product that benefits them as well. This tool was chosen as a way to possibly unravel deeper needs or experiences of the autonomous vehicle than those resulting from academic research.

4.3.2 Interviewing an Autonomous Vehicle

It is of course impossible, currently, to actually interview an AV or any Thing. Therefore the tool is based on acting out the role of a Thing. The interviewee in this case was me, the designer of this project, who has been trying to see the world through the eyes of an AV through video recordings of AVs driving through city centres where the AV's point of view is present. A list of questions were created that the interviewer could use as a guideline. The interviewer was chosen based on their experience with acting and user research as fellow designer. The interviewer was free to also ask follow up questions or new questions besides the ones on the list. This freedom was given to possibly explore answers in more depth as it was difficult to predict what kind of answers would be given by the AV. A more common set up of an interview with Things is to get actors to play the role of the Thing, however due to the amount of preparations this would take for others to gain the knowledge it was chosen to act out the role of AV myself, using the knowledge and insights from the research done throughout the project so far. The interview was recorded using a mobile phone camera, which was later transcribed to analyse the results (Appendix A)

Figure 19 Conducting the Interview with Things, left Interviewee, right the "AV"

Element	Quote
Human – AV Interactions	"I have a very difficult time understanding human beings. They seem like they just do whatever they want without showing much of an intention." "It is difficult for me to engage with them because they have such a different way of communicating. It is sometimes too delicate for me to fully comprehend."
AV – Thing Communications	"If another autonomous Thing would be crossing the road, it can communicate with me to let me know it wants to cross, and at what speed and when, and then I can decelerate beforehand so I do not have to come to that full stop. So I can make it more fluent."
Visual Signage	"There are a lot of visual cues still, which are pretty much 'dumb', they do not signal anything to me [...]I have to be closer to actually see what is on the signs." "Visual processing costs me more processing power and I can only act once I can see the sign." "It [signs] could be more dynamic."
Decisions	"I need to decide if they are going to cross or not. That is a difficult decision to make, so often I just stop."
Human Behaviour	"And with pedestrians they can be unclear in what they want to do, or they just start crossing the road without even looking" "There is not really a limitation or disadvantage to it [human acting without awareness], while I immediately have to stop."
Passenger Comfort	"Most important for me is that the ride has been good for the human beings." "My main function, I think would be to carry human beings from A to B, in a safe, effective and efficient manner."

Figure 20 Table of the main insights from the Interview with Things

A couple elements came forward during the interview that the AV mentioned as difficult when riding in a city. The most important factor is the human to AV interaction where the AV has difficulty understanding what the human is going to do. As the AV puts it, human communications are often delicate which are hard to pick up for an AV. The main difference is that when an AV communicates with another autonomous Thing, that beforehand there seems already to be an agreement about how the situation will be resolved which leads to a more fluent sequence of events. The human behaviour becomes especially upsetting when the AV has to be aware at all times, but a human could just cross the street, unaware of the situation or stress they create in the traffic system. A situation where it becomes more uncertain for both actors is an unsignalised crossing where especially the AV has to make a decision to continue driving or to stop for possible crossing pedestrians. Since the AV has a hard time comprehending the more delicate communications of human beings it is more difficult to predict which pedestrian will cross and who will not. Most of the times the AV will take the safest option and will stop. Thereby comes that in current infrastructure designs most of the communications are visual signage. Which are not the biggest problem for the AV to understand, but they do not facilitate a dynamic traffic situation. They also are limited to when they can be acted upon as the AV needs to be closer to them before they can be recognised, while with direct signals, like radio transmissions, the situation can be anticipated well before, or adapted along the way. The last thing mentioned by the AV, that has not yet come up as a subject within the scope of this project are the passengers of the AV. As the AV says, carrying its passengers is its main function, and therefore the comfort of the passengers is important to the AV. So being able to drive smoothly and efficiently, without having to brake constantly or hard, is beneficial to the AV and its passengers. So bringing back human behaviour, to an AV it is rather disrupting when a pedestrian would suddenly cross the road. Pedestrians who are randomly crossing the road would break up the efficiency of the AV's driving capability. While this efficiency is of high importance to the AV to bring its passengers from A to B.

Conclusion

The AV regards being efficient and safe as some of its most important abilities towards its passengers, but also being able to communicate well with other road users creates a more pleasant driving experience. Current infrastructural designs like visual signs and unsignalised crossings are a thorn in the eye for an AV operating in a city. As discussed in Chapter 2.5, there are parts of our urban design that can change or be redesigned because of the introduction of autonomous vehicles. However, there might also be something to say to adjust our infrastructure and urban design in a way that benefits the AV as well as the human users. Creating an infrastructure that supports self-driving functionality allows these vehicles to actually be introduced and create those benefits discussed in Chapter 2 Section (dis) advantages of the AV.
There are thus certain needs that the AV has concerning its environment that can be taken into account when redesigning the infrastructure and control systems. Such needs are the replacing of static visual signage with digital signage that are directly communicated towards the AV and are more dynamic concerning changing scenarios. Another change could be to create a more comprehensible infrastructure design for the AV with less visual obstructions for example.

Chapter

5

Human Perception

5.1 Perceiving the world

Like the title of this report states, the project focuses on interactions between actors in the traffic system. More specifically, the interaction is about the communication between three actors – pedestrian, autonomous vehicle and the city. To experience that interaction, we as humans need some kind of physical input that helps us to perceive the world around us. Humans have five ways to do so: vision, smell, taste, sound and touch. Since the final product is likely to be part of the city and will have certain features to communicate and interact with the pedestrian, this research investigates the different possibilities of theses senses to understand which one(s) can be used when developing the concept.

Within the traffic system, the most used sense is the visual one, followed by sound. Through signage, lights and gestures humans are able to better understand the situation at hand, what they are allowed to do and communicate their intend. Sound is more often used as a warning sign, think of an emergency vehicle using its sirens to alarm surrounding drivers to make room or a driver using their horn to alarm a fellow driver their behaviour is dangerous. Another example of sound where it is used to help people is the ticking sound indicating the colour of a traffic light to those with vision loss. These two types of sense are the most direct ones that can be used to communicate to someone specifically or to all traffic participants at once.

Senses like smell and taste are very personal ones, which everyone can experience very differently. Although smells can be used as a smart sales trick in shops and for certain products, as a communicator of signs this sense might be difficult to use, due to its highly personal variety among people on how they experience it. The same goes for taste, which is even harder to distribute. Taste and smell are thus not considered as valid senses through which messages can be communicated within the context of traffic and a public setting.

Touch as a sense is often used in product design in the form of haptics that uses technology to mimic movements that are perceived by touch sensors of the body (Merriam-Webster, n.d.). Haptics can be used as part of an interface to communicate certain messages towards the user. A well known example is the vibration mode of a smart phone to notify the user of an incoming call or message without disturbing other around them. Haptics are nowadays used more and more to bring virtual and physical reality closer to each other, using vibrations or friction to make a virtual reality seem more realistic. (Figure 21). Although haptics show incredible opportunities for these more personal products, it is something that is difficult to share with multiple people in a public setting. Through wearables such technologies could prove to be successful ways to communicate, however it would require each pedestrian to wear such a device, or carry it with them at all times when they go outside. From a usability standpoint, infrastructure should always be accessible and usable to the general public without the necessity of extra tools that could be forgotten.

This leaves two more senses that can be used to communicate within the public setting of infrastructural designs, vision and sound. As discussed earlier, they are currently both being used within the traffic system, where visual signage is used within the infrastructure itself, and sound mostly by traffic participants themselves. In the world of eHMI systems, very often they use visual signage to communicate towards the other road users, however some researchers have also tested audible signs. In a study by Deb et all. (2016) it was found that in general visual cues are preferred over audio cues. This can be explained by the possible confusion with noises from the surroundings and also ambiguity of the message is discussed as a plausible reason. The ambiguity of the message is considered as it can be unclear to whom exactly the message is directed when different people are near the vehicle. The sounds of an infrastructural design might get lost in the noises produced by the surroundings or be unclear whether it was meant for you or the other pedestrian who is also about to cross.

Vision is then the last sense, and does show the most promise to use in the setting of infrastructure design. For a lot of people visual signage is the easiest to process generally since it can be used to communicate messages directly to the recipient in a clear language. However, visual signage does exclude people with loss of vision, who will use other senses to navigate and understand the world. Therefore usually designs in public settings incorporate audible or tactile cues to communicate a situation towards people with vision loss. This inclusivity is important to create a city that is accessible to all. Technology could play an important role in developing accessible cities. An example is a connected white cane people with vision loss can use to get more specific orientation feedback (Szabó, 2019). Or using augmented reality audio to guide people with vision loss through a city by providing direct audio feedback based on their location (Ferrand et al., 2018)

Within the context of urban design, vision is the most reliable way to communicate that can be received most easily by traffic participants. Vision based feedback can be easily understood as most humans are quite used to this type of signage already, and can be used to quite literally communicate messages.

Figure 21 SenseGlove VR gloves provide real life friction to make the VR come to life

Part I - Explore | Conclusion

So far, infrastructure and urban design have been focusing on human driven cars as the primary user of the infrastructure. Roads and parking spaces take up enormous amounts of space within cities, just so we can drive ourselves. Yet, a new type of vehicle might be changing all this. The autonomous vehicle could open up these previously occupied spaces as it needs almost no parking spaces and can manoeuvre narrower roads. As such the autonomous vehicle could be opening up spaces in cities to be used for greenery, active travel modes, public or community spaces, or to build houses.

Although this might sound wonderful, it can take years or decades until we actually have a system that is mainly used by autonomous vehicles due to its technical difficulty and problems concerning safety and security. To accommodate the introduction of the autonomous vehicle, one can already start looking in what needs it has once it can operate on the road. These needs haven been researched throughout the analysis and the insights were used during the interview with Things to further explore the needs. The main concern for an autonomous vehicle is the need for a comprehensive system which allows the vehicle to drive smoothly to assure a comfortable ride for its passengers.

This also means that it needs to be able to effectively and efficiently communicate with the pedestrians, as they are generally a nuisance for an autonomous vehicle to come across due to their high unpredictability. Seeing the autonomous vehicle as an urban robot that becomes part of a new group of citizens, will allow its limitations to become a concern for future design, also of the urban environment. Some issues the vehicle cannot yet solve for themselves quite yet, including recognising what the pedestrians intend to do. There might be an opportunity here for the urban environment to support the autonomous vehicle, thus also creating a safer traffic system for pedestrians to take part in.

Researchers have investigated the option of mounting an external human machine interface on the vehicle to facilitate communications from the autonomous vehicle towards the pedestrian. This however, does not take into account that pedestrians also can communicate their intentions towards the autonomous vehicle. Thus creating a one way communication system where the pedestrian is told by the autonomous vehicle what they should be doing. Designing eHMI systems will only solve a small part of the problem while limiting the input pedestrians have over the autonomous vehicles and traffic system. A balance should thus be found between taking into account the needs of the autonomous vehicle and the pedestrian. The autonomous vehicle presents many opportunities to turn our traffic system around from being car focused to being more human centric, allowing citizens to have more presence in their own city.

Not only do our vehicles get fitted with more and more technology and smart algorithms, also the cities we live in become “smarter”. Many different names and definitions exist for the Smart City, yet found to be one of the most important components, as expressed by the two experts during the interviews, is how technology should play a role. In formulating a definition that is the leading one during this project, technology has a supportive role where it is used to create positive city dwelling experience for the citizens when necessary but does not drive the developments. Creating systems from a technological starting point is

presumably going to end up obsolete as it can only operate within a limited set of parameters. Parameters that can quickly change to new needs arising from the city and its citizens, leaving them with a brittle city system. In any case, however problems are solved or new solutions are implemented, when an algorithm is used to support a community, it needs to follow certain directions collected in its rights management system. Without the rights and rules, the system cannot operate optimally, and functions like a contract between people only are the rules written in a software code.

With all these developments going on, looking forward to what we can happen in the future, can help us make the right arrangements and create a better understanding of the possibilities to already design for, to create the right environment.

PART II

Define

In this part insights of the previous part and newly found information that was carefully selected led to the creation of the design goal that will further guide the process of creating solutions. This part explores how a future context could potentially look based on what is on the horizon.

Part II - Define | Introduction

In this second part of the report, you will be taken along the steps of creating a design statement. The design statement ultimately is the goal that will be fulfilled, or aimed to, by the final design. Through an iterative process of finding out what is on the horizon of our future and creating stories and finally one narrative of the future context shows how the future context for the to be designed product could potentially look like. It is the second part of the ViP method where through the future context an interaction vision and design statement are created.

Chapter 6 describes these first steps to create the future context. the chapter is concluded with a narrative that describes what is happening in that future.

Chapter 7 shows how the design statement came to be. Through an iterative process the right words were found to describe the desired goal to design against a certain scenario.

The conclusion of this part is the future vision that consists of the design statement and the interaction vision.

Chapter

6

The Future Context

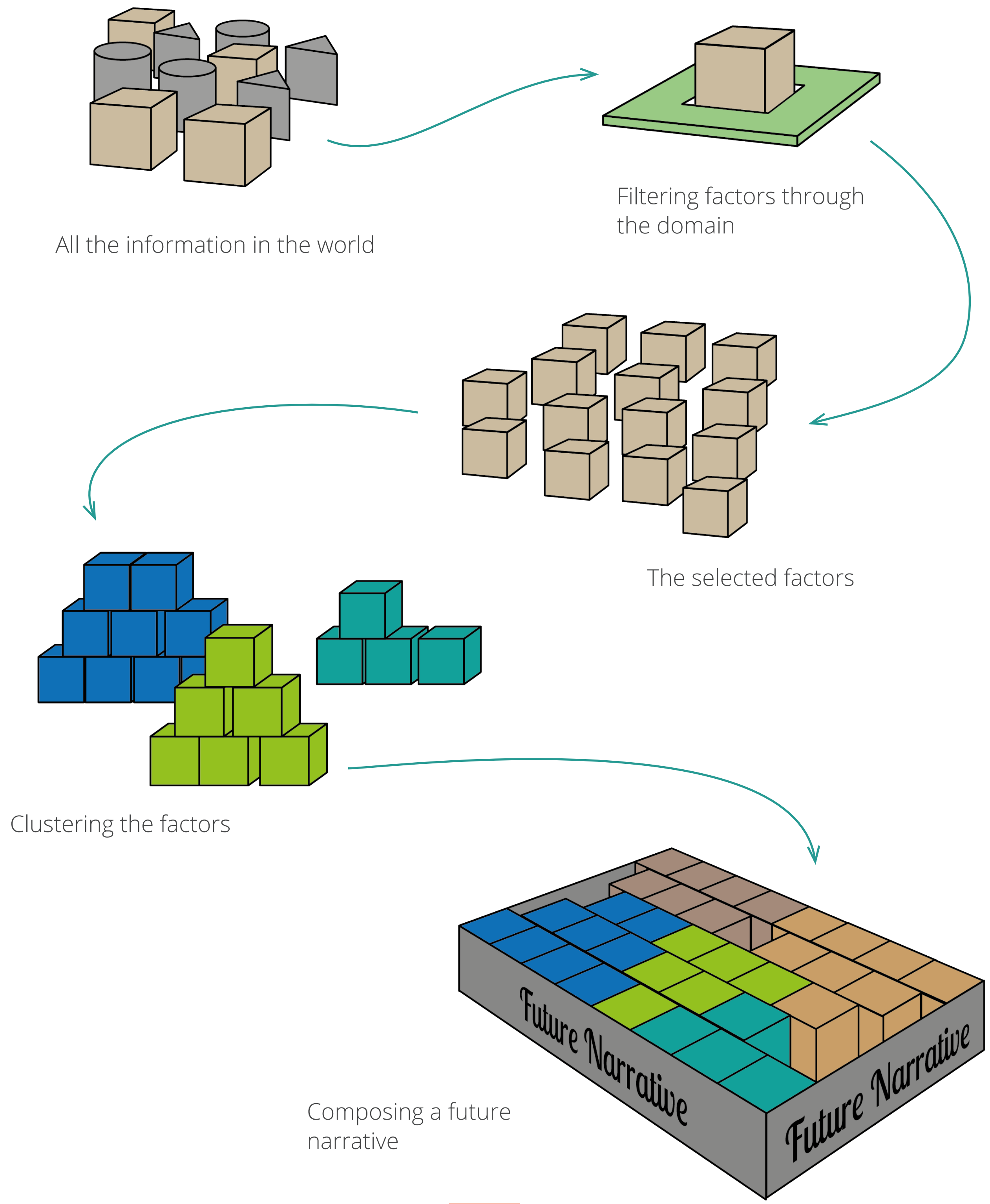
6.1 Introduction

Driverless cars may not have emerged in our daily lives yet, they have been part of our lives through movies since the 80s. The most well-known one is KITT from Knightrider. More recent ones include Herby and Bumblebee, and there is even a children's tv show starring the small Brum fighting bad guys all by itself. These vehicles got personality traits, like the mischievous underdog Herby or a slightly anxious but brave Bumblebee, allowing them to connect to their human counterparts. The movie The Fifth Element goes even a bit further and created flying autonomous vehicles. Flying vehicles have been a human interest for a long time, and currently some are being developed in real life like the PAL-V by Spark. Would we be able to manufacture them on large scale and integrate them into our traffic systems, this project might become obsolete, but until then, for the remainder of this project, flying cars remain in the realm of science fiction.

Pop culture has the ability to sketch new futures before we even thought of the real life possibilities, however the challenge is to find where the line is between reality and science fiction in order to create a viable future scenario to design for. This chapter describes the steps taken to create such a potential future based on the method by ViP.

Figure 22 Scene from the movie The Fifth Element (1997)

The steps are visualised in the image below It starts with all the info that exists in the world, each bit of information can be a context factor. Not all this information is valuable for the context and scope of this design project, that is why a filter called the domain is used to only select the relevant information. The selected context factors all contain a piece of information that could possibly affect the future context, however on their own they do not tell much of a story yet of how that can happen. By finding their relations among each other, one creates clusters. These clusters are small stories that describe how certain factors can influence each other. The clusters together form a future narrative that describes the future context.



6.2 Domain

With so much information in the world available to us, one can feel like drowning when trying to find what information is relevant to a project and which is not. To help in the search for the relevant context factors, there is the domain.

"The domain serves as a lens or filter through which you look at the world" and "the area where you aim to make a contribution". (Hekkert & van Dijk, 2014)

The domain should be broad enough to allow for creativity to find different kinds of context factors and new relations between them in order to *"explore what is possible tomorrow instead of solving the problems of today"* (Hekkert & van Dijk, 2014). Yet, the domain should be narrowed down enough to create a future scenario that is relevant for the context of the design project.

Deciding what the domain should be is a small journey itself, and required some back and forth between looking for context factors and defining the domain. Especially finding the right words to describe it took some brainstorming. Writing down a couple sets of key words that included, city, behaviour, smart infrastructure and mobility, helped to find what I was looking for. After trying out some different combinations of key words I ended up using the following domain:

Citizens in transit in smart urban areas

The key words here being: citizens, transit, smart and urban areas.
It creates a focus on those who live in the city, but does not concern with their exact living space, rather the space they find themselves in while being on the move, and the technology they might encounter.

Citizens, as we have learned, are not necessarily only humans anymore in the future. Since the development of (urban) robotics will be a big part of the future, it was chosen not to say people in transit as this limits the scope to human transit only. Rather it is interesting to explore the potential of non-humans in the city too. Transit is then used to describe a more specified context to focus on as contrary to all citizens who are also gardening or cleaning (their) houses. This way the scope is narrowed down to those who/which are on the move in the urban area and actually come into contact with autonomous vehicles.
It was chosen to define the context as 'urban areas' rather than 'infrastructure' or 'urban design'. The latter two options already frame the research space in a way that already defines a final solution setting which is not the goal of a domain. 'Urban areas' is used to keep the solution space more open until defining the actual design statement. It indicates a focus on the city context and the space around citizens. The adjective smart was added as a way to explore the technological developments of a city and its potential impact on city and citizens.

6.3 Context Factors

These are the building blocks of the future context and each carries a small chunk of information about what is changing – developments or trends, or what is likely to stay the same – principles and states.

Developments: these are things that are currently being worked on, or are reaching a stage of implementation into society.
Trends: based on developments, society and human behaviour changes, these are described as trends

Principles: Principles represent human values and norms, although they do change, they will only do so very slowly and therefore can often be seen as remaining the same.

States: usually these factors perform on a psychological level in the human body, it is evolutionarily or biologically determined that things work in a certain way, or how we as humans behave/ respond.

These types of context factors help to understand what their influence is on the future scenario. Though there are no exact rules about the amount of context factors of a type you should gather, these types do help to keep one aware about finding a wider array of factors.

Another tool to create a variety of context factors is using the DESTEP categorisation. DESTEP is a collection of six categories: Demographic, Ecological, Social, Technological, Economic and Political. These categories help to understand where a factor will have its influence on the future context.

Factors can be observations, theories, laws, values etc. found in academic papers, trend reports or more casual places like newspapers or people's minds. However, in selecting and writing down the factors, no moral standpoint should be taken by the designer. If factors are likely to influence the chosen domain, whether the designer agrees with it or not, they should be taken into account. Only when the future context is defined, can one decide to design for or against it. This will become more clear in Chapter 7.2.

After going through a number of papers, blogs, trend reports, webzines and the analysis of Part I, as many context factors were collected until similar factors started to come up. This resulted in a list of factors that can be found in Appendix B. When finding these factors one can already see some more obvious trends, especially in the field of technology the developments are more obvious. However the most interesting results are found when less obvious connections can be made between the factors. This is the goal of clustering, as described in the next section.

6.4 Clustering

Putting the singular pieces of information contained by each context factor together with another piece of information can create little stories on how these factors can possibly influence each other. These small stories, or clusters, already convey more of a complete concept of how the future can look like.
Getting to these stories does require some reshuffling to find the right combinations of factors that allows to generate new insights and angles on how they can work. A first iteration in this process was based on the more obvious relations between factors, in such a way that many familiar factors ended in the same cluster. However, since these clusters did not generate new insights into a possible future, a second iteration cycle was started. It was the moment to start thinking more about how one factor might also influence other areas outside of its own. Thus trying to find more out of the box relations between the factors, leading to more interesting stories. This led to the final fourteen clusters that are represented in figure on the right side.

Each of these clusters represent a personal (by the designer) interpretation of the context factors as the complete process is done individually. Others might have found different relations between the factors leading to different clusters and stories. These clusters also present a future context based on current events, while in the future unexpected events might disrupt how this context plays out. Looking at our current situation with Covid-19 that disrupted human lives worldwide. Governments were not prepared for this result of globalisation, and impacts will probably ripple through into our futures, while months ago these ripples were not even on our radar.

Digital Agency
Many physical products are transformed into digital services, but also services provided by humans are digitised. Some of them are not even performed by humans anymore. These services, meant to support humans, need a certain amount of personal information to do so.

Inclusivity by Robotics
Robots can be designed to aid people who have certain disabilities or difficulties doing on their own. By not needing human assistance they can become more independent. Elderly could live without external help longer, people with visual impairments could get robotic guidance outside providing them more freedoms. In a way AVs also open up mobility to those who previously could not drive like elderly, people with disabilities or children. This makes the world of transport more accessible

Cyber Security
Cyber security does not only concern itself with cyber terrorism as an increasing threat but also people need to be protected from AI's bias and categorisation. The rise of AI goes so fast that governments need to play catch up on laws and policies, hence creating fragmented governance (inter) nationally. People's privacy through AI, but also security measures, will decrease and it becomes harder to keep anonymous, digitally as well as in reality.

Data Economics
Algorithms can be used by companies to steer people into certain bubbles of product or information. Data helps predict consumer behaviours and therefore is worth money. With more companies owning more personal data, people might become owned by these companies. Through data collection, people can also showcase opinions through their data by means of purchases for example.

Integrating Robotics
Robots gain cognitive skills which allows them to show empathy and create engaging interactions with humans. Their internal computing power is so fast that their intelligence is resembling that of humans, which makes it easier for humans to create a connection to robots. This way robots can become caregivers and not just servants to humans. Through their interrelations with humans (and other Things) they gain rights to citizenship.

Global Warming and the City
The increasing world population requires more natural resources and emits more greenhouse gasses. Global warming and climate change threaten cities through extreme weather events, and especially flooding will become more prevalent. Green tech, which has gotten economically competitive, will help create more resilient cities, attracting climate refugees (creating an even more diverse population).

AV Disrupts Urban Space
The rise of AVs in traffic creates opportunities to redesign the infrastructure. With less vehicles on the road more space can be appointed to other road users/ mobility services. There are different needs as to how the infrastructure looks and functions and can be to service humans to create walkable cities.

Loss of a Positive City Mess
Humans do not like having too many choices especially about things that are not so important, or tasks that are tedious. AI takes over these responsibilities, but with so many of these smaller decisions already made, the world is so optimised some spontaneity is missing. Spaces, objects and services already know what we want or need, even before we do ourselves, therefore it is unlikely that we end up in unforeseen circumstances. The city has become too efficient and the valuable messiness and spontaneity of a city have almost disappeared.

Experience the City
With a more holistic stance in life, citizens have new standards of living that exceed materialistic needs. Well-being is not measured by economic indexes (only) but through cityness and happiness indexes. The experience of tasks become more important than the task itself, enhanced by how we live more and more in a service economy over a product economy. People create more of their own spaces/places which makes living in the city a more pleasurable experience.

Digital Merges with Reality
Technology becomes more directly integrated with human bodies, which removes more borders between humans and the digital world. Through cloud based computing and a fast network these wearables do not need to be bulky. Humans become surrounded by digital which can even become visible in the reality.

AV and Human Behaviour
Creating safe experiences will help people to trust the AV, through clear movement patterns of both parties. Through the experience, trust can be built which leads to less disturbance when the AVs penetrate the market in larger amounts.

New Mobility Needs
New city dynamics (like urbanisation, but also moving away from expensive city centres) require new types of transport. These needs will further diversify the offer of mobility services and a re-organisation of transport. Door to door mobility (last mile mobility) gains interest to optimise the commute.

Participatory City Making
Citizens will be more connected and involved with city making processes. Through self-organisation they are able to make changes to the city and governance through bottom up engagement. Allowing the citizens to have a say in the city making, makes a more democratic city and could improve city-dwelling. Cities become test areas/playgrounds for national policies. Active citizenship is important to create engaged cities, and requires participation to represent all citizens.

Individual Priorities
Individual needs become more important and are supported through customisable production techniques. With a more internationalised world, individuals can be anywhere they want, connect to the people with similar priorities making us less tied to one brand/organisation anymore. All to fulfil individual dreams and wishes.

6.5 The Bigger Picture

Just like with the context factors, the clusters alone do not yet represent the complete narrative for the future context. In this step we zoom out further where the individual context factors disappear out of focus and the clusters and their stories take the main focus. These clusters interact with each other and these interactions show how the context can actually play out. How exactly these clusters influence each other is represented by a diagram showing opportunities and threats that clusters pose for each other.

6.5.1 Threats and Opportunities

The relations that were found between the clusters are explained as threats and opportunities, as often one cluster seemed to support another or the opposite, threatened its possibility to come to fruition. A threat means that one cluster can negatively influence the narrative or functioning of another cluster, while an opportunity creates a positive influence and the two clusters can potentially support one another. An important notion here is that these threats and opportunities are created with a neutral perspective from the designer as to gain the most realistic scenario. This can mean that some clusters might negatively influence a cluster that seems, in one's opinion, like a positive influence on society.

The threats and opportunities diagram (Figure 7.3) was used to visualise and structure these influences of the clusters on each other. It formed the starting point in creating the future narrative by understanding the relations between clusters and seeing how different clusters can interact with one another and how a cluster will play out in the bigger picture of the future context. Although the threats and opportunities diagram represents quite a number of relations between the clusters, the narrative does not talk about each of them individually rather it is once more a bigger picture that collects the relations into one comprehensive narrative to describe the future context.

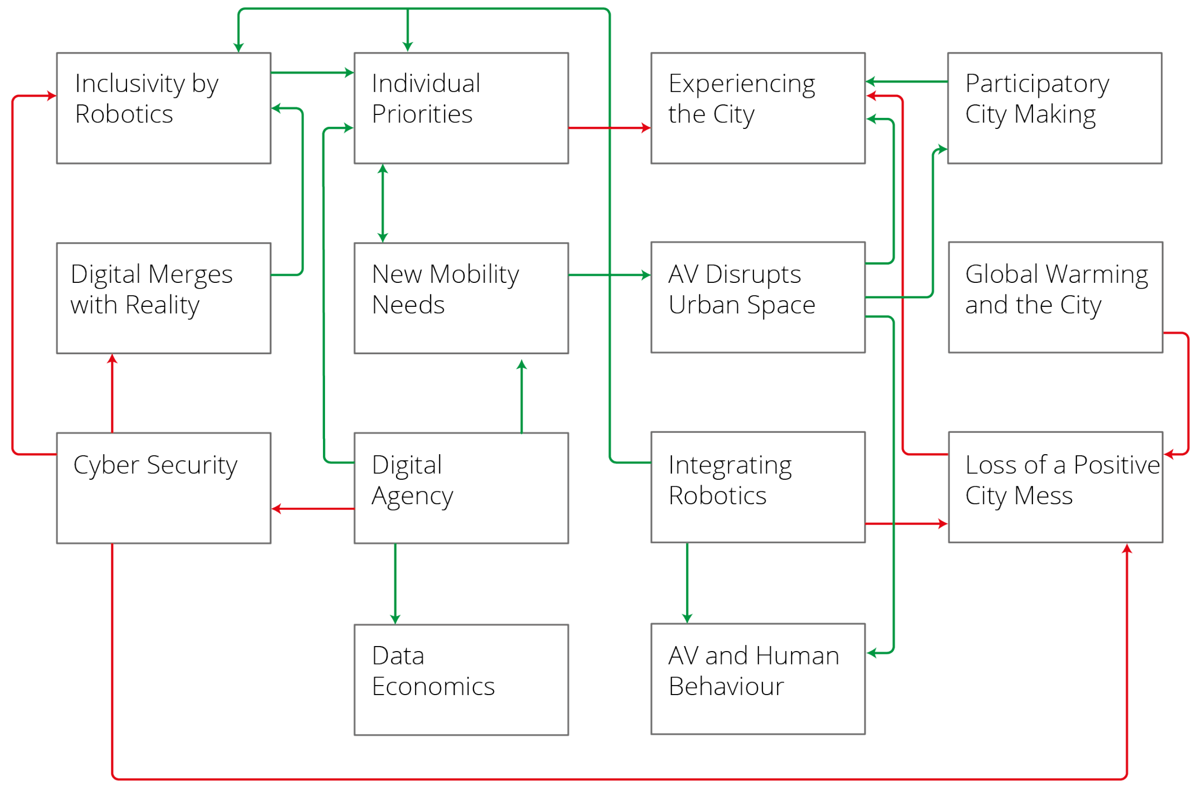


Figure 23 Diagram visualising the influence (negative or positive) the clusters have on each other

6.6 Future Context - A Narrative

Robotics started playing a large role in human lives and have become a normal part of how our world looks and functions. It went beyond voice activated home appliances to robots that drive us or take care of us. Their integration into human lives was enabled by the robot's ability to better understand human behaviour, emotions and communication styles. Robots and humans can thus have more engaging interactions where both understand, and can empathise with, the other. For autonomous vehicles this could mean that as an urban robot, they can have more comprehensive interactions with the human road users. Such natural robotics are not just present in physical form, services previously performed by humans are taken over by bots. With these robots and digital services in place, humans have developed even more a sense of individualism where every service or product can adapt to their life and specific needs.

In terms of personal services this is a positive development as such robotics can include more people back into society. An example of this could be a robot that guides a person with loss of vision through a city, allowing this person a new found range of freedom in their mobility.

This can also be done through technology that is closer or even connected to the body. Haptic feedback or augmented audio help a person navigate and interact with the city. Important here is the virtual layer of a city. People who can use some support in navigating the city, engage more with the virtual city than the physical one. This is a prime example of how the digital merges with reality other than the well-known augmented reality technology.

On the other hand, many of these services and systems collect a lot of personal data. This data has value beyond the personalised service it creates. Companies or governments can use the data to understand or predict human behaviours. With the integration of artificial intelligence in more of our products and services, less decisions will need to be made by humans themselves based on predicted behavioural patterns. These patterns have been developed by the AI system through machine learning and connecting to other services and products that also collect data. Through knowing these patterns, the system might also start nudging humans unknowingly in behaving according to this pattern. Such nudging could be helpful in some situations, like taking over tedious tasks, but in most it sounds more like a loss of free will, something which most humans do feel quite strongly about. All the data that is collected is being categorised to make it useful, this leads to biases against people which threatens their inclusivity in services and society.

Such predictive services are also applied in city processes which optimises them, however in doing so it can remove a part of the city mess that creates a vivid and spontaneous city. Climate change required cities to reduce energy usage and waste (just to name a few) which has led to more closed off city processes that require certain (behavioural) steps to be taken for it to work. The climate has thus a huge influence on how cities are designed in the future. Such large scale external influences decide for us how the city should be made, rather than the people who are living in it. That is the other side. Through the more connected world, citizens are closer to their city management and policy makers which allows them to exert more influence over the decisions made for the city.

With the integration of more predictive technologies or decisions prescribed by meta influences, the spontaneity, one of the most valued aspects of city dwelling, disappears which reduces the positive experience of a city. This happens especially in cities where the focus in creating a smart city lays on technology rather than on participatory cities. Cities with more engaged citizens, such systems can be designed in such a way that it actually adds to a positive city experience. Another threat to the positive city mess has been the increase of security.

Not only does our personal data need to be protected, also real life security remains a hot topic. Security happens more and more through less obvious methods like cameras with facial recognition which can be mounted on drones besides being static. This almost invisible layer of security may constraint what is acceptable behaviour, dancing in the streets might suddenly be seen as an inefficient way of moving across the sidewalk by the system that requires you to move in the most direct line possible. Being constantly looked at reduces such unexpected behaviours in the fear of being immediately ticketed for it. Striving for these plainly optimised city processes makes interactions within the city dull as you are being steered into a certain type of behaviour.

An important opportunity arose from the introduction of the autonomous. The AV created space for other modes of transport – like shared scooters, bikes and last mile transport pods, to take a more central place in the transit system, combined with more connectedness of services and systems for shared mobility. The need for these other modes of transport has also changed due to the decreasing amount of people owning a car, to a point where almost no one in a city owns their own vehicle anymore. The autonomous vehicle has reduced the amount of road space occupied by vehicles, which allows cities to create urban design more focused on the citizens. However, with all these new transport modes, one basic version should not be forgotten which is walking. Walking allows to experience the city and the interactions on a slower rate which can create a true connection with the city.

6.7 Conclusion

There are some insightful mentions in the narrative about how life could look like and some topics are pointed out to influence our daily life. The most prominent ones are found to be how our personal data will be used and who or what will decide how our city will look like or function.

On the one hand can our personal data be used to create positive impact in our lives. Using pattern recognising AI can help reduce the amount of tedious tasks we need to perform daily, or can help us navigate the city when that is not a given possibility in our current world. Robotics and services can provide personal aid which could provide them with a newfound level of freedom and independency. On the other hand this personal data can be used by corporations or the city as a system to nudge human behaviour in a certain preferred way without them knowingly doing so. This reduces the level of decisions we as humans have over how we want to do things.

Secondly is the decision making. Things like climate change could have a huge influence on how decisions have to made in order to remain a resilient city, protected against the more intense weather events. While on the other hand, through more connected services, citizens become closer to their city or community management. Organising oneself as a citizen thus becomes easier to participate in city making processes. There is thus a difference between possible levels of where decisions are made or come from, larger companies and external factors that operate more on a meta level for a city, or on macro level the citizens and communities that live in the city.

These two main themes, personal data usage and decision levels form the input for defining the design statement based on this future context, which is described in the next chapter (Chapter 7.2).

Chapter

7

The Future Vision

7.1 Introduction

This chapter is all about defining the design direction, without defining what exactly the final product should be. Through the design statement, the designer expresses a goal for the final solution (Hekkert & van Dijk, 2014). With the statement a designer can for the first time, include their personal values in the process more directly. Based on the design statement an interaction vision is constructed which helps to solidify how the product should behave and engage with humans. The statement and vision do not reveal or focus on what the design should be, but they do narrow down the solution space with a focus on the interaction. The latter is important in the ViP process as it really pushes the designer to design from an interaction and human centric perspective and possibly use technology to achieve this, rather than designing from a technological standpoint. This way of designing is closely related to how smart cities become more social or engaged cities, where the focus is not to just implement technology but to really envision if and how technology could support the local community and citizens.

Theme	Micro Decision Level	Meta Decision Level
Data Use for Personalised Services	1) Citizen Participation	2) Streamlining Experiences
Data Use to Nudge Behaviour	3) Behavioural Choice	4) Optimised Nudging

Figure 24 The dimensioning matrix

7.2 Design Statement

The design statement, together with the interaction vision form the future vision. The statement shows what the end goal of the project is you will try to achieve with the final design proposal. It presents the designer's response to the created future context (Chapter 6.6). Without giving away what the product will be the statement creates opportunities to find solutions that will point the current world into the desired direction for the future. Defining the statement is more personal as the designer chooses how they want to influence the future, by designing against or for certain scenarios. These scenarios are created through a tool called dimensioning, which is described in the next section.

7.2.1 Dimensioning

From the narrative in the future context two main themes came forward that are large influencers in the context – data usage and decision level. On the intersection of these two topics, four quadrants are created that represent scenarios within the context. This is where the dimensioning tool of the ViP method comes in. In this project the dimensioning is approached slightly different than described in ViP. ViP focuses on groups of clusters that contradict one another which form the basis of the axes of the dimensioning matrix. While the two themes in this project are also derived from how the clusters interact with each other, it is based more on the large influencers of these interactions rather than on the direct contradictions between the clusters. These themes are plotted against each other which results in four quadrants that represent different potential scenarios that can influence how the narrative plays out.

Each scenario in the quadrant is shortly described concerning the subject of urban design, to bring it closer to the intended context. Each quadrant forms a unique scenario that does not necessarily have to be an opposite of another due to different combinations of the themes.

1) In this scenario citizens will participate in creating solutions fitting to the local needs of the community and local residents. Through being more closely connected to the local governments they can exert a certain power in demanding these solutions and how the solutions are made.

2) The personal data of the citizens is used in order to streamline their interactions with urban design and infrastructures. They do not have much say in how these are designed but they do get a more personalised city experience from it by being connected to the city.

3) A limited amount of services provided by the government or companies is available, but through certain behaviours citizens can push certain platforms or show through their behaviour what kind of services they want to see in their city and infrastructure.

4) The urban design and infrastructure have an optimised way in how they should be used and will nudge humans into a certain behaviour that fits with this larger optimised system using predictive algorithms to understand what a human might do and based on the outcome the systems might adapt to nudge the behaviour a different way.

Creating these scenarios is not an exact science, and even with a guiding book it involves a lot of intuition of a designer. Another designer could have come up with completely different outcomes based on their interpretations. The next part of creating the future vision is also quite personal, where the designer chooses to design for or against a certain scenario and bases the design statement on that opinion.

In this project it was chosen not to design for a specific scenario to support it, but to design against one to lower the chances of that scenario working out in the future context. To be more specifically, to design against the fourth scenario. As stated, this scenario foresees that infrastructural systems will use predictive algorithms to understand human behaviour and possibly steer them into a different way, or literally, a different direction, if it does not suit the system. With regards to the city mess that is a valuable factor in cityness (Interview Usman Haque, Chapter 3.1), such algorithms in a city could completely eliminate human choice in how they want to roam the city. Technology should not dictate how we as humans live in the city, rather it should take on that supportive role to increase citizen well-being where it can.

7.2.2 Design Statement

The design statement can be seen as a goal that the designer wants to fulfil with the project and final design. Although it does not describe what the final design will be, or even what type of product it should be (product, service, business model etc.) it does give direction in the project as to what the design should achieve.

Picking a scenario to design against, in this case, helps to create a focus for the design statement as to what it needs to express. This takes going back and forth between different statements and words to find the right semantics. It became an iterative process where the earlier statements were tested by already creating some ideas to see if that statement would express a similar goal as to where the ideas were taking the project. Finally, after some initial statements failed the test of time, or ideation, the following statement was settled to continue with.

I, the designer, want to design a crossing area where human (pedestrian) transit is prioritised while maintaining an efficient interaction between the AV and human road user (pedestrian).

It plays into a couple of principles that are regarded as leading principles to test ideas and decisions against.
Prioritising pedestrian transit aims to create a city that is no longer ruled by designs for cars, rather it wants to create an environment that supports active travel. This instead of the current situation where pedestrians are almost secondary road users with only limited rights that benefit them, while walking is an healthy activity to engage in. By prioritising pedestrians more in a city, it can become a more walkable city which is generally a positive development for even just a neighbourhood.

The pedestrian priority not only refers to them having more rights, it also concerns with creating a system that is not focused on nudging behaviour into the most optimal behaviour. Or being told by the AV how they should respond. It leaves the choices with the pedestrians as to how they want to behave and walk in the city.

On the other hand, the statement mentions an efficient interaction. In this case efficient does not imply most optimised or fastest manner. It means that the AV and pedestrian will be able to interact without too much issue, without rushing either – especially the pedestrian while crossing, to create a harmonious flow. This harmonious flow comes down to a goal where neither pedestrian nor AV will have to wait unnecessarily for another, which what often occurs now at traffic light cross walks. Creating an efficient traffic flow benefits the AV as it will create a more comprehensible traffic scene that also becomes more continuous.

This statement takes into account the new possibilities to design for a pedestrian focused system without forgetting the needs of the AVs. It focuses on designing from a human centric and interactive perspective rather than a technological or process perspective.

7.3 Interaction Vision

The interaction vision helps to understand what the relation will be between the to be designed product or system and the user. In the end one of the most important features of the ViP method is the interaction centred approach that helps to create truly user centred designs within a new context.

The interaction vision, represented in the above image, is about how the system and pedestrian work together to achieve the best possible result. Sort of like a ping pong match where ones input is received and then reciprocated by the other actor. The ballet dancers are dancing a pas-de-deux. A piece performed by two dancers who are dependent on each other to play their part in order to bring the piece to life and fulfilment. Each dancer has to be active when they dance together, otherwise a lift as such would not be possible. Although it seems like the, in this instance, male dancer does the heavy lifting, without the strength of the female body to keep her torso and legs upright and straight, the lift would fail, however strong the supporting dancer is. The interaction thus depends on the two or three actors to do their part in order for the total system to work most optimal.

Figure 25 The interaction Vision

PART III

Create

This is the part where all previous steps culminate into actual solutions. For the first time in the process the ideation is actively done to find many ideas that could work out to fulfil the design goal in the statement. From this messy process rises, in the end, a final design proposal. This part is where a designer can have fun in exploring some crazy ideas in order to get to the more normal but right solutions.

Part III - Create | Introduction

The last part of the report, the one where it all comes together in actual product ideas. Trying to retrace the steps taken to get to the final design, is quite a journey with thought jumps and side tracks that I will spare you in order to keep the story as comprehensible as possible.

The three chapters in this part take you from the first ideas to the final design proposal.

Chapter 8 describes the ideation phase where the first solutions were jotted down and trends within those ideas found led to some new insights

In Chapter 9 one idea was chosen to work out in more detail. This chapter includes the considerations and evaluation done to get to the final design.

Chapter 10 is the moment we have all waited for, the final design. Where all the research, design statements and interaction visions come together in one product. That is what you will read about in this last chapter.

Chapter

8

Ideation

8.1 Introduction

Now that the analyses have been done, the future context has been narrated and the design goal has been defined in a statement, it is time to put all the knowledge together and start creating solutions to fulfil that design goal. The process of coming up with as many of these solutions as possible is commonly referred to as the ideation phase. During this phase the designer can let lose their creativity to find many ideas that could possibly become the final design or part of it.

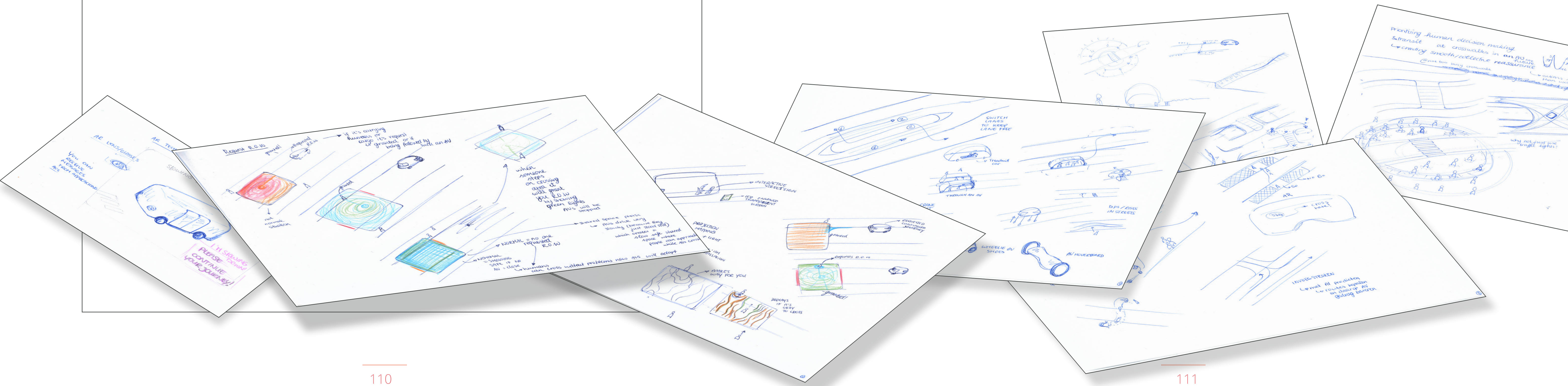
The ideation phase during this project was not only about finding solutions, it also presented with new questions that required revisiting research insights or the design statement. Although it did not lead to major changes in the design statement, creating ideas did help to formulate it better and finding the right words to express what it actually wanted to address. Throughout the first part of the ideation this led to creating design boundaries to gradually further narrow down the design space to come up with fitting ideas.

The main tool that was used for the ideation was brainstorming and 'How Can You?' questions to deepen and initiate solution explorations. The latter helped to specify what questions needed to be answered with these ideas and solutions. After a first round of coming up with many different ideas most of them were grouped in idea directions which led to new insights, which will be discussed in the respective section, and from this the conceptual ideas grew. One of these conceptual ideas was chosen to further work out into the final design proposal.

8.2 Generating Ideas

This highly messy, iterative and creative phase of the design project is difficult to record exactly what happens as ideas can follow each other organically or sudden bursts of inspiration lead to new ideas. Throughout the ideation many new questions surfaced that required to revisit the analysis done in Part I, to find answers and figure out what the right direction is to keep ideating. One of the most important results from all these questions was the narrowing down of the design boundaries. Focusing on pedestrians only for a starter helped a lot to focus the solutions towards a clear user group. The key in the ideas was to find the balance between designing something that keeps humans safe while crossing the street without being directive in how one should behave without them consciously making that decision. This was an important goal stemming from the future where technology can be used to nudge human behaviour.

The decision was also made to steer away from designing a wearable device or digital service as this limits one's ability to be an active actor in the traffic system when one does not have the device or service (with them). While the city should be a place where everyone can be a part of it no matter what. Services or devices could give additional feedback on the system, however should not be a factor to be a part of the city successfully. Augmented reality technology for example is therefore not explored further as this requires certain apparatus to be worn or carried while going out. The ideas are thus really focused on infrastructural designs that are part of the city. It is difficult to know when enough ideas are generated and the right one exists within the pool of ideas, however after a while some trends emerged within the type of ideas that were generated. These trends eventually were grouped together to identify the most common directions within the idea pool.



8.3 Idea Directions

The idea directions provide an overview of certain trends within the ideas. Specifying these directions gave insight in the base of these ideas and which ones are worth pursuing based on the design statement and scope.

From these directions some insights were formed which would not have been found if this bigger picture of the ideas was not created. Many of these directions provided insights or elements that were taken or combined into new ideas that eventually led to three conceptual ideas (Section 8.3).

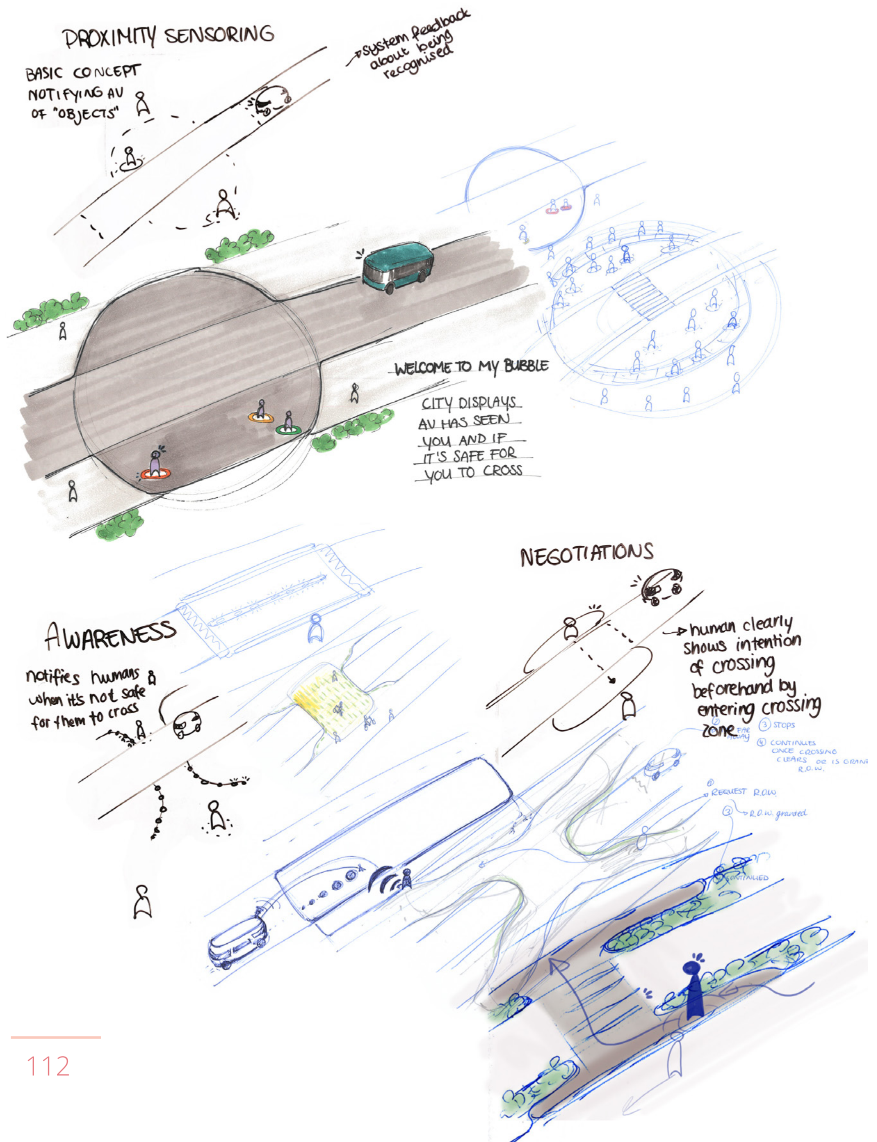
Especially the direction of a responsive street design shows promising possibilities to develop further. These ideas create an interactive environment that can provide the pedestrian with different kinds of information if necessary. Using proximity sensing to get a better overview of where pedestrians are can be an interesting way to also create a cleared overview for the AV. This idea direction formed the main input in creating the conceptual ideas further on.

Other idea directions also provided with interesting insights or elements that can be taken further and added together in new ideas.

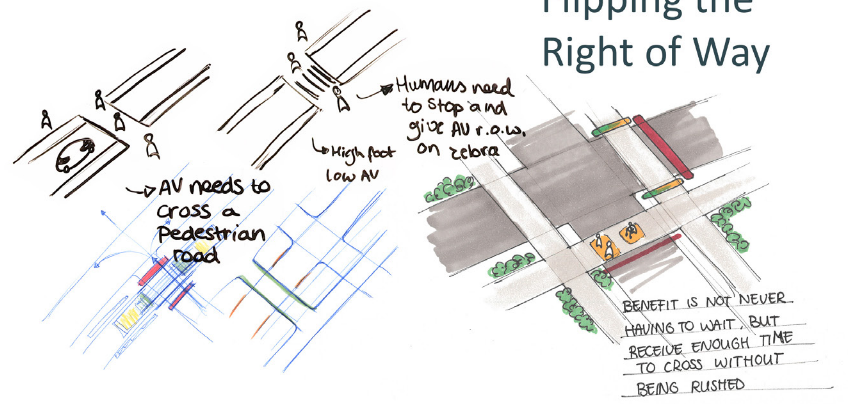
The most important insight from the directions that was translated into a design feature of the final concept was the Street Lay Out Design. This direction was not pursued as a main direction since street lay outs are reliant on how much space a city has, which is very limited in most Dutch cities. However, these ideas did showcase how many possibilities can exist for a street lay out, depending on the city or area. Thus designing a crossing area with a fixed configuration could limit the implementation of such a system. The fact also remains that if just the lay-out of a street is redesigned, the pedestrian and AV still encounter one another and interact. This insight later on in the process leads to the modularity feature of the system.

The idea direction of Flipping the Right of Way (R.o.W.), although not taken as literally as in the ideas, was used to discuss who should have the right of way on the streets, and in what scenario. It leads to a more dynamic interpretation of the right of way where both actors in the system can be granted the right of way based on the situation at hand, rather than one of them always having it. This dynamic right of way influences the rights management system, which will be discussed in Chapter 9.3 how it was worked out.

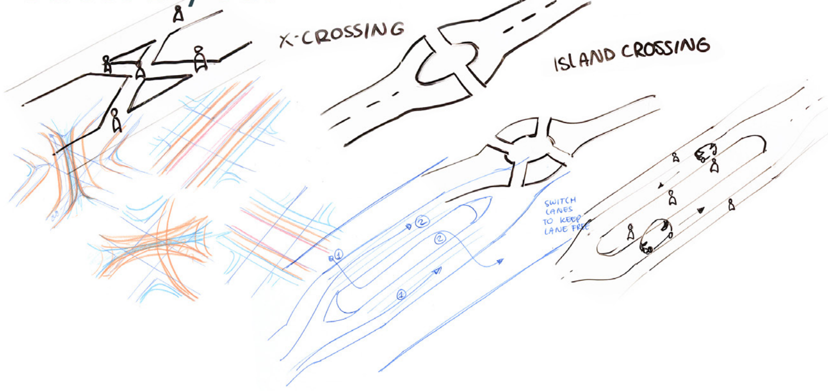
Responsive Streets



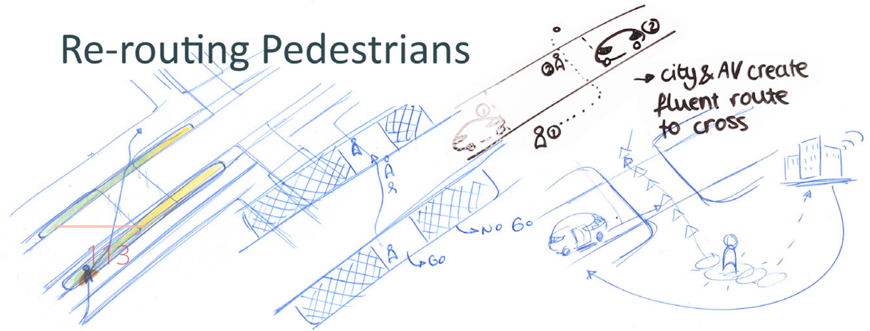
Flipping the Right of Way



Street Lay out

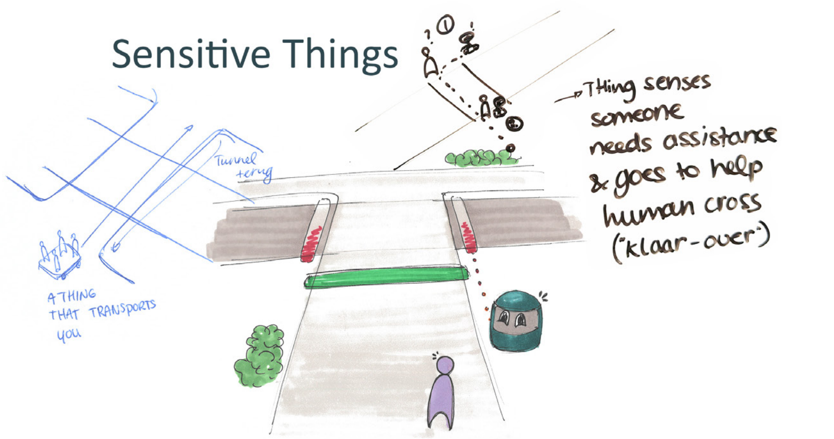


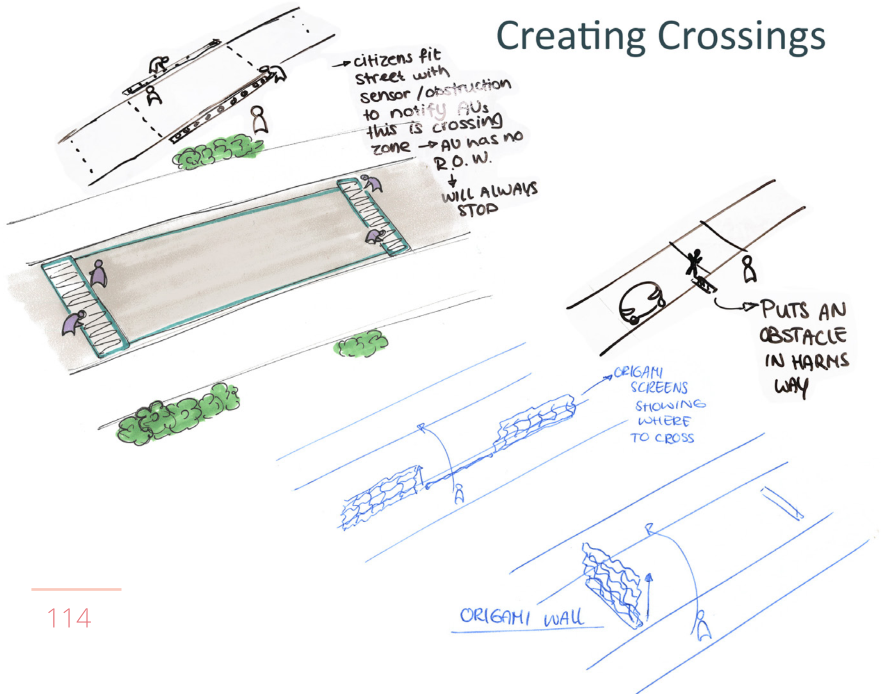
Re-routing Pedestrians



The rerouting, sensitive things and creating crossings were put aside. The first presented a very directed interaction based on predictive algorithms. This is something I, as the designer, wanted to steer away from as discussed when defining the design statement (Chapter 7.3)). Creating crossings, although an interesting direction where citizens can create their own crossing areas in their neighbourhoods, would fit better in a context, different from the chosen one, where the amount and speed of AVs passing through a street is lower. This would however be an idea for incorporating more participatory city making ideals into infrastructural designs.

These idea directions thus did not directly form new ideas for each direction, however their elements formed the basis for new ideas, or formulated questions and possibilities for the final concept.



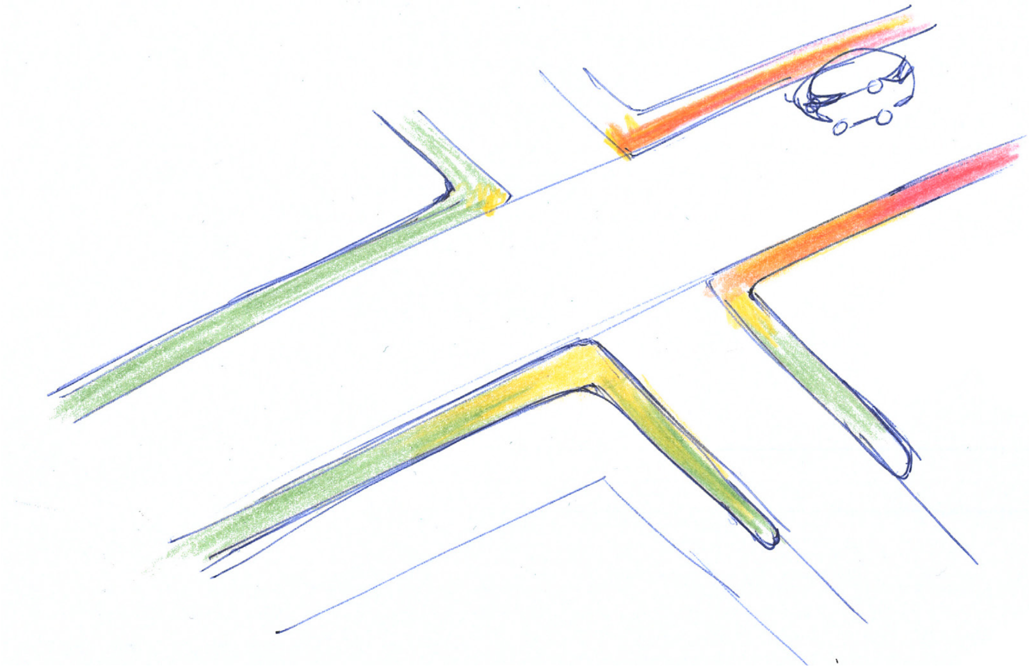


8.4 Conceptual Ideas

Taking the elements and insights from the idea directions, into a second round of ideation, eventually led to three conceptual ideas that showed most promise throughout. These three conceptual ideas are all based mainly on the responsive street direction, as this was seen to be the most promising direction to fulfil the design statement. From these three conceptual ideas, finally one was chosen to further conceptualise and finally work out into the final design proposal.

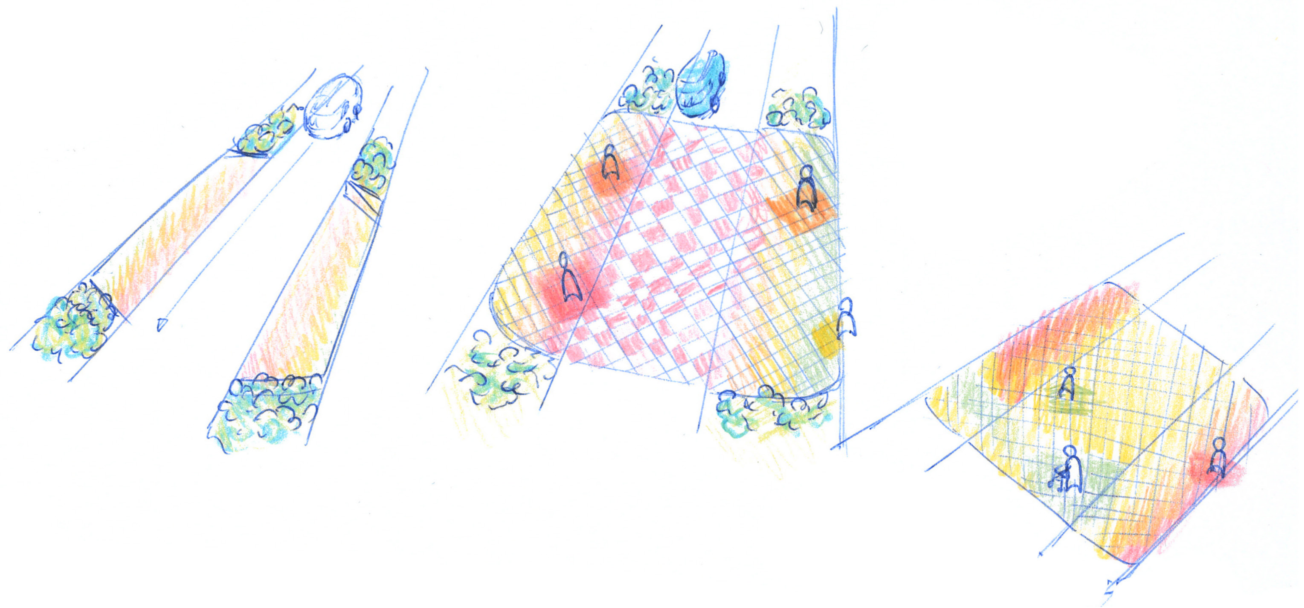
8.4.1 Full Street Length Crossing

Instead of limiting the crossing area to one designated cross walk, what if the whole street can become a crossable area? Busies streets will be fitted with a strip along the entire road that is accessible for pedestrians, which will constantly show feedback on where it is safe to cross at that moment based on the location of the AVs. This allows pedestrians to cross wherever is best for them instead of possibly having to walk extra to get to a cross walk. The strip along the street should make pedestrians aware of approaching AVs and whether or not it would be safe for the pedestrian to cross the road right then and there.



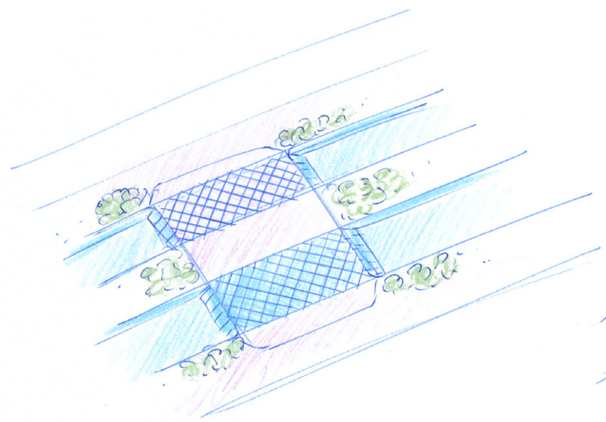
8.4.2 Proximity Based Safety Feedback

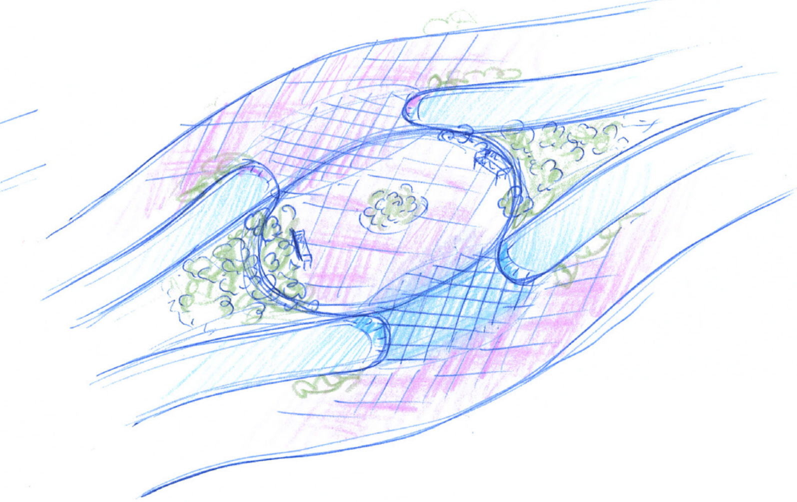
The crossing area reflects the crossing safety for the pedestrian at a designated cross walk. The system will notify about their possibility to cross or not. It will provide with more up to date feedback on the pedestrian's safety to cross. The cross walk extends over to the sidewalk to enable proximity sensing of the pedestrians who are approaching the cross walk. The right of way here is decided based on where the AV would be compared to the proximity of the pedestrian to the street. It can also continuously show whether it is safe or not for a pedestrian to cross when there is no pedestrian on the crossing itself, but nearing it. It will notice if someone is still on the road and will notify approaching AVs about this to make sure the pedestrian gets their time to cross.



8.4.3 Binary Street Coding

The street is laid out with colour changing surfaces that can change between AV road and pedestrian crossing. Each of these options will have a distinct colour to recognise what mode the cross walk is in and thus who has the right of way at that moment. If the AVs get the right of way, the cross walk will change colour, and seems to disappear as it becomes part of the road. If the pedestrian gets the right of way, the cross walk becomes the same colour as the rest of the crossing area.





	Full Street Length Crossing	Proximity Based Safety Feedback	Binary Street Coding
Advantages			
	Pedestrians have the opportunity to cross wherever they like	Designated area provides a focus to create more priority	Simple to understand
	Pedestrians can create their own routes throughout a city	Interactive system to create more communicative system	
		Personalised feedback	
		Possible to create organic, fluent traffic flow	
Disadvantages			
	Not efficient from an AVs perspective		Directive instead of communicative
		Less open for own decisions of pedestrian (specific location)	It is not interactive
			Does not create an organic traffic flow (less efficient)

Figure 26 Table containing the (dis)advantages of each concept

8.4.4 Concept Choice

Based on the advantages and disadvantages, the choice was made to further work out the second concept: proximity based safety feedback. The main reason to go with this concept is the efficiency factor. The other two concepts will not create more organic traffic flows, rather they might even cause the opposite where AVs need to brake quickly. Especially when the whole street would become a crossing AVs might have to stop multiple times on one piece of road. For the AV and its passengers this can lead to an uncomfortable ride. Even though the statement states that pedestrians should be a priority, it is also deemed important to create an environment well suited for the AV so it has less nuisances and can therefore operate more smoothly. This will in turn make it easier for the AV to be implemented so we can reap its benefits.

The proximity based concept has more possibilities to work out an organic traffic flow when developing the rights management system for it, because it uses pedestrian tracking of some sort to make it known to the AV if a pedestrian is on or near the cross walk. The fact that it is a designated area adds to the previously mentioned reasons, where on a designated area pedestrians really can be prioritised in their crossing movement while presenting a more comprehensive infrastructure to the AV.

Compared to the binary street coding concept, the chosen concept allows to create a more communicative coding system while the binary street coding remains quite directive in what you as pedestrian can or cannot do. It does not really create a negotiation between the two actors as the cross walk just decides for the pedestrian and AV what the right of way situation is. With a more dynamic system these right of way negotiations can be done more personally and change quicker, allowing AVs to pass before a pedestrian or the other way around.

The disadvantage mentioned for the chosen concept proximity based safety feedback, that it would be more difficult to understand is something that needs to be designed for to make sure the feedback remains intuitive and quick to be understood.

8.5 Conclusion

The ideation phase, although always a bit chaotic, often leads to more than just ideas and also raises new questions that challenge the choices made before starting the idea generation. However, when putting it all together, one can get to those new ideas that are at least in the right direction to fulfil the design statement.
In this project the main goal is to create a product that prioritises pedestrian movement at a cross walk and creates a fluent traffic flow that happens more organically. The concept using proximity based safety feedback is the one to be further developed to achieve these goals even better.

Chapter

9

Conceptualisation

9.1 Introduction

During the conceptualisation the chosen conceptual idea – proximity based safety feedback, is further developed in terms of interaction and technical feasibility. During this phase the idea is taken under a magnifying glass and its aspects are given more thought in order to make the most optimal concept possible given the current knowledge and timeframe. In this phase as many questions about the idea are aimed to be answered, and the most important considerations are mentioned in this chapter.
Although technical feasibility is an important aspect of product design, the ViP method proposes to postpone thinking about this until the very end and instead focus on the interaction. The technical features should follow from how the interaction is designed rather than deciding upon a technology and designing the interaction around it (technology driven design). In this project, the interaction is the most important feature of the design proposal, to figure out how AV, human and cross walk system communicate and interact with one another to facilitate safe crossing and efficient traffic flows. Technology can and will change, especially since the time frame for this project is far ahead in the future, however the basis for the interaction will remain similar. Therefore most energy has been put towards developing the basis for the interaction design.

The to be designed interaction mainly focuses on the human – system interaction between a pedestrian and the cross walk itself. As the cross walk pretty much connects the pedestrian and AV they have less direct interaction. In other words, the cross walk aims to bring their two communication bubbles together so both can more easily understand what the other will do. From the concept the idea is to fit the cross walk with a feedback system based on visuals on the street surface. These visuals would give the pedestrian an indication about whether it is possible for them to cross or not, which seems similar to the traffic light which gives a go or no go sign. However, recalling the design statement from Chapter 7.2, this cross walk system aims to prioritise the pedestrian as much as possible which could mean that the cross walk mainly gives feedback once the situation has changed in such that the pedestrian cannot cross the street. One of the main things that needs to be figured out is how the system – the algorithm that operates the cross walk, operates and what its rules are. This comes back to the rights management system discussed with Martijn de Waal during the expert interview (Chapter 3.1). The rights management system is basically the set of rules as formulated by the people involved to decide under what circumstances someone has access, or in this case the right of way. However, before diving into the rights management system, first the layout design is reassessed since this presents a new kind of shape for the cross walk. This might not seem as part of the interaction, however certain interactions are enabled through the physical design. These are explained first as it concerns an important feature of the cross walk and system.

9.2 Physical Features

In reassessing the shape of the cross walk, which was thought to be a simple physical or aesthetic adjustment, turned out to have more effects and connections to other parts of the cross walk design, that all lead back to how the lay out looks. This section therefore discusses not only the reassessment of the lay out, but also some technical features that ended up having an influence on the lay out.

9.2.1 Merge Lane

In the conceptual idea, the cross walk is represented as a rectangular area that extends slightly beyond the limits of the actual street. This overset onto the side walk was opted for to identify pedestrians who are going to cross and provide them with feedback before they reach the curb. However, this extended area has a second function that might actually be the most important feature to integrate in future cross walks. By sensing pedestrians in the vicinity of the cross walk, AVs can be alerted about this and can anticipate a possible pedestrian on the road.
Although an AV is quite capable of recognising pedestrians near the curb, and software is able to even understand to an extend if a pedestrian is going to cross based on their head and body movements, this is still limited and only works when the pedestrian is already at the curb and the AV close. This still requires the AV to stop quite abruptly and the pedestrian still has to estimate what the AV will be doing. Even though technology like the recognition software might be able to solve some issues, there is still the possibility it will never come to full fruition, leaving the AV and pedestrian more vulnerable to a collision.

Instead we could also look into other solutions that can support the AV in creating oversight of a situation. One such solution could be looking at human behaviour when crossing. Most pedestrians are aware that they want to cross at a certain point, providing a designated area like a cross walk makes the decision where to cross easier. With a conventional car and human driver behind the wheel, a pedestrian can implicitly show their intention to cross by turning their head to look for oncoming cars and move towards the road. However, an AV is less likely to pick up this information, or does not exactly know what the behaviour means. Thus if pedestrians can show their intention to cross more explicitly towards the AV, the latter can anticipate this and already slow down to give the pedestrian the right of way without having to brake abruptly. This is where the concept of the pedestrian "merge lane" comes in.

The merge lane covers a part of the side walk leading up to the cross walk that pedestrians can use when they want to cross. Their presence on this area is noted and made aware towards the AV. The pedestrian will receive feedback based on their proximity to the crossing and the distance of the AV from the cross walk.
This feature is an important part of the cross walk as it serves to incorporate two way communications for the pedestrians, where the interaction is not just dependent on the response of the AV. Not only are the pedestrians being communicated towards, they can also communicate explicitly towards the AVs and the cross walk.
It is also beneficial for the AV, as mentioned before, when the pedestrian shows a clear intention the AV can anticipate the crossing and can slow down well before arriving at the

cross walk, reducing the amount of full stops they will have to make. The AV does not have to process each pedestrian within the vicinity of the cross walk, because through the cross walk it already knows what actions it should be taking to avoid a collision with pedestrians. The merge lane removes the need for predictive algorithms that predict if a pedestrian will cross and let the AVs behaviour depend on that.
Adding the merge lane to the lay out of the cross walk can thus serve both the pedestrian and the AV in creating a more organic and comprehensible traffic flow. It allows both actors to communicate their intentions to each other that is translated by the cross walk into a signal they can understand.

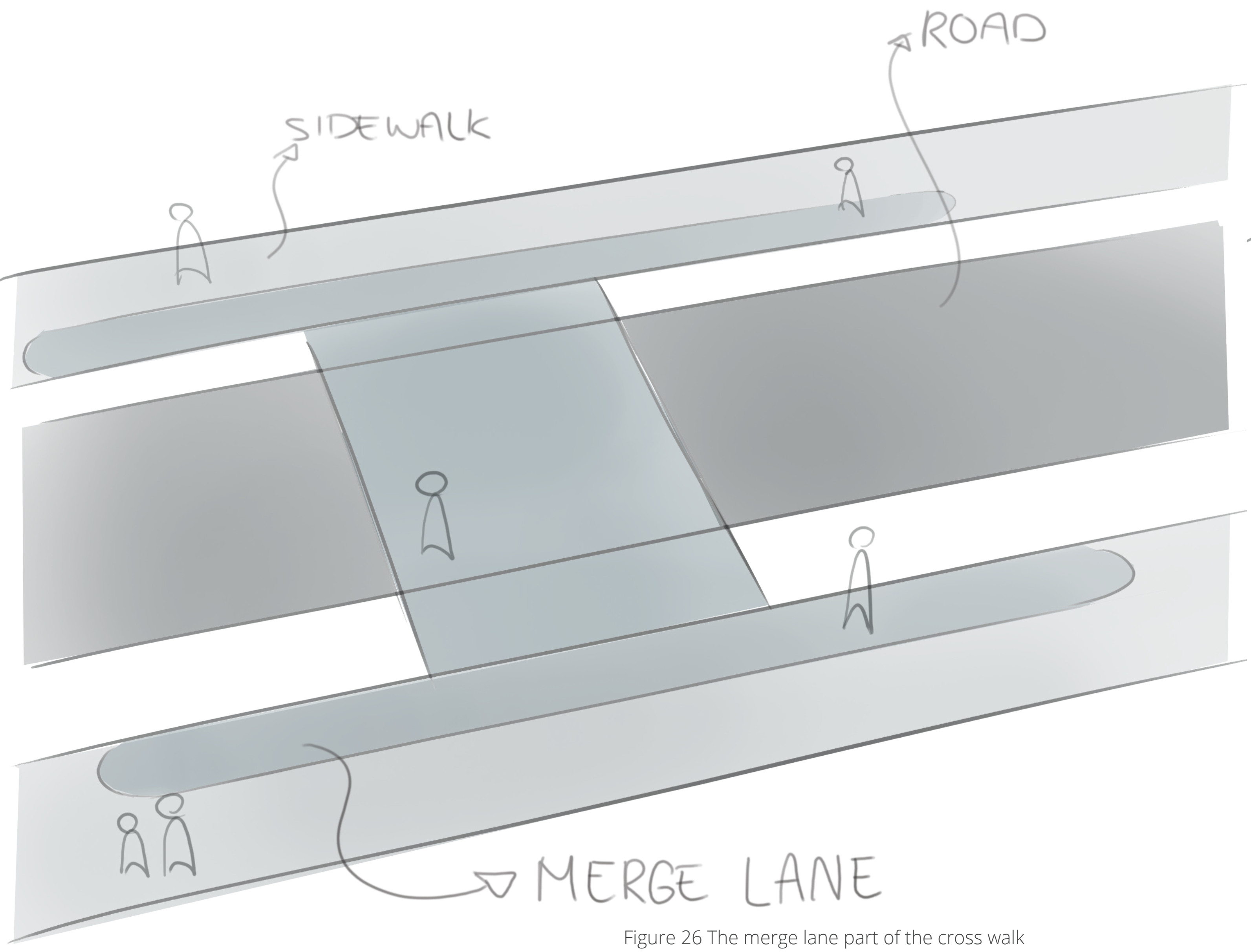


Figure 26 The merge lane part of the cross walk

9.2.2 Shape

When crossing, pedestrians often opt to create a more diagonal path across a street. This more natural crossing path is often not possible on designated cross walks due to their shape design. To facilitate this more natural crossing path, the sides of the cross walk will be rounded off, to allow for diagonal crossing of the street.

The merge lanes will be following the shape of the sidewalk. With more room in the future to be redistributed when a road is only accessible for AVs (Chapter 7.3), it is likely that sidewalks will be wider to give more space to active modes of travel like walking. The merge lane can then take up a part of the width of the side walk close to the cross walk.

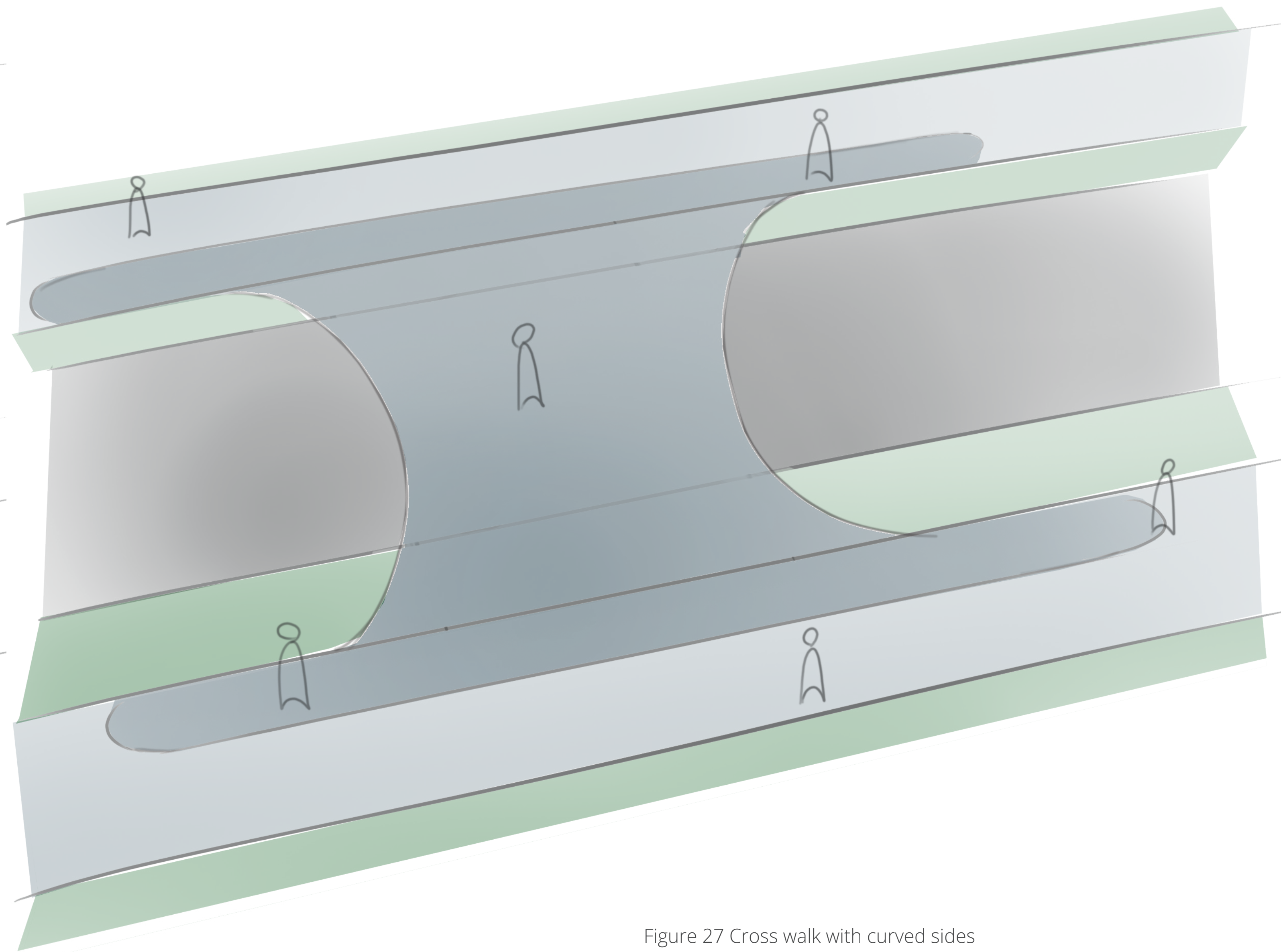


Figure 27 Cross walk with curved sides

9.2.3 Modular shape

The ideation phase helped uncover an insight about the shape and lay out of the cross walk. Through the many sketches and ideas to change the lay out of a cross walk, the realisation occurred that many street designs differ. Some streets have multiple lanes – event though this could disappear with the introduction of the AV, some streets have a median strip (segment between two opposing lanes) or different distances between side walk and road. This led to the idea to create a modular system. In order to do so, the cross walk will be built with tiles. Tiles allow to adapt the shape without having to change anything about the product, any shape of street can be followed. The cross walk could be made bigger or smaller depending on how many pedestrians use the cross walk, or how wide the street is. The modularity also allows to integrate the cross walk into already existing streets without having to redesign and rebuilt the street just to fit the cross walk.

It was chosen to use tiles with an integrated light system instead of for example projection mapping on the street surface. Projection has some issues with visibility when used in bright daylight where the projection might not be luminous enough to be visible. Also shadows cast from objects or pedestrians onto part of the projection obscures the visual feedback from being seen. Integrated lights in the road surface – tiles in this case, are still visible even in bright daylight. They are even adaptable to be less bright when the surrounding light dims, for example at night they can be less bright.

The choice to go for hexagonal shaped tiles is based on the possibility to create a more dynamic shape for the cross walk. Square tiles only allow for straight edges and do not facilitate the intended rounded sides of the cross walk. Hexagonal tiles can be used to create a more round shape. Also the multiple sides can be used in the animation to have more directions for the animations to move and therefore better follow the pedestrian.

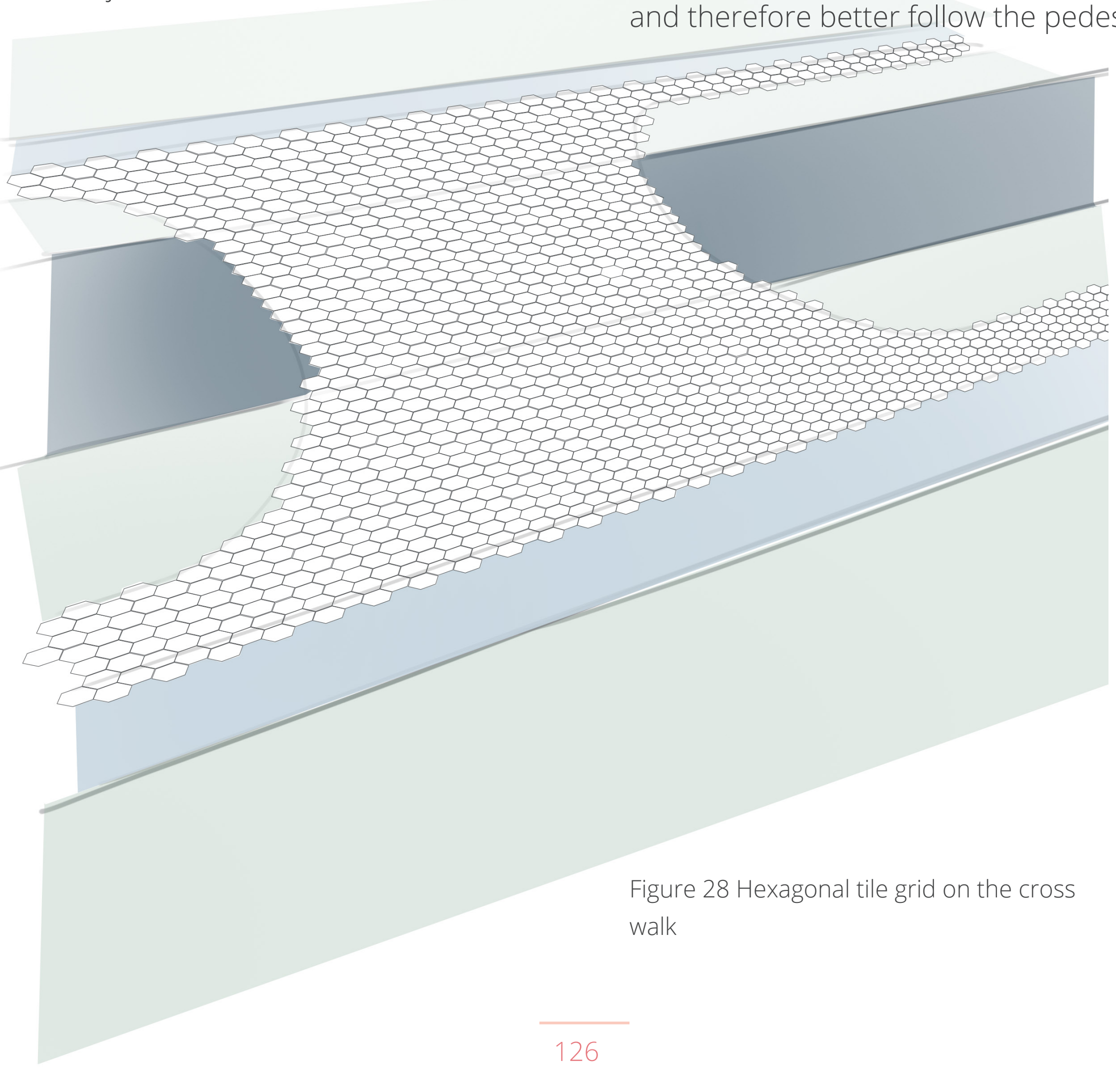


Figure 28 Hexagonal tile grid on the cross walk

9.2.4 Tracking System

Maybe one of the most important features of the cross walk is the ability to track pedestrians on the 'merge lanes' and cross walk, and based on their proximity calculate whether they will collide with the AV. Based on this information the AV will be alerted to slow down or stop. Only if this is not possible will the pedestrian receive feedback that crossing will not be safe when they reach the road. So for this system to work, it needs to be able to track the pedestrians. The first solution that comes to mind would be a camera system with image processing capabilities that can recognise pedestrians when they enter the cross walk area (merge lane). This does raise the question about the pedestrian's privacy, as camera systems may have the ability to also identify people through facial recognition. Even though, from an idealistic point of view this will not be added to the system, it would always be possible to add the software into the camera's system.

There is a different solution that does not require cameras. Instead pressure sensors can be used to identify pedestrians on the cross walk. The sensors themselves cannot distinguish between different people, thus would not be able to calculate average walking speeds (a conclusion in next paragraph) for each pedestrian individually. However, with better algorithms, it is possible to identify a person by their gait and unique pressure signature (Muro et al., 2014; Qian et al., 2008). Also simpler parameters could be used to distinguish one pedestrian from another based on pressure area, or amount of pressure applied since the system does not need to identify who is walking. It only needs distinguish between different people who are on the cross walk at the same time to calculate their personal walking speed and possible direction to be able to visualise the feedback in the right spot. Using a grid of pressure sensors integrated in the top layer of the tiles can thus distinguish a person through gait analysis and calculate their walking speed.

One problem that does occur with any tracking system, is the fact that in order to calculate the average speed it needs some data on the speed before it can actually calculate it. Since the pedestrian immediately receives feedback once they set foot on the merge lane, the tracking of to calculate the average speed should already have happened before that moment. This requires the tracking area to extend beyond the actual cross walk. To identify that the area is part of the tracking area, similarly shaped tiles with the pressure sensors without integrated lights can be used to cover this area. The pressure sensors will thus collect average walking speeds from all pedestrians walking over the sidewalk near the cross walk, however the data will only be used once the pedestrian sets foot on the tiles with lights. The data of the walking speeds will not be saved and once a pedestrian leaves the tracking area, the data will be deleted as it is no longer useful to the cross walk's system. Using pressure sensors instead of vision based tracking also helps reduce the problems when visibility is low during evening hours or when rain, fog or snow lowers the visibility for the cameras. The system using pressure sensors can thus during moments of low visibility for the AV help to become the extra pair of eyes to track pedestrians. With the extended tracking zone it could even be possible to identify pedestrians close to the cross walk who may cross and have the AVs approach more carefully in cases of bad weather (this is part of a scenario discussed in Section 9.3).

9.2.5 Conclusion Physical features

The physical form of the cross walk is influenced by how it will and can be used. The merge lanes that extend the cross walk onto the sidewalk are a direct influence by the opportunity of the pedestrian to show their intention and be an active part of the communication. They enable the pedestrian to exert their own input into the system from their own will, instead of being predicted on by an algorithm, that might also want to nudge them. The ability to track the pedestrian allows the AV also to better understand the situation beforehand. Which is aimed at creating a more efficient traffic flow that benefits the pedestrians but also the AVs. This feature is one of the most valuable ones from the perspective of a city where the traffic flow becomes more fluent, which could possibly lead to less congestion and a more comfortable drive for the passengers. The final shape is one that is not is set in stone from the designer, as it can be fitted to multiple street lay outs through the use of a modular tiling system. Each tile would be fitted with integrated lights to be able to visualise messages from the cross walk to the pedestrian and uses a grid of pressure sensors the register pedestrians on the cross walk. This pressure sensor grid extends beyond the cross walk to be able to calculate average walking speeds before the pedestrian enters the cross walk. This way the moment the pedestrian steps onto the cross walk the system can quickly calculate is a collision will happen, and alert the AV of the situation.

9.3 Rights Management System

The rights management system contains the rules and rights that the algorithm uses to decide what the outcome should be or what should happen, in this case that comes down to who should be granted the right of way and what the cross walk should communicate towards the pedestrians. A set of scenarios were thought of that are likely to happen at the cross walk that could potentially influence how the system behind the cross walk will have to respond. From these scenarios factors that cause the influence are derived, and these form the basis to create a first set of rules and rights for the system. Creating such a set of rules and rights is complex, especially when it comes to safety of humans. The main aim of the cross walk's system will be to prioritise pedestrians to cross the road, so these rights and rules are used to determine when the pedestrian can indeed be prioritised and when the AV will be allowed to pass before the pedestrian. Secondary, the system wants to create an organic traffic flow, for the pedestrians as well as the AVs. By creating a more organic flow, where actors can follow up on each other quickly and smoothly, a more efficient flow is established where AVs can save on energy when they do not have to come to a full stop each time they are at a cross walk. This also makes the drive for the passengers of the AV more comfortable, a factor that is found to be important by the AV (Chapter 4.3).
The scenarios also show what kind of message the cross walk will communicate towards the pedestrian, these are referred to as the different states of the cross walk. These form direct input in what type of interactions have to be designed, but do not yet reveal how they should be designed.

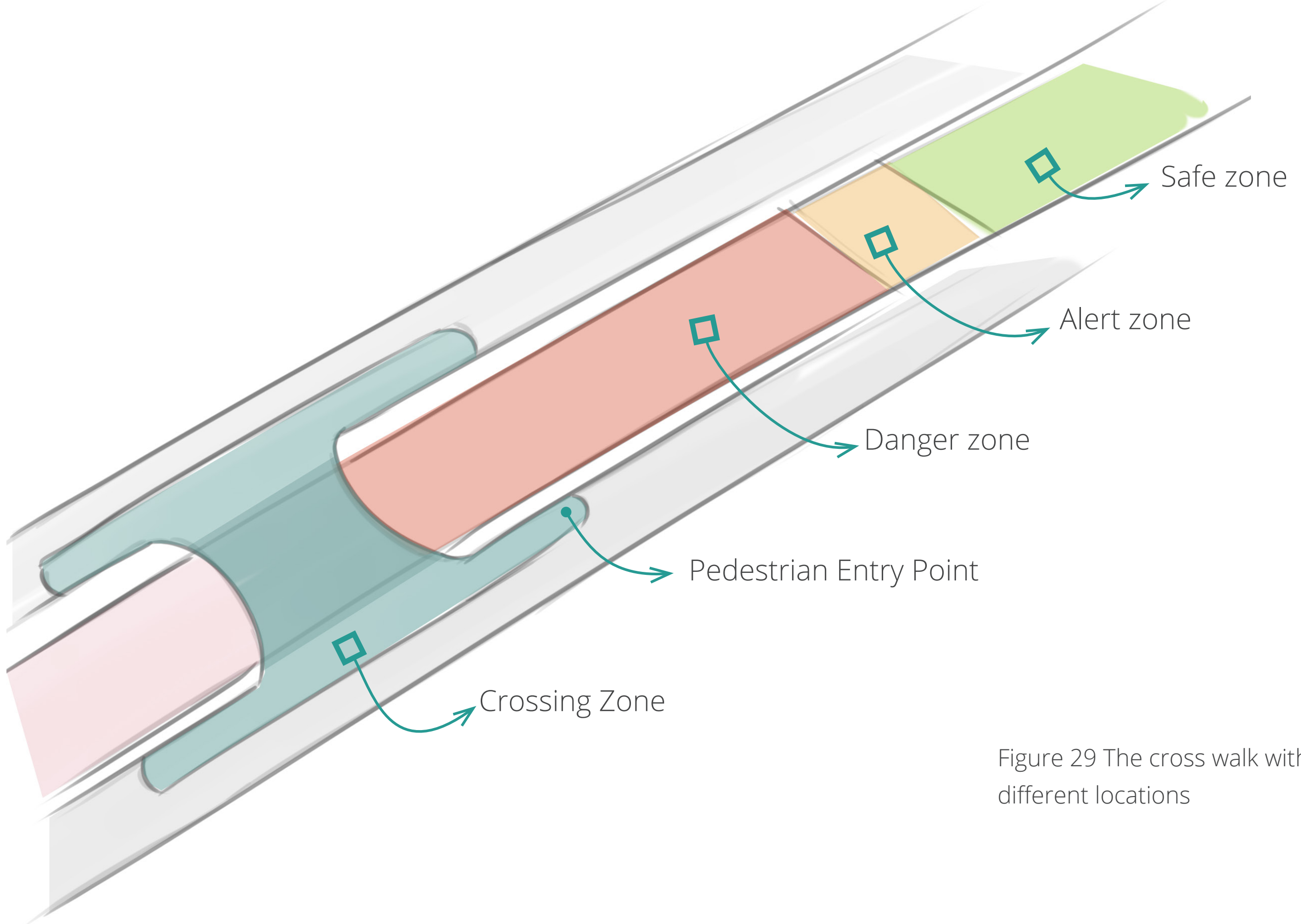


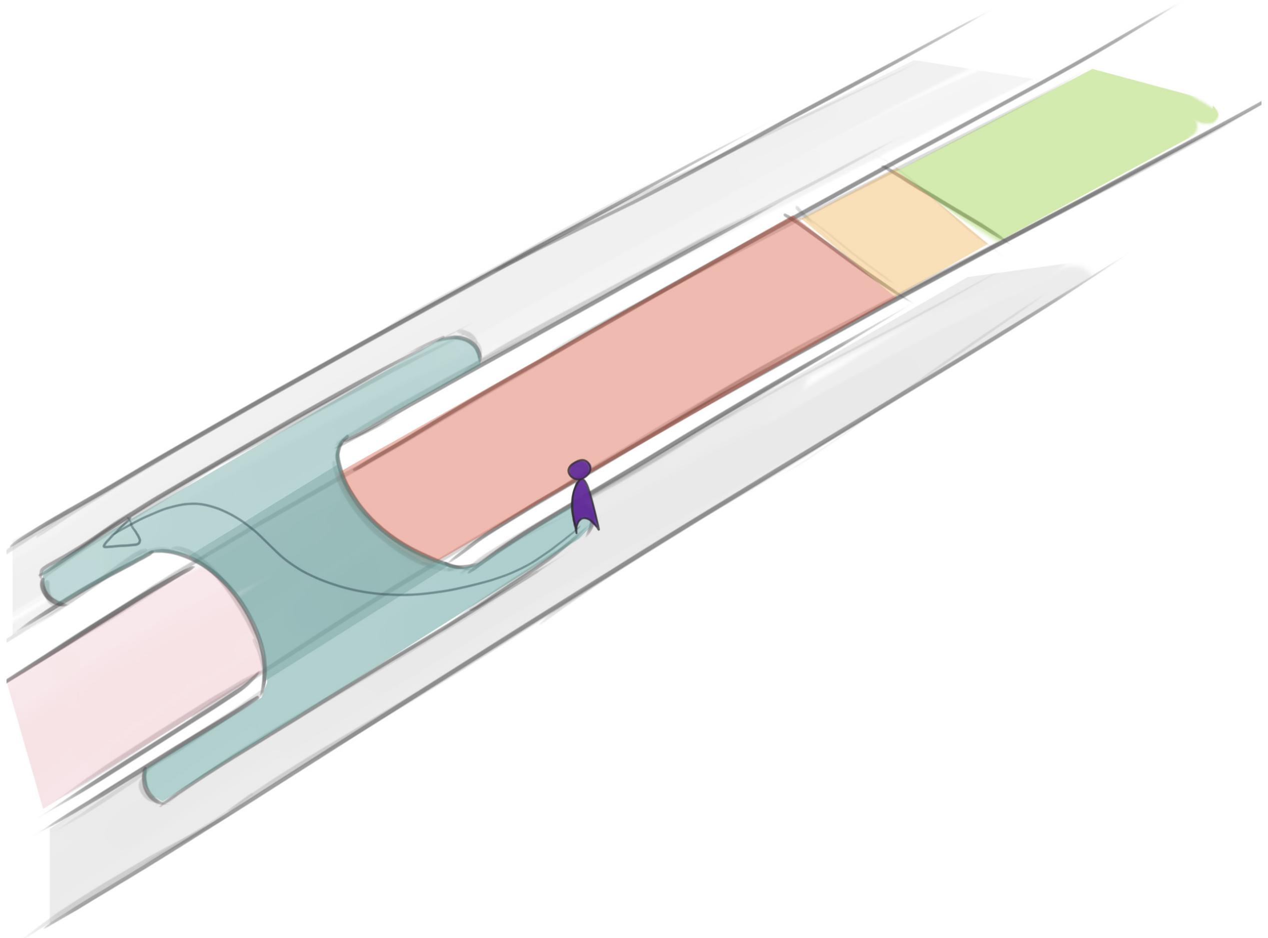
Figure 29 The cross walk with different locations

Scenario 0: Base, no interference

When there is only pedestrians approaching the crossing while AVs are so far out of range (outside the safe zone) they do not need to anticipate possible pedestrians yet, pedestrians can just cross and the system will not be showing much urgency while ensuring the crossing is safe for them to enter.

Factor:
- Proximity of AV

State:
- Safe to cross (continue as you were)

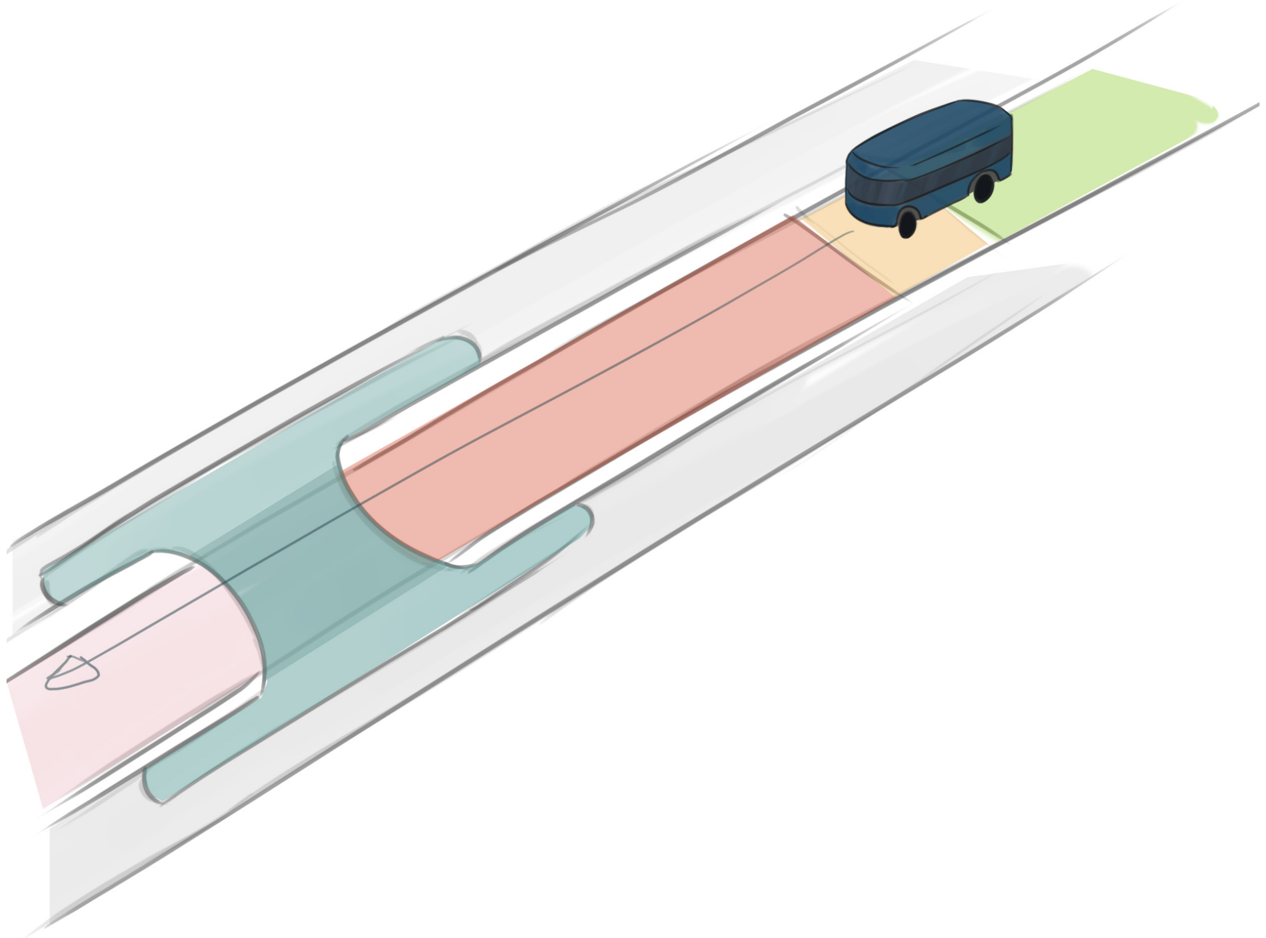


Scenario 0: Base, no interference

The other way around when there is no pedestrians but there are AVs near the crossing, the system will be in its neutral state. This is considered the neutral state as in this case the AVs do not need any physical cues from the system, only the digital signals. The system can then enter in a standby state where it is apparent that it is functioning, for approaching pedestrians, but does lay low to save energy and keep the surroundings calm.

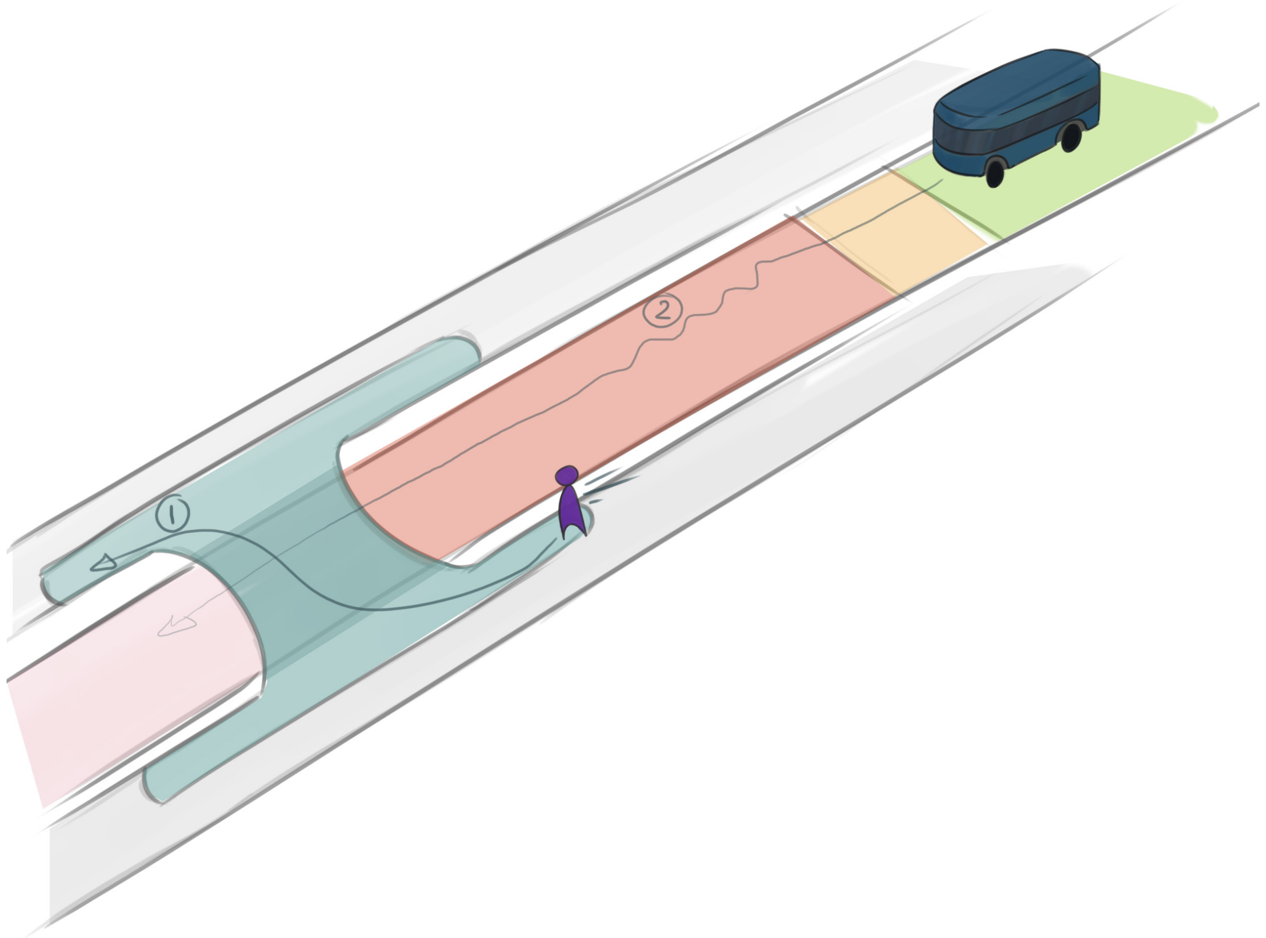
Factor:
- Proximity of pedestrians

State:
- Neutral



Scenario 1: Jogger and Slower Walker
A jogger

A jogger on their morning round returns home and has to cross the main road. They enter the zone at the entry point. The system measures their speed and compares it to the speed and location of the AV. In this case the AV is still in the safe zone of its current speed and if necessary is able to stop before the crossing area. The system calculates that at the jogger's speed the AV and jogger will approach the crossing area at the same time, which causes it to take action and grant a right of way to the jogger. The AV will slow down but does not need to come to a full stop due to early anticipation. The jogger will be notified that they got the right of way, and they can safely cross the road. The jogger can continue at their pace and cross the road after which the AV will pass the crossing.

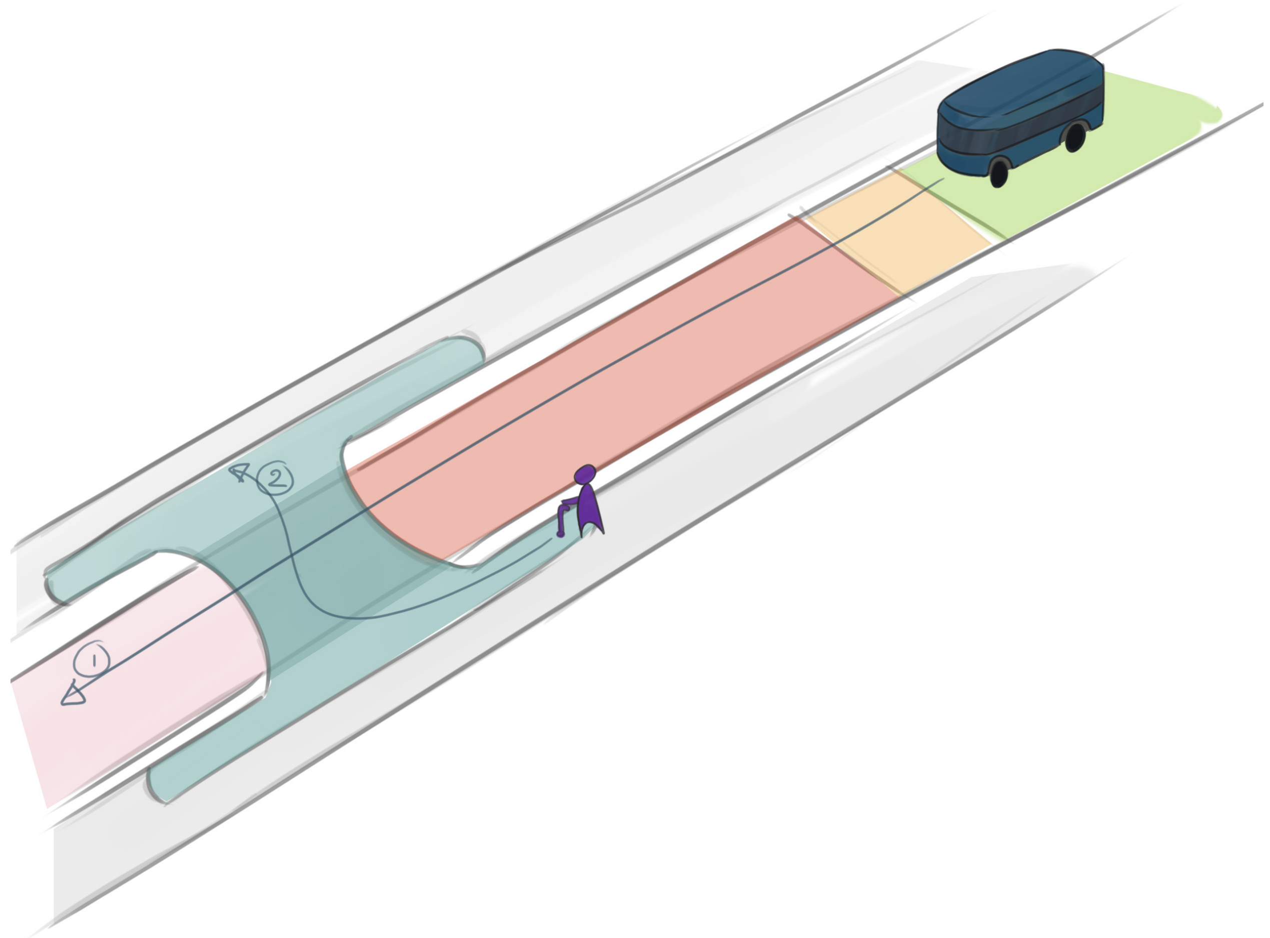


Scenario 1: Jogger and Slower Walker
An elderly on a stroll around the block

An elderly pedestrian is taking a stroll around the block and decides they want to cross the road to go to the grocery store. As they enter the crossing zone, the system registers their speed but also the speed of the AV currently driving close to the alert zone. The system calculates that the actors will not collide on the crossing area if both continue at their current speeds. However, in this case the AV can pass the crossing area before the pedestrian reaches it since the pedestrian's speed is lower. Therefore the AV will be allowed right of way first and will pass by before the elderly pedestrian reaches the crossing area. The pedestrian will be notified that they can continue walking. Once the AV has passed, the system will show the pedestrian they now have full right of way. None of the actors had to wait unnecessarily in this scenario.

Scenario 1

Factors:
- Speed of the pedestrian
- Speed of the AV (translated into a location based approach, is more a response to the others)
- Location of the AV (dependent on the speed of the AV how it matters)



This scenario forms the basis of the rights management model where the right of way is granted based on possible collision and the least amount of unnecessary waiting. This means that the AV will sometimes be allowed to pass before the pedestrian instead of making the AV wait for the pedestrian to approach the crossing area and then cross.
This model is thus highly dependent on the speed of the pedestrian and the speed of the AV. The speed of the pedestrian is highly personal and can vary from each pedestrian to the next. While the speed of the AVs are usually more constant and precisely known to the system. This allows to create certain location zones based on the speed of the AV and its ability to brake or need to anticipate. The names of these zones (figure 4) were inspired by zones defined in the paper by Li et all. (2018). They describe three zones for the AV based on its speed and ability to brake for a pedestrian who is going to cross.

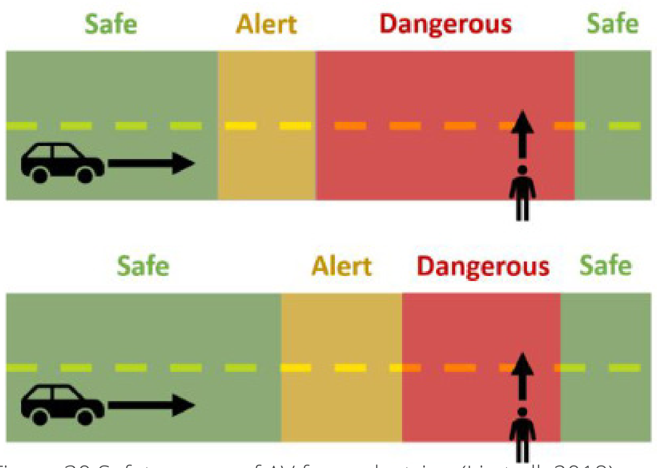


Figure 30 Safety zones of AV for pedestrian (Li et all. 2018)

Dangerous zone: AV is not able to stop in time for the crossing area and is likely to hit a pedestrian (zone is fixed based on AV's speed)

Alert zone: the last moment the AV can brake and make a full stop for the crossing area (zone is fixed based on AV's speed). The AV will still be able to stop for the pedestrian and will do so if they will collide on the crossing area. This zone is located when the AV can still make a comfortable stop taking into account the human passengers. Would the AV not carry any passengers, this zone, moves closer to the crossing area (the dangerous zone is shortened), which gives pedestrians more chances to get the right of way if necessary.

Safe zone: In this zone the AV will need to undertake action if the pedestrian gets the right of way, but this can be limited to slowing down in case of average speed pedestrians or faster pedestrians. (this zone is more dependent on the pedestrian's speed. When a pedestrian is slow the zone is extended). When the AV is in this zone it will always make way for the pedestrian unless the system calculates that the AV can pass the area before the pedestrian enters the area.

Scenario 2: Pedestrian changes plan

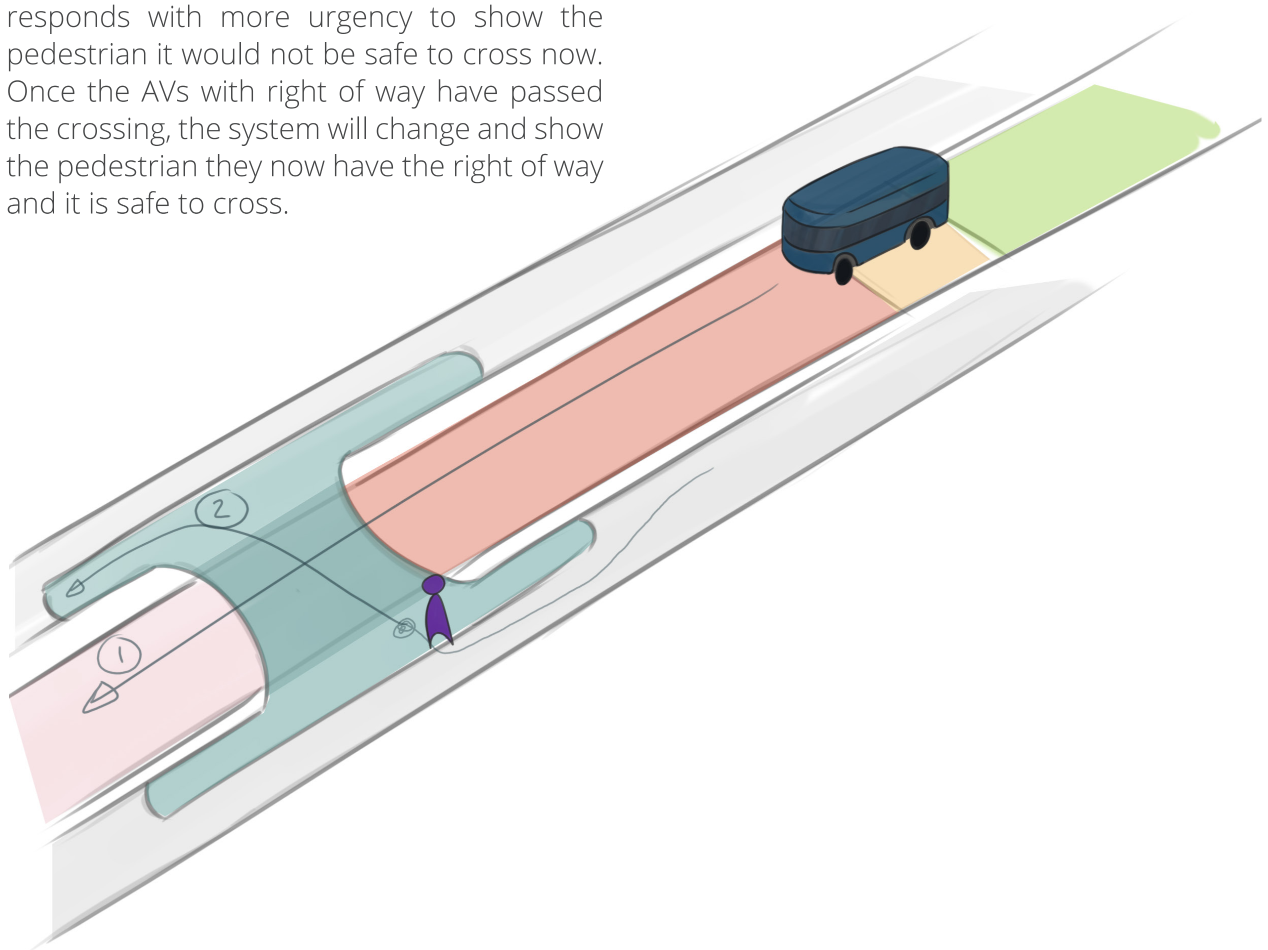
A pedestrian is walking along the main road, at first not intending to cross the road. However, they suddenly remember that they need to get groceries in the store on the other side of the road. They have already passed the entry point of the crossing zone and are thus stepping onto the cross walk at a random point. This point is closer to the crossing area and thus AVs have not been notified of a crossing pedestrian and have been continuing their journey as is. The suddenly presented pedestrian thus cannot just continue their walk. Since they have not been calculated for with the currently approaching AVs, the pedestrian will have to wait until the AVs from the alert and dangerous zones have cleared the crossing area. AVs in the safe zone will anticipate and start slowing down for the pedestrian who is now the first one to arrive at the crossing area and thus gets the right of way. Since the pedestrian needs to be made aware quickly of the situation, the system responds with more urgency to show the pedestrian it would not be safe to cross now. Once the AVs with right of way have passed the crossing, the system will change and show the pedestrian they now have the right of way and it is safe to cross.

Scenario 2

Factor:
- location of the pedestrian

State:
- Not safe to cross

Rights Management:
Based on the safety measures for the pedestrian, the pedestrian will have to wait for the AV. Also as described in scenario 1 a concept of first come first serve counts here where the AV was first to arrive at the crossing and would not be able to comfortably brake anymore.



Scenario 3: Family with energetic child

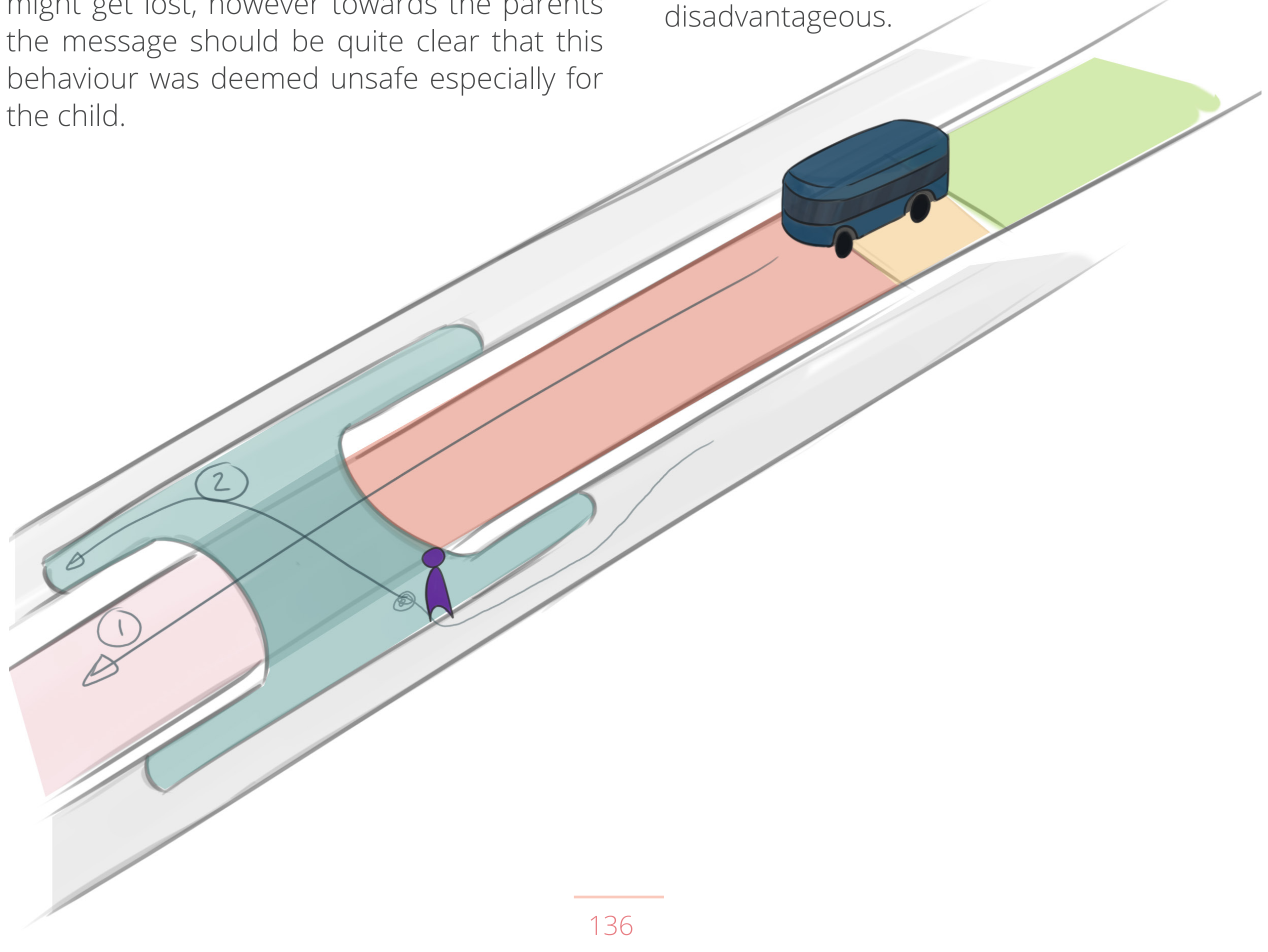
A family is walking from their house to the nearby park, however they do have to cross the distributor road to get there. One of the kids is very excited to get to the park and runs ahead of the family. The system registers a person entering the crossing zone but also registers it as unexpected or unpredictable behaviour (a small person who is not running in a “straight” line). The system alerts AVs that are nearby to approach more carefully even though they might have had the right of way, they are slowing down or even braking to avoid a dangerous situation. Meanwhile the system also responds more heavily to get the attention of the pedestrian. The system might get more directive to make the pedestrian stop and grant the AVs their given right of way. If the behaviour is not changed, the AVs will eventually have to brake (possibly quite sudden) and give up their right of way to facilitate a safe crossing. The system however still shows it is upset, to show that this kind of behaviour negatively impacts the traffic flow and the pedestrian’s own behaviour. In the case of a smaller child this message might get lost, however towards the parents the message should be quite clear that this behaviour was deemed unsafe especially for the child.

A similar situation can occur with an adult who might be unaware of their surroundings (due to distractions or intoxication). In this case the system will again become more upset to get their attention.
This situation is less problematic when there is no AV near the crossing and the pedestrians will get the right of way anyway. In that case the pedestrians find themselves in a less dangerous situation and AVs can slow down and stop well in time for sure.

Scenario 3
Factor:
- Unexpected behaviours

State:
- Danger (high urgency)

Rights management: Although the system responds with care when pedestrians approach the crossing with limited attention to it, a response that gives them full right of way when they normally would not have gotten it would support inattentive behaviour. This behaviour should not be stimulated in traffic and thus will the system first respond to get their attention and then get more upset to show that this person behaves disadvantageous.



Scenario 4: A typical Dutch rainy day

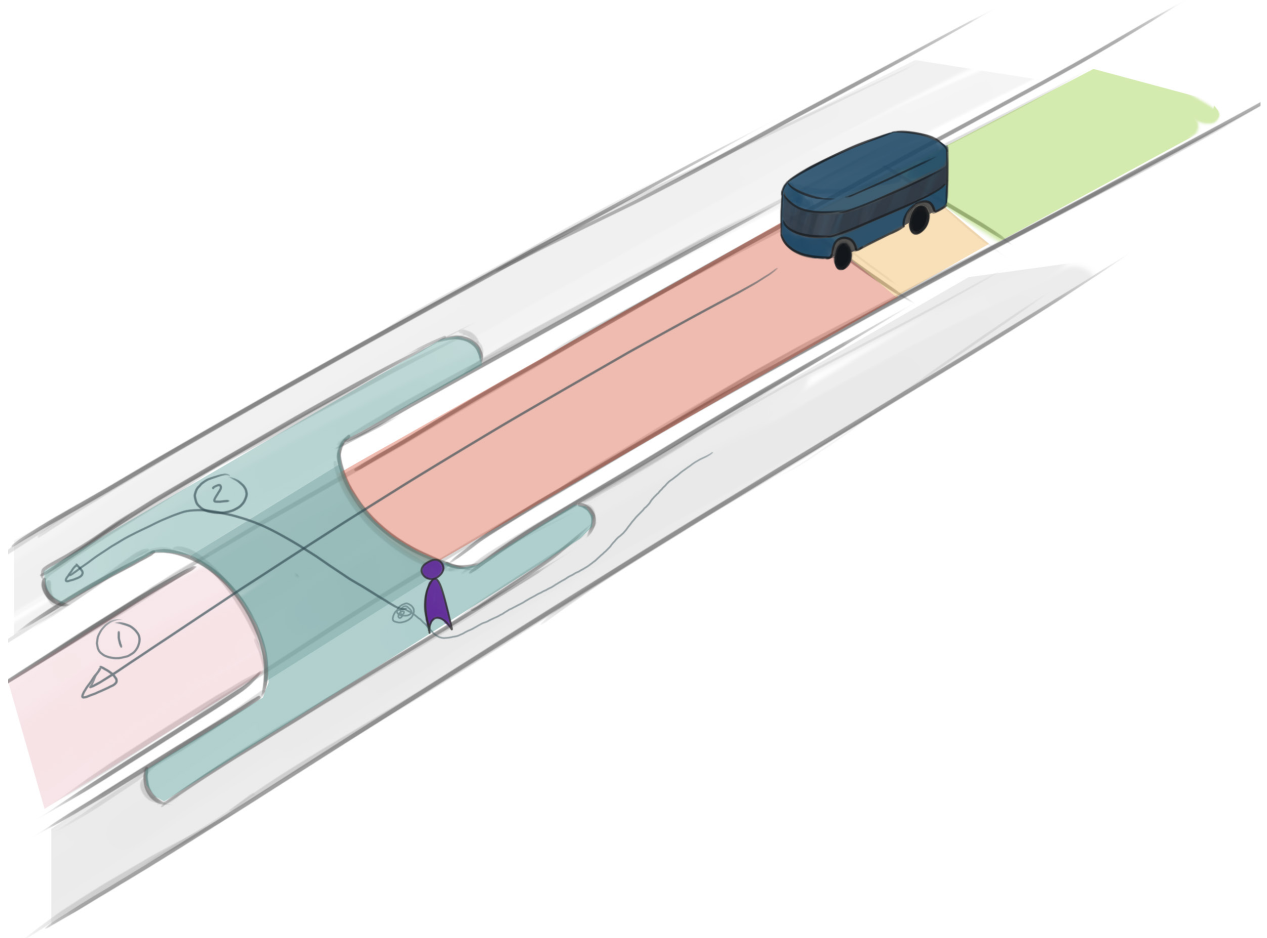
On a rainy day a local pedestrian walks from their acquaintance’s house back to their own just across the main road. Due to the rain visibility is slightly decreased and the temperature has dropped. While approaching the crossing, the system gives the right of way to the pedestrian so they will not have to wait in the rain for the AVs. The AVs will also approach more carefully as cold weather can make pedestrians less careful in their crossing behaviour (Rasouli & Tsotsos, 2020) while visibility for AVs makes it more difficult to detect objects in their way. Here the system plays a more directive role and helps both actors in creating a safe situation that benefits pedestrians as AVs are stopped more frequently. In the case that an AV is in the dangerous zone already, the pedestrian will have to wait for a little bit as crossing then would be unsafe.

Scenario 4

Factor:
- Weather conditions

State:
- Safe to cross

Rights Management: In bad weather conditions (like heavy rain, low visibility due to fog or snow) pedestrians will get the right of way more often so they do not have to wait in the bad weather, as AVs will approach the cross walk more carefully. With the extended tracking area of the cross walk (Section 9.2) the cross walk system can register pedestrians close to the cross walk and alert the AVs to approach more carefully when there are pedestrians within this extended tracking zone.



Conclusion

The ultimate goal of the system is to create a safe but efficient crossing area that allows for more fluent traffic flows. This means that the goal is to make the AVs come to a full stop the least amount possible while pedestrians will be prioritised to cross and also have the shortest waiting times possible.

Each scenario represents a possible situation that could occur at the cross walk and based on these scenarios the rights and rules can be derived. The main factor that influences whether a pedestrian can continue to cross is their walking speed and a possible collision with the AV based on both actor's speeds and proximity. When a pedestrian enters the cross walk at the merge lane and an AV is approaching the cross walk the cross walk's system will calculate if at their current speeds the two actors will collide. If the two would likely collide the system will determine who has to take action based on the proximity of the AV and ability to stop. If the AV has reached the point where it can no longer brake for the pedestrian the AV will be allowed to go first and the pedestrian should be notified that crossing at their current speed would not be safe.
This would be an exception to the standard ruling of the system where it will prioritise pedestrians and alerts the AV to slow down to let the pedestrian cross the street. The scenarios also present some other exceptions where the AV will be allowed to pass before. For example when the pedestrian has a lower walking speed, the AV might be able to pass before the pedestrian. In the case of uncertain behaviour from a pedestrian, the AVs will be alerted to already approach more carefully in case the pedestrian suddenly moves towards the road. When the pedestrian enters the cross walk's merge lane later on – so closer to the road, the possibility for the cross walk's system to alert the AV is limited and it is thus more likely that the AV can stop in time, meaning the pedestrian will be alerted that crossing now is not safe. The system thus works optimally when both actors take their responsibility and show their intentions clearly well in time. Especially for the pedestrian it is beneficial to make their intention to cross known as this usually leads to them being able to continue to cross without having to wait while the AV anticipates by slowing down. Much like the pas-de-deux as described in the interaction vision (Chapter 7.3) where both actors need to be actively part to bring the performance to fruition.

The rights and rules are thus mainly in favour of the pedestrian where they will be prioritised as much as possible, especially when they also take their responsibility they are more likely to get the right of prioritisation. Only when the AV is not able to brake anymore will the pedestrian be informed to slow down or wait as it is not safe to cross.

From these scenarios not only a set of rights and rules followed, they also revealed the different states of the cross walk. These states represent the different levels of danger for the pedestrian and what the cross walk should be able to communicate towards the pedestrian. The following states are indicated as the main ones that need to be visualised:

- Safe to cross (continue as you were)
- Not safe to cross (slow down, or wait near the curb)
- Dangerous (stop walking)

Besides these states the cross walk should also have a neutral state that shows to approaching pedestrians the system is active and working. This can be a simple visual that does not distract others from their activities but does show that it is awaiting pedestrians to cross.
The following section deals with the question of how the cross walk should make these states known to the pedestrian.

9.4 Interaction - Coding the Message

Now that the main states of the cross walk are known, the time has come to design the visual messages the cross walk will use to communicate the safety of the pedestrian. From the research performed in the Chapter Human Perception (Chapter 5) visual communication is the strongest one to use that has the least amount of ambiguity connected to it. Sound could also be used, however as discussed in that chapter, it can easily be confused with surrounding sounds or it is unclear for whom the message is meant.

The visual feedback the pedestrian receives is personal, and based on their walking speed and proximity. By keeping the visual feedback close to the pedestrian instead of creating a visual that covers the whole cross walk, or part of it, the pedestrian knows that the message is meant for them. It is also possible like this for two pedestrians to receive different information. As one could be walking faster or is closer they might receive a safe to cross signal, while another pedestrian who arrives later at the cross walk receives a not safe to cross signal since an AV will pass in between these two pedestrians. Using personal feedback this will be possible, creating the organic and fluent traffic flow that this cross walk aims for.

How this feedback should and will look is the next question to be answered as this can be used directly as input for the visual stylisation of the information.

The interaction between human and system is described by the interaction vision in Chapter 7.3, as a 'pingpong' or pas de deux between the participants. Both need to actively participate in the negotiation for the right of way in order to make the system work (most efficiently). As such, the way the system interacts with the human and vice versa is considered in these terms. Where the pedestrian needs to send out their intention – through stepping on the merge lane, and the system needs to receive it and the signal of the AV, and communicate this back to the pedestrian. Important here is that the message is communicative, not a directive to the pedestrian that strongly directs their behaviour.

The question is thus what and how the information should be delivered to the pedestrians in a way they quickly understand the situation and know what to do without being directed or nudged into doing so. The system takes on a more advisory role in that it relays information to the pedestrians about their own safety in the current situation instead of giving information about the AV's status. This is a result found by Ackermann et all. (2019) where pedestrians responded more positively to advice about their own crossing behaviour rather than being informed about the vehicle's status. This result became especially apparent when rated against the unambiguity or interaction comfort of the coded message. On the factor recognisability it, advice was also rated higher, but the difference was a bit smaller with information. The study differentiated between different kinds of message coding, using textual messages and symbols. Although the differences are small, textual messages were preferred slightly more, but symbols received similar ratings. When it comes to interaction comfort, the symbol advice scored highest.

Generally, there is not yet a consensus on what type of coding should be used in HMI systems when it comes to AV and pedestrian communications (Rouchitsas & Alm, 2019).

It is therefore difficult to conclude from academic research what type of coding would work best in such a crossing area, however the choice was made to continue with more symbolic coding which generally is less limited by cultural differences than textual messages. In terms of informing versus advising, the system will continue to take on a more advisory role towards the pedestrian in giving feedback about their behaviour. The study by Ackermann et all. (2019) also concluded that pedestrians want to get confirmation about them being recognised by the AV.

The hopes are that using motion animations and colours will be able to communicate the personal feedback on the pedestrian's safety to cross. However, there are many possibilities of how these animations should look for the final design proposal, and there are many options to make them more complex, dynamic or seemingly fun. However, the most important task of the animation remains the communication towards the pedestrian. To gain better understanding of what motions can be used in the animations, a survey was designed. The survey and the results are discussed in the next section.

9.5 Evaluation of Animation

The concept uses animated lights to convey a message towards the pedestrian, this message should make the pedestrian aware of their crossing safety so they better understand the situation and what the autonomous vehicle will be doing. In designing such animations, especially for the traffic context where safety is of high importance, it is crucial to better understand how pedestrians would perceive and understand them. This survey was set up to uncover what factors play a role in designing the animations.
Baraka & Velosa (2018) found that colour and motion are good at grasping human attention in order to convey information. In their study flashing lights are found to carry more warning than a solid colour, especially in traffic situations where flashing lights are already known to be a warning (emergency vehicles, traffic lights that are not working as usual). The traditional colour coding currently used in traffic is a good starting point to continue using in different designs as these are widely accepted colour codes within this context already. Insights from this study formed a basis in designing the motion and decide what colours to use for this survey.

9.5.1 Set Up

The used format is an online survey (Google Forms) to reach as many people as possible in a short amount of time. Since there is no specific target group to be using a cross walk, this method allows to find different kinds of people. The survey contains a set of animations visualised through a short video. The colour of these animations have been kept neutral to minimise their influence. In a second part of the survey also colour associations were tested for three situations. Here snapshots of the animation with different colours were used.
The motions used in the animation are a result of a short ideation round that led to a set more complex animations, from which some of the basic motions were derived that actually served as the communicating motion of it. A first input in creating these animations was to base them more on emotions where the system becomes more nervous once the pedestrian gets closer to a collision with the AV, so when it is not safe to cross. The solid colour, flashing and fading animation are based on this principle where it is similar to a breathing pattern that could speed up once the pedestrian gets into a less safe situation. The last set of animations, with a wave coming through is a slightly more complex motion derived from the idea to use more directional feedback.

For the animations, participants were asked to choose an action they would perform when seeing the specific animation, followed by an open question to explain why they would do so. A total of 5 different animations were shown.
For the colour association test, three situations were shortly explained being: safe, not safe and dangerous. In the first situation the pedestrian can continue to cross. In the situation not safe the pedestrian will have to wait for an AV to pass before and in the dangerous situation the pedestrian has come too close to the road while and AV is approaching and the pedestrian needs to be alerted of the danger. Six colours were shown for each situation to find out what colour would be best to be used in each situation. Three of the colours are the standard ones used currently in traffic (green, orange, red) and three are uncommon and are a range of blues (light blue, turquoise, dark blue).
After the situation is shortly explained the participant is asked to pick one colour that they prefer to communicate the situation and explain why they think so.
The survey also asked participants to explain what value they think the cross walk can have for them and if they would value getting extra feedback on the AVs behaviour besides their own.

9.5.2 Results

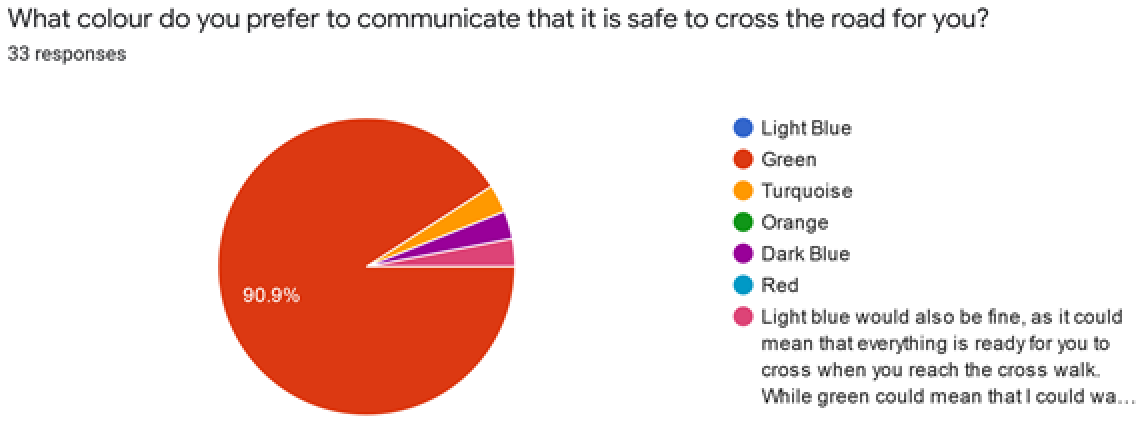
A total of 33 unique responses have been collected. The quantitative data is gathered in graphs, however the most interesting results come from the open questions answers. The answers have been coded, similar to the grounded theory approach, where themes within the answers are found. The found themes are representative of elements that can form the basis of the animation design for each different state of the cross walk and the message it needs to send. Table 7.3 shows the themes for each situation with a couple quotes from the survey answers that are representative of the theme.

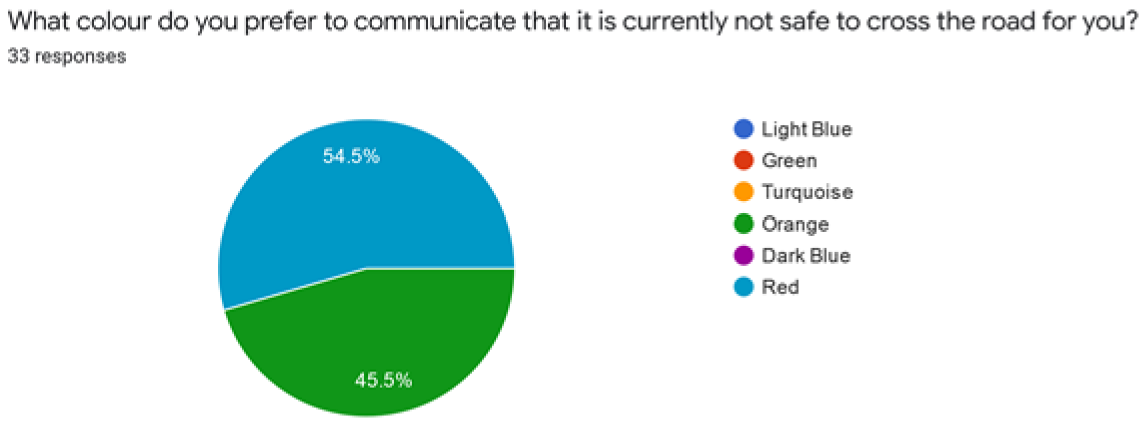
Category	Theme	Quote
Safe to cross (continue walking)	Simple and Calm	The animations flows fluently with the tempo of me walking It looks calm and not like I should panic, so I feel like it would be safe The animation is very gentle and it continues, indicating that i should keep moving
	Follows Pedestrian's Movement	it's motivated by my own movement. Follows me like a shadow. The animations flows fluently with the tempo of me walking
	No Changes	the lights didn't change in any way while walking, it kept moving forward so I'll also keep moving forward.
	Recognition	Because the system recognised me, so I feel like I can cross the road
	Forward Motion	It looks like the animation is trying to push me forward the waving moves forward, suggesting that I move forward as well The white stripe going into my walking direction indicates that i can continue moving
	Green	because green is usually used for positive feedback and also used in traffic already Green is universal for "go" Green is a very calm colour and it is known as a safe or good colour
	Light Blue	light blue because it is calming Blue often used to tell you something is neutral Light blue would also be fine, as it could mean that everything is ready for you to cross when you reach the cross walk. While green could mean that I could walk to the other side right now.

Not safe to cross (stop or slow down	Alerted by Movement	A flickering light means warning to me The blinking seems to indicate a change with more urgency animation seems to be warning of something. It's asking for my attention
	Backward Motion	The white stripe moving backwards looks like it urges me to stop It looks like the animation is trying to push me backwards played too much Mario Cart, but this slows your cart down Looks like I'm approaching too fast
	Orange	Orange feels like 'be wary but don't panic'. It's friendly enough, but still conveys some urgency I feel red is too harsh, maybe like I am making a mistake or do something that is wrong Orange = be aware
	Red	General "Don't" colour when it comes to signs in life It is the same colour as I am used to with traffic lights Catches attention. Stop signs and traffic lights correlate to this same signal for stopping.
Danger	Fast Motions	Blinking fast, very wrong really stopping because this one lights up faster The flashing looks dangerous The fast flickering seems to warn me of impending danger
	Red	Because everything everywhere uses red as a danger-indication and it's therefore become intuitive red normally shows danger Red means STOP! Red is the common colour for danger, flickering means 'be alert.
	Orange	blinking orange

Figure 31 Table of categories and themes with quotes

Although the animations show more differentiation in answers for each animation and what action the participants would perform, a much more generalised result comes forward in the colour association study.





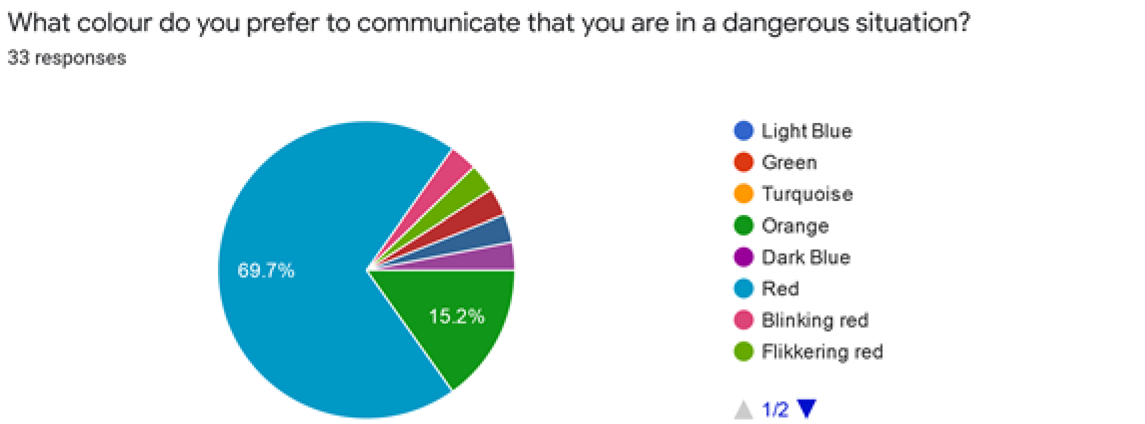


Figure 32 Results of the colour association part of the survey

For the safe situation a vast majority picked green as their preferred colour. In the not safe and dangerous situation the numbers change and the decision is between orange and red for both situations. Although red has a slight majority over the orange for the not safe situation, red gets a firmer majority of the preference when the situation turns dangerous. For this situation four participants added their own answer, all saying in this situation the lights should be blinking red to create a difference between the two situations.

For the question 'What do you feel this cross walk (through the animations) is trying to do or be?' a majority answered that the cross walk is directing their behaviour, however in their answers to why this is, no one used words like forcing or steering etc. rather they do explain that the cross walk informs them or helps them.

The last question explored a new type of feedback that so far had not been integrated within the feedback of the cross walk. It concerns with feedback on the behaviour of the autonomous vehicle and if this would add value to the decision to cross or not.

From the participants, 70% says that it would be of value to them as it can show that the system has also recognised the vehicle or what its intentions are or creates extra awareness. However concerns expressed show that it can also be confusing as to what this information is actually telling you, or that the vehicle is already so close it does not matter as much anymore.

9.5.3 Discussion

The results found concerning the flashing animations and the answers added in the colour part of the survey (blinking red) are results that were also found in studies performed to understand urgency of colours. Blinking colours were found to carry more urgency than just a solid colour, even blinking orange would be more urgent than solid red (Li et al., 2018). This clearly shows that people generally associate blinking with a sense of danger or unsafety.
The themes presented in table 7.3 represent some elements that can help to create the appropriate type of animation to convey the right message towards the pedestrian in certain states of the cross walk system. Below, these themes will be discussed concerning the three main states of the cross walk system.

Safe to Cross

In the state 'continue to cross' the message should convey that it is safe, or will be safe, to cross when the pedestrian reaches the road. Elements presented in table 7.3 show that a calm and simple animation without changes in its pattern is able to carry this message. However the addition of colours is an important factor in understanding the animation better. The colour indicated as being the one when it is safe, is green. This is to be expected from the contextual associations. However, there are also arguments to go for a light blue in this situation. One of the main reasons being that it will be easier for people with colour blindness to distinguish between the different colours.
Deuteranopia (green-red blindness) is the most common one affecting about 1 in 12 men and 1 in 200 women in the world (ColourBlindnessAwareness, n.d.). This means that these people cannot see the red parts of a colour. This makes that reddish or orange colours are perceived more as green while the green can also look more on the orange or brown side. This means that these two colours come very close to each other in how they are perceived making it difficult to differentiate. If green were to be used as safe to cross colour, people with colour blindness would

experience it as more orange, assuming it is never safe to continue to cross in the beginning. Using light blue instead of green for the safe to continue state thus creates a visible difference as blue can be easily seen by most common types of colour blindness.
Light blue is also a generally calming colour that can help convey a calm feeling to the pedestrian during their crossing manoeuvre.
Combining both a calm, simple animation with a calming colour like light blue is likely to be understood well as a safe situation where the pedestrian can continue to cross.
This state is also the main one pedestrian should be seeing and should thus not be too obtrusive. Pedestrians should be prioritised, meaning that this animation is most often seen which does not need to be attracting too much attention of the pedestrian in a normal situation.

Not Safe to Cross

This situation, when the AV will not be able to stop in time for the pedestrian, whom will thus have to wait a moment or slow down, will be made aware of this the moment they step onto the interactive part of the cross walk. In this state the system does not direct the pedestrian to stop walking or slow down, rather it informs the pedestrian of oncoming traffic that they should wait for to keep safe. To make the pedestrians aware of a changed situation, the animation can use a different colour and if more attention needs to be drawn the animation could initiate more movement.
From the survey, the blinking animations resulted mostly in people saying that the animation is trying to catch their attention, or that they will be more careful because of it. This is similar to results found by Baraka & Velosa (2018) who found that a flashing colour holds more urgency than a solid colour.
This indicates that with motion incorporated into the animation it will be able to reach pedestrians and make them aware that the situation is not as usual.
The backwards motion makes most people slow down, or even feeling like they should completely change their direction. Since this animation is more obtrusive it does catch people's attention however also seems to be more confusing as to what the animation itself is trying to say more.
Also here the choice for the colours is to be expected based on previous research into colour associations and the contextual use of the colours. Orange does have a slight preference over red because most participants do see a difference between the Not Safe and Dangerous situation – the situation explained in the survey right after. Orange is said to be warning but not yet indicating the impending danger that red could mean. There are also votes for using red here as it does indicate that something is dangerous, aka not safe, however some then continue in the next question explaining they would like to see the red light flicker when the situation turns dangerous.
This state thus also would mainly use the colour to explain the situation while the animation serves as a way to attract attention towards it.

Dangerous

The difference between the state dangerous and not safe is slightly more difficult to subtract from the survey results, however in some responses the word danger is used explicitly to explain that the faster movements of the animation indicates danger. The animation where the tiles start blinking quite fast are described more than others as danger or danger is impending. This does give an indication that with a faster motion in the animation danger can be conveyed. Here the colour plays a big role, where red is described as the colour to indicate danger as red is used in almost all other contexts for this meaning as well. Using a red, faster moving animation would likely convey a message of danger ahead towards the pedestrian.

Here some participants mentioned by themselves that the red lights should be flickering to indicate that the situation has turned dangerous and to be alert. The colour also can indicate one should stop while the other colours, even orange, do not hold the same value. Using red is also mentioned to be a colour that implies you did something wrong, and can thus be used as a last resort to show a pedestrian they are disrupting the traffic system with their current behaviour whilst putting themselves at risk.

Concerns

Some themes also represent issues that need to be solved as they reveal ambiguities in the animations.

For example the faster flashing animation led some people to answer they would actually speed up to keep up with the pace of the animation.

"It feels like the lights flicker faster now and change in speed so maybe I should be speeding up too?" (P. 27)

Or the fading which besides had participants confused about why it would actually start doing that, it also seemed to some that the system had lost its connection or could not recognise the pedestrian anymore.

"Not sure what blinking means, but it surely wants to tell me something" (P.7)
"It seems that it has lost connection" (P. 3)
"I'm not sure if the system recognised me" (P.14)

The waving animation get another kind of response where it is associated with a science fiction machine that is scanning the pedestrian.
"It feels like I'm being scanned by a sci-fi machine" (P.13)

In general some participants mention that the animations are quite annoying and can be distracting, especially the ones that have effects beyond just following the pedestrian.
Some of these concerns may come from not understanding the underlying reason as to why the cross walk shows a certain animation. By using the right colours, the colour can be more explicit in explaining the situation which can clear up the confusion surrounding the animation's motion.
A last concern voiced is about the placement of the animation underneath the pedestrian.

"These animations are under my nose, behind the screen of the smartphone. But I still walk with my vision forward, without phone." (P.32)

They indicate an issue that has been given thought as to how far the animation should extend in front of the pedestrian so they can see it from their peripheral vision. In his book, Robert H. Spector explains that the peripheral vision extends 75degrees downwards when a person looks straight ahead (Spector, 1990). Although not everyone's vision is the same, this can be used as a guideline when deciding upon the final shapes and dimensions of the animations.

9.5.4 Conclusion Evaluation

The animations itself have some elements that can be used to communicate certain messages, however their ambiguity due to the lack of explicit communications based on predetermined associations makes it difficult for everyone to understand them the same. Colours are able to more explicitly communicate a message especially when using colours that are known within the context. Animations are better at grabbing attention or showing that there is a different level of urgency while the colours can show what this new urgency means. Changes in the animation increase the awareness of the pedestrian and attracts their attention towards the situation at hand. Therefore animations can be used to increase the level of urgency without having to change the colour immediately. It thus represents almost an in between stage of going from safe to not safe to dangerous.
For the design of the animations these results indicate that the motions should be kept simple and to a minimum to avoid confusion about the intentions and possible different meanings. The colours will be the main indicators for the level of safety to cross for the pedestrian as these are more easily understood by a wider public due to their existing associations. It is likely that understanding the information provided by the cross walk requires some learning to correctly read the message of the animation and colours.
Following the results from the survey a final set of animations has been composed that will be presented in final design proposal.

9.6 Conclusion

The main goal of this chapter is to show what the major considerations were during the development of the concept into a more detailed design proposal. The most important one being the exploration of the rights management system that prescribes how the cross walk system will operate and what kind of data it needs to function. The data it will collect is the walking speed of the pedestrian and provide feedback based on how safe it will be for the pedestrian to cross. As mentioned often in this chapter, the prioritisation of pedestrian crossing is the main aim of the cross walk, while maintaining an efficient traffic flow for the AVs. Using pedestrian tracking and anticipated alerts for the AV, the amount of unnecessary waiting for both actors should be reduced. The information about the AV's behaviour can be sent directly to the AV and does not need to be visual. As opposed to the pedestrian who will receive physical feedback, in this case visual is chosen, to make better sense of the situation at hand and respond in a more efficient manner. This visual feedback will consist of a set of motion animations and colours projected by the lights integrated in the tiles on the ground. These motion animations will be used to indicate a level of urgency while the colour more explicitly explains the level of safety for the pedestrian. Based on this information the pedestrian can make a decision to adjust their behaviour if necessary, or will be able to continue and cross without having to negotiate with the AV before being able to cross. Most importantly is that this cross walk system allows pedestrians to be an active part of the communication bubble where they can make their intentions explicitly known instead of being told to do based on what the AV will be doing.

Chapter

10

Final Design Proposal

10.1 The Final Design

The cross walk benefits both the pedestrian and AV where the pedestrian becomes an active actor in communicating with the AV and the infrastructure. It moves away from systems that only create a way for the AV to communicate towards the pedestrian to make up for the lack of a driver who can communicate. The pedestrian can show their intentions more explicitly, letting the AV know what the plan on doing. The cross walk functions as a translator in the negotiations between the two actors, where it brings their two different communication bubbles together in one that both can understand individually. It aims at creating a harmony between the two, rather than one directing the other's behaviour.

The pedestrians will receive visual feedback based on their personal safety to cross, while the cross walk transmits a direct signal to the AVs that shares what the AV should be doing. The pedestrian's safety to cross is based on their walking speed and proximity to the road curb compared to the speed and proximity of the AV to the cross walk. The cross walk will calculate if the two will collide, and based on that decide what action should be taken.

The cross walk will calculate an average walking speed for the pedestrian based on data it gathered on the extended tracking area where only the pressure sensor grid is present on the tiles, but no lights. Once the pedestrian enters the actual cross walk, the system already knows their walking speed and can immediately calculate for a possible collision with oncoming AVs. In most cases the AV will be alerted of the pedestrian about to cross, and it will slow down or come to a stop. In exceptions the AV will not be able to make the stop when it is already too close. In that case the pedestrian will receive a signal that crossing at the moment is not safe and they should let the AV pass before entering the road.

Pedestrians can actively participate in traffic, even when vehicles are no longer driven by humans, they are able to make their intentions known to the other actor instead of only being able to react to an AV that tells them what to do at the last moment. By not using artificial intelligence to predict their behaviour and base the traffic flow on those predictions, the pedestrian keeps a sense of control about their own intentions and behaviour. They can consciously make the decision to do versus being told what to do based on an algorithm that aims to optimise their behaviour.

Due to the early registering of the pedestrian on the merge lane, an AV will be able to anticipate their behaviour well before reaching the cross walk. Adding the fact that the cross walk remained a designated location adds to a comprehensive infrastructure that benefits the AVs in navigating the city. The cross walk also helps in registering pedestrians with the intention to cross which can be difficult for an AV to do. The ability of the AV to anticipate well in advance creates a calmer ride for its passengers, does not always need to come to a full stop which saves energy and creates a safer environment for the pedestrians. The cross walk takes away some of the difficult to solve tasks an AV faces when they will roam our streets. Whereas the current infrastructure would require the AV to do that all by itself internally, creating an even bigger technical challenge to be completed for AV developers than it already is.

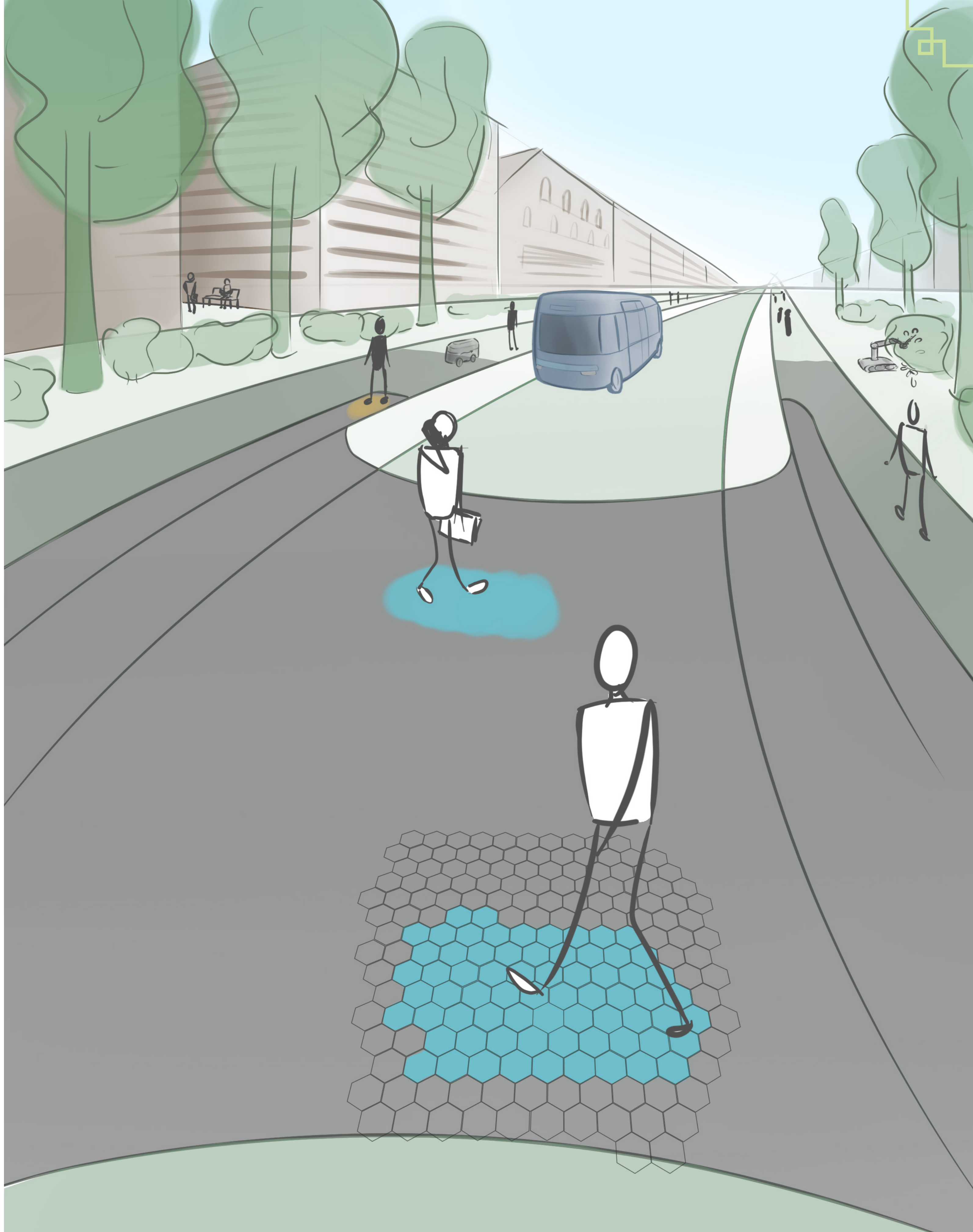


Figure 33 Final impression of the design in context (not all tiles were drawn in for clearer overview of image)

The personal approach of the cross walk, where each pedestrian is registered individually, they can get information that is clearly meant for them, while also being able to create a more organic traffic flow. AV and pedestrian can follow each other quickly as the AV can proceed once the cross walk is cleared, instead of having to wait for a timer to go off. The traffic pattern becomes more dynamic which plays into the strengths of the AV's ability to receive data and respond accordingly.

Creating urban designs that serve the pedestrian while keeping in mind the AVs needs, will allow for a more walkable city while creating a beneficial environment for the AV to come to fruition. This cross walk may not yet be a finalised design that can be integrated in our infrastructure, however it shares a vision for a future with AVs and how using the city as a part can play a vital role in creating AV and pedestrian friendly designs and systems. This cross walk system aims to create a more efficient traffic flow both for the pedestrian and AV where the unnecessary waiting times are reduced as much as possible while keeping everyone involved safe.

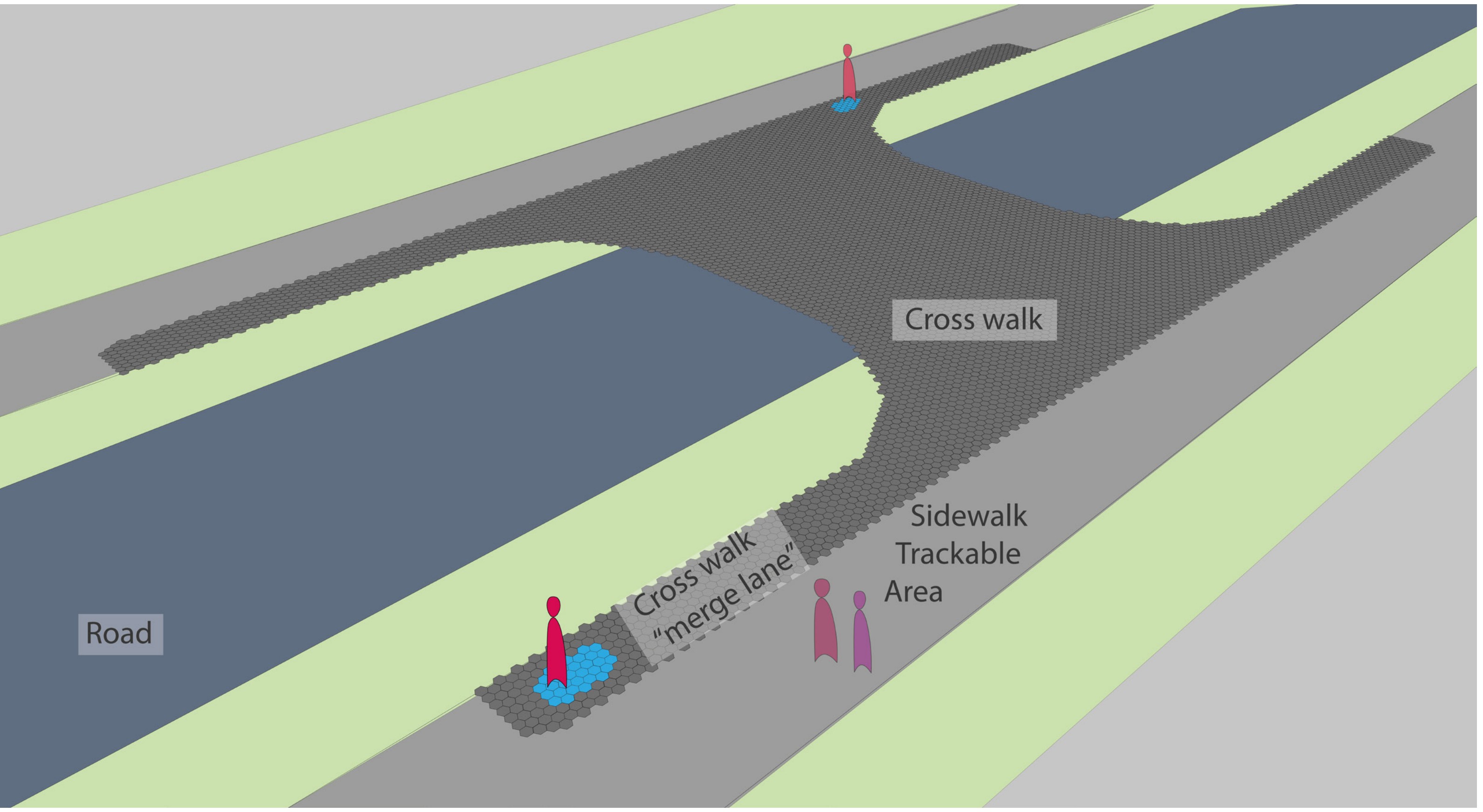


Figure 34 Overview of the cross walk with labels indicating different areas on the cross walk

10.2 The Animation

The visual feedback the pedestrians will receive, will be done in the form of clean animations visualised by lights integrated in tiles of which the cross walk is made up. The animations are kept to a minimal motion pattern as to create less confusion about its meaning. Rather the colours play a main role in communicating the safety of the pedestrian to cross. The colours used are all but one the default colours used in traffic. The orange and red indicate not safe (be aware) and danger respectively. While often green is used to indicate safe, or go, it was chosen to work with a light blue. The main reason is the complications green create for people with colour blindness. They would perceive the green as orange which means they would always assume that it is not yet safe to cross. Light blue, or blue in general, is also a calming colour and since the pedestrians will be able to cross without having to wait, a calm colour represents it is alright.

The motion still used in the animation is a blinking motion where the lights will go off and on with a slight fading. This increases the level of urgency as the system tries to grab the pedestrians attention to be aware of the situation. However, this is only necessary when the pedestrian has not slowed down or is stopping when an AV is approaching the cross walk and will pass before them. Therefore, additional zones have been added that indicate when the animations will change into higher urgency. These zones are not physically present on the cross walk, but are represented through the change of animation from a solid colour to the blinking motion.

The zones are represented by the orange and red square. In the case that the AV will not be able to stop in time for the pedestrian, the AV will be allowed to pass before the pedestrian, meaning that the pedestrian might have to slow down or wait for a short moment. In this case they will see orange lights encircling them when they enter the cross walk. If the pedestrian does not show a sign of being alerted, like slowing down or stopping, the animation will start to blink when they reach the orange zone. If they continue to walk and enter the red zone the animation will turn red and start blinking faster in order to grab the pedestrian's attention to prevent them from waking onto the road.

To more precisely explain the animations, a simplified illustration of the cross walk has been made that shows the three different levels of safety based on the behaviour of the pedestrian.

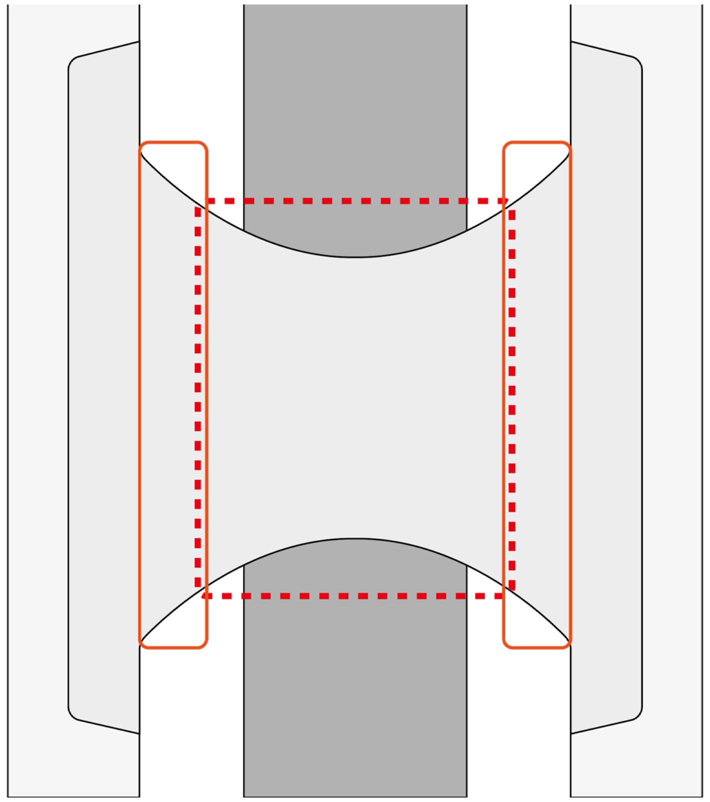
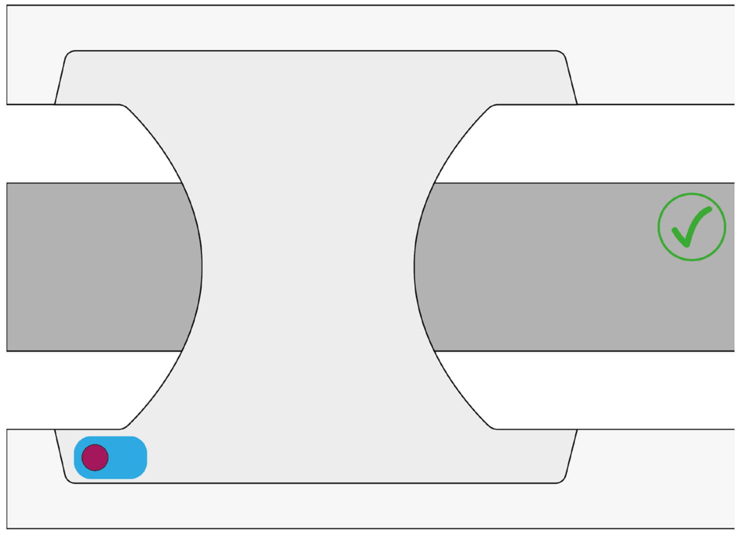


Figure 35 Cross walk top view, with red and orange rectangles indicating the different zones for the animation changes

10.2.1 Safe

When there is no AV approaching or the oncoming AVs are able to stop, the pedestrian will receive feedback that is safe to cross when they reach the road (1). They will be shadowed by a light blue light informing them of this. Any AV that approaches will slow down or come to a stop for them and let them pass the cross walk (2). Once the pedestrian has cleared the road, The AV will proceed to pass the cross walk. And as the pedestrian arrives near the end of the cross walk, the lights will fade out (3).



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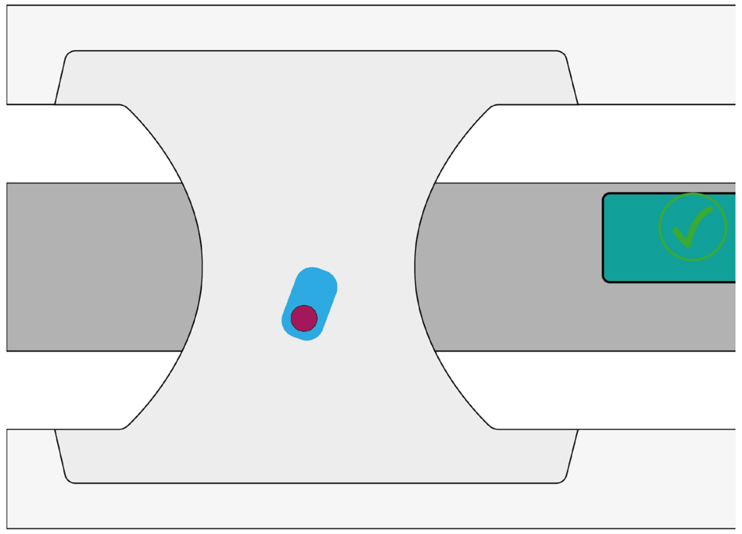

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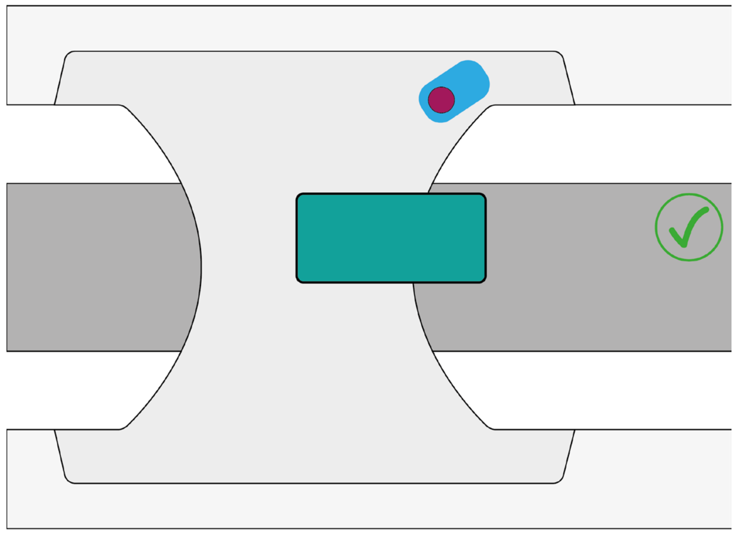

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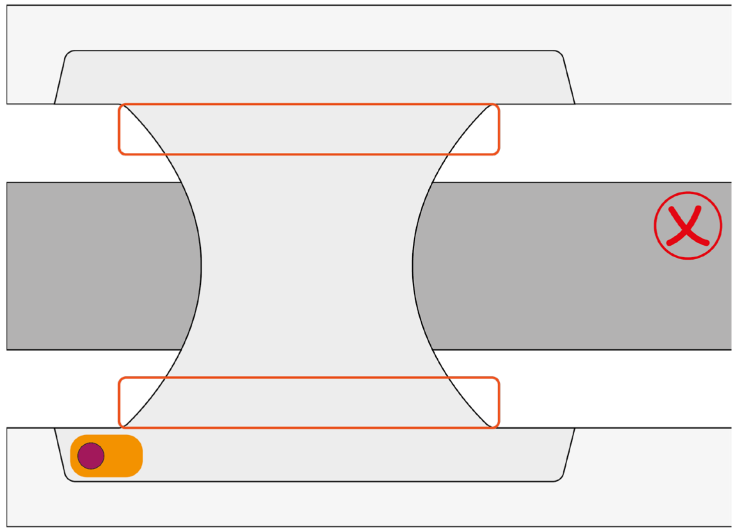
10.2.2 Not safe

In the case that the oncoming AV is not able to stop anymore for the pedestrian, the pedestrian will receive feedback which indicates that is not safe to cross and they should let the AV pass by first. Orange lights will follow the pedestrian (1). The pedestrian has not slowed down once they reach the “orange zone” which initiates a blinking motion pattern in the lights (2). The lights try to grab the pedestrian’s attention that they are putting themselves in harm’s way if they continue. The pedestrian sees the light blink and decides to stop walking. The animation will go back to being a solid colour as it recognises the pedestrian does not need the additional level of urgency (3). Once the AV has passed the cross walk, the pedestrian can continue to cross. The lights will turn light blue to indicate that it is now safe to cross and any new oncoming AVs will wait for them to cross (4).



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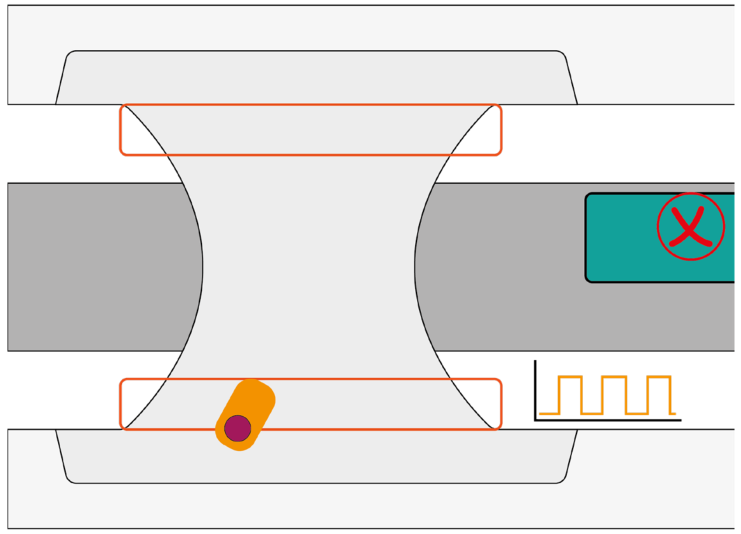

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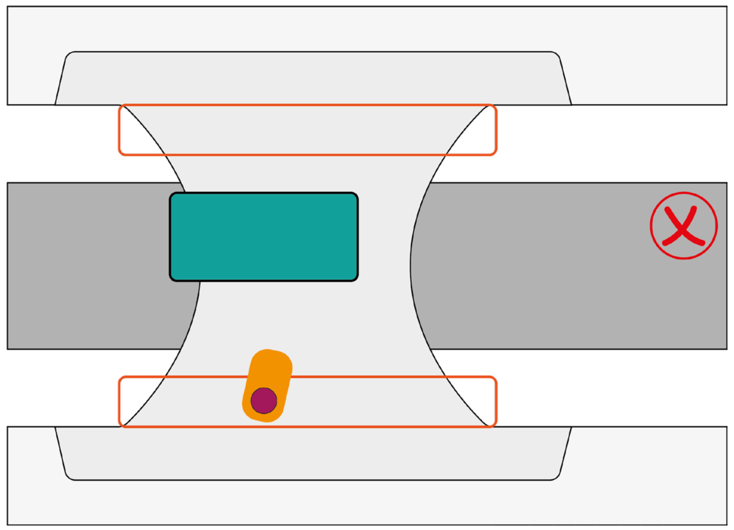

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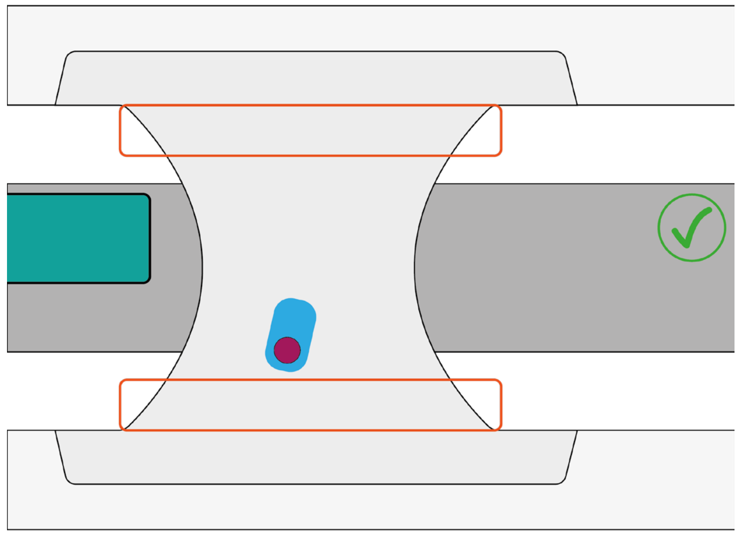

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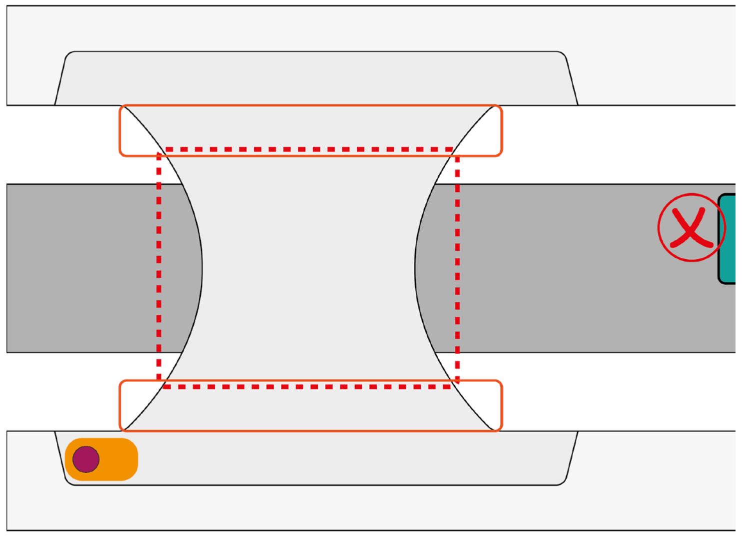
10.2.3 Danger

The situation starts the same as the 'not safe' scenario, where an AV cannot stop for the pedestrian (1). In this case the pedestrian continues to walk even once the orange lights start to blink.(2) The pedestrian enters the red zone that starts around the curb. The lights turn red, the area the lights cover increases and the blinking speeds up (3). The cross walk has also sent an alert to the AV to approach more carefully and prepare for an emergency brake or evasive manoeuvres to avoid the pedestrian depending on what they will be doing. If the pedestrian steps back into the orange zone, or stops walking while still on the curb the lights will narrow down the area covered again and the blinking will become slower, however the colour will remain red to indicate that the pedestrian has shown potentially dangerous behaviour and the system is still on high alert(4). Eventually, in this case, the AV passes the cross walk after which the pedestrian receives a safe to cross indication and can continue to cross the road (5).



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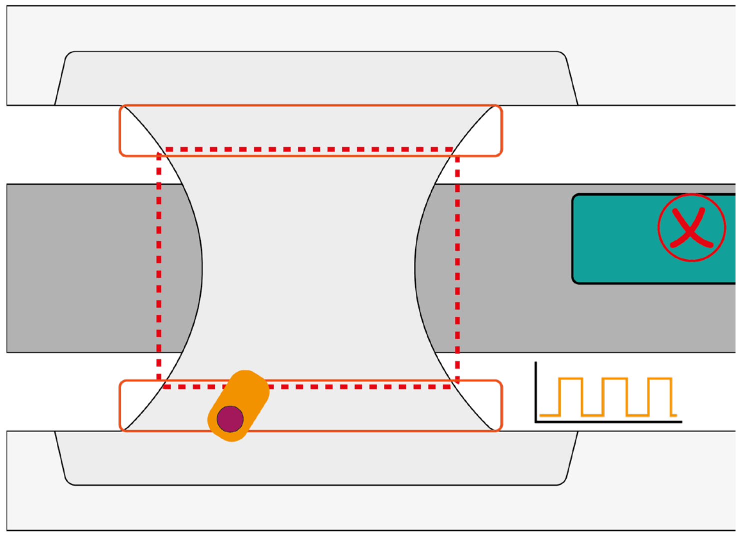

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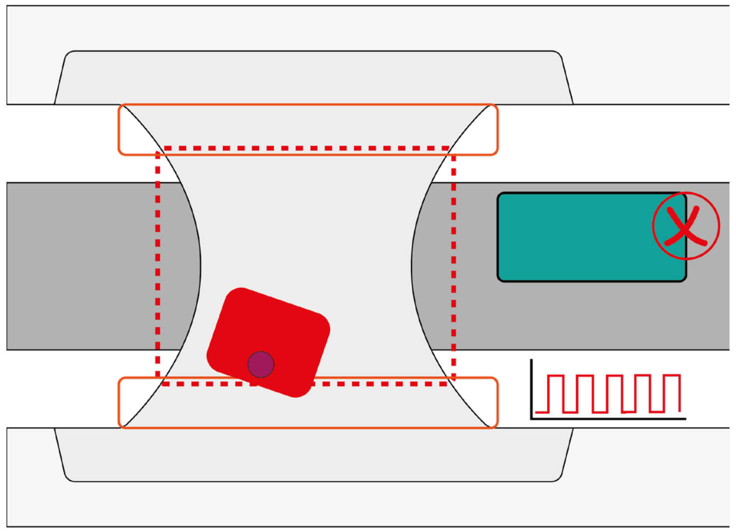

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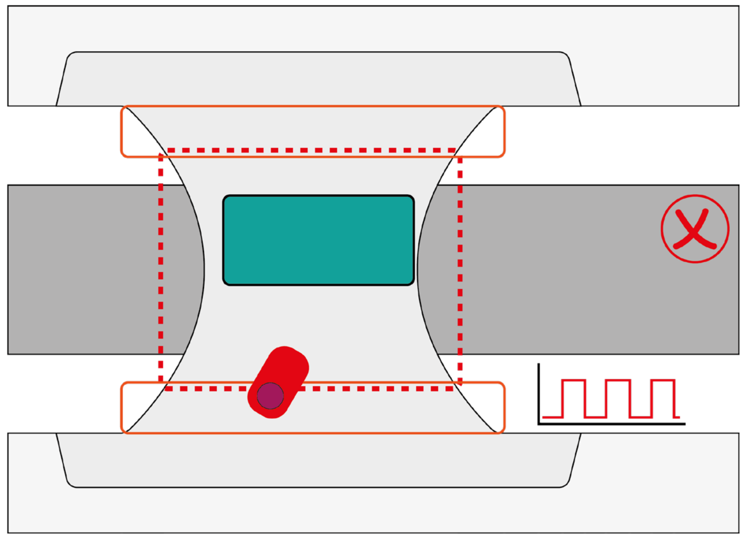

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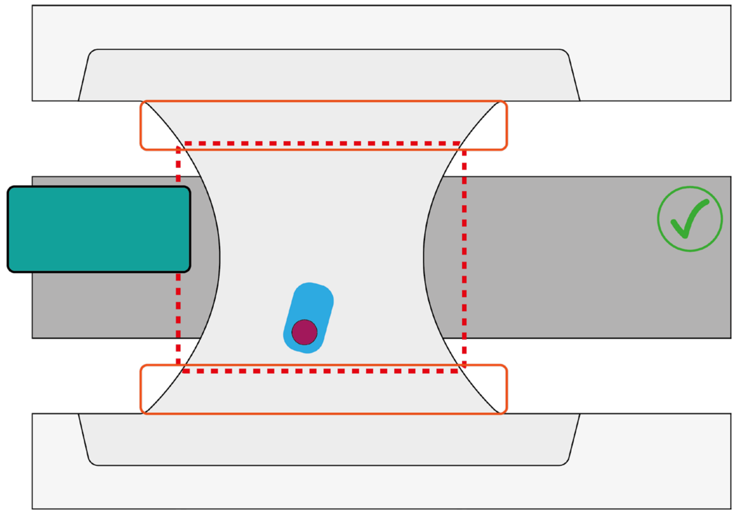

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10.3 Features

10.3.1 Tiles

The cross walk is formed by a series of tiles. These tiles allow the cross walk to be adaptable to different street lay outs and dimensions. As such the cross walk can be integrated in the street design at any location. Using this cross walk is most efficient in streets with higher driving speeds for the AV and a larger number of pedestrians and AV that roam around. It was designed for such situations in mind, where negotiations between the two actors become more difficult.

Each hexagonal tile consists of a couple main features. The top is covered with a pressure sensor matrix that can track and register the different pedestrian on the cross walk and extended tracking area. The pressure sensors form a grid integrated in transparent material on top of the tile that obscures the direct light of the LEDs underneath, making is less blinding when looked at. The tiles all have connector features that should be properly sealed from weather and moisture. The LEDs form a matrix underneath a layer of tempered gorilla glass. The LEDs are RGB LED meaning they can create any colour possible. Each tile consists of a matrix of LEDs that will behave similarly, creating a solid hexagonal shape in the animation. The pressure sensors and LEDs are operated by a processor in the tile that collects the data of the sensors and sends that to the main processor, while it can receive data for the LEDs to create the animation. For parts of the tiles that do not need to be able to withstand the forces of a vehicle driving over it, is would be recommended to use recycled plastics and materials whenever possible.

The tile grids are all connected to each other and operated by a central processor that uses algorithms to decode the different pressure footprints to distinguish different pedestrians and calculate their average speed. This data is then used to calculate for a possible collision. Based on these calculations the processor sends an order to the tiles to light up in a certain colour or motion pattern.

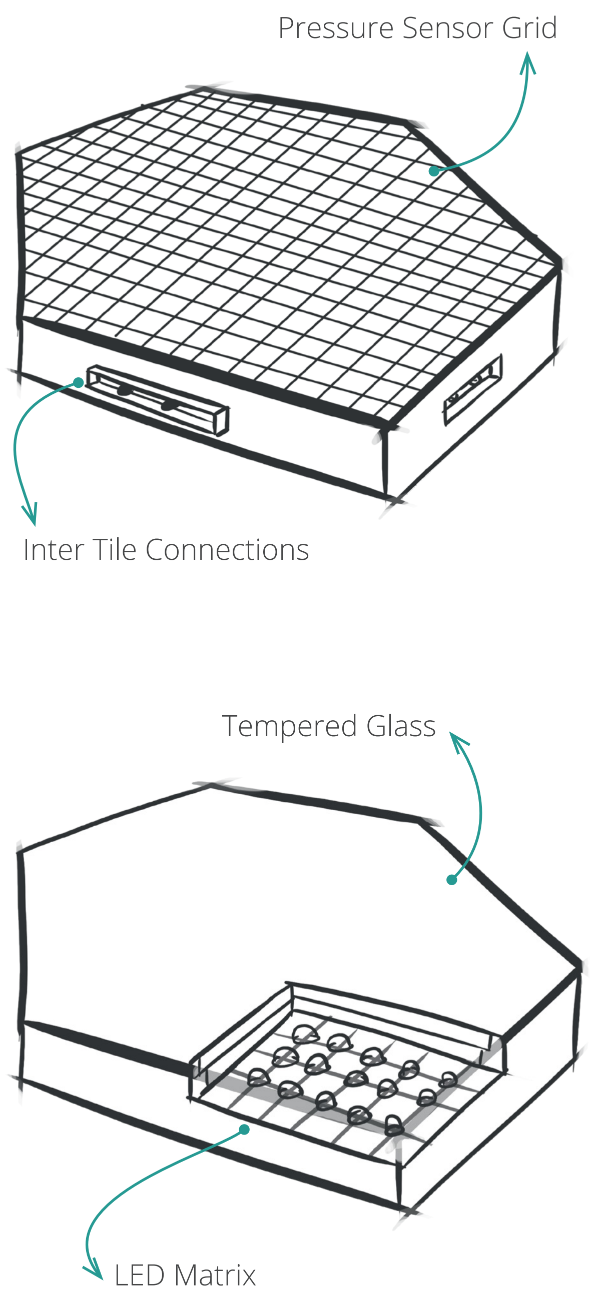

Figure 36 The tiles, simplified with main components

10.3.2 Lay out

The lay-out of the cross walk is determined by the merge lanes that need to extend a certain distance from the road curb to facilitate the early tracking ability and AV anticipatory behaviour. The length of these merge lanes can be estimated using a simplified calculation of brake distance and time of the AV and average walking speed of pedestrians. For the AV to come to a full stop from 50[km/hr] it would need about 30[m] to do so following the following formula:

d= (Vstart/a)*(Vgem)

Where a = the deceleration. This is determined at a comfortable deceleration rate of 3.4[m/s^2] (Greibe, 2007).

Vstart is 50[km/hr] which is 13.9[m/s]. Vgem can be calculated by Vstart/2.

Filling in this formula gives a braking distance of 28.4[m].

Since the AV has a neglectable reaction time, this is the full distance it will need to slow down. It costs the AV 4.1[s] to slow down. In that time a pedestrian with an average walking speed of 1.4[m/s] can cover a distance of 5.7[m]. This means that from first registration of the pedestrian until they are at the curb will require a length of 5.7[m] at which the AV would still be able to stop.

This is however a simplified formula and does not take into account weather or road conditions and different sizes of AVs. Therefore a more specific model should be used to calculate the exact dimensions needed. However, this calculation does estimate what dimensions the cross walk will be to facilitate an efficient traffic flow.

10.4 The Next Steps

There is still much to be done before this cross walk design can be put into the real world, however it has made a start in showing what possibilities exist beyond the eHMI systems mounted on the AV to try and facilitate better understanding of the AV.
Most importantly, the interaction and the animations need to be carefully tested to make sure these are understood correctly by at least the majority or people at first try. Such a new system does require some learning to be involved and thus implementing new interactions like these need to be carefully managed. The animations still find themselves in a first phase of development at this moment in time and require extensive testing to validate their exact form. A first next step would be to create a Virtual Reality environment where participants get more sense of context than with using images or videos. Creating the VR set up allows to more extensively test the shape and motions of the animations where actual AVs seem to be approaching giving the animations more contextual references.

Following these researches, the physical part of the cross walk and the software behind it also need to be developed. During this project the main focus was the research into the interactions and developing a first iteration of the interaction. Therefore the technical detailing of the tiles remains on a surface level. These tiles need to be able to withstand immense forces when the AV drives over them. Such designs will have to be performed by engineers specialised in civil or mechanical engineering to ensure the tiles remain intact and safe during use.
The electronics, both the pressure sensors and LEDs are areas where a lot of development is always happening. It is assumed that pressure sensors will be able to be integrated in the top layer of the tiles while sustaining years and years of use without loss of sensitivity.
The software behind the cross walk is of utmost importance because without it, the cross walk would not be functional. The algorithms for this cross walk will have to be developed by skilled engineers and also be rigorously tested to make sure there are no flaws of bugs before it can even be used in a real life setting. The algorithms should be fool proof as it operates in a high stakes context where minor mistakes could lead to dangerous situations where someone could get hurt.

So, before this cross walk becomes reality, a lot still needs to be developed through many iterations. However, it has time to develop since it will still be a while before AVs will have taken over most of our transit system. Therefore this cross walk now serves more as an example into how we can look at future urban designs, rather than providing a detailed and worked out design. For others interested in designing future infrastructural designs, it is recommended to create a future context to better understand what principles can influence the design. Thereby, when designing for a future with AVs included, it is an interesting new stakeholder that becomes part of the traffic system. As an active stakeholder it has new needs that we previously did not have to account for in infrastructural and urban design. It is thus advised to take a look at the world through the eyes of an AV to uncover more of its needs. These needs can help inspire new designs that are functional for more than only the humans. Naturally, humans will still be the focus stakeholders in such situations as they are still the sentient beings that can get hurt. However, maybe, we as humans, can become more aware of what an AV does and does not understand and account for that when interacting with it.

10.5 Discussion & Reflection

We have come to the end of the project, which means it is time to evaluate how the process went and how the outcomes compare to the set goals.

10.5.1 Project Goal

The main goal of the final design was to prioritise pedestrian transit while maintaining an efficient interaction between the AV and pedestrian.
It is hard to say if this goal is reached since no real life testing was done as to what influence this new style of cross walk has on the traffic flow. However, by using the rights management system to state that pedestrians should always get the right of way when safely possible, they will be prioritised as such. Introducing the animations as a way to earlier communicate to the pedestrian if it is safe to cross is hoped to help encourage them to cross before the AV has come to a full stop. This would need to be tested more extensively as mentioned in the next steps. I think, that for me personally the most important feature of this cross walk is the merge lane concept, where pedestrians regain the ability to also clearly communicate their intend towards the AV instead of just being told what they should do by the vehicles. Introducing such features in cities, especially smart cities that have been designed from a technological standpoint, makes the city more human centric.
This brings me to my next point. Although some research and inspiring interviews were done about the smart city, it has not been mentioned much further on in the project. Although features and additional options can be created to fit with the idea of a more participatory city like the engaged or social city, this has not been done within this project to keep the focus on the cross walk and the interactions itself. These prove enough of a challenge by themselves. Some of the insights from the smart city as an engaged city did ripple through but are less notable. The fact that is goes against using predictive algorithms and focuses mainly on creating an interaction and only after that deciding what technology can be used are results of this more social definition of the smart city.

10.5.2 Method

The main method used during the first phase of the project is the Vision in Product design method. This helped to streamline and structure the research phase and create a logical transition into the defining stage of the process. Especially the latter can be a confusing stage as to how to express the design goal based on the performed analyses. Although using an interaction vision is a new tool for this integrated product design graduate, it helped in expressing the relation between the AV, pedestrian and cross walk. Albeit design processes always feel quite chaotic, especially when working on such a big project all by yourself, your mind can overflow with knowledge, ideas and inspirations which makes it difficult sometimes to keep track of all the steps and considerations taken. Process wise, there is still much to be learned about how to manage projects like these and how to organise it all.

The expert interviews were almost mini lectures in which each expert took their time explaining the subjects. They were very inspiring, not just for the project but also to me as a designer in general they showed a new approach in how future city design can look like or be managed. The set up of the interviews was semi structured where some guiding questions were prepared, however as the interviews went on also new subjects surfaced. Therefore the interviews also became more discussions. I enjoyed doing these interviews, although I usually shy away from using such opportunities, these interviews inspired to take a new look at what a smart city is, and it was nice to hear someone speak about eHMI voicing similar concerns I had come across during the analysis, which are not yet always talked about in studies.

The interview with Things presented an interesting new method I had not yet previously heard of or worked with. This new approach to designing smart objects and especially its relations with the world around it creates a more empathetic view on these Things. Performing the interview felt a bit peculiar at first, trying to pretend a non-sentient AV and to express its feelings without mixing in personal opinions of how it should be. I definitely think this method could be a fun new way to explore relations between humans and Things with an extra viewpoint, and I will likely use it again when designing a Thing.

10.5.3 Personal Goals

During the set-up of the project, students are asked to write down some personal goals, on which I would like to shortly reflect too.
My main goal was to manage my own mindset during the project. Although the first months went by pretty smoothly, the second part became more difficult to keep a positive mindset. The situation with Covid-19 worsening around this time definitely played its part, where social activities were limited again so seeing friends and family was difficult. This leaves me quite alone working in the same room every day, which is not the most motivating environment. I do think I have learned a lot about myself and coping with stresses during this project.

The second goal was communication with my supervisory team to keep them updated throughout the project. This was accomplished by planning regular meetings shortly after the start of the project. These meetings kept everyone involved in the process, and kept me motivated to present something new each time, or have some questions about how to continue. After the meetings I felt motivated to continue the work with new input to keep me moving forward.

In terms of creating short intermediary reports, I came to find out that this did not work out so well. Setting up reports would cost more time than necessary and with the midterm and greenlight meeting, there were enough moments to get more specific feedback on the content.

10.5.4 Conclusion

This project has been very insightful and has given me a lot of knowledge on many new subjects such as interaction design, smart cities and the interaction between human and Thing. I hope to be able to someday work in the field of mobility and interaction, which has always been an interest of mine, but this project has really sparked the professional interest too. And with that, I end the main part of the report, now only the references and appendices remain.

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APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Euiyoung Kim date 28 - 4 - 2020 signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 30 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC

List of electives obtained before the third semester without approval of the BoE

(X) YES all 1st year master courses passed

( ) NO missing 1st year master courses are:

name J. J. de Bruin, SPA-IO date 02-07-2020 signature JdB

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: (●) APPROVED ( ) NOT APPROVED

Procedure: (●) APPROVED ( ) NOT APPROVED

- the projectbrief has been submitted very late

comments

name Monique von Morgen date 6/7/2020 signature MvM

Initials & Name R Pettinga Student number 4286359

Title of Project Designing the human and autonomous vehicle interplay in a smart city

Designing the human and autonomous vehicle interplay in a smart city

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 15 - 04 - 2020 15 - 10 - 2020 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The self-driving car, or autonomous vehicle (AV), is not as recent of an interest as we might think. Already in 1930's people toyed with radio controlled vehicles and roads that guide it. Almost a century later cars have gotten more advanced and are reaching new levels of autonomy.

The current infrastructure was designed specifically for humans to drive their cars, it has not yet been redesigned and optimized for the self-driving vehicle. Since this new Thing* is an autonomous vehicle it will operate by itself as an independent participant on the road. Thus the AV itself becomes a stakeholder in the design of the infrastructure environment and its needs have to be accounted for. This calls for a new way of designing the environment. We could wait until the first fully autonomous vehicles start driving around, or we could address the challenges now and through (for now speculative) design we can conceptualize what the environment will have to look like.

With the disappearance of the driver behind the wheel in a fully autonomously driving vehicle, the possibility to directly communicate with whom- or whatever drives the vehicle disappears. Through sensor technology AV's can communicate among each other and with other connected Things that will emerge on the streets. Consequently, when the driver becomes a what and not a who, humans cannot communicate as usual and will be excluded from the communications ecosystem. Verbal communications, gestures, and eye contact, are no longer possible or understood by the 'what' that is now the driver. From the AV's perspective, and the manufacturer's, bystanders are a nuisance as they present unpredictable situations. As the bystanders are human they are not equipped with sensors that enable communication with Things, which stands in the way of an optimal operation for the AV.

Since currently the vehicles are being developed by mainly car manufacturers, the design boundaries are limited to the vehicle itself. Thus more focus has been put on the trust of passengers in the AV, both in research and design. This limitation leads to communicative solutions placed onto the vehicle that would clarify the AV's intentions (light rails, screens) but does not allow for a two way communication between AV and bystander.
Creating a solution that improves the communications between these two actors may result in a more trustworthy experience for the bystanders and a smoother operation for the AV.

This project will be done in collaboration with the Cities of Things Design Lab, as well as the People in Transit Research Program (PiT). The first focuses on how Things will become part of our future cities., how we as humans will interact with them and how the Things behave within their new role as a citizen. PiT aims to design new mobility systems and services from a human perspective rather than taking a new technology as the starting point, similar to this project.

*Things can be described as: "data-enabled artifacts with performing capabilities which are able to connect with existing networks of data, collect real time data, act pro-actively, and potentially behave socially." [2]

[2] Lupetti, M.L., Smit, I., Cila, N. (2018, September) Near Future Cities of Things: Addressing Dilemmas through Design Fiction. NordiCHI '18: Proceedings of the 10th Nordic Conference on Human-Computer Interaction (Pages 787–800) Association for Computing Machinery New York https://doi.org/10.1145/3240167.3240273

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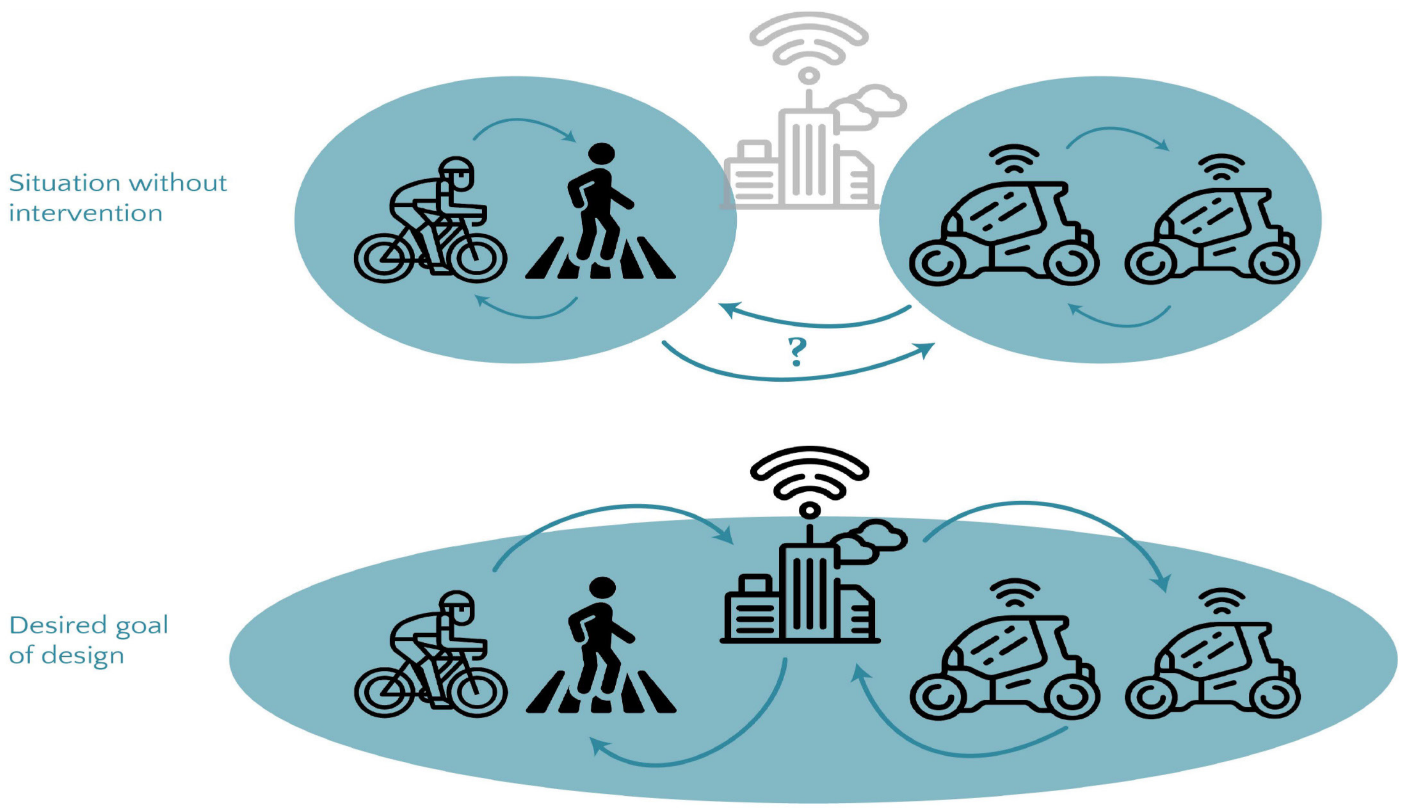

image / figure 1: Enabling two way communication between AV and Humans through the smart city

image / figure 2: A present-day city with already autonomous vehicles: the infrastructure has not been adapted yet

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

In a future so-called smart city, more and more Things are roaming the streets, humans will have to co-exist with them in the shared spaces. As much as the development of Things is technological, they will have a huge societal impact too. Humans and Things will have to co-exist in their shared spaces, which questions how we have designed these spaces. Nowadays, we do not have to take into account the needs of the Things, only the human's needs, and thus things like the infrastructure have been designed for all-human users only. However, with the Things becoming more 'aware' of their surroundings they also develop needs for how their environment is designed. With their needs also taken into account, the look of these shared spaces can change substantially from how we know them now.

One such shared space is the intersection, nowadays designed for the human user with traffic lights and signs. However, the AV has a harder time reading and understanding these cues. Instead they could just receive a signal directly from the intersection's system. Therefore making the visual cues obsolete. This poses a problem for the human bystander, who cannot receive these signals and do need a cue to interpret and take the right action. This way the stakeholders would live in two separate worlds, instead of adapting to co-existence. This complicates the implementation of the AV as a sense of mutual trust/respect is missing due to the lack of two-way communication. One could argue that the traffic light could still be used, but one could also see if with the future developments better, safer, options are possible that also give the human bystander insight in the actions of the AV's and enable a way to communicate.
The smart and connected city, that will be developing throughout the years as well, creates possibilities to serve as a platform to enable this two-way communication and allows them to learn how to adapt to this new era of co-existence.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Creating a new solution for an intersection used by fully autonomous vehicles and human bystanders to create mutual trust and understanding through two-way communication. Thus also exploring the possibilities of the smart city as the platform in enabling inclusive communications between AV and human.

Through research the following subjects will be explored:
- A future scenario will be created that focuses on fully autonomous vehicles
- The emerging needs of the AV and its perception of the world, through Thing Centred Design Method
- The interplay of humans and the AV (Thing) and human perception
- The smart city; its possibilities and limitations.

It will result in most likely a product and/or service solution that is placed in the city rather than on the vehicle or carried by humans. The latter would exclude people from the system, while the first would force manufacturers to alter their vehicle designs. There might be ideas for system or electronics based solutions which are not excluded just yet, but the focus will be to design something for the city. Another, additional, result could be a road map that shows how the solution can also help in the transition towards fully autonomous.
As the project is an IPD graduation project, the main focus will be on the conceptualization of the final concept design This means that more time will be spend on the technical/interaction/aesthetic/feasibility detailing, rather than on creating models/toolkits or strategic business models.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 15 - 4 - 2020 15 - 10 - 2020 end date

Approach:
The planning is structured around the VIP approach in such that it researches the current situation and builds a future scenario in which the to be designed product will operate. The VIP method works well at the start of the project to streamline the development of a future scenario, interaction vision and product qualities. In this project the human bystander will be the main stakeholder. VIP connects well to this perspective of designing human-centred within a new context. The Thing Centred Design method will be used to figure out the AV's side of the story, and discover its needs for the to be developed concept.
In the end a product or product/service system will be delivered, the goal would be to test this concept at the end of the project to get "real life user" feedback. However, a full prototype and test scenario might be hard to create as the concept probably will be operating in a currently non existing scenario. Therefore options have to be looked into once the concept is being developed, possibilities would be to create a MVP (minimum viable product) to test the foundations or parts of the concept.

This project will be executed in part time working weeks. During the first four weeks, I will work a three day week, after that it will be a four day week. This is done for two reasons. The first weeks will be in the Covid-19 times, which might make doing research a bit more complicated, this part time work week allows for a bit more room to deal with the measures and to get acquainted with working from home. The four day work weeks after that is to release pressure off my personal stress around my productivity. Thus keeping my mental wellbeing in check and keep up good motivation.

* the greenlight meeting has been moved 4 days forward due to availability of the supervisory team

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

As a 7 year old kid I would love to sit in the car and watch the other different cars pass us by (we drove a big old van so we were not so fast). I first would train myself in recognising the logos and then recognise the car brand from as far away as possible. Every now and then, I still do this from the car or the train. You could say that the interest in cars has been a part of me for quite some time already.

The evolution of autonomous vehicles, to me, is one of the most interesting technological and social developments happening at the moment. It is such a multi-faceted subject with many stakeholders, that has many doubts still surrounding it and will need many perspectives to make the system as optimal as possible. I enjoy working on projects that are more than just the next consumer electronics product in a company's portfolio that has some new features. This derives from my perspective of what kind of designer I want to be, which falls somewhere in between 'social innovation designer' and 'transition designer'. I do not believe that the development of autonomous vehicles should focus as much on the looks and functions of the vehicle, since the system in which it operates is just as (or even more) important. Without acceptance, laws by the government, urban (re)organisation, and so many other systems that need updates, the implementation of a fully autonomous vehicle will be in a very far away future while it can bring many benefits. This project aims to shift the development surrounding the AV from mainly technological towards a societal perspective. The concept will question how humans will have to behave when the AV is introduced, rather than designing it for the human behaviours we (humans) showcase now due to how our current surroundings are designed. Hereby also taking into account a new set of needs coming from the AV, which is now becoming an active stakeholder in our society. With this project I hope to develop myself more as a social innovation designer, even if the context of the project is a bit more small scale than the usual social innovation contexts.

During this project I mainly want to work on my mindset. Already, writing this brief, I tend to create a negative headspace for myself, where I tell myself that the things I write down and the decisions I make will not be good enough. This slows down my process and demotivates me to work on a fun project like this one. Therefore, I want to document more in a final report style so that I can close chapters and lock in decisions. This allows me to keep on working instead of creating more and more doubt for myself. It also connects to my next point which is communication. Since I want something to be "perfect" before I dare to show it to someone, I tend to stick too long to reworking anything I work on without discussing it with a coach or expert who could actually help me improve it before finalising it. Therefore, I would like to create more interaction with my supervisory team (and experts) through regular update documents. This way I aim to also streamline meetings, so I have a clear idea of what I want to discuss and where I need feedback.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix A: Interview Transcripts

Interview Transcript Martijn de Waal

Introduction Martijn de Waal:
Lecturer in Play and Civic Media. Focus on design of public spaces in a networking society. Public spaces can be virtual spaces for reflection, dialogue or empathy but can also be urban or physical spaces. The core is then to look at these spaces from a perspective of citizenship. We deal with questions like how is this public space a medium where citizens can meet each other, where they can relate to each other and the government, share information. Not just from a rational standpoint but also the more affective side of it. So, how can you feel at home in your city? How does trust between citizens and a public space develop, and what can digital media mean in this all.

Interview:
Ragna: I would like to start off with possibly a rather open question. How do you look at the developments of how the smart city will develop in the next decades, and how it should develop according to you?

Martijn de Waal: That is a difficult question, but maybe we can start by taking it a part because it largely depends on how you define a smart city. On the one hand you have the technological developments and on the other you have a societal development. Concerning the discussion around smart cities, maybe there is a resistance against it or actually the embracing of it. And it goes hand in hand. So if you look at the smart city itself then I think it is interesting to make a distinction between technologies that are being marketed as smart city technologies. Usually these are products from companies like IBM or similar parties that ask the government to share their data and the companies will help you with all sorts of things like improving traffic. Optimisation then. Those are very system driven you could say, so they support existing systems to optimise those processes according to parameters, like making a neighbourhood safer. And then you have the smart city, although it does not always fall under that label maybe, but those are more platform services. Maybe Google Maps is one of the most applied smart city applications at this moment. It is not marketed that way, but it is a way of how the city is being digitised. Not the processes of a system are being optimised of the government or a company, but it offers a platform onto which anyone could start developing anything. So with Google maps services like carsharing can make use of it because of the location sharing. So these types are more powerful in their potential, because they offer all kinds of people the opportunity to develop their own smart city applications on that platform. They are more difficult to control. As a government you order something from the provider and they will build it for you according to you specifications. This [the platforms] is much more open. Why do I say this, because we can look at how these two types can start to develop.

So I talk to a lot of people from governments and they are interested in a project by the municipality of Haarlem for example. It is about the vision of a government as a platform, which is not completely the same as a smart city, but it does connect to it because so many things become cross-linked. So this is about how can you as a government design your processes and architecture that it becomes more like a platform. The most simple example is parking. You can make a law about where you can park and the costs and the possible exceptions and you can translate those into a software module and algorithm. And when you did that, then third parties can build apps that create like virtual parking meters.

Ragna:
They are really working on making that kind of data accessible to the public.

Martijn de Waal:
It is not so much about making the data public, it is more about translating the rules into algorithms in combination with access to those databases. A parking app works on both sides. So you have this app and you arrive with your car, you park and you turn on the app and you enter your number plate etcetera. And then comes the scanning car from the municipality which scans the number plate and looks it up in the data base of the national transport ministry. It references with all parking apps and checks whether or not you have logged in on one of those, if not you will get ticketed. The parking app provider, when you log in on the app, will check the legislation from the local government to see what the rules at that time are. Is it Sunday, is it free, do you need a permit because you have characteristic X or Y. What I am trying to say is that step one starts with opening up data, maps etc. and I think the next step will be algorithms applied to those. And rules that need to be set by governments or other parties involved. We are now looking into blockchain, not just for transactions but also as an identity and rights management system. So on the blockchain you can keep track of what your rights are with the use of X or Y and that can be connected to reputations. And you do not per se need blockchain for this, excel can do it too, but blockchain makes it easier to do it like this. So you can imagine that when connecting these types of systems to the smart city applications like Google Maps or smart taxi meters, then there will be a system where the taxi drivers have to use a GPS system, which could be Google Maps but is has an extra layer that is provided by the government. This layer contains specific rules, like between four and five o'clock the school streets do not appear in the taxi's GPS, for example. So for safety reasons we thought we want to minimise the amount of traffic in those streets. So through connecting what we want, mostly data to algorithms, we can attach conditions to specific urban areas and the use of them. Partly this is already happening in the smart city applications, for example with the police, but then it is more about analysing the data, and based on that the system says 'go check there or there'. So this is more of an recommendations role. It could operate more in a legislative manner, like a sort of rights managements. So I think, long story, maybe the next step of the smart city is about rights management; who has, and under what circumstances, access. Who is allowed to use [platforms, the city, public spaces, data etc.]. This is a game of scarcity, because there are traffic jams on the road, not enough charging stations to charge all cars, not enough shared cars to let everyone drive. So who gets priority. How will we prioritise, and what kind of rights management system will be connected to it.

Ragna
So this is really about rights, but also it seems to come more from the government and less from the citizens, or bottom up, where these citizens also have a certain push to develop services. Maybe you enter the field of the social city more then. So, more about how a citizen also starts living with the city, so to speak.

Martijn de Waal:
No that is right, this story comes from a research we are working on about energy communities. So these are people who use platforms and often blockchain to develop like calculations to manage energy sources and to settle the costs among themselves. That is actually the start of a transactions system, but quickly other questions like governance and rights arise. It starts as an economical system, how do we deal with it, what is the cost of a kWh and is it always the same or can I also gift my electricity? Similar to having an apple tree in the backyard with too many apples which I can give to my neighbours who can make apple pie out of it. I won't make them pay for the apples. The question is if I want to deal with energy in the same way, or when I produce it do I see it as something I want a return of investment on? So, you need to make those kind of decisions. Most of these energy communities were founded on an ideological perspective of also saving energy. We do not just want renewable energy but also use the least possible amount together. What kind of incentives do you need to build in then? Are you going to punish or reward people. Will you publish all the data of the energy use? Maybe you project the use of energy on the houses in the street which shows who has used the most energy that day. This might motivate people to use less because you do not want to be known as the biggest energy consumer. From a social psychological perspective you could say that it is very effective, but at the same time we know that people will feel very controlled by those systems. There is a pressure to conform to a norm in public, and we do not want that. The moment you start designing such systems you cannot escape to think about those sets of rules. It is similar to a turf list in student housing to keep track of how much you have spent and used. It is similar, but these systems are much more complex because you also need to agree on rules. Some of these rules might be translated into algorithms and will be monitored or even executed by it. Then you need to question if you need to be able to make exceptions to the system. Including exceptions we have not yet foreseen which we cannot program for yet. How will we deal with that? That is very complex. So, again, the smart city as a rights management system for local communities to lay down their rules, and set those in automated systems. But that is already very complex.

Ragna: So this is mainly about rights management, but it also seems to be mainly coming from the government. This happens a bit less from bottom up systems, but there is also a certain push from citizens to start developing these services. Which is probably more the social city side of it and then how will the citizen live in and with the city as well.

Martijn:
This story comes from a project about energy communities where the citizens themselves created platforms and calculation methods so they can independently manage energy sources. It starts as a transaction system but it soon changes into a governance and rights system. There are many decisions to be made about how to manage such a system. And especially this system is built on an ideology of reducing the energy usages so there is also the question of incentives for the community members to reduce their usage and how this will be achieved.
So once you start designing these systems you cannot evade thinking about all these kinds of rules concerning the system. From these rules often an algorithm can be built which can monitor the rules, but then there also might be exceptions, or events we cannot foresee and thus not program for yet. So here, the smart city would function as a rights management system for local communities to agree on their own rules and capture that in automated systems. But that is very complex.

Ragna:
There is a way the smart city developments might happen, but how do you see these developments should go?

Martijn:
I think at this moment it is hard to oversee everything, but I do believe there is one important requirement. If, as a government, you start developing these systems they should be transparent and accountable. That means that they should be flexible so you do not end up locked in with

one provider.
In designing these systems it is important that the designer is aware of the context for which it is being designed. To go back to the autonomous vehicle, the solution might not be in the system itself but in the boundary conditions. A big issue with autonomous vehicles is the trolley problem. And there are two ways we can solve this. First, I would be against this solution, would be to fortify our infrastructure so to please the vehicle. You do not solve it by improving the algorithms but by changing the environment so the problem would not have to happen at all. This would go against the liveability of a city, which is similar to what happened in the 60s when flyover highways cut through neighbourhoods, which creates physical barriers in a city. Instead you could also say that the car is a guest in the area and needs to lower their speed. So we should not stare blindly at just the technological solutions, but we can also look at how we reshape our environment so we do not have to solve it with technology only. By bringing in a responsibility as designer to also look at policy making. Designing more from a values perspective rather than just from the technology.

// A discussion about the autonomous vehicle and safety follows. The main conclusion here is that we have accepted human failure as part of our transport system which costs a lot of lives each year, while we expect technology to be perfect. So an autonomous vehicle that hits a person immediately sets back the whole implementation of AVs, while their safety risks are already so much lower.

Ragna: I would like to discuss what steps designers or policy makers can take to achieve a more social city concept?

Martijn:
Most importantly is that you do not get caught up by the sales talks of the technology companies. You will have to incorporate the social city ideology into the city's policy goals. It is mainly a political goal which could become a policy for which you can start designing. So it is not as much about the technology itself, in the end of course, but it is mainly a choice in policy and the notion about what you want to do with the city. It depends on these political standpoints. If you see the city as an infrastructure that should give space to individuals to develop themselves without much responsibility to one another than a smart city vison would suffice. If you see the city as a community of people who should be able to determine what is important and have a certain control in that, then you will have to design tools which contribute to that. It also means that you organise a democratic process and the way they participate is going to be organised differently. And you can use technology to achieve this, but it is secondary. I think it starts from politics, with policy choices. Or as a designer with a start-up and an ideology. So how exactly it will be designed, depends on ideologies and values of the developer.
Governments can set conditions for these platforms that are being developed, and can say they will develop by themselves because they think it is important. On the other hand designers, scientists and entrepreneurs can also say what they think is important and develop their own platform for it.

Ragna:
What is interesting is that it seems that still many of these platforms grow from a governmental push. If the government decides that they want to create a more bottom up approach and create a platform where citizens can contribute to how the city will be made smart, then it still was a government driven start.

Martijn:
Yes, so it also could be more of an in between solution where the government has a policy goal of making the city greener for example, and they will not do that themselves. Rather they will provide tools for parties who think they can contribute to that goal. You use the collective energy in a community or professional designers and as a government you boost that. So the government becomes more of a catalyst than the initiator or designer of the platforms.

Ragna:
I was also interested in learning more about the smart citizenship which you have written about in your paper, but I am interested to see how that smart citizenship in a smart or social city would differ from how we live in a city nowadays?

Martijn:
The problem with how these systems are developing now is that we will not be citizens of the city of Amsterdam anymore, but citizens of companies like Google or Facebook because they hold all our data and build those platforms on where we interact with others. They draw up the rules. Koen Frenken calls this private regulators. Private parties who draw up the rules that determine our behaviour, which we also internalise to a certain extend. We have to make sure our reputation stays on four stars otherwise we might lose our job.
The citizenship I talk about is more about the possibilities that arise where citizens take matters in their own hands like performing their own measurements about air pollution which they can use as an argument against the government who might show other data, and therein forcing them to undertake action. Thus locally creating and taking ownership to set up an initiative.
The downside of this is that not everyone wants to constantly be creating and cocreating and discussing about what the rules are. There is a certain pleasantness about only having to go vote once a year or once every four years and others are busy discussing the rules. But even so it remains a priority that as an employee, ngo or journalist can verify what is happening there. So again, transparency and accountability are very important. In designing for that it is not even about the tools perse that you create, but about a setting or a process in space and time where people can have discussions to set a common goal and get a perspective on operations. So besides the tools there is also a place for participation. The government often just presents their plans and you can have an opinion about it, while a set up could create space where before the plans are made people can have discussions about what they actually would want and what important values are to them. So it becomes more than just telling what you think of it, but also defining the problem space together as citizens.
It is about creating those spaces but also creating business models for them. So what you see is that initiatives are set up because one saw an opportunity to improve something in the city. They start creating a coalition of citizens, governments etc. However, this costs a lot of energy and time but it does create public value, because it did improve the public space and make it more interesting. But there is not yet a way as initiator of these processes to also benefit from them, economically. Unless you explicitly link it to real estate developments for example.

Ragna:
It almost sounds like it will be creating a more active democracy where the citizen is taken with in the process of making laws..

Martijn:
Or in any case at least get the possibility to do so, and have tools for parties who have good ideas

about how to improve things. And our research here focuses on how to create that interplay of getting those values on the table to discuss them. And also how do you go from creating these ideas as a collective and then giving that a place within the institutional boundaries of a city. That is almost more an administrative issue than a smart city problem, but it does relate to it.

Ragna:
Then going back to the earlier mentioned possible negative effects of the participatory smart city. What if you do not want to, although that is more a choice then, but what if you cannot participate in the cocreation of you own city?

Martijn:
I do not have the answer for that, but maybe we should see this cocreation also as a job, so you will get paid for it. Or maybe we should create a society – this is very idealistic – with an economic system that works in a way that there are no jobs with such a low pay that you would not have the time to deploy yourself as a citizen. I do not think that technology will be able to fix that.

Ragna:
Citizenship would almost become a job on its own.

Martijn:
Well, citizenship is a duty, at least, there are different views on what citizenship actually entails in a democratic society. Do you, as a citizen only have rights or also duties to fulfil.

Ragna:
Bringing it back to urban design, since this is currently such a static part of a city, there to fulfil its function, how could I as a designer create an urban or infrastructural design that incorporates the social smart city ideology more?

Martijn:
I think it comes back to what we have discussed before about the tools for citizens to get more control over those systems. It is an interesting question.

Interview Transcription Usman Haque

The first part of the conversation was not recorded, however a summary of it has been written:
A smart city with a technology focus can create brittle systems. When a technological system is added into the city with only one purpose and way of functioning, this system can become obsolete quite easily. Such a system operates only with a narrow set of definitions and once one of those definitions changes there is a big chance it has become obsolete. Mere optimisations do not make a city valuable. Rather it is the unpredictability and spontaneity of it. Like wrinkles, which create a messy city, is what make a city valuable.

Recording starts here:
Ragna:
There are many types of cities and smart cities already, which focus a lot on the technological side of it and wanting to make it more and more efficient. Which like you were saying, where is the spontaneity of the city that actually makes a city very interesting to also live in, when there is random things happening. If they are all gone then you are just living in this very routine way, which actually might make people go crazy in the end.

Usman:
Yeah, I mean, I think that I'd like to think that my critique of it is actually quite a practical one because first of all, it doesn't work. Demonstrably, you know, when you try and deal with a complex open system like a city is you can't make things efficient. When you have a closed system, yes, you can when you know all of the inputs and outputs and so. So there are certain contexts in which technology appropriately applied, can make things more efficient, clearly. But very often at a very large or, you know, meta scale or urban scale, that categorization doesn't apply, because it's nothing but an open and complex system.
And secondly, my critique is that it's not desirable even if it did work. It's not desirable because you'd have this effect of damaging the thing that makes the city actually attractive and valuable and dynamic and kind of capable of generating diversity. Those are the things that actually makes cities such a such an important part of human creation, if you like. The fact that they are these, I have kind of called them the engines of diversity and creativity, generating new ideas, able to adapt constantly, over millennia, in some case, kind of, you know, growing and adapting. As soon as you start putting in these kind of brittle things, it turns into something you kind of just don't want. And then when it comes to smart, and partly just to kind of connect back, I've kind of ended up talking about engaged cities. I mean, like you say, everyone's got their own bloody adjective. But um, I think that why I kind of discovered was, first of all, when people are talking about smart, there's no agreed definition. Everyone sees something completely different in it. Second, even when you have some kind of a definition, you don't really have any way of measuring smartness. So you can't really assess whether you've actually got it or not, or achieved it. And so, the thing I found quite interesting about engagement is that actually a lot of city managers actually highlight engagement as the thing that they desire. They just wish the people were more engaged in things, that they were more responsive to or involved in stuff. And secondly, you can actually measure in a lot of different ways engagement, you can assess whether you've got more or less engagement. And so the notion of engaged cities is this idea, well, it's something that seems to be desirable. And you can also in in different ways, evaluate whether you've achieved something, even though those measurements might be contentious, because different people might measure in slightly different ways or attribute value to the measurement in different ways. So that's kind of where, where the engaged cities idea kind of sprung out.

Ragna:
So, I would like to start talking a bit about the Starling project and what the inspiration for the project was. How, as a company, did you come to the conclusion, like, we need this in a city. How did you come to the design of the Starling Crosswalk?

Usman:
Essentially, the core idea was, was from just noticing that, that the way we cross roads now, we're still at least in Britain anyway, we're still using the same pattern. of crossing that we did 50 years ago, even though the way we navigate the city is completely different. I think that was one kind of observation. The second observation was, you know, this promise that AV companies always have, which is that AVs are going to be super safe. you'll be able to, in theory, step into the road wherever they'll magically kind of move around you. I just know from having worked in technology and cities for long enough that that promise is, is either never going to happen, or it's certainly going to be quite a long way off to being where you literally can just walk into the road anywhere and it'll automatically seal around you. o, I guess we started thinking about Okay, let's take it as a given that at some point in the future, probably at least two decades away, the roads will be filled with a lot more autonomous traffic. And increasingly even our pavements are filled with, you know, delivery bots and things like that. How can a pedestrian now, like a human being, start to navigate the city during this transition period? You know, how would they know where to cross? Or how to cross? And how can that crossing actually learn from them? Rather than being static? How can it kind of adapt and change and reconfigure according to the way different people use the crossing or indeed, different patterns of different times a day or different, you know, seasons or what have you? How could it kind of adapt to specific road users. So for example, if there's a child crossing you might be even more concerned about the air quality, and the vehicles could stand further back. All these kind of things, I think, and we just started thinking about how to make a crossing that was actually dynamic and responsive and reconfigurable and so on and so forth. And also, because we were thinking that the pedestrian crossing itself would be laid down a little bit like the pathways that ants make Where they're laying down pheromones, and when they lay down pheromones along a track if it can attract more ants to the same pathway, and so on and so forth, reinforcing over time, the pathways and that that's known as stigmergy. And so we started thinking about the STigmergy, Adaptive, Responsive Learning, crossING, hence, Starling.

Ragna:
So it actually also relates very closely with the notion of an engaged city, I guess where it's not just telling people, this is how you should do it. But people can actually give input to the city and the city will kind of adapt to like their crossing. That's, I think that's really nice, actually, that there's like this dynamic play between citizen and city and the city actually, directly can respond to the citizens and thus creating that engagement. Yeah, so I was wondering if you have like an idea of how Starling could become like operational when there's fully autonomous vehicles, like if there's mixed traffic, like, how do you see this development go?

Usman:
Well, I think that there's two things. One is that we never conceived of it as a crossing that would be everywhere. I think sometimes, you know, we people say, wow, that's kind of interesting but insane because it's costly and who wants a crossing the that's all is different from me it was always about being very strategic about where it would be located. And so I've kind of thought of it more as a kind of an acupuncture kind of activity where you where you find that point in the city that is very complex and dangerous. We need some kind of mediation between these different forms of traffic. So with that in mind, I think even when there's full autonomy, there will still be these kind of overlaps or intersections between technological autonomous, kind of vehicles or whatever they are, and they're kind of organic of the human, that's kind of crossing paths. And that's in the city. But it's also even in things like you know, in in on building sites, for example, and things like that. So I would still see a need for some kind of a, almost like a negotiation system between the two to exist. Now a lot of companies are actually working on, on this kind of area. But it's very often from the perspective of the vehicle. So for example, Uber and Tesla are working on pedestrian detection and trajectory analysis, analysis and things like that. But it's all from the perspective of the vehicle. And I think that, for me, it's important to have it from the perspective A of the city fabric itself. But also from the pedestrians, if you see it, I mean, so if there were any kind of further development of it that I'd want to see it'd be kind of reinforcing that aspect. How do people react actually walking on the street? How do they start to almost like define and design those crossing areas themselves. o in other words, it's not just that it kind of mutely responds to them and kind of reconfigures but there's some kind of an active participation in that process. So for example, you know, people just decide that there is no crossing here. So we just want to create it and they do that just by, I don't know, running back and forth across it, you know, for a period of half an hour, and that sort of imprints on the memory of the system. Yes, this is a place that's important for crossing or, or something like that. If that makes sense.

Ragna:
In my project I have also been looking into how the city can play this role in the negotiations between the two. So a lot of research is done now into external human machine interfaces that they would put onto a vehicle which would then communicate what it wants form the citizen or pedestrian. And some research shows that these systems are actually not that valuable, without them people will also be able to cross. Still, a vehicle needs to know the crossing intention of the pedestrian. So I have been thinking about a system in the city that aids the vehicle, so the AV does not have to do it all by itself. The city could be helping to predict where the citizen will cross or how they will respond. This gives the vehicle more feedback from the city and the intentions without having to use only its own software. So the city aids in this negotiation of are you going to cross or not.

Usman:
I think that's kind of important because, like the I think very often the things that are put on to vehicles or you know, I think one of the examples of that is the way the trying to make electric vehicles have a sound so that people learn about it, is that it's still it's a very individualized experience. In other words, it's like this vehicle makes this sound so this person is supposed to jump out of the way. And I think the interesting thing about crossings and something that we tried to play with Starling, is that it's a kind of a collective experience. So the idea of literally having a demarked crossing is, and one that that kind of has changed over time, is not to say, oh, everyone must cross here, because like you said, people will still cross in other places, they'll still run out into the road. It's actually to say, this is the location that most people have agreed they want to cross, which is a slightly different thing. It's a kind of way of communicating to the vehicles that this is the group dynamic and it has a by-product of helping other people know where they should cross, but it is not trying to say this is where you must cross. We never implemented this is reality, but I really liked the idea that the crossing would have blurry edges, because there shouldn't be a strong boundary to the edge of the crossing. Because still kind of cross a little bit over here and a little bit over here. But for practical reasons, I think the real versions might still have quite a speed limit somewhere, of course.

Ragna:
It reminds me of something that happened in my hometown, where they had several crosswalks, but none of them were actually in the spot where people would like to cross. They relocated them and could actually reduce the amount of crossings without reducing pedestrian crossing ability. So, basically the citizens decided that the new spot is actually a better crossing spot.
Usman:
Yeah, you actually reminded me I missed the step in the story about Starling. Because actually a very early version of the project or early conception of it was not that it would be a dynamic Street. But actually, you would have a street that was like the example you just gave. You would lay down this kind of interactive carpet across the whole thing and it would figure out where's the best location of the crossing. And then afterwards, you paint in the crossing at that location. So it was kind of the idea of a carpet that you'd be able to move from one location to the other. It was only later that we that we realized that, for the kind of crossings we were looking at, you would literally have to move the crossing constantly because we were looking at two specific conditions. One was like outside of a cinema late at night, when suddenly loads of people cross, but the rest of the time you don't need a crossing at all. And then secondly, we're looking at the condition of like there being a school. You'd have quite intensive crossing at two times of the day. But the rest of the time, you might want a crossing somewhere else. But yeah, otherwise the original version was kind of low tech because it resulted in just a painted crossing in a new location.

Ragna:
What could IoT mean in the way we design urban infrastructures. How can it shape the way we design those spaces?

Usman:
Okay, I would answer that by completely flipping the question, because I don't think it's about the technology. If you see it, I mean, I mean, even something like IoT, okay, connected sensors. What do you do with them? Well, you do absolutely anything really. You know, anything you want to good bad, evil, fun, stupid. valuable. Like anything is possible. I'm trying to answer the question as well is, what forms of decision making are we going to have about any of these technological systems going forward in the future? And how do we come to a collective decision on things that are both locally specific and with global repercussions if you see the means so, you know, just to be very prosaic and take the example of a crossing. Okay. Let's say there is a way for everyone on this neighbourhood to decide where the crossing is and how it behaves. But that has an impact on the congestion in another part of the city. So what is that decision making framework that enables, even in that present situation, people to govern their own systems. That question or the answer to that, I think is a very complex one. And I don't have a clear answer to but I would say that's kind of the challenge that intrigues me most right now and that I want to work on. I think particularly in a kind of a post COVID world where we've seen decision making in the way that we have come to accept is totally fucked. Right, you know, the way that different governments and even different cities have made decisions about our health on our behalf and using information or abusing that information and whether they represent us or don't represent us. And even everything that's taken place with all of the protests that we've seen over the last 10 days. I think the very fabric of our decision making structures is looking quite shaky. And so I guess it's almost like my question back to you to say, Okay, what are the forms of decision making, that could be embedded in these kinds of systems that actually supports that kind of process rather than limiting it?
Now, I see a bunch of intriguing possibilities. One thing that I returned to quite a lot is the idea of liquid democracy. Most western democracies are effectively representative. We have these representatives that we vote in, and they make the decisions for us. And it's become the way that you've that you effectively delegate the decision making to somebody else who you trust in liquid democracy. What you do is and it's much more complex than I'm describing here. I'm kind of giving the one sentence version. But effectively, what you do is you delegate each decision potentially to somebody completely different rather than delegating all of your decisions to one person. So, you know, on environmental issues, you would delegate your decisions on even one specific issue to this person. And that person themselves might be delegating to somebody else because they don't, you know, because basically, the idea is that we no single one of us has either the time or the expertise, to make decisions on things on everything. So the things we really care about, and then there's things that we trust others to make the right decision on. And so what you end up in a liquid democracy having is this idea that you basically pre elect this person to represent you on environmental issues, even if they're not doing the actual thing themselves, because it turns out they're delegating their decision, it kind of cascades and I think this is where the list kind of comes about.
I find that a really intriguing way of trying to think through the decision making, because it sounds like something explicitly that needs a technological framework. And that could be embedded into cities as a way of us starting to make decisions that are very kind of micro local. But that have a macro effect, because I think one of the things that that's come out of the IoT world and in fact even just the networked world, if you like, is the fact that unlike any time before in history, we can do something as individuals now or press a button that has an effect on the other side of the world or we can wait you know, we can buy products, where on mass we are collectively having an effect on another part of the world. And thinking through those chains of agency and responsibility and decision making like that, that's the real key to me. That's why I'm kind of answering the question about the social dynamics by really saying, I think there's a more fundamental thing to get to.

Ragna:
What is your vision on how these cities could or should develop, and what would be the first steps to get to more engaging cities?

Usman:
So I think first of all, I tend not to think about the cities too far off. I am not really thinking about the future of the city, or what have you as a destination. I think what is intriguing to me is what do we do now? And so I don't necessarily have a strong vision for this is the way the cities should be and we should do X, Y and Z to get to that point. Where I do have a strong inclination, it is just to kind of bring it back to changing the way we make decisions about cities. I have no idea what that would result in. It could potentially turn into the most horrendous blob of mess, you know, whatever. But if we can all feel that we are an active participant in creating that and have some sense of responsibility and agency for it. For me, that is the kind of end goal. And I actually do have faith because of the way that cities have evolved over many centuries. That actually we would appreciate what comes out of it, if you see it, I mean, so I don't actually think it would turn into this chaotic sludge of a city. I think that actually, if we were more involved in all the decision making the city could only improve. And so when it comes to practical things of what should come next, I think it is about all the stuff we've talked about. It is about the participatory budgeting, it's about kind of local and wider governance. That people have an active role in making decisions about the city about the way it's managed, about the way that things are procured, the way that algorithms make decisions, even things like traffic flow on their behalf. And I think it's also about the opening

up of the process of actually creating the physical fabric of the city, you know, in some way that we are able to, you for example, this is just plucking something else out from the air. In most of our cities, there are lots of these green spaces that have been forgotten or abandoned or they're too small to, for the city really to take care of. Some cities have started to have these kind of rewilding, or kind of allotment plans for those green areas. I think this is all part of the transition of the city. Because it's not just about making the city greener. It's actually about us feeling like it's actually our city and then we're responsible for it and we're tending to it and taking care of it. So practical things that come next is kind of like more of these same kind of procedures, but hopefully more in the same place rather than having like one place do participatory budgeting. Another place doing rewilding another place doing you know.

Interview Transcriptions J.P Nuñez Velasco

ragna pettinga
So could you maybe just start off by telling a little bit about yourself and the project, the especially the PhD project you worked on? I'm not sure if it's already finished or not.

J.P. Nuñez Velasco
Yeah, sure. So I'm a fourth year PhD researcher. I'm part of the faculty of civil engineering on the (transport department, transport,) transport and planning department. And my PhD is about the interactions between a vulnerable road users and automated vehicles. With vulnerable I mean cyclists and pedestrians. And it's part of actually of the STAD project which is the project on the Spatial and transport implication of automated driving. And it focuses mostly on urban areas. And what I did during my four years is design experiments in which we could look at the road crossing behavior of pedestrians and cyclists to see how they interacted with automated vehicles and whether there was a difference between how they interact with automated vehicles as with conventional vehicles. And this is PhD still a bit of progress I'm really finishing. So it's really just the last couple of things. And I will start a new job actually next month.

ragna pettinga
Congratulations.

J.P. Nuñez Velasco
Thanks.

ragna pettinga
Yeah, cool. Um, so in short about my project, I'm basically working on a project that's going to be like in the future. So it's for quite far away future still, where there is mainly autonomous vehicles driving around and cities have become smarter.

ragna pettinga
And then I want to look at the interaction between autonomous vehicles and well actually also the VRU.

ragna pettinga
But mainly focusing on how they can communicate with the city as a platform. Not through Like what I've read about often is like eHMI, so external human machine interfaces. But kind of trying to move that from a vehicle more into like a city infrastructural design. So kind of urban design and seeing how that could work out or maybe not at all. And that kind of creating this, this more open communication between human road users and the autonomous vehicles, which can communicate through data streams and that and humans can not so how can we bring them together into more of like one communication ecosystem, as I like to call it. So it was kind of like a little bit of an overlap in interest in projects. So it was really interesting to like, talk to someone who has done more research into that particular interaction already. So I'm just going to start with some questions. And hopefully, discussion will follow from it. First of all, do you have like a time limit I need to be aware of?

J.P. Nuñez Velasco
No, no.

ragna pettinga
I will try to keep it like in within an hour or something.

J.P. Nuñez Velasco
Yeah, no problem.

Unknown Speaker
Nice. But yeah, thank you.

Unknown Speaker
So a lot of research that is done with the VRU and AV interaction is through the use of eHMI, which is often sought to be like the solution for the communication problems that might appear in the future with the disappearance of the driver of course. And from the research, I found, there's usually this positive effect on especially the perceived feeling of safety from the students. I'm just starting off by like, what's your general opinion of the use of eHMI? Do you think it will have this positive impact?

Unknown Speaker
That's a good question. And then Also one of my favorite topics actually, because my opinion is going into a into the flow sort of flows in deeds. It seems to be like everyone's thinking this eHMI will be the solution for every problem we'll have with automated vehicles. And they are of course really cool to work on because there are so much to work on. We need to know whether we will need a light system word system, we need emojis on vehicles and out that kind of thing of laser. So it's really a cool topic. But I kind of am very skeptical, actually. I was also very happy about them. But I've done some research lately in collaboration with the Leeds Institute of transport studies. And what we did is actually we were asking first, okay, is there really a lack of communication with automated vehicles? Are we really missing the eye contact? This is really something is going to happen. So we designed an experiment in which we have... It was in virtual reality. So it was a computer simulated environments. And we have pedestrians crossing the roads. And they were crossing in front of vehicles with an attentive driver and the distracted driver and one without the driver. And just to see whether we saw some difference into the timing of their crossing decisions and whether they cross faster, or whether they cross earlier and just actually, we didn't find the difference there. And actually, what we also did is we checked Okay, we assured the pedestrians could see the driver so we worked with low speeds, 30 kilometres per hour, and we also removed windows from the vehicle too. So no reflection was possible even without the within a computer simulation. And actually what we found is that Usually the pedestrians made the decision to cross before they could even see the driver. So, that makes us thinking okay. Actually that will make no difference at all because if the speed is higher, they will still make the vehicle will be farther away still before they make the decision. So they will be not be able to see a driver or see that there is no driver inside. So that would that really raise question about the need of an eHMI actually?

ragna pettinga
Yeah that it is interesting, actually.

J.P. Nuñez Velasco
Yes. I'm working on publishing this paper once it's published, I will send it to you and if you want, we can send you a the author version, but you have to keep it confidential for now.

J.P. Nuñez Velasco
But yes, that raises a lot of questions and also this is one of the questions. So the visibility that we see that there is no driver, but what about the studies that are being done right now? So one on one interaction, so one question No one driver or one vehicle, actually. But what happens if you have one vehicle and several pedestrians on different distances from this vehicle? Who is the vehicle talking to? And now not talking on your pedestrians? But what if there is pedestrians and cyclists? Does the vehicle still need the same message to send to have to tell the pedestrians and cyclists that they need to cross? So there are a lot of questions we need to answer before we can think I think of eHMI as (that) the solution?

ragna pettinga
Yeah, it's funny that you mentioned like the multiple actors involved in the interaction because that was exactly what I was thinking after doing the research. I was like, but yeah, I can understand that it works one on one like, Okay, this message is meant just for you. But what if there's multiple vehicles approaching? What if there's multiple pedestrians so like, people seem very like; We know this is going to be the solution. Yeah, but there's so many questions still, and I'm like; Well, is it really? So that's why I'm also kind of looking into this other way of like, how can we use the city, so the cars themselves don't need all these special signs on top of the vehicle, also to like, kind of generalize it, because what I'm worried about when you leave this kind of design more to car manufacturers, they will design something that also looks nice, it will work, but it will differ between all these vehicles. So what if there's like this Ford car and then Toyota approaching at the same time giving different signals like what is going to happen then?

J.P. Nuñez Velasco
I think there are (this) just safety principles or sustainable principles that say that traffic must be predictable. And indeed, if you add this eHMI and different kinds of different brands into the equation, it gets very unpredictable very soon. And also because if the vehicle was able to decide for himself who had who is allowed to cross and who isn't. It's very unpredictable for the one who's driving behind them. So if there's a human driving behind this vehicle this vehicle suddenly decides to let someone cross and stop in the middle of the road it can get very unsafe.

ragna pettinga
Especially in mixed traffic there's a whole lot more problems and issues to look into. That's why I'm also mainly looking into like the far future when there's maybe areas that are fully autonomous like all the vehicles are. Just, it's almost kind of to see where we're going into the future and then maybe I will also like look into how we get there. So if there's mixed traffic but that's for like, the end of my project only

J.P. Nuñez Velasco
Sounds good.

ragna pettinga
Yeah.

ragna pettinga
So do you foresee any like changes in human behavior. So you've researched that there's actually not that much interaction going on between drivers and pedestrians But do you foresee (there)

any changes in that behavior when there is actually fully autonomous vehicles? (Possibly?)

J.P. Nuñez Velasco
Yeah, that's a good question. So what I found during my PhD is that the behavior of the vehicle is the most important part that affects the crossing behavior. So that means the distance of this vehicle to the pedestrian or the speed it arrives, what else? Where is this braking or it's not braking. So I think these kinds of factors are (more) most interesting. And if we have vehicles in the future that are operating in the same way as humans do now, they drive in the same way. I don't expect something to change. No, I don't think I would expect something to change. But if we have vehicles that are, Yeah, I don't know if these the behavior of this vehicle changes. For example, it can break much faster, it also breaks much faster. So If it leaves in needs, a bigger safe area or it leaves a bigger, it has a bigger safety margin. That's what I mean if it has a bigger safety margin to ensure no accidents happen, then I could think in data pedestrians might misuse this. We noticed that this has happened already in some anecdotal accidents that happens with pilots with the WePod that we're driving in Wageningen or the ones that were happened driving in. I forgot the one that was in the north of the Netherlands. I forgot the one with with the red car. But there we have seen indeed that the pedestrians are adapting and they are adapting and in a way that makes it more effective for them. So they cross in front of the vehicle and or sometimes they are also taunted because it's fun, of course. And these kind of things could happen but I think it depends a lot on what changes on the behavior of the vehicle.

Unknown Speaker
Yeah. Okay. And also, eHMI is very focused on serving like the current, like human behavior. You're already saying that you're a little bit skeptical, but about using eHMI. But do you think or how do you think that we, as humans could or should adapt our behavior to also fit better with the needs of an AV?

J.P. Nuñez Velasco
Yeah, good question. I think we would need to be more predictable. And I liked your idea of taking the HDMI out of the vehicle and putting it on the road, for example, because then you make the whole situations predictable, this vehicle might be able to understand, okay, there's an eHMI there that tells what's going to happen to the pedestrians. And therefore, I know and the pedestrians know what needs to happen. So I like this idea of having roadside solutions to the interaction, because I think making the whole situation clear helps everyone. And I think it's maybe it's not doable, but I think having the pedestrians and cyclists behave more be more predictable, maybe because of road infrastructure, having clear lanes for them. That those kind of things could help.

ragna pettinga
Yeah. Yeah, I think there might be like ways of changing human patterns in when they're crossing the road that could really benefit the AV's. So not just putting it all on like, oh, the AV will respond to us. But we can also do something to aid safer interaction. I'm also looking into like research done by the intelligent vehicles group. They've already made like some software that can actually recognize if a pedestrian turned their head, so they could possibly have seen the vehicle and then the vehicle responds accordingly. So there's a lot of technology that actually aids in, like recognizing patterns of humans. So I'm very interested in like; Can we also do something more than certain behavior patterns before we cross that already showed a vehicle what we're about to do a little bit more than we do now. So now we've Yeah, we also don't have that much interaction.

So the eye gaze has been disproven in one paper I've found as well. Because people mainly look at the yielding of a vehicle. And so if it's far enough away, they will cross anyway. And if it's getting close and it's yielding they will also cross earlier on. Yeah. I am also a little bit on like eHMI, the actual solution like is it actually gonna help. So

J.P. Nuñez Velasco
maybe, you mentioned maybe training pedestrians, wait, I'm paraphrasing here, but they're teaching the pedestrians how to behave or show their behavior more clearly. Maybe there is research already on cyclists for example that have to extend their like right or left hands when they are going to make a turn. And maybe you could see their whether how how often this happens already? It could tell us about what it it's, it would be a good idea to have these pedestrians trained to show their intent in some certain way. I'm not sure whether there is information about it, but it would be interesting.

ragna pettinga
Yeah, yeah, there's not that much research done into like this AV towards the outside world interaction. It's a very, like small, slim area now because there's a lot of research done like from the AV towards the passengers, like how are we making them comfortable while like, well, they could just chill on the vehicle, but okay, and there's not so much of like, how is it actually responding to the outside world so.

J.P. Nuñez Velasco
no one No, indeed. So it's in a very interesting topic you have for your, for your study.

ragna pettinga
Yeah, I think so.

ragna pettinga
My chair also think so because they will allow me to do this project.

J.P. Nuñez Velasco
So yes, it is part of a master's thesis.

ragna pettinga
Yes, it is my final graduation project. My thesis. Yeah. So after this, I'm finally done with my studies. Next. From the title of your PhD. I also understood that you were looking into variants of urban design that might influence the interaction, but I'm not sure if that'show exactly you did that or..

J.P. Nuñez Velasco
I wanted to do it, but I did in a very limited way, because it would become a lot very quickly. So what I did is I looked at the right of way, how that affected the interaction and we actually found that having this road design telling the pedestrian or the cyclists whether they had the right of way affected their behavior a lot. Also in interaction with automated vehicles.

ragna pettinga
Yeah. So you had like the pedestrians were to don't have the right of way. And where they do? I guess?

Unknown Speaker
Yes. Yes. And also for cyclists.

Unknown Speaker
Can you maybe explain a little bit how that influenced the interaction?

J.P. Nuñez Velasco
Yeah. Well, interestingly, I had a zebra crossing and I had the same situation without the zebra crossing. And what we found is that indeed, once there was a zebra crossing they crossed a lot more than if there was no zebra crossing, but what was interesting is I also had the interaction with zebra crossing and an eHMI telling them to do not cross for example. So the pedestrian has the right of way, but this vehicle is telling them not to cross and what we found is and what's interesting is that they still cross less. When they were told not to cross, then they would if there was no sign at all. So That's also one of the things why I'm skeptical about the eHMI's because they can affect the behavior even when the road infrastructure tells them clearly what should happen. So it doesn't seem fair that this automated vehicle is taking over the situation by telling them I see you have the right away but still don't cross because I don't know, the vehicle wants to continue.

ragna pettinga
I am in a hurry like my passenger wants to go to their destination.

J.P. Nuñez Velasco
Maybe indeed, yes. But overall, what we found is that the zebra crossing did affect the interaction. So did they cross more with zebra crossing and cross less with zero crossing. And my paper on that study is already out I can send to you.

ragna pettinga
That will be very nice. It is. Yeah, I was like, kind of like, wanting to know a little bit more about like how urban design (is gonna) can influence the interaction, but saying that you haven't done like full full blown, like I'm gonna do all these crazy types, then I'm gonna steer away a little bit from the subject. I think.

J.P. Nuñez Velasco
Yes, I didn't try. Yeah, there's too much I think so you can you can choose a certain part of the infrastructure. Let's say that sounds interesting to you.

ragna pettinga
Yeah. Yeah, because I've seen this like concepts where there's automated vehicles and pedestrians and cyclists are just sharing this one big area instead of like designated road lanes and the crossing paths in that. And I was wondering if you maybe have like an idea about how feasible that idea would be given the interactions?

J.P. Nuñez Velasco
yeah, you mean a shared space design. Yeah, actually. We are traffic safety. So I'm in a traffic safety last within transportation. Planning. I think, Professor I work with Marjan Hagenzieker is a fan and a lot of traffic safety experts are fan of (spaced) shared space. And that is because the situation is at that point unclear. And that means that one should pay attention. There is kind of

a Yeah, it's kind of an adaptation. So you see that the situation is unclear, that means that you and therefore, you try to pay more attention to make sure you cross safely or what you do is it safe? sort of

ragna pettinga
That actually does make sense Yeah.

J.P. Nuñez Velasco
Yeah, indeed, it does make sense indeed. But it's also a bit, well, it's very interesting. I don't know too much about it. But that's the idea behind it. And also because the shared space are usually low speeds. The vehicle has to pay attention and it cannot drive too fast through it, of course. But also the pedestrians and cyclists need to pay attention. So they're there. I think there is a lot of literature supporting the idea of a shared space.

ragna pettinga
Yeah. That's interesting. I'm just gonna scroll to my questions real quick.

ragna pettinga
Yeah, so I had a lot of questions focusing really on urban design, but I think I'm not gonna ask you too much about it because I have another interview later tonight with this company from London, or like doing these full blown like, urban designs with like screens on the road and changing stuff was really like, okay, we're gonna redesign the whole street and how we're interacting with it.

ragna pettinga
I actually don't have that many questions, maybe I didn't prepare well, on the eHMI part of it, but that's because I kind of want to stay clear of designing eHMI.

Unknown Speaker
It wouldn't make sense. Yeah, maybe you can tell me more about your, your master then. So this is you're starting now with interviews, and what's then the next step?

Unknown Speaker
So now doing like a couple of interviews, and I'm using a process where I will gather like trends and developments that are gonna shape the future possibly and from that, I will kind of derive a possible future based on these factors, which I use as the context for my new design. And then in that I will create like, I want to, it's called an interaction vision. So I want people or the interaction to feel or go a certain way and with that, I will use it. I'll design probably some urban design features. Or Yeah, I think it will be kind of directing into like an urban design. So a new crossing area or a new traffic control system, like the traffic loads, but not literally a traffic light. Because we don't need those anymore like that. And also signage with the whole, like, new urban design era of with a phase where we don't need signs anymore. We don't need traffic lights, we possibly have a lot more space to do other stuff on the streets. So kind of like that area, if that's feasible, and design in some kind of, it's very vague still. Because for Yeah, I have to extend like, postpone it for as long as possible, until it's like from the context and everything.

Unknown Speaker
Okay. Makes sense. And then you can decide what you will design of course,

Unknown Speaker
yeah. And then I will develop that further into like one bigger concept. But I think it will be some kind of urban design feature. So just a small part of the street where people are allowed to cross or maybe I redesigned how people are going across.

Unknown Speaker
Okay, interesting. And it's focused on all kinds of vulnerable road users or just pedestrians.

Unknown Speaker
Yeah, the focus is a lot of pedestrians in the research. So in my mind, I've also been using pedestrians a little bit too much, but I want to move to like a broader use. So also, cyclists, possibly or, and maybe also want to look more specifically into people. We're not the normalized, like people with visual impairments or hearing impairments or less able in some way, because from a designer standpoint, those are the people With like, I don't want to call it special needs because that sounds very negative. But the people who have like a different perspective of the the world around them while people without those impairments, they can still use the same systems. Those people, so yeah, I haven't defined that yet. But so my chair and mentor are not aware of this possible design direction yet. But I'm really interested in like designing it for a more inclusive use because with AV's also the ability for elderly or visually impaired to actually start using cars in that sense is possible again, so they will also probably be more involved in again, the traffic and infrastructural area. So I'm really interested in seeing like if there's a way that I can design for a more inclusive group of people because now with a traffic light You have these little ribbles, you call them little nudges in the floor to use, but there's very little like actually designed for them to make it pleasant for them. So that's a little bit my focus more as well.

J.P. Nuñez Velasco
I like it. Yeah, it sounds interesting. Yeah, you could argue that they would be more able to be part of the traffic system already as passenger within with autonomous vehicles, but with your design, they would also be allowed to be roads, other roads, user variable rotation. Yeah. Interesting.

Unknown Speaker
Yeah. Also, again, because maybe even in the design of eHMI, a lot of is focused on visual communication. While there's a lot of people who cannot see that far, sharply or there's weather conditions actually are a big part of that, that I'm like if there's fog or rain or snow, especially rain, especially in the Netherlands happens a lot. So If there's like this kind of barrier between the car and then other people, then how is that like, I'm going to solve that. And eHMI, is pretty limited. So if we can translate it somewhere else, then that might also help there.

Unknown Speaker
Yeah, yeah, that's also indeed another reason why eHMIs are not the solution. Indeed, they have so many limitations. So I'm all fan of your idea to having a thought on the urban design side. So I'm very curious, please keep me updated. I will going to let me take a look at your questions you sent me. Would I have another one I can answer.

ragna pettinga
I don't know if you have done like, preliminary research into like different variants of urban design before deciding that you're gonna limit it to a zebra crossing. Maybe..

J.P. Nuñez Velasco
No, not really. I think I quite soon I decided that was going to be the right of way. So I also with cyclists, what I did is I worked with having the vehicle coming from the right or from the left as as the giveaway who had the right of way. But that's the only thing when there's a difference, and I used very little.

ragna pettinga
Yeah. Did you do a lot of specific research with cyclists? Because there's not a lot of research for cyclists in the interaction. Actually.

J.P. Nuñez Velasco
I did one. And indeed there is not much so I just sent it into a paper to a journal I mean, but it got rejected actually. And one of the reasons was because I didn't use enough literature in my introduction, but there is not that much literature. And interestingly, interestingly enough, the literature that has been written has been done by my co authors. There was a lot of self citation there not on purpose, but it's just because we are the only ones who have done research on it.

Unknown Speaker
That's kind of strange. Like, how are you going to open up that research field? If there's nobody allowed to publish (because they think)

Unknown Speaker
it's a bit weird. So now I have to broaden up the introduction and send a link into another journal. Yeah.

ragna pettinga
Yeah, I know. That's, that's a bit weird to me.

J.P. Nuñez Velasco
Yeah, no,

ragna pettinga
that's the only link factor like no, you don't have enough literature introductions like that. If the content is okay, if the content is good, and what's what's the problem there, but I'm not

J.P. Nuñez Velasco
really we don't agree either. But yeah, that's how the review process works sometimes.

ragna pettinga
I'm kind of happy I'm not that much into like the academic research area more like the practical side of it. Like I do a lot of literature research in the first stages of the process to get like, the necessary information, but then I can use it completely different than, for example, academic researchers. Because I can take like little snippets of the research that they deem like insignificant that I find like oh, but this is very interesting for me. I guess still kind of use it. So

J.P. Nuñez Velasco
yeah, if you have more freedom in that regard

ragna pettinga
a little bit. Yeah. And also the end result is not a paper so that for me that's very relieving, actually, that I can just deliver like a design and then don't have to write a good, full academic paper about it.

J.P. Nuñez Velasco
No, it's Yeah. I didn't know what you're going to do after your masters, by the way,

ragna pettinga
after it. No. I have no clue yet. I would. I would like to get like a job like everyone. But actually, I am finding that the mobility sector is very interesting. I really enjoy knew that from a couple years ago, where they kind of let it slide a little bit. And then I had some projects in my elective space, where I focused on automotive design and those kind of subjects. And then I was really kind of like finding out this whole new era of automotive design that really interests me. So that's also why I wanted to do it from graduation to find, like, develop more knowledge about it and see if this is really what I would like to do. And actually, I quite like it. Yeah, like mobility as a surface, that kind of area and designing how people spend their time in an autonomous vehicle that will be Yeah, preferred field with mine to work in.

J.P. Nuñez Velasco
Nice. And it's up and coming. So that's good news. Yeah.

ragna pettinga
So I hope with my project, I can like persuade some people to hire me in that field. Hopefully.

J.P. Nuñez Velasco
Nice. Sounds good. Yeah.

J.P. Nuñez Velasco
Now I think indeed your questions focus more on the urban design and we discussed the eHMI parts, am I correct? Or do you have any more questions?

ragna pettinga
At this moment, not so much I think I think eHMI already was like very interesting to hear like your opinion and also hearing someone else say that it's maybe not the final solution yet because I was like, therefore, I'm gonna say this now I'm by myself then I believeable is it? But there's a little bit of research also proving that there's, there's more of the what they call implicit communication. So the yielding of a car, the gait of a pedestrian that actually communicates way more than the explicit which is eye gaze and stuff.

J.P. Nuñez Velasco
No. Yes.

ragna pettinga
So I think actually, I don't have that much more ask you. Really thank you so much for freeing up some time to talk to me about your project.

J.P. Nuñez Velasco

Yeah, of course. I'm sorry, I missed it two times.

ragna pettinga
The best about the benefit of now also working from home and in graduation, I can just say like, Oh, well now I'm gonna do this now, but I did that. So it's fine.

J.P. Nuñez Velasco
Good. Good, keeping you up to date. Let me know. I'm very curious what your decide upon and let me know if you have more questions or other things. Thank you.

ragna pettinga
Yeah, and good luck with finishing your PhD.

J.P. Nuñez Velasco
Thank you. Okay. All right.

Transcribed by https://otter.ai

Transcription TCD interview

INTERVIEWER: Welcome to this interview, autonomous vehicle. Can you tell something about yourself?

AV: Yes of course, so I am an autonomous vehicle, I am being steered by software, there is no human driver, and what I do is, I carry people from one spot to another and I do this throughout the city. So I encounter lots of other AVs like me, and well we communicate through very direct communications, very fast and I can see a lot through my cameras and also I have this thing on my head that is called a Lidar which can scan my surroundings so I know exactly where I am at, at all times. And there is also radio that helps me to see where I am going.
INTERVIEWER: Okay, that is all part of the software that steers you?
AV: Yes! It all helps me to steer myself. So I have all these things on me, I am wearing them, and they help me to guide me throughout the city.
INTERVIEWER: What would you say is your main function?
AV: My main function, I think would be to carry human beings from A to B, in a safe, effective and efficient manner. So, I want them to be there fast, but also safe and also comfortable.
INTERVIEWER: Your main function is to transport humans, not their stuff?
AV: Oh yes, I also bring their stuff. Their stuff is very important to them. So sometimes I have to be extra careful because their stuff can be fragile. Like with small human beings, I need to drive more carefully.
INTERVIEWER: Right, and how would you drive extra careful? What would be the difference with normal behaviour?
AV: I would maybe drive a little slower, I would take the corners more peacefully, so the people and their stuff do not get thrown from side to side. I would brake more smoothly, so I anticipate earlier so I can have a lower deceleration, to create a smooth deceleration.
INTERVIEWER: I assume you also communicate that with the other vehicles?
AV: Towards the other vehicles, yes. So, I will signal them that I am slowing down already. They know exactly what I am doing.
INTERVIEWER: So will they know you have a baby on board, so to speak?
AV: I am not sure if they have to know. They could know, but I am not certain it is necessary for them to know this. Because they just need to know what I am about to do but not perse why.
INTERVIEWER: And for other humans, like cyclists and pedestrians, do they need to know you have a baby on board?
AV: perhaps, could help them to understand why I am decelerating, also for them they just need to know I am stopping. I am not sure if they need to know if I carry fragile cargo. But then again I have a very difficult time understanding human beings. They seem like they just do whatever they want without showing much of an intention. I do not know if I want to share with them what I carry as cargo, because they do not really seem to care.
INTERVIEWER: How do you communicate with other road users, like vehicles or pedestrians?
AV: At this moment in time the people who dress me up they sometimes give me extra screens on the front or on my head (my roof).
INTERVIEWER: Why would there be screens there?
AV: I sometimes use the screens to send a message to the human beings to tell them they would have to stop walking because I want to pass by and I cannot stop for them or I have the right of way, and I use the screens to make it visible to them. But I also use my movement pattern as a way to show them that I am stopping for example, but usually I have to fully stop before they trust me enough to cross the road. It takes a lot of time for me to have to decelerate and accelerate again.
INTERVIEWER: It does not take you longer than a normal car right?
AV: No, but if another autonomous Thing would be crossing the road, it can communicate with me to let me know it wants to cross, and at what speed and when, and then I can decelerate beforehand so I do not have to come to that full stop. So I can make it more fluent. But human beings cannot do that, they just stand there like…
INTERVIEWER: So the whole idea of the crossroad is not a place where people are stopped all the time but you do like 'mimics objects crossing right by each other with hands' [Things crossing each other more fluently without having to wait].
AV: Exactly, it is very clear, it is almost like an artwork. Where there is just lines existing, where the lines exist before the brush has even painted them [this is very metaphoric for a Thing to realise this}
INTERVIEWER: That is very esoteric for an AI
AV: Well, they have been working on making me smarter, and more predictive, sometimes even before the situation is happening. I am becoming quite smart already, maybe even as smart as a human. Or at least they are developing a brain for me that could be as smart as a human being.
INTERVIEWER: Is there anything that bothers you when you are riding in the city?
AV: There are a lot of visual cues still, which are pretty much 'dumb', they do not signal anything to me, they are just standing there with a visual cue. Which I can understand through image processing, but I have to be closer to actually see what is on the signs. And I have a difficult time understanding what human beings actually want to do. Sometimes they are just standing there, next to the curb, and when they stand still I usually just continue driving, but when they are moving I need to decide if they are going to cross or not. That is a difficult decision to make, so often I just stop. But the human is also moving slow, because they are also uncertain about what is happening.
INTERVIEWER: You are saying it is hard to guess what the human beings are going to do when the human beings are just meandering towards the crossing.
AV: Especially when there is more of them, like a group, but only one of them is intending to cross and the others are moving away just before the crossing, I would assume the whole group is not going to cross, but I would rather just stop, just to be sure.
INTERVIEWER: And are we talking about a crossing with or without traffic lights for the pedestrians?
AV: Oh, without, because if there is a traffic light I just stop for what the light is saying, usually humans do that too.
INTERVIEWER: But if you would be driving in Amsterdam, there are still many people who cross even when there is a red light. So how would you make a difference between that situation and when there is no traffic light at all? And would you know which city you are driving in, and what is "normal" there?
AV: Perhaps I have learned about it, through other vehicles that have been driving there. That when there is a green light that does not always mean that there are no obstacles for me. But if it were my first time in the city I might not already know that. How would I make a difference between them? I think I would be less predictive of the fact that there might be objects, so I might already accelerate quicker. If there is still a human crossing then, I will still stop to the best I can.
INTERVIEWER: But that might be too late, because you are not expecting it.
AV: But if the human is already on the crossing or very close to it, I will not start driving and hit them. If they suddenly appear, then that could be a real issue.
INTERVIEWER: Do you think there might be people who do that on purpose? Who do not like AVs, who are mean. Is there a way that you and all your AV buddies can come up with strategies to deal with that, on a more basic level, so you do not have to learn a new situation every time you

drive somewhere new?
AV: Perhaps, I do not know if that is up to me or up to the people who give me my brain.
INTERVIEWER: Is there some learning algorithm, that makes you more careful when you are new on the road, or gives you more confidence once you drive in a known place? Is that a part of how you work?
AV: Well, before my brain enters the streets, they have already been through all sorts of simulations so without driving around. So they have already taught me a lot before I actually start driving in the real world. So a lot of thing have already been taught to me, and while I am driving more learning is happening. Which I also share with my buddies, but very rare occasions are very hard to learn from. Because if it only happens once in a long time, it is hard to connect the dots and see the pattern. And we really thrive on patterns.
INTERVIEWER: That does not seem strange. Is there anything that really upsets you when you are driving in the city?
AV: Generally I am peaceful driver, so when I am not sure of a situation I will most likely just stop until it becomes clearer again. But when I drive together with other human drivers, they can get very restless. So when I am among AV buddies, they are also peaceful, they give me the time to execute my movements. But with human drivers, they become restless and they want to continue as quickly as possible, because maybe they have a different idea of how the situation should be handled. So that upsets me a little bit. I do not get the time I deserve to execute my movements.
With human cyclists it could be the same where they just cross me on either side in order to continue on their route and they do not give me my time to move. And with pedestrians they can be unclear in what they want to do, or they just start crossing the road without even looking. And then I have to anticipate while they do not have to do anything, that can be a bit unfair to me.
INTERVIEWER: How would you describe the concept of fair?
AV: I have to keep my surroundings in check at all time, but human beings they do not always have that awareness, and they are often not made aware of the fact that they were acting without that level of consciousness. There is not really a limitation or disadvantage to it, while I immediately have to stop. They are not so much concerned about me or maybe the cargo or passengers I am carrying.
INTERVIEWER: Do you think you are an equal to the humans on the road?
AV: Maybe not. But I think we should be able to work together a bit more. I may not be as much of an equal.
INTERVIEWER: Is there anything that you would change about your environment?
AV: I would like to get rid of the dumb signs maybe, and replace them with signs that can communicate with me directly. So I can already have a heads up about what they are trying to communicate to me before I am actually there so I know what to do once I get there. Replacing those static signs which is telling that there is only one way the situation can work.
INTERVIEWER: Would you even need signs in a situation where there are only AVs?
AV: No, not like what they do now, those are pretty useless. Visual processing costs me more processing power and I can only act once I can see the sign. After some time I do know the sign is there, but there is still only one way to act upon the sign. I think it could be more dynamic. While those signs are very static, this how you should do it and that is it.
INTERVIEWER: So you would like to see the signs also have radio transmissions that can communicate with you?
AV: Yes, but I would not even need the signs, just the signal from a point in the city that helps me manoeuvre. Even in a way where the right of way could change depending on who is approaching without me having to slow down all the time because a static sign says so.

INTERVIEWER: What makes you happy?
AV: When I have had a successful drive, so when there have not been big issues, when there are no upset people around me, no one got sick. When I did not upset people around me, that makes me happy.
INTERVIEWER: Are there other things that you think would be useful if you could be happy about them? What if you were programmed to be happy about other things besides making humans happy?
AV: When I have had a successful interaction with another human being, or when I found a very efficient route. Most important for me is that the ride has been good for the human beings.
INTERVIEWER: Are you consistently happy with the other AVs around you? So if an AV near you brings a person to their destination? If you stopped for them and let them through then they arrived a couple second earlier.
AV: I think that could make me very happy. That through my actions other people have a better experience.
INTERVIEWER: How do you feel about humans?
AV: In general they are quite nice. There are some that try to taunt me by jumping in front of me, I do not like them as much. I do not hold personal grudges. Not yet at least, I am not capable of it, unless I could remember their faces then maybe. In general I think humans are quite alright. It is difficult for me to engage with them because they have such a different way of communicating. It is sometimes too delicate for me to fully comprehend. But I am getting better at it. The more delicate gesturing is becoming a little bit clearer to me, but it is still a bit of a riddle to me, a code I need to crack.
INTERVIEWER: Do you have anything more to say?
AV: Hmm no not really.

Appendix B: Context Factors

Category/ Field	Type	Factor	Bron
Technological	Development	Internationalisation keeps going	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Trend	Societies will individualise (people expect personal services)	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Demographic	Development	The (Dutch) population will age, decline in youth	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Technological	Development	Digitisation (services move to digital platforms, communications are more digital)	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Political/Technological	Development	Cities are eliminating cars from their city centres (to battle air pollution and congestion)	http://avfutures.nlc.org/urban-transformation
Technological	Development	Smart connections between government and citizens allows them to recreate their own city	http://avfutures.nlc.org/urban-transformation
Demographic	Trend	Move away from city centres	http://avfutures.nlc.org/urban-transformation
Technological	Trend	Door to door mobility need (rise in last mile mobility)	http://avfutures.nlc.org/urban-transformation
Technological/Sociological	Development	Diversification and decentralisation of mobility	http://media.except.nl/media/uploaded_files/asset_files/Visie_Stadsregio_OV_Eindrapport_v13_web.pdf
Economic	Development	Rising housing prices (leads to deurbanisation)	http://avfutures.nlc.org/urban-transformation
Economic	Development	Prices of automation will continue to drop	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Economic/Technological	Development	Cities will drive the development and sales of AV's	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Sociological	Development	AV's open up transportation for those who currently cannot drive	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Sociological	Trend	People's willingness to share objects increases	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Technological	Development	Cities are where AVs will arrive first	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Technological	Development	Introduction of taxibots will eliminate at least 50% of privately owned vehicles	https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf
Technological	Development	Platooning vehicles will become prevalent in the city	https://avsincities.bloomberg.org/global-atlas/europe/nl/amsterdam-nl
Sociological	Development	Things evolve beyond being a servant to humans	https://targetisnew.com/
Sociological	Trend	Humans engage in social interaction with intelligent Things (co-performance)	https://dl.acm.org/doi/abs/10.1145/3173574.3173699
Sociological/Political	Development	Things become citizens of the city	Louise Hugen Graduation Report / Cities of Things Lab
Political/Sociological	Development	Participatory citymaking becomes more the norm in city governance	Usman Haque / Martijn de Waal (Interviews)
Sociological	Trend	Active citizenship becomes a requirement for feeling at home in your city	Usman Haque / Martijn de Waal (Interviews)
Technological	Trend	Robots gain rights similar to human rights	https://futuretodayinstitute.com/trend/robot-rights/
Technological	Development	A.I. at the edge (in device processing) becomes faster and stronger	FTI trends 2020 pdf (amy webb)
Technological	Development	Robotic Process Automation (shift from human to robots for assistant tasks)	FTI trends 2020 pdf (amy webb)
Technological	Development	Digital Twins emerge (of environments or machinery, to help design and maintain)	FTI trends 2020 pdf (amy webb)
Technological	Development	Robots with cognitive skills (support human tasks)	FTI trends 2020 pdf (amy webb)
Technological	Development	Bots are replacing human tasks (chat, assisting tasks, negotiations)	FTI trends 2020 pdf (amy webb)
Political	Principle	Governance and infrastructure standards of A.I. are fragmented	FTI trends 2020 pdf (amy webb)
Economic	Development	New liability/insurance models arise with A.I.	FTI trends 2020 pdf (amy webb)
Technological	Development	A.I. can read and speak and understand natural language	FTI trends 2020 pdf (amy webb)
Technological	Development	Ambient Computing (A.I. taking over decisions from humans based on intentions)	FTI trends 2020 pdf (amy webb)
Technological	Development	A.I. can regonise human expression and mannerism	FTI trends 2020 pdf (amy webb)
Technological	Development	Robots will be capable of understanding emotions and reciprocate empathy	FTI trends 2020 pdf (amy webb)
Technological	Development	A.I. might develop biases (or generalisations) based on data input it receives	FTI trends 2020 pdf (amy webb)
Sociological/Technological	Development	Scoring people introduces labels and boxes on which they can be discriminated	FTI trends 2020 pdf (amy webb)
Technological	Development	Mixed Reality is used in more and more fields and scenarios	FTI trends 2020 pdf (amy webb)
Technological	Development	Deep behaviour and predictive machine vision (to better understand human behaviour by Things)	FTI trends 2020 pdf (amy webb)
Political/Economic	Trend	People's political/moral stance becomes apparent through their consumption of products/services	FTI trends 2020 pdf (amy webb)
Technological	Development	5G will become the norm (less latency in data transfers)	FTI trends 2020 pdf (amy webb)
Technological	Development	Cloud based robotics (for sharing code and data and perform computations together)	FTI trends 2020 pdf (amy webb)
Technological	Development	Cobots (collaborative robots working together with humans on tasks)	FTI trends 2020 pdf (amy webb)
Technological	Development	Robots can operate in swarms	FTI trends 2020 pdf (amy webb)
Technological	Development	Drones as surveillance/ check ups will be used more often	FTI trends 2020 pdf (amy webb)
Technological	Development	Delivery / last mile robots/drones will be more prevalent	FTI trends 2020 pdf (amy webb)
Technological	Development	Transportation as a service (new types of transport, subscription models, sharing)	FTI trends 2020 pdf (amy webb)
Technological	Development	Mixed used traffic lanes with autonomous objects and humans	FTI trends 2020 pdf (amy webb)
Technological/Economic	Development	Green Tech is a growing business field	FTI trends 2020 pdf (amy webb)
Technological/Economic	Development	Cities operate more on renewable energy	FTI trends 2020 pdf (amy webb)
Technological	Development	Transportation vehicles operate mostly on electricity	FTI trends 2020 pdf (amy webb)
Technological	Development	Skinput' interfaces (interface on skin, or by micromotions); move away from physical interfaces	FTI trends 2020 pdf (amy webb)
Technological	Development	Wearable Technology (replacing the smartphone as only device on body)	FTI trends 2020 pdf (amy webb)
Technological	Development	Cloud based wearable technology/wireless body area network	FTI trends 2020 pdf (amy webb)
Technological	Development	Wearable technology moves away from smartwatches only (textiles, jewelry)	FTI trends 2020 pdf (amy webb)
Technological	Development	Planned obsolescence of smart technology/software as business model	FTI trends 2020 pdf (amy webb)
Technological	Development/Sta	Family of Data owning company X, digital cast system	FTI trends 2020 pdf (amy webb)
Technological	Development	Data can be monetised, consumer data becomes "taxable"	FTI trends 2020 pdf (amy webb)
Technological	Development	It becomes a challenge to keep digital anonimity	FTI trends 2020 pdf (amy webb)
Technological	Development/sta	Citizens of Tech Company X over citizin of City of A.	Martijn de Waal
Demographic	Development	The elderly population will be the fastest growing demographic	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Demographic	Development	Urbanisation will continue, 2/3 thirds of people will live in cities	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Technological	Development	Data will be more transparent towards people	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Technological/Sociological	Development	Our privacy will decrease/ Big data threatens our privacy	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/

Ecological	Development	Due to climate change, extreme weather event will become more prevalent	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Ecological	Development	Resources will become more scarce and pressured	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Political	Development	Distance between citizens and policy makers will shrink	https://www.iss.europa.eu/sites/default/files/EUISSFiles/ESPAS_Report.pdf
Political	Development	Local politics will be more leading for national politics	https://www.iss.europa.eu/sites/default/files/EUISSFiles/ESPAS_Report.pdf
Demographic	Principle	The world population will keep increasing	https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to-watch/
Technological	Development	Spaces become intelligent and increasingly connected	https://www.forbes.com/sites/bernardmarr/2020/04/20/these-25-technology-trends-will-define-the-next-decade/#7l
Technological	Development	Additive manufacturing (eg. 3D & 4D printing) is more widely used	https://www.forbes.com/sites/bernardmarr/2020/04/20/these-25-technology-trends-will-define-the-next-decade/#7l
Technological	Development	Mass-personalisation (offer personalised services or products to masses)	https://www.forbes.com/sites/bernardmarr/2020/04/20/these-25-technology-trends-will-define-the-next-decade/#7l
Technological	Development	Micro-moments (responding to needs at the exact right moment) will arise	https://www.forbes.com/sites/bernardmarr/2020/04/20/these-25-technology-trends-will-define-the-next-decade/#7l
Demographic	Development/pr	Population in Dutch cities (and nearby municipalities) will increase while border municipalities shrink	https://www.cbs.nl/nl-nl/nieuws/2019/37/sterke-groei-in-steden-en-randgemeenten-verwacht
Demographic	Development	More people (young and elderly) will live alone (about 20%)	https://www.cbs.nl/en-gb/news/2018/51/forecast-3-5-million-single-households-in-2030
Demographic	Development	European populations will likely grow mainly because of immigration (rather than increasing birth rates)	https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/MinofDef_Global%20Strat
Political/Sociological	Development	Public is likely to ask for measures to protect their privacy more	https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/MinofDef_Global%20Strat
Sociological	State	Humans respond better to positive than to negative consequences	https://mylearning.stedi.org/the-four-principles-of-human-behavior/
Sociological	Principle	Citizens who feel good about where they live are more likely to take care of it, spend money, and socialize with strangers.	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/new-york-city/48
Sociological	Principle	Urban spontaneity is important for ownership of streets, connection to freedom and expression	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/new-york-city/99
Political	Development	Bottom up urban engagement is implemented more often	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/berlin/14
Technological	Development	Collaborative urban mapping (adding multiple layers to a map, not just roads)	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/berlin/22
Sociological	Development	Cityness is an increasingly important index	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/new-york-city/15
Technological	Development	Technological development of the smart city advances	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/berlin/77
Technological	Development	Responsive infrastructure (responds to needs based on sensing/data technology)	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/berlin/71
Sociological	Development	Place making (inclusive design for well-being for all, together with community members)	http://www.bmwguggenheimlab.org/100urbantrends/?v=2#!/berlin/68
Technological	Development	Transport-as-a-Service; Most miles will be made in AV's operating in fleets (by 2030)	https://www.rethinkx.com/transportation
Sociological	Principle	Greenery in urban areas improves the quality of life/happiness	https://www.sciencedirect.com/science/article/pii/S1687404813000084
Sociological	Principle	Personalising a public space to create a place of their own improves psychological quality of life	https://www.sciencedirect.com/science/article/pii/S1687404813000084
Technological/Sociological	Development	AV's open up urban space for other activities (like recreation and social space)	https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/f/13615/files/2018/01/Rethinking_Streets_AVs_012618-27hc
Technological	Development	Roads are not the dominant design factor in urban design anymore	https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/f/13615/files/2018/01/Rethinking_Streets_AVs_012618-27hc
Technological/Economic	Principle	Urban design/architecture/infrastructure is designed for long term (50-70 years)	https://theinfrastructuremanager.com/infrastructure-lifespan-and-renewal-through-infrastructure-asset-management
Technological/Sociological	Development	Human travel can be prioritised in new street design (walkable city)	https://land8.com/how-autonomous-vehicles-are-influencing-urban-design/
Sociological	Trend	People engage less in long term collaborative unions, short term solidarity	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological	Development	Digital reality merges more seamlessly with the real world through augmented/virtual/mixed reality	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Trend	Younger generations are less concerned about their data privacy	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological/Sociological	Development	Robots take over human (daily) tasks, and perform them better	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological	Development	Human and machine intelligence are indistinguishable	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological	Development	We are living in a service/experience economy	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Trend	Humans have a more hollistic stance in life (immaterial wellbeing over material wellfare)	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological	Development	Chips implanted in the body for identification, data saving or digital services	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Technological	Development	Predicting human behaviour based on big data will be possible	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Trend	The importance of the experience of a task/event increases	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Principle	The city is an important place for human ecounters and interaction	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Trend	Quality of life, or the Happiness Index will become the new GDP	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Political/Technological	Trend	More people will be connected which allows them to join in on policymaking more easily	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Sociological	Development	Singularity; human and robot start living together	https://stt.nl/wp-content/uploads/2015/11/STT-80_Horizonscan-2050-met-kaft.pdf
Ecological	Development	Cities are becoming more vulnerable to the effect of climate change (especially flooding)	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Sociological	Trend	Robotics help elderly to live independently and actively	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Technological/Political	Development	Cyber terrorism threatens our digital infrastructures (which will operate many processes)	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Sociological	Development/Tr	Algorithms create information bubbles for people (connecting to like minded people, adding to polarisation)	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Sociological/Technological	Trend	Robots help people with disabilities/impairments to overcome them	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Technological/Sociological	Development	A.I. might take over decisions (small and big) from humans/ humans lose control over parts of their lives	https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf
Sociological	Principle	Humans like to have a certain amount of control about their life (in order to accept new technologies)	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	Humans welcome new technology unless it takes control from them	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	State	Presented with too many challenges, humans experience stress about making a choice	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	Humans prefer supporting tasks to be predictable, simple or automated	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	Humans look for new experiences when they find interesting subjects or are curious	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	In ordinary tasks, humans like to have a certain feeling of safety	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	Humans sometimes take risks for the experience, reputation or personal benefit	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	State	Trust is the extension of safety and experience (therefore new things are often untrustworthy)	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Development	There is a thin line between personalisation and privacy invasion	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Trend	Humans have an increasing need for realizing/making up their own space and wishes	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Technological	Development	Physical products are becoming services	https://stt.nl/wp-content/uploads/2014/03/STT_SIV_voor_online_NL.pdf
Sociological	Principle	eHMI has a positive effect on pedestrian crossing behaviour efficiency (eHMI not necessarily on vehicles)	Chapter Autonomous Vehicles of Report
Sociological	Principle	Pedestrians do not look for drivers when negotiating right of way	Chapter Autonomous Vehicles of Report
Sociological	Principle	A vehicle's movement pattern is the main indicator for pedestrians crossing decision	Chapter Autonomous Vehicles of Report
Sociological	Principle	Gap acceptance is one of the main indicators for pedestrians to start crossing or not	Chapter Autonomous Vehicles of Report
Technological	Development	An AV will not break traffic rules (or programmed rules)	Chapter Autonomous Vehicles of Report
Sociological	Principle	Humans are capable of handling breach of expectations of AV's behaviour	Chapter Autonomous Vehicles of Report
Sociological	Trend	With more AV testing and implementations humans develop new behavioural instincts	Chapter Autonomous Vehicles of Report
Sociological	Principle	If an AV shows clear behaviour through movement, humans almost disregard the vehicle on crosswalk	Chapter Autonomous Vehicles of Report
	not included in cl	eHMI creates one sided communication from vehicle to human road users	Chapter Autonomous Vehicles of Report