Transport & Planning

Safety of Pedestrians and Cyclists when Interacting with Automated Vehicles: A Case Study of the WEpods

Paola Rodríguez

Delft University of Technology

Safety of Pedestrians and Cyclists when Interacting with Automated Vehicles – A Case Study of the WEpods

by

Paola Katherine Rodríguez Cabezas

In partial fulfilment of the requirements for the degree of
Master of Science

Civil Engineering - Transport & Planning

Thesis professor: Dr. Marjan Hagenzieker
Daily supervisor: Dr.ir. Haneen Farah
Thesis external supervisor: Dr.ir. Riender Happee

May 2017

Keywords: Cyclists and pedestrians, perceived safety, crossing behaviour, unsignalised intersections, automated vehicles, WEpods.

PREFACE

The present graduation project “Safety of pedestrians and cyclists when interacting with automated vehicles – a case study of the WEpods” concludes my studies at the faculty of Civil Engineering and Geosciences at Delft University for the master programme Transport & Planning. I was engaged in this research from April 2016 to January 2017.

The case study of the WEpods took place at Wageningen University & Research, during the period of my thesis, I had the support and assistance of different people. I would like to thank the supervision of Prof. Marjan Hagenzieker who came up with the idea to carry out this investigation on the WEpods and for the time she dedicated to the grammar and spell checking of this report. Furthermore, I am thankful for the support and guidance of Dr.ir. Haneen Farah as my daily supervisor, who kept me on the right track with her critical review of the work performed. I would like to give special thanks to my external supervisor from the Faculty of Mechanical, Maritime, and Materials Engineering (3mE) Dr.ir. Riender Happee his advice helped me in the development of the current work. I am grateful to the project leader of the WEpods, Mrs. Marieke Kassenberg, on behalf of the Province of Gelderland and the steward of the WEpods Mr. Tahir Ehetasham for facilitating the study by providing information on the WEpods' project. Additionally, I would like to thank Pablo Nuñez for providing me with material and information to carry out the statistical analyses and to the staff department “integral Facility Management” of Wageningen University for uploading the survey into their intranet.

Last but not least, I am thankful to my family, Abel, Betty, Luisa, Gabriela, and Tatiana for supporting me emotionally throughout this work. Even from the distance, they supported me, gave me confidence and wise counsel to overcome the problems I faced during the progress of my studies.

I hope you enjoy reading my thesis.

Paola Rodriguez,
Delft, 2017

SUMMARY

Current research on automated vehicles focuses mainly on the drivers of automated vehicles, on its potential to improve the efficiency of traffic operations, safety, congestion and societal benefits, public's acceptance of automated vehicles as a transport system and the willingness to buy automated vehicles. Nevertheless, there is a research gap in an equally important topic of research; the interactions of the automated vehicles with Vulnerable Road Users (VRU), i.e., cyclists and pedestrians.

The WEpods (shuttle buses) are the first automated pods on public roads amidst other traffic, for an extended period of time in the province of Gelderland, in the Netherlands. The main research question revolves around the safety perception of vulnerable road users (VRUs) when interacting with automated vehicles, specifically at unsignalised intersections, and their crossing behaviour in comparison with traditional motor vehicles. The data on road users' perception was gathered through face-to-face interviews ($N = 22$), a focus group ($N = 8$), and an online survey ($N = 198$). The results of this research showed that in terms of perceived safety, in general, VRUs (pedestrians and cyclists) feel significantly safer when sharing the road with the WEpods (max. speed of $15\,km/h$) compared to traditional motor vehicles (max. speed of $30\,km/h$). However, cyclists reported feeling less safe when interacting at unsignalised intersections with the automated vehicles, while there was not significant effect on pedestrians. Similarly, pedestrians more often opted for crossing facilities in the presence of the WEpods than in the presence of traditional motor vehicles (this can be interpreted as the result of perhaps feeling less safe), while no significant difference was reported for cyclists.

Some of the reasons that could explain the trust in the WEpods are its low operational speed and the trust of most (81.1%) of the VRUs in the automated technology. This makes them expect the WEpods will stop in all possible instances, even when other traffic participants violate traffic rules. Surprisingly, a significant proportion (63.2%) of the participants were not aware of the presence of the steward on board of the WEpods. On the other hand, variables such as the awareness of the steward and having interacted with the WEpods increased the perceived safety amongst VRUs. Moreover, eye contact and gestures use as part of the actual interaction with human drivers of traditional motor vehicles particularly when crossing, was reported to be of importance by the respondents and has also been previously reported in the literature. The VRUs who said that they rely on cues given by drivers, more often indicated a preference to cross at dedicated facilities in the presence of the WEpods than those who stated not to depend

on this type of communication. In order to substitute this lack of “real” interaction, information about the WEpods’ operations appeared to be desired by most of the participants in the form of visual information or a mix of auditory and visual. Finally, it was found that individual characteristics of the VRUs, such as their gender and other demographic variables could also have an impact on their perceived safety of VRUs interacting with the WEpods.

The findings of this research point at a cautious attitude of cyclists and pedestrians in their interaction with automated vehicles. Nevertheless, this conservative mindset could be balanced by informing VRUs about both the features and the limitations of the WEpods, in conjunction with a suitable communication of intentions of the vehicle to its surroundings to achieve a safe interaction between VRUs and automated vehicles.

CONTENTS

1. **Introduction** ... 1
   1.1 Historical overview ... 1
   1.2 Problem definition ... 2
   1.3 Scope of the current study ... 4
   1.4 Scientific relevance ... 6
   1.5 Thesis outline ... 7
2. **State of the art** ... 8
   2.1 Interaction VRUs and traditional motor vehicles ... 8
      2.1.1. Interaction pedestrians and traditional motor vehicles ... 8
      2.1.2. Interaction cyclists and traditional motor vehicles ... 13
   2.2 Interaction VRUs and automated vehicles ... 16
      2.2.1 Public opinion automated vehicles ... 16
      2.2.2 Automated transport initiatives – Citymobil2 ... 18
      2.2.3 Other approaches ... 19
   2.3 The technology of the WEpods ... 21
   2.4 Conclusions ... 22
3. **Research questions and hypothesis** ... 24
   3.1 Step 1: Sub-research questions ... 24
      3.1.1 VRUs interacting with traditional motor vehicles vs. the WEpods ... 24
      3.1.2 VRUs´ perception of safety interacting with the WEpods ... 24
   3.2 Step 2: Operationalisation ... 25
   3.3 Step 3: Research Hypotheses ... 26
      3.3.1 VRUs interacting with traditional motor vehicles vs. the WEpods ... 26
      3.3.2 VRUs´ perception of safety interacting with the WEpods ... 27
4. **Research methods** ... 29
   4.1 Step 1: Face-to-face interviews ... 29
   4.2 Step 2: Focus group ... 30
   4.3 Step 3: Self-administered survey ... 30
5. **Results** ... 34
   5.1 Face-to-face interviews ... 34
      5.1.1 VRUs interacting with traditional motor vehicles vs. the WEpods ... 34
      5.1.2 VRUs´ perception of safety interacting with the WEpods ... 36
   5.2 Focus group ... 37
      5.2.1 VRUs interacting with traditional motor vehicles vs. the WEpods ... 37
      5.2.2 VRUs´ perception of safety interacting with the WEpods ... 38
   5.3 Self-administered survey ... 39
      5.3.1 VRUs interacting with traditional motor vehicles vs. the WEpods ... 40
      5.3.2 VRUs´ perception of safety interacting with the WEpods ... 45
6. **Conclusions & Discussion** ... 57
   6.1 Main findings ... 57
      6.1.1 Problem and research gap ... 57
      6.1.2 Findings of the present research ... 58
   6.2 Discussion ... 62
   6.3 Conclusion ... 66
7. **Recommendation for future research** ... 67
8. **References** ... 69

Appendices ... 79
Appendix A - Citymobil2 results ... 79
Appendix B - The technology of the WEpods ... 81
Appendix C - Operationalisation of Sub-research questions and Hypotheses ... 83
Appendix D - Self-administered Survey ... 85
Appendix E - Face-to-face-interviews ... 102
Appendix F - Focus group ... 110
Appendix G - Statistical tests ... 113

LIST OF FIGURES

Figure 1 Fatality rate per distance driven with conventional vehicles as a function of the driver age, with four possible risk scenarios for self-driving vehicles....3
Figure 2 Sub-questions related to VRUs interacting with traditional motor vehicles vs. the WEpods....5
Figure 3 Sub-questions related to VRUs´ perception of safety interacting with the WEpods....5
Figure 4 Overview of research methods....6
Figure 5 Zebra crossing at Wageningen UR campus....9
Figure 6 Unsignalised intersection at Wageningen campus....16
Figure 7 Comparison of the perception of safety, with and without road markings....18
Figure 8 Sensors in the WEpods....22
Figure 9 Frequency in which respondents interact with human drivers....36
Figure 10 Frequency of exercising and commuting of VRUs on campus....40
Figure 11 Comparison of the perceived safety of pedestrians sharing the road in general with traditional motor vehicles and with the WEpods....41
Figure 12 Comparison of perceived safety of cyclists interacting at unsignalised intersections with traditional motor vehicles and with the WEpods....42
Figure 13 Comparison of level of concerned of cyclists who interact and do not interact with human drivers....45
Figure 14 Comparison of the level of concern of pedestrians who had and had not interacted with the WEpods....46
Figure 15 Knowledge of the technology....47
Figure 16 Types of indications of intentions that VRUs want to receive from the WEpods....64
Figure 17 Types of indications of intention VRUs want to receive from the operations of the EZ10 vehicle in Lausanne (Switzerland) according to Citymobil2....64
Figure 18 Types of indications of intentions that VRUs want to receive in La Rochelle....79
Figure 19 Types of indications of intentions that VRUs want to receive in Lausanne....79
Figure 20 Types of indications of intentions that VRUs want to receive in Trikala....80
Figure 21 Environmental sensing 5x360° view- 4 physical principles....82

LIST OF TABLES

Table 1 Parameters that influence the pedestrian behaviour 10
Table 2 Parameters that influence the cycling behaviour 14
Table 3 Safety perception of VRUs sharing the road with the WEpods vs. sharing the road with traditional motor vehicles........ 34
Table 4 Safety perception of VRUs at unsignalised intersections with the WEpods vs. with traditional motor vehicles........ 35
Table 5 Reported crossing behaviour of VRUs with the WEpods vs. with traditional motor vehicles 35
Table 6 Perceived safety and reported crossing behaviour of VRUs when interacting with traditional motor vehicles (V) compared to interacting with the WEpods (W) 40
Table 7 Perceived safety and reported crossing behaviour of VRUs who interact with a human driver (I) compared to VRUs´ who do not interact with a human driver (NI)........ 44
Table 8 Perceived safety and reported crossing behaviour of VRUs´ who had interacted (S) compared to VRUs´ who had not interacted (R) with the WEpods 45
Table 9 Safety perception and reported crossing behaviour of VRUs according to their familiarity (F) with the technology, awareness (AW) and knowledge (K) of the WEpods 47
Table 10 Safety perception and reported crossing behaviour of VRUs according to their awareness of the steward (AS) and their trust in technology (T) 49
Table 11 Safety perception and reported crossing behaviour according to VRUs demographic characteristics - gender (G), age (A), nationality (N), cycling experience (C) and occupation (O) 52
Table 12 Operationalisation of questions and Hypotheses 83
Table 13 Description and assumptions of the statistical tests 113
Table 14 Type of variables and statistical tests for the data analysis in SPSS 115
Table 15 Partial association of the variables........ 120
Table 16 Parameter estimates for the hypercritical Model (Awareness the WEpods* Awareness automated technology) and (Have seen the WEpods? *Awareness the WEpods) 120

1. INTRODUCTION

The current chapter introduces the reader to the research; first, the history of the VRUs in the Netherlands is described, followed by the problem definition. Then the description of the current study, the research objectives, the societal and scientific relevance are described, and finally, this chapter is concluded with the outline of this research. ***N.B.:*** There are different terms to refer to vehicles that can drive themselves (automated, self-driving, autonomous and driverless). Considering that the WEpods have a level 3-4 (conditional/high automation) [1], the term automated is used in the present document, except where reference is made to literature that uses different terminology.

1.1 Historical overview

Dutch people consider cycling to be a fundamental part of their national identity. The bicycle was introduced in the Netherlands around the year 1870 and the first bike paths were built in the 1890s. These cycling facilities are nowadays assumed as a safety measure to separate slow traffic (bicycles) from fast traffic (vehicles). Back then, the facilities had the same purpose, but being the bicycles being the fast traffic [2]. From the 1920s and onwards, the bicycle became the most popular mode of transport for quite some time and its use increased rapidly [3]. From 1950 to 1975, the bicycle was entirely excluded from the government's policy and the construction of bicycle facilities was replaced by the construction of vehicle facilities [2]. The bicycle began to be replaced by mopeds and subsequently, by motor vehicles. As a result, the total number of trips and kilometres travelled by bicycle started to decline.

The traffic behaviour, the regulations, and infrastructure were not adjusted to the dominant role of motor vehicles, resulting in the deterioration of traffic safety. In 1972 incidents reached a peak; 3,264 traffic fatalities and 70,000 casualties were registered, from which 17% and 32% respectively were cyclists, which was a 200% increase in fatalities and a 250% increase in casualties over a span of 20 years [3]. This gave rise to protest movements such as *Stop de Kindermoord* (Stop the Child Murder) which was focused on (child) traffic deaths [4]. This along with other factors, such as the oil shortages in 1973 - 1974, resulted in governmental measures to regulate the car traffic and build safer streets. Furthermore, the first *woonerven* (small shared space residential areas where pedestrians have priority and vehicle speeds are restricted with traffic calming) was created to make cities more people-friendly and liveable [3]. Nowadays, the importance of the VRUs´ safety in the Netherlands is clear, which is reflected in different measures, such as extensive cycling rights of way, urban design with adequate facilities that improve protection to people [5] and broad traffic education for all road users supporting the use of non-motorised modes. Additionally, to discourage the use of motor vehicles, restrictive policies, regulations and enforcement, were created making it far more expensive and much less convenient [6].

Cyclists and pedestrians played an important role influencing the popularity of the motor vehicles in its inclusion into the society. The question that may arise now from revising the above-mentioned historical context, is how the future inclusion of a new technology such as automated vehicles into VRUs´ daily life could be affected by their perceived safety. Furthermore, it will be important to know if the technology will be completely adopted or if it will have its ups and downs as its predecessor, the motor vehicle. Presently, these future scenarios can only be theorised. However, given the above-mentioned conditions in the Netherlands, it is expected that the VRUs status quo of preference can prevail in future automated environments, where their safety is prioritised.

1.2 Problem definition

Automated vehicles are an interesting new technology due to the change in responsibility from the driver to the machine. Nowadays, human errors and traffic violations are contributory factors on many road incidents. Inattention or distraction, hazardous speeding, misinterpretation of the traffic situation, inexperience or driving under the effect of psychoactive substances are risk-increasing factors that contribute to crashing [7]. Contrary, sensors combined with computer technology can perform the driving tasks, do not commit these violations, are always attentive to the road and do not get tired as humans do. They are able to systematically outperform human drivers under certain conditions because they can detect objects and process information faster than persons and the chance of a machine failure is potentially smaller than a mistake by a human being [8].

The Netherlands believes in the potential for significant change in road mobility with the introduction of Intelligent Transport Systems (ITS). By establishing the Netherlands as a country for testing autonomous vehicles and ITS, the minister of Infrastructure and Environment wants to make the country a fertile ground for these innovations and facilitate its development, with road safety being an important condition in its progress [9]. It is clear that these systems must be very safe because one accident could be a death sentence for these projects [10]. For that reason, the causes of current accidents with traditional motor vehicles should be examined, the document of [11] highlighted the fact that not all crashes are caused by drivers, some incidents are the consequence of vehicular factors such as brakes or tyre failures, road factors such potholes; leading to loss of vehicle control, environmental factors; such as fog or inappropriate actions by other traffic participants. For instance, considering that pedestrians are responsible for 80% of the pedestrian crashes at intersections. Even self-driving vehicles would find it difficult to cope with these situations [11].

There is a lot of debate around possible future scenarios, and not all of them are optimistic. It is important to consider that even if the automation of driving prevents human errors, new types of errors will arise in both, *the vehicle* (e.g., system failure or find situations that they are unable to deal with) and in *other road users* (e.g., unjustified trust from pedestrians and cyclists in the technology) leading to unsafe situations [12]. As this technology is still in development, there are some *vehicle* limitations. For instance, the criticism done by [13] who mentioned that the auto industry and the press have overrated autonomous vehicles. It appears that already relative simple driving situations and encounters with other road users pose big challenges to software engineering. It is also argued by [13] how the software for autonomous vehicles should achieve higher standards than anything currently found in customer service (e.g., laptop), as a delay in the software response as little as one tenth of a second represents dangerous situations in traffic, where decisions should be made within fractions of seconds. Achieving these requirements will be difficult as time and money are needed for innovations in signal processing and software engineering capable of responding to difficult and unexpected conditions.

Furthermore, *other road users* represent a challenge for the technology. For instance, if a drunk pedestrian or a person intending to test the vehicle suddenly steps into the road, leaving a short distance between the vehicle and the pedestrian, the limiting factor might not be the reaction time but the stopping distance of the vehicle [11]. Therefore, even if a self-driving vehicle in principle could be able to respond faster than a human driver and provide optimal braking performance, it still might not be able to stop in time due to its braking limitations, therefore, the crash could be imminent [14]. Hence, it is important to consider that even if automated vehicles perform as they are expected to do with high standards, they could compensate for some but not all incidents caused by other road users. It is difficult for the automated technology to predict VRUs´ intended behaviour, as robots are not good dealing with inconsistent behaviour [12].

The study made by [11] showed a figure with a U-shaped function of the relationship between driver age and the fatality rate per distance driven (the original graph with the exact values of fatal passenger vehicle crashes in 2001 - 2002 can be found in [15]) with conventional vehicles together with the four possible risk functions using self-driving vehicles (Figure 1). The question that may arise, is which scenario is more probable, Case 1 with zero fatalities; Case 2, which is lower than the minimum; Case 3, which is the minimum with human drivers or Case 4 with a value that is higher than the minimum fatality rate per distance driven in 2001-2002. The contribution of other factors above-mentioned exclude Case 1 from a future reality; hence, the reality will be Case 2, Case 3, or even Case 4. However, it is expected that self-driving vehicles with a risk scenario like Case 3 or higher will not be actually allowed. The arguments described in the above paragraphs support the conclusions drawn by [11], who noted that the expectation of zero fatalities with self-driving vehicles is not realistic. This premise was also confirmed with the first killed person inside a self-driving vehicle in the United States in May 2016 when the sensors of the Tesla vehicle failed to recognise a tractor- trailer on the highway [16].

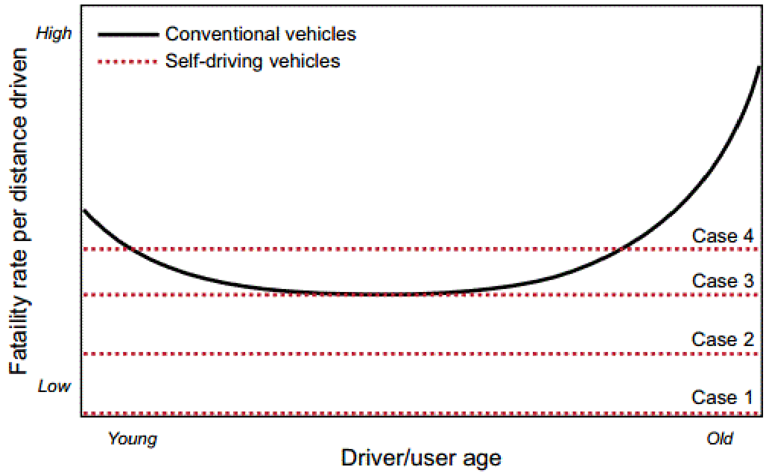


Figure 1 Fatality rate per distance driven with conventional vehicles as a function of the driver age, with four possible risk scenarios for self-driving vehicles [11]

The driving environments commonly seen in the literature are: highway, rural and urban. All these three environments have different characteristics, e.g., pedestrians and cyclists can be encountered frequently in the urban environment, but much less frequently in rural environments and are not allowed on highways in the Netherlands at all. Given the interaction with VRUs, urban areas are very challenging for the development of automated vehicles [17], which is the environment where the WEpods operates. In addition, recognising and negotiating with other unusual road users can be mentioned as another challenge. For instance, the presence of scooters for handicapped, skaters and even microcars driving on the cycle paths; which are moving at different speeds than pedestrians and cyclists, to which automated vehicles should respond in a different way.

Furthermore, the current interaction between a human driver and other road users is an important step in the process of decision making. This is for example done by making eye contact and proceed according to the feedback received from other human drivers or road users [11]. Although frequently mentioned in the literature, there is no empirical evidence on, for instance, how often this eye contact is actually taking place. With automated vehicles, this feedback is absent, and especially the perception of VRUs towards this new technology may change. Finally, the complexity of automated vehicles is reflected in [18] where a scenario analysis was conducted for future development paths of Automated Vehicles (AV) in the Netherlands. It was stated that the difficulty of urban environments and unexpected incidents may influence the development path of these vehicles. In conclusion, the implications of the inclusion of automated vehicles sharing the road with other road users are among the main uncertainties of this future transportation system.

1.3 Scope of the current study

Currently, the province of Gelderland in the Netherlands is doing a pilot with two automated vehicles (with no steering wheel nor pedals) called WEpods. The vehicle adopted by the WEpods project is the EZ-10 of EasyMile that was used in the trials by CityMobil2 [19]. The WEpods consortium equipped the vehicles with additional technical equipment to improve different aspects of the project; amongst others, the safety of VRUs. This project was a world premiere, the WEpods consortium was the first organisation to demonstrate automated shuttles on public roads amidst other traffic for an extended period of time [20]. The test phase started in November 2015 and the WEpods have been driving from February 2016, fairly frequently on the campus of Wageningen University (1.9 km) with a maximum speed of $15\ km/h$. Nowadays they transport passengers inside the campus of the University every Tuesday on a designated route and schedule. From October 2016, the route was expanded along the Food Innovation Strip, to the Ede-Wageningen railway station (9.1 km) [21]. This is a residential area (speed limit of $30\ km/h$), where the WEpods should share the road with other road users. However, there are also distributor roads with a speed of $50\ km/h$ where the driving is changed from fully automated to semi-automated operation and as a safety measure, a steward is controlling the WEpod's speed (maximum of $25\ km/h$) [22].

The current study consists of an attempt to examine the perceived safety, acceptance, behaviour and awareness of the students and staff members at the Wageningen University interacting with the automated vehicles. The development of the research and the necessary methodology to create the planned study required the formulation of the main research question. The aim is to answer this question in the present thesis:

How is road safety perceived by vulnerable road users such as pedestrians and cyclists, when they interact with the WEpods during its test phase?

The answer to this main research question can be given by answering several sub-questions, these questions are divided into two groups. The first four sub-questions are related to the safety perception and crossing behaviour of VRUs in their current interaction with traditional motor vehicles compared to interacting with the WEpods, as it is shown in Figure 2.

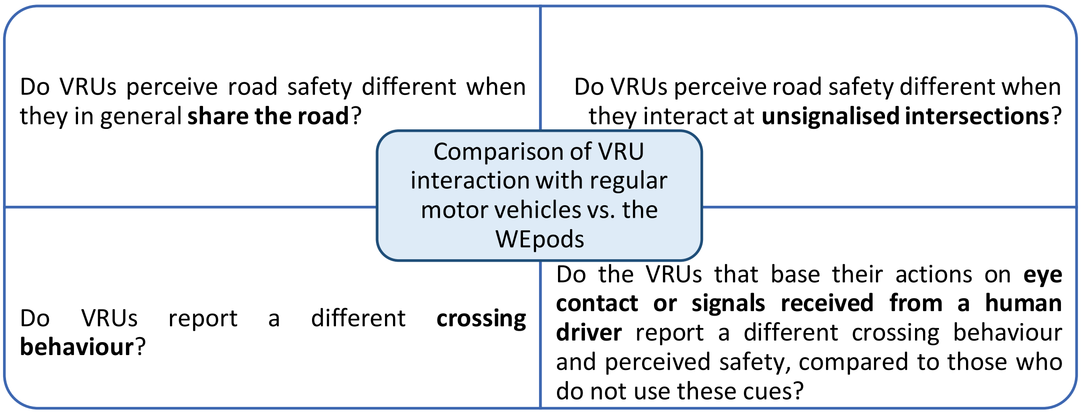


Figure 2 Sub-questions related to VRUs interacting with traditional motor vehicles vs. the WEpods

The remaining four sub-questions address how the safety perception and behaviour with the WEpods differ between different VRUs´ groups according to different aspects. For instance, regarding their knowledge of the technology, information of the WEpods, demographic data and whether they had (revealed preference) or had not (stated preference) interacted with the vehicles as shown in Figure 3.

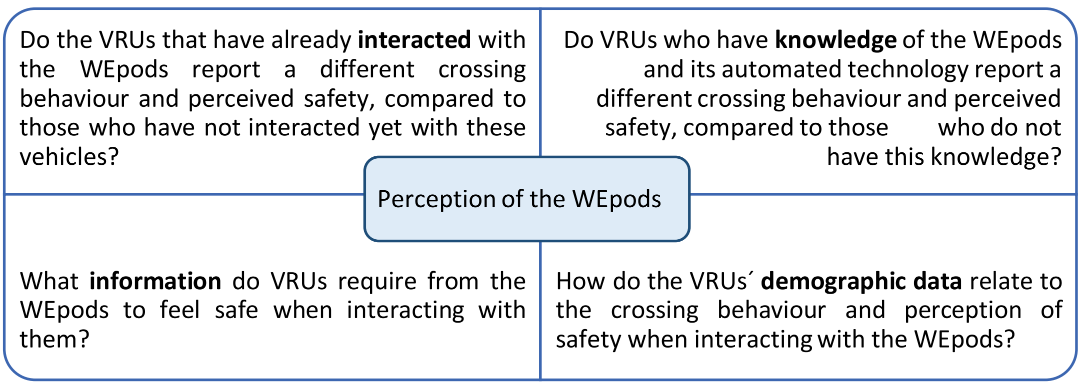


Figure 3 Sub-questions related to VRUs´ perception of safety interacting with the WEpods

At the beginning of this research, a comprehensive literature study regarding automated technology was carried out. Given the knowledge gap of automated vehicles as became apparent from the literature, and the fact that the operational phase of the WEpods was still under development at the time of this research (second half of 2016), the selected research method included face-to-face interviews and a focus group. The outcome of these qualitative approaches gave hints to the researcher of general thoughts of the VRUs and the aspects that appeared to explain and influence cyclists´ and pedestrians' perception of safety and behaviour. This data was used as an input for the online survey that was distributed to the students and staff of the University. Finally, the outcome of the survey was compared with the literature regarding the current interaction of VRUs with traditional motor vehicles, and the results of research regarding automated vehicles. An overview is illustrated in Figure 4.

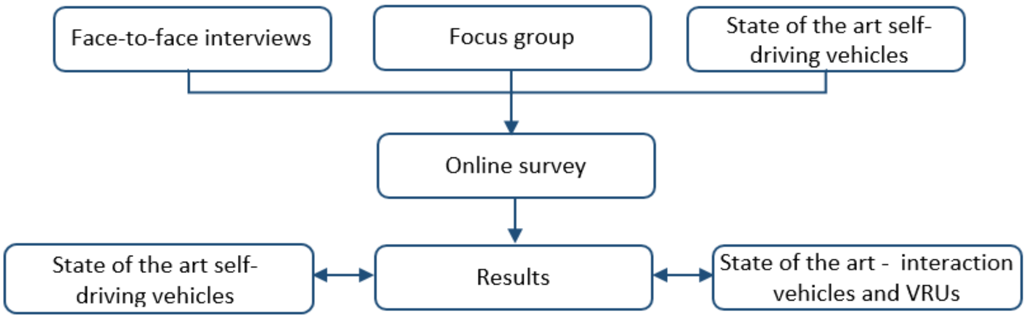


Figure 4 Overview of research methods

1.4 Scientific relevance

Current research on automated vehicles focuses on different aspects. For instance, the interactions between human drivers and automated vehicles, such as taking over control or loss of control [23] [24] [25] [26], on its potential to improve the efficiency of traffic operations [27], technology developments [28], safety, congestion and societal benefits [29], public's acceptance of automated vehicles as a transport system [30] or the willingness to buy an automated vehicle [31]. However, there is limited information regarding the perceived safety of VRUs interacting with automated vehicles. Among the few studies on this topic, there is a stated preference survey conducted by [32], this research concluded that cyclists preferred an increased separation and protection from traditional motor vehicles as its volume and speed increase. Moreover, this preference significantly increased when they had to consider the future presence of autonomous vehicles. Other research on this topic was done by CityMobil2, carrying out trials with automated vehicles in three different European cities. That study aimed to understand the attitudes, perception, and interaction of VRUs with automated vehicles through interviews, surveys, focus groups and videos [33]. The published results showed that there is a lower perceived safety in environments with no road markings, demonstrating the significant safety relevance of road markings for VRUs [34].

Other studies were especially focused on the vehicle-to-pedestrian communications with external vehicles' interfaces. Given the limited access to the technology, these studies simulated automated vehicles [35]. On the one hand, the results of [36] indicated that the AVIP (Automated Vehicle Interaction Prototype) interface was easy to interpret, it improved comfort and could potentially increase safety. On the other hand, [37] concluded that pedestrians will rely on legacy behaviours (existing crossing strategies) instead of being influenced by external information on an external display. In the present research, knowledge was gathered regarding the safety perception and reported crossing behaviour of VRUs in their interaction with automated vehicles (the WEpods). This knowledge will help to fill in some of the knowledge gaps on how VRUs will interact with this new technology.

Furthermore, it is useful to gather information regarding the road user's behaviour in the presence of automated vehicles, since this information could be further used in modelling. Different types of conceptual behaviour models are used in studies by researchers and practitioners, it is considered an important tool for traffic safety research. Having a better understanding of behaviour, its causes and integrate them with quantitative traffic models, could create much better traffic safety models, making possible to create better predictions of traffic behaviour in changing conditions [12]. However, it should be considered the fact that not all road users are a homogenous group, there is no such thing as the "average road user", there are wide differences in their capabilities, knowledge, motivation, behaviour and state-of-mind [38]. Hence, the task of modelling becomes even more difficult, when we realise that it is not possible to observe and quantify all the factors that influence behaviour [12].

Even though this research does not directly measure VRUs´ behaviour given the early stages of the development of the technology. It is expected that the present findings could contribute to understanding the perception and preferences of VRUs in their interaction with automated vehicles, this information could be introduced into future conceptual models in further research.

1.5 Thesis outline

The structure of this thesis is as follows, *Chapter 2,* the state of the art related to the current interaction of VRUs with traditional motor vehicles and with automated vehicles is reported, along with some information about the technology that drives the WEpods. In *Chapter 3* the proposed sub-research questions, operationalisation and research hypotheses to answer the main research questions are described in more detail. *Chapter 4* describes the methodologies used to tackle the research questions, followed by *Chapter 5* that provides the results for the quantitative and qualitative methods. *Chapter 6* presents the conclusions and discussion based on previous studies regarding the interaction of VRUs with traditional vehicles and with automated vehicles. This report concludes with *Chapter 7*, that includes recommendations for future research.

2. STATE OF THE ART

A lot of questions may arise from the interaction of VRUs with automated vehicles. For instance, how will the presence of the WEpods change VRUs perceived safety, preferences and behaviour? Or, will VRUs prefer separated infrastructure like the type of systems already in operation, where automated vehicles have segregated lanes compared to the current conditions of the WEpods where they drive in mixed traffic? Or, what type of notifications they would like to receive from the operations of the automated vehicle? One of the main objectives of this research is to identify if there is a difference in the perceived safety of the VRUs in interacting with the WEpods compared to interacting with traditional motor vehicles. For that reason, the literature review related to the interaction of VRUs with traditional motor vehicles is first reviewed, followed by the description of the limited information available regarding the interaction of VRUs with automated vehicles, then it is described the technology of the WEpods and finally, this chapter finishes with the conclusions.

2.1 Interaction VRUs and traditional motor vehicles

The vulnerability of cyclists and pedestrians can be determined with the inequality factor. This factor expresses the difference in crash severity, which is the product of the ratios of the numbers of casualties in the group of more vulnerable road users (pedestrians, cyclists, and (light-) moped riders) divided by the number of those in the less vulnerable group of road users (car, van or lorry). This value is two for pedestrians and cyclists in case of a collision with a motorcycle and drastically increase to 43.3 for pedestrians and 32.1 for cyclists in case of involvement with motor vehicles [39]. This demonstrates the degree of vulnerability cyclists and pedestrians in the cases that their opponent is a motor vehicle. As reported by [7] the primary causes of many road accidents are human errors and traffic violations. Based on optimistic scenarios, it is expected that additional to these measures, the development of new technology like automated vehicles brings new benefits, especially in the reduction of serious injuries and fatalities [11] [40]. To get a deeper understanding of the perceived safety of the VRUs in interacting with the WEpods in comparison with traditional motor vehicles, the first part of this section describes the existing literature on the interaction of VRUs with motor vehicles. This step can be compared with the literature review regarding traditional motor vehicles made for the project *VENTURER: introducing driverless cars to UK roads* done by [41], considering the limited literature related to automated vehicles.

2.1.1. Interaction pedestrians and traditional motor vehicles

The vulnerability of pedestrians

Since 2005 the number of fatalities among pedestrians in the Netherlands has decreased by 36%, to approximately 57 deaths (9.2% of the 621 total road fatalities) in 2015 [42]. In 2005, 799 pedestrians were involved in serious road injuries [43] this number increased by 29.5% to approximately 1,035 incidents (5% of the 20,700 total road injuries [44]) that were registered in 2014 [45]. It is important to bear in mind that the registration rate of road injuries among pedestrians is low so this number is likely to be underestimated. When considering the period from 2007 to 2009, 86% of the pedestrian casualties in the Netherlands occurred in urban areas, where 6% of the road deaths and 20% of serious injuries were registered on $30\ km/h$ roads. Being motor vehicles the most frequent crash opponents of pedestrians, accounting for 67% of all the reported incidents and being mostly children and people over 75 years, the age groups with higher casualty rates [46]. The vulnerability of pedestrians can be observed by the average crash severity that is measured with the lethality rate (ratio of the number of deaths and the number of serious road injuries), over the period 2005 to 2009 this value was 22 for pedestrians (above the average for all road users, which is 14) [39].

Infrastructure

One of the goals of the Dutch traffic policy was and still is to improve the pedestrian´s facilities to increase pedestrian safety and walking rates. This is done through the change of the road design that includes extensive car-free zones in city centres and footpaths on both sides of the roads, and calming measures such as speed bumps, chicanes or lateral shifts [47]. In order to protect pedestrians crossing wide roads; kerb extensions and staggered pedestrian crossings such as mid-block crossing and refuge islands were implemented. Moreover, conventional techniques such as clearly marked zebra crossings (that are present on Wageningen UR campus, see Figure 5) and technological measures such as pedestrian-activated crossing signals both at intersections and mid-block crossings have separated the pedestrian both spatial and temporal from the vehicles. Additionally, the creation of shared spaces has enabled all road users to coexist in the same road, reducing the dominance of the motor vehicles and improving the movement and comfort of the pedestrians [48].

Figure 5 Zebra crossing at Wageningen UR campus

Pedestrian Behaviour

The existing literature on pedestrian movement and behaviour models can be divided into two categories of pedestrian behaviour: route choice and crossing behaviour. Route choice models concern some factors influencing pedestrians' decision making processes regarding the optimal path, among some alternatives. The studies in this area include crowd and evacuation dynamics that are modelled by means of simulation techniques. Crossing behaviour models are related to pedestrians' decision making based on the time and/or location of road crossings. These models normally use gap acceptance theory or utility theory and other statistical analyses such as level-of-service or discrete choice models that are obtained by observations and stated preference data [49]. It is mentioned in [50] that the variation in pedestrian movement's characteristics is due to parameters such as their speeds, compliance with traffic signals, speed-flow-density relationships, and gap acceptance while crossing the road.

In gap acceptance behaviour, each pedestrian is supposed to have a critical gap in mind in which to cross the road between vehicular traffic [51], this event is influenced by factors such as age [52] [53] [54], gender [51] [55], nationality [56], presence of other pedestrians [51], volume [55], speed of the oncoming traffic [52] [57] [58], pedestrian speed [52], roadway geometry (e.g., number of lanes in the road) [55] [59], waiting time [57], distance and size of incoming vehicles [51] and risk tolerance [60]. On the other hand, utility maximisation theory describes how the pedestrians find their way through the walking facilities. This means that pedestrians choose their destinations to maximise the utility (travel time, comfort, effort, etc.) of their trip [61].

A study related to road-crossing behaviour done by [55], mentioned three types of pedestrian crossing manoeuvres. First, in a single stage: where the person crosses the road in one manoeuvre independent of its width. Second, in two stages: when the pedestrian crosses up to a median and afterwards crosses the second part of the road, and finally the most dangerous rolling gap when pedestrians do not wait to cross the road for all the road lanes to be completely clear; instead, they anticipate that the lanes would clear as they walk crossing the road. As discussed by [51], the decision to cross or not the road is influenced by different variables. For instance, the distance from the approaching vehicles (rather than its speed, which could be more difficult to assess), the waiting times of pedestrians, type of approaching vehicle, the presence of illegally parked vehicles and the traffic gap.

As mentioned by [62], age, gender, group size, pedestrian flow and pedestrian signals are associated with pedestrian violations, as well as maximum waiting time (red light phase). Moreover, intersection clearance time is an influencing factor on violations and on the number of dangerous crossings committed. The authors showed the importance of proper timing of pedestrian signals in reducing violations. Table 1 provides a partial summary of conclusions of pedestrian behaviour found in the literature.

Table 1 Parameters that influence the pedestrian behaviour

Parameters	Conclusion
Age	▪ Older people appreciated pedestrian crossings, signalised intersections and cycle paths significantly more than younger people [63]. ▪ Young people had a more positive attitude towards committing violations than adults, they perceived the subjective norm to be less inhibitory, reporting more violations, errors, and lapses than adults [64]. ▪ The proportion of time pedestrians pointed their head down instead of looking the traffic while crossing a road could be explained by the fear of falling (associated with old age) [65].
Gender	▪ When crossing the road, women were more influenced by their social environment (presence and behaviour of other pedestrians), whereas men

	seemed to be more concerned with the physical conditions of the setting (traffic volume) [66]. ▪ Age and gender had the most significant effects on crossing speed [65]. ▪ Old women made more unsafe crossing decisions, leaving smaller safety margins and become poorer at estimating their walking speed [67].
Human behaviour	▪ Lower risk taking in crossing behaviour was associated with having been involved in a traffic collision, owning a private vehicle (drivers are more aware of risk), being female, crossing with children, and being older [68]. ▪ Committing rule violations at signalised intersections is a potential human behavioural contribution to pedestrian injury [69]. ▪ Pedestrians can change the crossing behaviour according to their own characteristics rather than to characteristics of the external environment [70]. ▪ Behavioural characteristics like driver yielding the right of way, the rolling gap, and frequency of attempt were important in pedestrian uncontrolled road crossing [71]. ▪ Social and psychological variables and perceived behavioural control predicted the manner of crossing the road [72]. ▪ Different means of communication with drivers: Pedestrians use eye contact and hand signals to anticipate when it is safe to cross. Signals of gratitude (*Thank you!*) are also employed (hand waving, nodding, smiling) [73].
Gap-acceptance and waiting times	▪ Pedestrians waiting at refuges (or medians) were more willing to accept shorter time gaps than those beginning the first stage of a road crossing [74]. ▪ The 85th percentile accepted gaps by pedestrians is between 5.3 and 9.4 s, with a trend of increasing the gap length as the crossing distance increased [75]. ▪ Familiarity with crossing point was associated with higher risk taking and less waiting time [68]. ▪ Reducing the waiting time for pedestrians was likely to decrease the probability of pedestrian crossers being hit by a motor vehicle [70] [76].
Volume of the traffic	▪ Trip-making activity and crossing strategies were modified due to changes in traffic conditions, especially changes in parking and traffic volumes [77]. ▪ With high traffic volumes, pedestrians seek rolling gaps [75]. ▪ Compliance with traffic signals was affected by the number of conflict points with vehicles, traffic volume, road and intersection width [78].
Speed of the traffic	▪ The higher the traffic speed, the lower the percentage of drivers that yields the right of way to pedestrians at unsignalised crosswalks [79]. ▪ The number of attempts to cross was reduced if the approaching vehicle was a large bus (even though it has a lower approach speed) [68]. ▪ Middle aged pedestrians, involved in bigger groups, looked at vehicles more often before crossing or interacted with buses rather than with cars [80].
Shared space	▪ Pedestrians preferred to share space when their presence to the drivers was ensured, with low vehicular traffic, pedestrian-only facilities, high pedestrian traffic and good lighting [48]. ▪ Female and older pedestrians feel less comfortable sharing space [48]. ▪ Pedestrians avoid conflict with vehicles, diverted away from their most direct path, yielding the right of way to vehicles in most cases and felt safer under the traditional road layout than sharing space [81].

Presence of other pedestrians	▪	Pedestrians reported greater likelihood in crossing the road when other pedestrians were crossing the road [82].
	▪	As the number of pedestrians increased, the waiting times were reduced [68].
Commit traffic violations (red light violations)	▪	Being male and young adult increased the proportion of violations [63].
	▪	Males crossed during a red light more frequently than females [66] [83].
	▪	Longer waiting time at signalised crosswalks increased the risk of pedestrian violation [84] [85] [86].
	▪	Pedestrians in a group tended to cross less with red light than when individually [83].
	▪	External (environmental: topographical, infrastructure and control system) and internal (objective of crossing based on task: getting to school, going shopping, etc.) variables were involved in traffic violations [87].
Weather conditions	▪	Road crossing behaviour in inclement weather conditions was less safe than in good weather [88].

Regarding age research, [63] studied the preferences and behaviour of older pedestrians and cyclists (70 years and above) by means of a questionnaire, the older respondents appreciated pedestrian crossings, signalised intersections and cycle paths more than the younger respondents (40-49 years old). Older pedestrians felt that it was dangerous to cross the road where these facilities were missing and they found the presence of a sidewalk pavement very important on their route, while the younger pedestrians more often focused on a fast passage. The older pedestrians were more influenced by the fact that an action was illegal than the younger pedestrians.

For crossing behaviour, a field observation experiment was done by [80] of 254 pedestrians at an unmarked roadway in China indicated that 65.7% of them did not look for vehicles after arriving at the kerb. It was mentioned that pedestrians preferred crossing actively in tentative ways rather than waiting passively, which represented safety issues. These patterns were checked in the same research at an additional site with 105 pedestrians and in terms of safety, pedestrians who were middle-aged, involved in bigger groups, looked at vehicles more often before crossing when interacting with buses rather than with cars, this shows the influence of age, size of group and type of vehicle in the behaviour of pedestrians.

The paper of [48], investigated the importance of certain personal characteristics, context and design-specific factors affecting the perceptions of pedestrians and drivers in the urban design of shared space, based on the responses of pedestrians and drivers collected through two web-based stated preference surveys. This research concluded that pedestrians felt most comfortable in shared space places under conditions that ensured their presence in the road for the drivers, with low vehicular traffic, pedestrian-only facilities, high pedestrian traffic and good lighting which improved their perception.

Finally, the research of [72] by means of questionnaires included three dangerous road crossing scenarios to measure social psychological variables such as attitude, perceived behavioural control, subjective norm, self-identity, and intention. The research concluded that the perceived behavioural control (control over performing the behaviour) was the strongest predictor of pedestrian crossing intentions. Similarly, [70] also concluded that human factors play an important role in crossing behaviour, they stated that pedestrians can change their crossing behaviour depending on their own characteristics rather than to the characteristics of the external environment, which in part explains why some people still violate road rules knowing the danger they are facing when doing so.

2.1.2. Interaction cyclists and traditional motor vehicles

The high rates of cycling in the Netherlands are the result of different factors such as a wide range of coordinated policies, techniques, and programs that had generated enthusiasm and wide public support. As reported by [6] this success is the result of the implementation of measures such as safe separate cycling facilities, traffic calming structures in residential areas, extensive rights of ways in urban areas, bike parking facilities integrated to the public transport, along with land-use policies for a compact development that generate shorter and more bikeable trips. Furthermore, it is also the result of Dutch policies discouraging the use of motor vehicles to make it expensive and inconvenient through taxes and restrictions of accessibility in some areas of the cities, along with rigorous traffic training for both motorists and no motorists, putting emphasis on strict traffic regulations to protect bicyclists [47].

The vulnerability of cyclists

Contrary to pedestrians, the number of fatalities amongst cyclists increased during the period between 1996 and 2014. Even though the large majority of cyclist’s deaths at the beginning of the period were the result of the collision of bicycles with motor vehicles per kilometre, this risk dropped by 3.8% per year [89]. While the risk of cyclist deaths in crashes without motor vehicles (single-vehicle crashes) had the tendency to grow by 7.0% per year, these phenomena could be partly explained due to a higher cycling rate among the elderly who have an elevated risk. Furthermore, even though most fatal injuries among cyclists are the result of crashes with motor vehicles, the majority of hospital admissions and injured people in the emergency department are caused by single-bicycle crashes [90]. In 2005, 8,382 cyclists were involved in serious road injuries [43], this number increased by 55.6% to approximately 13,041 incidents (it accounted for 63% of the 20,700 total road injuries [44]) that were registered in 2014 [45]. In 11% of the cases (2,277 crashes), a motor vehicle was involved [45].

Infrastructure

To consider the bicycle as a safe mode of transport, an adequate route infrastructure was needed. In many European countries, including Germany, Denmark, Sweden and the Netherlands, the need of cyclists to be separated from fast and heavy traffic is considered a fundamental principle of road safety considering their vulnerability and risk of severe injury imposed by motorists [91]. This policy has led to systematic traffic calming on the streets and the provision of vast networks and especially cycle tracks (physically separated from motor vehicles) in busier streets [92]. The importance of separating cyclists from fast and heavy traffic seems obvious considering their vulnerability and their large speed and mass differential from motor traffic (following the principle of homogeneity of the Dutch sustainable safety vision) [93].

The bicycling infrastructure in the Netherlands can be classified into four levels based on its separation, which depends on the bicycle intensity, traffic speed and car intensity [94]:

1. Shared streets and shared lanes: no dedicated bicycle space.
2. Protected and non-protected bike lanes: it is at the same level as the vehicular road, it is differentiated with a change in texture, colour and signalling if protected it is separated by roadway striping.
3. Separated cycle paths: located on the sidewalk, cycle tracks and shared-use paths along a road, physically separated from traffic.
4. Advisory cycle lane: used as an alternative to cycling lanes to deal with the problem of stopping of motorised vehicles.

The design manual for bicycle traffic in the Netherlands suggested that bicycles can ride in mixed traffic in areas with a maximum speed of $30\ km/h$ and with less than 5,000 vehicles per day. However, when daily traffic exceeded 4,000 motor vehicles per day with roads of two lanes and no parking lanes, bike lanes are preferred. In the case of parallel parking lanes and higher speeds ($50\ km/h$ and $70\ km/h$), it is recommended separated cycle paths on sidewalk level [94]. Furthermore, on streets too narrow, advisory cycle lanes are used, which had a central driving zone surrounded by two bike lanes that are usually signalled by dashed lines [92].

Cyclist behaviour

For cyclists, the variables that have been found to influence their cycling behaviour include facility characteristics, traffic characteristics, demographics (cycling experience, age, income, gender), trip characteristics (destination, length, duration), and external factors (weather, topography, built environment, political and public support for cycling) [95]. Table 2 provides a partial summary of conclusions of cycling behaviour found in the literature.

Table 2 Parameters that influence the cycling behaviour

Parameters	Conclusion
Age	▪ Older people appreciated signalised intersections and cycle paths significantly more than the younger respondents did. Older people felt that it is dangerous to cross the road where these facilities are missing [63]. ▪ Younger cyclists were less concerned for their safety when motor vehicles passed close to them than older cyclists [96].
Gender	▪ Female commuter cyclists have more risk aversion, they preferred to use routes with maximum separation from motorised traffic [97] [98] [99].
Level of cycling experience	▪ Experienced cyclists detected and anticipated on more hazards than novices [100]. ▪ The cyclists who had been cycling regularly for longer than two years expressed a reduced concern for traffic compared to cyclists who had cycled for less time (if they stopped cycling in their youth or never started) [96]. ▪ Contrary to other studies on the topic, that had found that experienced cyclists prefer less separation from traffic (lanes over paths or no facilities at all), it was found that even confident cyclists preferred routes that reduce exposure to motor vehicle traffic [101] [102].
Human behaviour	▪ Attitudes on direct benefits, awareness, and safety influence bicycle commuting [103]. ▪ The presence of other road users had a preventive effect on the probabilities of red light infringement [104].

	▪ The "safety in numbers" effect is explained by how drivers adapt their scanning routine with high levels of cycling, thus the risk faced by each cyclist declines as the number of cyclists increases [105] [106]. ▪ Near collisions (occur more frequently) may be a significant cause for levels of people´s fear associated with bicycle riding, even more than actual collisions [101]. ▪ Variables related to cyclist's behaviour, influence each step of events leading to single-bicycle accidents [107].
Type of cycling facilities	▪ Bicycle-specific facilities reduced crashes and injuries among cyclists compared to cycling on-road with traffic or off-road (sidewalks) with pedestrians [106] [108] [109] [110]. ▪ Sidewalks were more demanding and hazardous environments for bicyclists than bike paths [100].
Configuration of intersections	▪ The design in the priority of unsignalised intersections affected cyclist safety. At intersections where cyclists had the priority, one-way bicycle paths were safer than two-way bicycle paths [111]. ▪ Cycling in proximity to an intersection increased the risk of an incident fourfold, and if the intersection had visual occlusion (i.e., buildings and hedges), then the risk would be twelvefold [112].
Volume and speed of the traffic	▪ Reducing the amount of traffic and its speeds and increasing separation may increase levels of comfort and cycling rates [99] [113]. ▪ The more motor vehicles on the road, the higher becomes the risk encountered by pedestrian and cyclist [105] [111].

The safety of cyclists at unsignalised intersections was analysed by [111], this study focused on the connection between the characteristics of priority intersection design and the Bicycle Motor Vehicle (BMV) crashes. A total of 540 priority intersections were included in this study, in which 339 failure-to-yield crashes with cyclists were reported to the police. The authors found that two-way bicycle crossings diminished cyclist safety at unsignalised priority intersections due to a visual scanning problem of right turning drivers. Additionally, the probability of a crash for cyclists in an intersection raised proportionally to the percentage of traffic flow entering or leaving the side road. Finally, they concluded that elevated bicycle paths for crossing and additional speed reducing measures were effectively decreasing the number of crashes at priority intersections, while red colour pavement and other markings had an opposite effect increasing cyclists´ speed and diminished their visual scanning. Some unsignalised intersections where the cyclist has the priority are present on the Wageningen campus as the one shown in Figure 6.

Figure 6 Unsignalised intersection at Wageningen campus

Some other variables that influenced the preferences of cyclists were found by [114] that used GPS units to observe the behaviour of 164 cyclists in Oregon, U.S. for several days. The authors found that cyclists were sensitive to the effects of distance, turn frequency, slope, intersection control (e.g., presence or absence of traffic signals), and traffic volumes. Regarding safety in the Netherlands, [106] described that separated bicycle paths and intersection treatments decreased the likelihood of bicycle-motor vehicle crashes. Additionally, the perception of lack of safety is a deterrent to cycling. An analysis of the existing literature done by [101] found that fear to motorised traffic was disproportionate to the actual levels of risk of bicycle riders, rather than actual collisions creating the basis of people's fear, it appeared plausible that near collisions (which occurs far more regularly) may have been a significant cause for the exaggerated levels of fear associated with bicycle riding. These perceptions of risk discouraged bicycling and could differ from real risk. Additionally, this risk had a strong correlation with traffic volume and speed and also varied according to cultural influences and the individual characteristics of the cyclist who experienced the fear [113].

2.2 Interaction VRUs and automated vehicles

As mentioned before, the existing literature on the interaction of VRUs with automated vehicles is limited. However, in this section a compilation of the most important research on the topic is made.

2.2.1 Public opinion automated vehicles

Most of the available information on the topic of automated vehicles has been made through stated preference surveys, most of them are related to the general opinion of automated vehicles, except for [32], whose research took the point of view of VRUs into account. The main findings of these studies are described in this sub-section:

IEEE: the participants were IEEE's social media community (294 followers) and members of the IEEE Intelligent Transportation Systems Society (119 experts) [115]:

- Main concerns: safety (f = 54.3%; e = 62.6%) and trust in the technology (f = 20.7%; e = 15.9%)
- The safety of this new technology should be determined, demonstrated, and documented so it does not only includes expert's opinion but also public opinion at large.

UMTRI: 1,533 respondents in the three major English-speaking countries—the U.S.A., the U.K., and Australia [116]:

- People in the United States were more likely to have heard of self-driving vehicles (70.9%) and were likely to have a positive view (56.3%) of such vehicles, contrary to people from the U.K. (66% have heard of the technology) who were somewhat positive (52.2%). Australians were least likely to have previously heard of self-driving vehicles (61%) but were the most positive (61.9%).
- In all countries, a great percentage of respondents (90.1%) had concerns that self-driving vehicles would not drive as well as human drivers. The vehicle could get confused by unexpected situations, U.S. (95.6%), U.K. (94.3%) and Australia (94.1%).
- Interaction with VRUs: U.S. (very concerned – 42.1%), Australia (very concerned – 35.6%) and U.K. (moderately concerned – 35.5%).
- Females expressed higher levels of concern with self-driving vehicles than males.

UMTRI: 1,722 respondents in China, India, and Japan [117]:

- Most respondents had previously heard of self-driving vehicles (China – 87%, India – 73.8% and Japan – 57.4%) and had a very positive initial opinion of the technology (China – 49.8%, India – 45.9%) or neutral in the case of Japan (50.3%).
- Most respondents expressed high levels of concern about safety issues (system failure). Respondents were moderately concerned with vehicles not performing as well as human drivers (China – 46.7%, India – 38.3% and Japan – 46.2%).
- Interaction with VRUs: China (very concerned – 42.6%), India (very concerned – 40.4%) and Japan (moderately concerned – 48.5%).

KPMG: Focus groups with 32 participants (drivers) in three different cities in the U.S. [118]:

- Many participants were doubting if the technology would work, probably because they have not seen it working yet.
- They did not believe that vehicles could react safer and more efficient than human.

Blau: 767 respondents in the Ohio State University [32]:

- Respondents were asked about their facility of preference (wide shoulder, bike lane with and without buffer, and cycle track) in two scenarios (with and without the presence of autonomous vehicles) with different types of street (Type 1 - *quiet residential street*, Type 2 - *moderately busy avenue*, and Type 3 - *major boulevard*).
- An Ordered Logit Model (explanatory variables: gender, age, race, education, mode choice and confidence level) was used to conclude that cyclists preferred to increase separation and protection from vehicles in situations as volume and speed increased (the latter two were used as control variables).

- Preference for segregated and controlled environments will significantly increase in the future presence of autonomous vehicles.

2.2.2 Automated transport initiatives - Citymobil2

Currently, there are several automated transport systems in operation around the world, including Group Rapid Transit at Rivium Park Shuttle (NL), Morgantown (USA), Personal Rapid Transit at Heathrow airport (UK) and in Masdar (UAE). These systems have proven to work efficiently and safely over the years. However, they use exclusive and physically protected infrastructures that make it difficult to integrate into urban areas [119]. The EU's Seventh Framework Programme for research and technological development (FP7) co-founded a company named *CityMobil2*, demonstrating automated vehicles on public roads with exclusive lanes and with a steward on board. *Citymobil2* carried out different trials and research in different European cities, including large-scale demonstrations with a duration of four months that were done in three cities, West Lausanne Region in Switzerland on the campus of Ecole Polytechnique Fédérale de Lausanne (Switzerland), La Rochelle (France) and in Trikala (Greece).

The outcome of one of these studies is described by [30] and refers to the public's acceptance of automated vehicles as a transport system, using the Unified Theory of Acceptance and Use of Technology (UTAUT). The authors found that factors that influence the user acceptance of this technology are the social influence, effort expectancy and performance expectancy, being the later factor the one with the strongest impact. Additionally, they suggested that other factors should be considered in the future, such as perceived safety and onboard comfort. Additionally, this company carried out a research that aimed to build an understanding of how cyclists and pedestrians feel about automated vehicles and what information VRUs require from the vehicle in their interaction, through structured questionnaires ($N = 664$), interviews ($N = 26$), and focus groups ($N = 20$), in the three cities [33]. In the survey, it was found a significant effect of road marking in perceived safety, people expressed they felt safer when they had road markings on the route of the automated vehicle as it is illustrated in Figure 7.

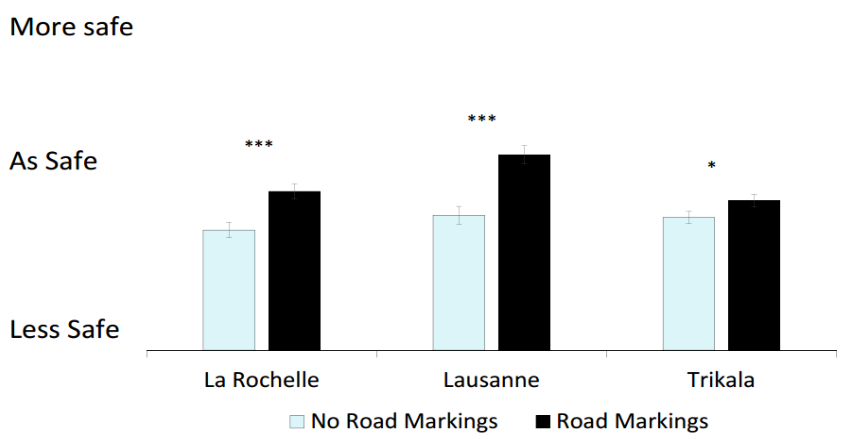


Figure 7 Comparison of the perception of safety, with and without road markings [33]

Respondents stated that they would like to receive information from the operations of the automated vehicles given the non-presence of road markings. In general, in the three cities, the most important information was to know if they were detected by the vehicle and the least important was its speed of travel. People in La Rochelle (see Appendix A - Figure 18) said they wanted to know whether the automobile is turning with visual signals (lights). In case the vehicle starts moving or detects a person, they preferred sound signals. In Lausanne (see Appendix A - Figure 19), they preferred lights for manoeuvres (except the case where the vehicle started moving, in this case, they preferred auditory signals). Lastly, people from Trikala preferred lights for turning and stopping and sound to know if the vehicle has detected them (Appendix A - Figure 20). Regarding priority, two-thirds of the participants believed they had the priority over the automated vehicles when road-marking was absent, this rate decreased to one-third in the presence of road markings [34].

In the *focus groups*, the main conclusions were that the direction of travel was not obvious and they were not sure who had the priority on the road. The group also mentioned their preference for route demarcations, they had doubts if the automated vehicle could identify hazards and finally it was suggested to use horns and lights for detection and communication. As additional comments, people expressed their concern for the visibility (brighter colour will make it easier to see) and lack of sound (represents a problem for its localisation). Finally, it is mentioned an open discussion, questioning if it was needed for the operation of automated vehicles to install a totally new or only a modification of the actual signage, road infrastructure, traffic rules and road safety training [33].

2.2.3 Other approaches

As shown in the last section, the existing systems with highly automated test vehicles are quite a few, independent research has limited access to the technology and the options of creating automated working systems are time-consuming [35]. For that reason, some researchers have used techniques such as the Wizard of Oz (WOZ) to obtain data, this method simulates a fully self-driving vehicle in realistic traffic simulations. In this technique, a human operator seemingly drives the vehicle using an additional steering wheel and pedals installed on the left side of a right-hand steered vehicle. The real steering wheel is hidden and it is operated by the wizard, hence from the pedestrians´ perspective, it appears to be a standard left-hand vehicle. The results of some research made with this method are described in this section:

Wizards of Oz approaches

Three case studies were carried out by [35] to analyse the interaction with self-driving vehicles. The present research is particularly interested in the case that compares how pedestrians experience encounters with a manual versus the simulated self-driving vehicle in real traffic.

- Data collection with semi-structured interviews and Self-Assessment Manikin – SAM questionnaire (measures the pleasure, arousal, and dominance of people effective reaction to stimuli).
- The pedestrians´ willingness to cross the road (was used as an indicator of perceived safety) decreased in the simulation of self-driving technology, with the inattentive (fake) driver (talking on the phone or reading newspaper). The pedestrians felt unsafe and

experienced discomfort, they did not suspect that the vehicle was "automated" or driven by a wizard.
- Given the importance of eye contact with the human driver, automated vehicles need to communicate its intents to their surroundings with vehicles' own motion patterns or with external interfaces.
- A true validity of the WOZ method is difficult to prove because it is not possible to do a comparison with real systems.

From this field experiment and SAM questionnaire, further conclusions were drawn in [120]:
- From the questionnaire: most pedestrians (8 out of 10) would cross the road when they make eye contact with the driver. This willingness to cross decrease in encounters with "self-driving vehicles"; fewer participants (2 out of 10) would feel comfortable crossing when the driver is not paying attention (looking forward, reading a newspaper or sleeping) and only 4 out of 10 would cross when the driver is making a phone call.
- Pedestrians highlighted the importance of eye contact and they motivated their unwillingness to cross due to the lack of feedback.
- Regarding the emotional experiences, drivers giving eye contact were perceived as pleasant for pedestrians making them feel calm. Drivers talking on the phone and looking forward were slightly more unpleasant, and finally reading the newspaper or sleeping made pedestrians feel unpleasant and frustrated.
- To maintain high levels of perceived safety amongst pedestrians, it is beneficial to provide information, for instance with external vehicle interfaces.

Communication of the vehicle with the surroundings

Due to the lack of cues given by the driver in their interaction with pedestrians in future self-driving scenarios, an external vehicle interface called AVIP (Automated Vehicle Interaction Prototype) was developed by [36] and initially assessed with naturalistic conditions in two experiments using WOZ:
- Visual interfaces are more used in frequent interaction with other road users (e.g., turn and brake). While auditory interfaces are mostly used for less frequent communication (e.g., horn). Given the frequency of interaction, a visual display was selected, an auditory signal could be included at a later stage.
- The light interface (AVIP) showed visual signals on top of the windshield, displaying four types of information: "I am in automated mode", "I am about to yield", "I am waiting" and "I am about to drive".
- The interface was easy to interpret by pedestrians, improved comfort, making it a calmer experience, and potentially increased safety perception.

A similar study regarding vehicle-to-pedestrian communication was carried out by [37]. This research used a van as a simulated self-driving vehicle presenting information on a 32-inch LCD screen to the pedestrian. The screen displayed indications on when to cross the road and its speed in two locations; an unmarked midblock location and a marked crosswalk to 50 participants:
- The lowest average decision time to cross the road was in the control situation (no device) in the crosswalk (4.35 seconds) and in the midblock (7.66 seconds).

- It was concluded that given the limited time of pedestrians to detect and interpret symbols, the messages must be simple, familiar and salient.
- The most important decision to cross was the distance to the vehicle (56%), followed by the speed of the car (46%) and the traffic density (24%). Most of the participants saw the display (76%) but only 12% of the respondents said it influenced their crossing.
- From the experiment, it was concluded that there were not significant differences between the displays; using a display is as effective as not having any display at all. Furthermore, pedestrians will rely on legacy behaviours (existing crossing strategies) instead of being influenced by information on external displays. However, many respondents agreed that additional displays will be necessary for the future interaction with self-driving vehicles.
- It may be more important to comprehend individual differences (personality, crossing position, gender, and age) that affect the crossing behaviour than the development of information on displays.

2.3 The technology of the WEpods

The vehicle adopted by the WEpods project is the EZ10, it was used in the trials by CityMobil2 that included a safe stop system and four lasers. The WEpods consortium equipped the vehicles with additional technical equipment, due to the change of environment from closed tracks to public roads and wanting to improve the safety of its interaction with pedestrians, cyclists, and other road users [121]. Although the WEpods can respond faster than human drivers, its braking distance is the same as conventional vehicles. In the presence of an obstacle or other road users, the sensors release a signal to activate the braking system, but the steward is the one who takes final responsibility. The vehicle emits one beep when it starts moving and two beeps in the case of an emergency stop when it detects an obstacle on the road. It also counts with lights which show the turning direction of the vehicle. The WEpods do not drive during peak-hour, on slippery surfaces or with bad weather conditions [20]. The next sub-sections explain the attributes of the systems included in the WEpods, that contribute for the detection of VRUs.

Sensors

A sensor system monitors the environment to detect, classify, measure the speed and predict the route of other road users. Furthermore, it has navigation support through landmark positioning; measuring the vehicle position relative to typical solid objects along the route.

In order to comply with this functions, the WEpods have sensors such as cameras, radars, and lasers at the four corners (see Figure 8). These different sensors work on different physical principles. The data of the sensors will be selected and combined (sensor fusion) for a robust estimation of the position and the speed of relevant objects in the area (highly important for the detection of pedestrians and bicycles) [122]. According to [121] the sensor fusion as a generic controller has two steps; eight camera-radar pairs (fusion step 1) and combine eight pairs (fusion step 2). Additionally, the emergency stop relies on the four lasers and is independent of radar camera sensing (additional information on RADAR and LIDAR can be found in Appendix B).

Figure 8 Sensors in the WEpods [121]

Navigation

The vehicle knows its way in each position, which is required to be able to follow the route safely and reliably. A special, highly accurate digital map of the route is made from all view objects (e.g., trees and lampposts) in addition to the geometry of the road. The vehicle *absolute position* is done with the GPS coordinates for the position of the vehicle, road and objects have high detection accuracy (+/- 10 cm = 20 cm range), and it is determined by a combination of subsystems (see Appendix B) [121]. In addition, the camera (to follow lines) is combined with RADAR, to measure the exact position in relation to fixed objects (landmarks).

HL vehicle controller

The WEpods are equipped with many controllers (onboard computers), all of which provide their information for the so-called High-Level Controller, which combines all information and makes the decisions that used to be done by a human driver. The HL Controller gives orders to drive, to stop and to steer, to respond to other road users and sudden changes. Important data (e.g., measurements of the sensors and the functioning of the systems) are stored and can be accessed afterwards [122].

2.4 Conclusions

There are many uncertainties about future scenarios with automated vehicles. There are optimistic views such as *ITS Action plan*, which mentioned that from a review of the causes of accidents of traditional motor vehicles, there are some factors which have an important influence on the number and severity of injuries and fatalities. Amongst them, speeding, alcohol, non-observance of VRUs by the driver and insufficient braking distance in case of emergency [123]. It is expected that with automated vehicles, most of these errors and violations are not committed. However, there are also less optimistic scenarios where new types of errors may arise. These scenarios include technology limitations (e.g., possibilities of system failures in which the automated technology will not be able to respond in time to different situations) and other road users´ behavioural adaptation (e.g., blindly assume the automated vehicle will stop for them). As the present research is focused on the perceived safety of VRUs, the state of the art had an emphasis on the interaction between VRUs with traditional motor vehicles and with automated vehicles.

The literature reviews of the current interaction of VRUs with traditional motor vehicles outlined the importance of the collection of demographic variables (e.g., age, sex, cycling experience, etc.). Additionally, variables such as volume and speed of the traffic, weather, and road design are factors that affect safety perception and behaviour. However, these factors remain constant in the present research, hence do not influence the results of this study. Moreover, it is considered that human factors are complex variables in crossing behaviour, which means people take decisions based on their personal characteristics. Hence, the decision to commit traffic violations do not only rely on environment characteristics.

Around the world, there are several safe and efficient automated transport systems operating in exclusive and physically protected infrastructures, which makes the WEpods the first to operate in mixed conditions for an extended period of time. In the recent past, different stated preference surveys of public opinion. In general, have been carried out to have a better comprehension of the level of acceptable and social risk that this new technology of automated vehicles can bring in the future. Most of these results expressed a positive initial opinion of the technology, but also a degree of concern about safety issues of automated vehicles with VRUs, including the results of [32] indicating an increased perception of fear from VRUs with the inclusion of automated vehicles.

The on-going R&D has been focused on different topics for the introduction of automated vehicles on the roads. However, this research does not include topics such as the perceived safety, level of acceptance, the level of trust, change of behaviour, the level of acknowledgement of the technology and the information needed by VRUs in their interaction with these vehicles. This is mainly because the projects related to this innovative topic are in their early stages and the vehicles with this technology are not yet accessible for researchers that are interested in the topic. Fortunately, in the current research, it was possible to directly collect valuable data from the VRUs in the surroundings of the WEpods. Among the information collected, it was possible to assess the differences in safety perception and reported crossing behaviour of people who had interacted (revealed preference) with the WEpods and those who had not interacted with the WEpods (stated preference).

3. Research Questions and Hypothesis

There is an urgent need to research and assess if the perceptions regarding the potential benefits and disadvantages that automated technology could bring to the VRUs´ safety are in line with VRUs real perception of this technology. Using the literature review and the above-mentioned discussion, the objective of this research is clear, this study tries to answer the question: How is road safety perceived by vulnerable road users such as pedestrians and cyclists when they interact with the WEpods during its test phase? To answer this research question three steps were considered; first, the formulation of eight sub-questions considering different aspects of VRUs – vehicle interactions. The second step was the operationalisation of this sub-questions into questions in the survey. Finally, the third step comprised the formulation of hypotheses related to each sub-question with the objective of carrying out statistical analyses. It can be observed in Appendix C the relation between the sub-research questions, the survey questions and the hypotheses.

3.1 Step 1: Sub-research questions

The following eight sub-questions were divided into two groups. The first group referred to the current interaction of VRUs with traditional motor vehicles compared to their new interaction with the WEpods, this part included the general term "*share the road"* that referred to the action of making use of a space and mix with other road users such as pedestrians, cyclists, and vehicles. Additionally, there was a special focus on the perceived safety of VRU in specific situations of interaction, i.e., crossing behaviour and interacting at unsignalised intersections. The second group was related to the safety perception of VRUs interacting with the WEpods.

3.1.1 VRUs interacting with traditional motor vehicles vs. the WEpods

a. Do VRUs perceive road safety different when they *share the road* (in general) with traditional motor vehicles compared to sharing the road with the WEpods?

b. Do VRUs perceive road safety different when they interact with traditional motor vehicles compared to interacting with the WEpods at *unsignalised intersections*?

c. Do VRUs report a different *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods?

d. Do the VRUs that base their actions on *eye contact or signals* received from a human driver report a different crossing behaviour and perceived safety in their new interaction with the WEpods, compared to those who do not use these cues?

3.1.2 VRUs´ perception of safety interacting with the WEpods

e. Do VRUs that *have already interacted* with the WEpods (revealed preference) report a different crossing behaviour and perceived safety, compared to those who *have not interacted* yet with these vehicles (stated preference)?

f. Do VRUs who have *knowledge* of the WEpods and its automated technology report a different crossing behaviour and perceived safety, compared to those who do not have this knowledge?

g. What *information* do VRUs require from the WEpods to feel safe when interacting with them?

h. How do the *VRUs´ demographic data* relate to the crossing behaviour and perceived safety when interacting with the WEpods?

3.2 Step 2: Operationalisation

The second step was to translate the research questions into items in the survey (see Appendix D for survey questions). In the first part of the survey, the participants were unaware that this research was about automated vehicles to avoid bias or change of perception. In this section, they were asked to rate their perceived safety when they, in general, share the road with slow (max. speed of $30\ km/h$) and few traditional motor vehicles (*question 6*). Additionally, they were requested to describe their crossing behaviour on campus (*questions 7 and 8*) and to rate their perceived safety in two specific unsignalised intersections that are found on the campus (*question 9*).

To make the comparison between the traditional motor vehicles and the WEpods to answer *sub-question a, b and c*, the same survey questions above-mentioned were formulated but now regarding their interaction sharing the road (*questions 31 and 37*), at unsignalised intersections (*questions 34 and 40*) and their crossing behaviour (*questions 32, 33, 38 and 39*) with the WEpods. ***N.B.:*** On the one hand, the questions regarding perceived safety sharing the road and at unsignalised intersections had rank scale options from “I feel strongly unsafe” to “I feel strongly safe”, which means the participants could directly rank their perceived safety for these situations (these items were later processed by the researcher as ordinal variables). On the other hand, the questions regarding crossing behaviour had four options with no intrinsic order from the point of view of the participants (this item was later processed by the researcher as categorical variables). More information regarding the processing of the data can be found in section 4.3 Data preparation.

These questions regarding their interaction with the WEpods were also used to answer *sub-question d,* along with the *question 10*, regarding how often they base their actions on cues from the human drivers in their current interactions with traditional motor vehicles. To answer *sub-question e*, participants were asked if they had previously interacted with the WEpods (*question 29*). Based on these answers, the survey was divided into stated preference questions (for those respondents who had not interacted with the vehicle – *questions 36 to 40*) or similar revealed preference questions (if they already interacted with the WEpod – *questions 30 to 35*), regarding their perceived safety and reported crossing behaviour with the WEpods.

Furthermore, participants were questioned about their familiarity with the automated technology in general (*question 25*) and specifically with the WEpods (*question 26 to 28*), information that was used to answer *sub-question f*. To know what information VRUs knew and how it affected their perceived safety to answer *sub-question g*, participants were questioned about the driving style of the WEpods (*question 35*), about their awareness of the presence of a steward inside the vehicle (*question 41*), their expectations about the vehicle stopping in emergency situations (*question 42*) and what type of signals or warnings they would like to receive from the WEpods (*question 43*).

Finally, to know how the demographic data of the VRUs affect the perception of safety and reported crossing behaviour when interacting with the WEpods to answer *sub-question h*, information about participants´ age (*question 44*), gender (*question 45*), occupation (*question 47*), nationality (*question 46*) and cycling experience (*question 5*) was collected.

3.3 Step 3: Research Hypotheses

The last step is based on the previous mentioned sub-research questions and its operationalisation into survey questions. A set of null and alternative hypotheses were formulated and used as the basis for the data analysis and statistical testing.

3.3.1 VRUs interacting with traditional motor vehicles vs. the WEpods

$\boldsymbol{H_0^a}$: There is no statistically significant difference in the perceived safety of VRUs *sharing the road* in general with traditional motor vehicles compared to sharing the road with the WEpods. VRUs will report felling equally safe sharing the road with traditional motor vehicles as with the WEpods.
$\boldsymbol{H_1^a}$: There is a statistically significant difference in the perceived safety of VRUs *sharing the road* in general with traditional motor vehicles compared to sharing the road with the WEpods. VRUs will report feeling significantly safer sharing the road with the WEpods than with traditional motor vehicles.

$\boldsymbol{H_0^b}$: There is no statistically significant difference in the perceived safety of VRUs interacting with traditional motor vehicles compared to interacting with the WEpods at *unsignalised intersections*. VRUs will report feeling equally safe with traditional motor vehicles as with the WEpods at unsignalised intersections.
$\boldsymbol{H_1^b}$: There is a statistically significant difference in the perceived safety of VRUs interacting with traditional motor vehicles compared to the WEpods at *unsignalised intersections*. VRUs will report feeling significantly safer when interacting with traditional motor vehicles than interacting with the WEpods at unsignalised intersections.

$\boldsymbol{H_0^c}$: There is no statistically significant difference in the VRUs *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods. VRUs will report the same crossing behaviour when interacting with the WEpods as with traditional motor vehicles.

$\boldsymbol{H_1^c}$: There is a statistically significant difference in the VRUs *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods. VRUs will report safer crossing behaviour when interacting with the WEpods than interacting with traditional motor vehicles.

$\boldsymbol{H_0^d}$: There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that base their actions on *eye contact or signals* received from a human driver compared to those who do not use these cues. Both types of VRUs will report feeling equally safe with the WEpods.
$\boldsymbol{H_1^d}$: There is a statistically significant difference in the perceived safety and crossing behaviour of VRUs that base their actions on *eye contact or signals* received from a human driver compared to those who do not use these cues. VRUs that do not interact with the human driver will report feeling significantly safer interacting with the WEpods.

3.3.2 VRUs´ perception of safety interacting with the WEpods

$\boldsymbol{H_0^e}$: There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who have already *interacted with the WEpods*, compared to those who have not interacted with the automated vehicles. Both types of VRUs will report feeling equally safe with the WEpods.
$\boldsymbol{H_1^e}$: There is a statistically significant difference in the perceived safety and crossing behaviour of VRUs who have already *interacted with the WEpods*, compared to those who have not interacted with the automated vehicles. VRUs who have interacted with the WEpods will report feeling significantly safer than those who have not interacted with the automated vehicle.

$\boldsymbol{H_0^f}$: There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who have *knowledge of the WEpods and its automated technology*, compared to those who do not have this knowledge. VRUs will report feeling equally safe, regardless of their knowledge of the WEpods and its automated technology.
$\boldsymbol{H_1^f}$: There is a statistically significant difference in the perceived safety and crossing behaviour of VRUs who have *knowledge of the WEpods and its automated technology*, compared to those who do not have this knowledge. VRUs who have knowledge of the WEpods and its technology will report feeling significantly safer interacting with the WEpods than those who do not have this knowledge.

$\boldsymbol{H_0^g}$: There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that consider that the *vehicles will always stop and that it has a steward* compared to the VRUs that do not know this information. Both types of VRUs will report feeling equally safe with the WEpods.
$\boldsymbol{H_1^g}$: There is a statistically significant difference in the perceived safety and crossing behaviour of the VRUs that consider that the *vehicles will always stop and that it has a steward* compared to the VRUs that do not know this information. VRUs who consider

that the vehicles will always stop and that it has a steward will report feeling significantly safer interacting with the WEpods than those who do not know this information.

$\boldsymbol{H_0^h}$**:** There is no statistically significant difference in the perceived safety and crossing behaviour within different VRUs´ *demographic groups* (age, gender, occupation, nationality and cycling experience). All groups of VRUs will report feeling equally safe interacting with the WEpods.
$\boldsymbol{H_1^h}$**:** There is a statistically significant difference in the perceived safety and crossing behaviour within different VRUs´ *demographic groups* (age, gender, occupation, nationality and cycling experience).

4. Research Methods

In general, it is difficult to assess road safety objectively, what is perceived as safe by one road user may be sensed as unsafe by the next. The selected methods to analyse the interaction between VRUs and the WEpods included qualitative approaches such as face-to-face interviews and a focus group. The results of these methods gave a direction to the researcher of the general thoughts of the VRUs and the aspects that appeared to explain and influence the cyclists and pedestrian's perception of safety, and how they perceive the transition in their interactions from traditional motor vehicle to automated vehicles. This information additional to the literature review was used as an input for the elaboration of the online survey, which was distributed to the students and staff members of the Wageningen University. Finally, the outcome of the survey included different aspects that were previously mentioned, such as perceived safety, reported crossing behaviour, level of acceptance, level of trust, level of acknowledgement of the technology, the importance of the current interaction of VRUs with human drivers and the type of information needed by VRUs to feel safe in their interaction with these automated vehicles. The information collected was analysed considering previous studies such as the existing literature of current interaction of VRUs with traditional motor vehicles and the results of the limited research regarding automated vehicles.

4.1 Step 1: Face-to-face interviews

Despite the rise in popularity of online surveys, face-to-face interviews still remain a popular data collection method. This method was chosen because it provides advantages over other data collection methods, the researcher could maintain control of the interview and it was possible to request additional information next to the initially planned questions to elaborate on the subject using open questions. However, one drawback was the time needed to complete each of these interviews (longer than the time needed to fill in an online survey). To assure the quality of the collected data, the researcher used a similar interview protocol for all the participants trying to avoid biasing the respondent. The face-to-face interviews were conducted using open questions. Examples of the open questions were: How familiar are you with the concept of automated vehicles? Are you concerned about your personal safety when you are sharing the road with the WEpods ($V_{max} = 15\ km/h$)? If so, why? Do you expect the WEpods to stop in all possible instances, even though when other traffic participants violate traffic rules? (the face-to-face questions can be found in Appendix E). The information collected from this step was subsequently used to formulate the questions of the focus group.

The face-to-face interviews were carried out on the 19th of July from 12:30 pm to 4:00 pm at Wageningen University close to the Forum building. At the beginning of the interviews, the WEpod were operating around this building. A total of 22 persons were interviewed in the area (3 women and 5 men frequent pedestrians on campus, and 7 women and 7 men frequent cyclists on campus). Two more respondents were later added because two of the initial respondents did not see the WEpod operating in the zone. However, their answers were considered in the analysis. The range of the ages varied from 20 to 63 years old ($M = 29.6,\ SD = 9.9$), the group was heterogeneous and composed of 6 Bachelor and 6 Master students, 6 PhDs, 1 Post doc, and 3 employees, a total of 12 nationalities were interviewed. Given the number of participants (less than 30 participants), no statistical methods were carried out, instead a descriptive method was used to analyse this data.

4.2 Step 2: Focus group

The main purpose of the focus group was the possibility to create new ideas, as a result of the discussion of the main topics initially not considered by the researcher. Additionally, the focus group allowed the researcher to obtain information beyond the simple response often given in isolated activities such as the online surveys [124]. This research method has been used in other studies to examine possible solutions to complex transport policy initiatives where different stakeholders were involved, and it was needed to reach a consensus [125]. One example of a topic discussed in the focus groups was: how are factors such as the absence of interaction with a human driver or the presence of a steward influence the perception of safety (the focus group questions can be found in Appendix F).

To recruit participants for the focus group, a Facebook message was published one week before the event. There was no response from the public, so the researcher decided to do the recruitment personally at the campus, two days before the event and offering a reward for their participation, a lottery of two cinema coupons. The focus group was carried out on the 28th of July from 15:00 to 15:45 at Wageningen University at the Plus Ultra building (in a meeting room near the garage of the WEpods). A total of eight people participated in the focus group (four men and four women). Age varied from 24 to 31 years old ($M = 27.2,\ SD = 3.2$), with a total of five nationalities (4 Dutch, 1 Mexican, 1 Belgian, 1 Pakistan and 1 Indonesian). All the participants of the focus group had seen the WEpods on the campus at least once.

4.3 Step 3: Self-administered survey

Research has shown that in the analysis of travel behaviour in the field of transport, *stated preference* (SP) techniques have several advantages over *revealed preferences* (RP) methods. On one hand, *revealed preference* techniques use observations of actual choices made by individuals to measure preferences, its advantage is the reliance on the actual choices (avoiding the problem associated with hypothetical responses) [126]. However, there is a drawback, only the final choice is observed, it is difficult to determine how respondents came to their final decision. This limitation is due to a large number of existing choices, not always the information of these options is fully known by the individual and even in the case of identifying all the alternatives, it could be difficult to evaluate if the decision maker has considered all the possibilities [127].

It is possible to overcome these limitations using *stated preference* surveys, with this method the researcher controls the choices and the respondents are asked to choose the best alternative over hypothetical scenarios (entirely described by a set of attributes generated from the design) [127]. However, individuals´ stated preference may not always correspond to their actual preferences, this can vary due to bias in SP responses or in difficulty completing the SP task [128]. For the reasons mentioned above, these two methods have been employed jointly in the transportation sector to overcome the constraints of these two types of data, examples of these methods can be found in research done by [129] [130] [131]. Additional advantages of this method are its economically efficient and the fact that more people can be reached and can be completed in any timeframe, the respondents feel comfortable with, giving them more time to think and leading to more accurate answers. For the advantages previously mentioned, a self-administered online survey was selected as a quantitative method.

Recruitment

The self-administered survey was uploaded the 24th of August on different Facebook pages related to the Wageningen University. After one week, the number of respondents was not enough (only 7 people), for that reason the researcher decided to go to the campus on the 6th, 8th and 9th of September to ask directly to students to fill in the survey on two tablets. Fortunately, at the end of these three days, it was possible to obtain 90 respondents. Additional, in order to obtain more respondents, a staff member of the integrated facility management uploaded the online survey on the intranet for the students and staff members the 8th of September. It was important to have a minimum number of participants to achieve a good sample representation, higher reliability, and feasible results. It was mentioned by [132] that only a very limited number of studies have investigated real or simulated samples size with less than 50 people because this number is considered the absolute minimum threshold. According to [133] the adequacy of sample size might be estimated roughly in this scale: 50 - very poor; 100 - poor; 200 - fair; 300 - good; 500 - very good and 1000 or more - excellent. Furthermore, using [134] to calculate the desired sample size, considering a margin of error (also called confidence interval) of 5%, a confidence level of 95%, a response distribution of 50% and a population of 16,801 people (11,740 PhD, Bachelor and Master students [135] and 5,061 staff members [136]) the result of the desired sample size was $N = 376$. Considering the above-mentioned information, it was decided that an ideal sample size should be 200 respondents, this sample size gives a margin error of plus-or-minus 6.9% [134].

A total of 198 persons filled in the online survey (23 women and 20 men frequent pedestrians on campus, 70 women and 77 men frequent cyclist on campus, and 3 men frequently use bicycle and bus). From the remaining 5 people; 3 said the bus was the most used mode of transport, 1 said: "I never travel inside the campus" and the last one did not answer this question. From these 5 people, the ones who usually take buses as a mode of transport answered that they frequently walk or cycle on campus mostly for commute trips. For that reason, their answers were considered in the analysis. However, the other two participants (No. 42 - I never travel inside the campus and No. 116 - empty) were excluded from the analysis because their answers could not be in line with the target of the current research. Therefore, the answers of 196 participants were considered for this analysis. The range of the ages varied from 18 to 64 years old ($M = 26.4$, $SD = 10.1$) the group is heterogeneous and composed of 160 Bachelor or Master degree students (81,6%), 8 PhDs or higher degree (4.1%), 26 people working full/part time (13.3%) and 2 people currently unemployed (1.0%), people of 27 nationalities filled in the self-administered survey.

Data preparation

The online questionnaire was designed and distributed in Google forms. To codify the information, the data was downloaded with an Excel Add-in called Data Everywhere, that instantly filled in excel sheets with the answers received online. Once the answers were in Excel, it was possible to check the missing data and code the questions to be processed in SPSS. For effective use of the answers in calculations, values were assigned in an ascending way (from negative to positive) in the different Likert scales. Hence, the lowest values were allocated to the negative aspects of safety, followed by a range of values which led to the highest value, that was assigned to a positive response regarding safety. For instance, for questions regarding perceived safety when sharing the road and at unsignalised intersections, a value of one was given to the option "I feel strongly unsafe" and a value of five was given to the option "I feel strongly safe". For questions regarding the level of concern a value of one was given to the option "Extremely concerned" and a value of five was given to the option "Not at all concerned". Likewise, the only open-ended question that requested to express their prior knowledge of the WEpods in a few words was similarly ranked and coded.

The crossing behaviour was also used as an indicator of perceived safety. The questions with options regarding crossing behaviour did not have an intrinsic order from the point of view of the respondent, hence were processed as categorical variables. However, the researcher later assessed these answers allocating the lowest value of one to the riskiest crossing preference (as a function of the waiting time and location of crossing); "*wait in a convenient place to cross until there is an acceptable gap",* which was interpreted as that they felt safer to cross the road in a convenient place and time rather than using dedicated locations in the presence of the vehicles. The highest value of four was given to the safest crossing preference (as a function of waiting times and location of crossing); "*walk to a crossing facility and wait for the vehicles to stop",* which was interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the vehicles.

Dealing with missing values and outliers

After coding all the questions, the data was transferred to the SPSS software. Fortunately, in total only 32 out of 7,850 cells (0.40%) were unanswered questions. The only questions that had a big percentage of missing values were the ones related to the frequency in which they walk or cycle inside the campus especially for exercise purposes. In order to do a proper analysis, it was important to test the hypothesis that missing values are completely at random (It is possible to ignore or omit missing data when the data is missing at random) [141]. To this end, MCAR test (Missing Completely At Random) was used, this analysis had a positive outcome, it was concluded that the missing values were not statistically significant $(p = 0.10)$, meaning, the data is missing in a random way. For this reason, the data was left as it was, hence missing values were not replaced by other values and the answers of the respondents in the rest of the questions were kept in the data set, using the option in SPSS of test-by-test deletion. Furthermore, not extreme values were removed this was done to understand different opinions and perceptions. After the preparation of the dataset with the information mentioned above, it was possible to start the analyses using different statistical tests.

Statistical tests

The selection of the adequate statistical tests that were run in **SPSS** was based on the number of dependent and the nature of the dependent and independent variables, following the specifications found in [137], and always complying with the assumptions of each specific test (for more details see Appendix G - Table 13). All the chosen statistical tests were non-parametric (see Appendix G - Table 14). Parametric tests generally provide a more powerful test of a hypothesis; however, this advantage may be negated if one or more assumptions are violated (normally distributed data, homogeneity of variance and independence). However, as demonstrated with numerous examples by [138], most of the time a parametric test and its non-parametric analogue were employed to evaluate the same data, and it led to identical or similar conclusions. For these reasons, it was more appropriate to carry out the analyses with these non-parametric tests that are more conservative. The techniques used to carry out and interpret the results of the tests were based on two sources [139] and [141].

5. RESULTS

This chapter contains the results obtained from the three research methods. The first two sections describe the qualitative results obtained from the face-to-face interviews ($N = 22$) and the focus group ($N = 8$). The last section describes the results of the statistical tests carried out to analyse the self-administered survey ($N = 198$). The results show the differences in perceived safety and reported crossing behaviour of VRUS interacting with traditional motor vehicles in comparison with their interaction with the WEpods. Furthermore, it is addressed how factors such as the interaction with a human driver, awareness of the steward, knowledge of the automated technology, demographic data and having interacted with the WEpods have an influence on the perceived safety amongst VRUs. This section also includes the information needed by VRUs to feel safe in their interaction with these automated vehicles.

5.1 Face-to-face interviews

5.1.1 VRUs interacting with traditional motor vehicles vs. the WEpods

Perceived safety traditional motor vehicles vs. the WEpods

Most of the participants felt safe sharing the road in both scenarios, with normal vehicles (18 out of 22) and with the WEpods (17 out of 22). Some of the reasons given by the respondents who felt concerned about sharing the road with normal vehicles were: "Vehicles can still hit you at low speeds" or "I cannot trust in all the drivers of vehicles". Additionally, people who stated that they did not feel safe sharing the road with the WEpods mentioned that "there is nobody inside the vehicle to brake, I feel unsafe", "I am extra careful, since it is still in test phase" or "Yes, I am concerned because I have no communication with a human driver". There was only one less participant concerned sharing the road with traditional motor vehicles (4 out of 22) than sharing the road with the WEpods (5 out of 22) (see Table 3). *This means there was hardly any difference in the perceived safety of VRUs sharing the road with traditional motor vehicles compared to sharing the road with the WEpods.*

Table 3 Safety perception of VRUs sharing the road with the WEpods vs. sharing the road with traditional motor vehicles

		Concerned sharing the road with the WEpods		
		No	Yes	Total
Concerned sharing the road with traditional motor vehicles	No	14	4	18
	Yes	3	1	4
Total		17	5	22

Regarding interaction at unsignalised intersections (see Table 4), most of the participants felt safe in both scenarios, with normal vehicles (18 out of 22) and with the WEpods (19 out of 22). One of the participants who is concerned with interacting with traditional motor vehicles said that the reason was the lack of traffic signals and therefore, he had to be more cautious in his interaction. Another participant mentioned he had a confusing situation with a bus at one unsignalised intersection where it was not clear if he should stop or keep moving to cross, which generated mistrust in these intersections. Additionally, people who were not concerned argued that they were more distressed by other cyclists than by normal vehicles. As illustrated in Table 4, there was only one participant who was more concerned at unsignalised intersections when comparing traditional motor vehicles (4 out of 22) with the WEpods (3 out of 22). *This means there was barely any difference in the perceived safety of VRUs interacting at unsignalised intersections with traditional motor vehicles compared to interacting with the WEpods.* Furthermore, it was found that from all the four respondents that had already interacted with the WEpods at unsignalised intersections, none of them were concerned about their personal safety, one of the respondents stated: "Not at all concerned, the vehicle is steady".

Table 4 Safety perception of VRUs at unsignalised intersections with the WEpods vs. with traditional motor vehicles

		Concerned at intersections with the WEpods		
		No	Yes	Total
Concerned at intersections with traditional motor vehicles	No	15	3	18
	Yes	4	0	4
Total		19	3	22

Finally, for crossing behaviour, most of the participants reported crossing at the most convenient place in both scenarios, with normal vehicles (15 out of 22) and with the WEpods (16 out of 22), which means there is only one more person who preferred a riskier crossing behaviour with the WEpods. *This means that there was hardly any difference in the VRUs crossing behaviour in interacting with traditional motor vehicles compared to interacting with the WEpods.*

Table 5 Reported crossing behaviour of VRUs with the WEpods vs. with traditional motor vehicles

		Reported crossing behaviour with the WEpods		
		Convenient place	Go to a dedicated facility	Total
Reported crossing behaviour with traditional motor vehicles	Convenient place	12	3	15
	Go to a dedicated facility	4	3	7
Total		16	6	22

Additionally, from the five respondents that had actually crossed the road in the presence of the WEpods, two respondents waited at the most convenient place to cross until there was no traffic coming and then crossed the road in both situations (e.g., with normal vehicles and with the WEpods). One respondent who used to cross in a convenient place with slow traffic (30 km/h) took more precautions with the WEpods: "I took more distance to walk around it, in case it moved". However, two respondents who reported to go to a dedicated crossing facility (zebra) with traditional motor vehicles, chose to cross in a convenient place with the WEpods. One person mentioned: "I stopped, the WEpod passed and then I passed". This means that 2 out of 5 of respondents who have interacted with the WEpods, chose a riskier crossing option, from using zebras to crossing at the most convenient place.

Interaction with human drivers

The driver is important for most of the VRUs, especially eye contact, to take decisions on the road (see Figure 9). One participant stated "I make eye contact a lot, especially in roundabouts", another participant mentioned "Often eye contact, especially if I see it is coming fast or doing wrong actions" or "I always communicate, if it is not clear or if the vehicle is going to stop and if he had noticed me as a cyclist". Additionally, the *respondents who rarely or never interact with a human driver were not concerned when interacting with the WEpods.*

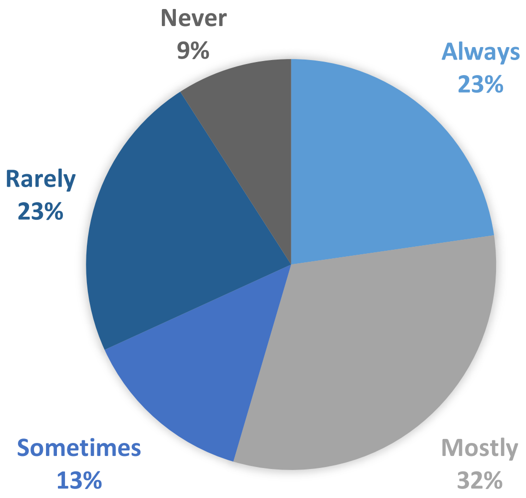


Figure 9 Frequency in which respondents interact with human drivers

5.1.2 VRUs´ perception of safety interacting with the WEpods

Knowledge of the technology and the WEpods

From the 22 people interviewed, only 9.1%, (two respondents) had not seen the WEpods, 27.3% (six respondents) had seen it only once and few times. Furthermore, 22.7% (five respondents) had seen them several times and 13.6% (three respondents) answered that they had seen it very frequently, over 20 times. This means that *most of them were aware of the operation of the WEpods on campus* and they have had at least a basic comprehension of the technology. Additionally, it was questioned if they knew who had the priority on the roads (VRUs or the WEpods). 12 out of 17 people knew that the *VRUs still had the priority above the WEpods* at these unsignalised intersections on campus and were not concerned when sharing the road with the automated vehicles. The remaining five respondents thought the WEpods had the priority. Finally, for most of the respondents, *it was not clear the driving direction* of the WEpods (45.5% - it was not clear and 36.4% - only clear if it was moving), the driving direction was only clear for just under a fifth (18.1%) of the respondents.

Required information of the WEpods

Most of the respondents *were not aware of the presence of the steward inside the WEpods* (27.3% - it doesn't have a steward and 31.8% - I do not know), only two-fifths (40.9%) of the respondents knew it had a steward. All the nine respondents who knew that the WEpods had a steward were not concerned when sharing the road with the WEpods. Moreover, most of the respondents believed that *the WEpods would stop in all possible instances* even when traffic rules were violated (77.3% - I expect the WEpods to stop) and the remaining 22.7% did not expect them to stop. Some of the comments of the people were: “Yes, with the sensors it should behave as normal vehicles” and other participant stated: “No, technology may not be good enough, as shown in the recent Tesla accident”. Finally, most of the respondents (90.9%) considered *it important to be notified about the WEpods operations*, the most preferred option was only lights (40.9%) followed by sounds together with lights (27.3%), which is comparable to a traditional motor vehicle.

Demographic data

Women were more familiar with the idea of automated vehicles (ten out of ten) compared to men (five out of twelve). Additionally, most people (eight out of nine) with an age between 20-25 years preferred to cross at the most convenient place, contrary to the respondents (three out of three) with an age between 31-40 years, who reported to go to dedicated crossing facilities.

5.2 Focus group

5.2.1 VRUs interacting with traditional motor vehicles vs. the WEpods

Perceived safety traditional motor vehicles vs. the WEpods

Half of the participants (four out of eight) claimed they were somehow concerned when sharing the road with (slow and few) traditional motor vehicles because drivers can always make mistakes. The other half said they felt confident due to factors such as the low speed, proficiency in biking and not having previous incidents. Regarding unsignalised intersections, six out of eight of the participants said they look with more precautions to motor vehicles and cyclists coming from all directions. Finally, for the crossing behaviour with traditional motor vehicles five out of eight of participants said they preferred crossing at the most convenient place (look left, right, left again and then cross), the other three said if the road gets busier, they prefer to go to a dedicated crossing facility.

All the eight *participants claimed they would not change their behaviour* when sharing the road with the WEpods, they claimed to trust in the technology. Its low speed makes them not worry much about them, so they are not concerned when sharing the road with the automated vehicles. One of the participants added that he would not do any action that could intervene in its operation. Similarly, at unsignalised intersections, one participant mentioned that after being more familiarised (seeing the WEpods more times), he will start treating it as a traditional slow motor vehicle. In general, the participants would not change their current behaviour at intersections either. Finally, for their crossing behaviour, two participants changed their behaviour from “going to a dedicated facility” to “crossing in a convenient place”, the other six participants claimed they keep the same crossing behaviour with the WEpods as they do with traditional motor vehicles.

Interaction with human drivers

Regarding the interaction with human drivers, two out of the eight participants only look at the motor vehicles and its approaching speed, so the lack of a human driver did not affect them. The other six participants *look often or sometimes to the driver*, they thought it was an important factor that will be missing in automated vehicles, but they affirmed that the speed of the WEpods was not high enough to consider them as a threat.

5.2.2 VRUs´ perception of safety interacting with the WEpods

Knowledge of the technology and the WEpods

All the eight participants were *somehow familiar with the concept of automated vehicles*. Half of the participants based their knowledge on news of systems such as the Google cars, the other half with their experience with the WEpods. Furthermore, half of the participants said *they trusted the WEpods* (especially if they are already on the roads) without the need of further knowledge of the technology that controls the vehicle, the other half of the participants claimed they would like to know the distance (range) of detection of obstacles, which is a deterrent, that could affect their current confidence towards the vehicle.

All the eight participants agreed that the WEpods should follow the same traffic rules as traditional motor vehicles and *VRUs should keep having priority*. Additionally, one participant suggested if the WEpods could ride in bus lanes due to its low speed and be considered as a public transport mode, another participant added if it was possible for the WEpods to operate in exclusive lanes since high volume of cyclists can cause congestion (fortunately the WEpods only operated during off-peak hours). It is important to highlight the fact that the reasons suggested for the segregation of the WEpods, were the speed and the congestions, none of them were related to personal safety concerns. Additionally, all the eight participants agreed that the intended *driving direction of the WEpods (due to the shape of the vehicle) was not clear*, which was especially important when the vehicle was standing still. They suggested taking additional measures to solve this problem, for instance by using different markings in the front and in the rear of the WEpods.

Required information of the WEpods

Half of the participants knew the WEpods had a steward (two had seen the steward inside the vehicle and two had seen it in the news of other automated systems). Two of them did not see this as logical, due to the idea that automated vehicles are self-sufficient. One of the participants mentioned that it was a waste of vehicles´ capacity, and the other participant mentioned she expected the steward to be only during the test phase for a short period of time. From the other half of the participants that were not aware of the steward, two participants did not change their feeling of confidence towards the vehicle and the other two participants perceived it as an *additional safety measure that increased their trust*. Additionally, all the eight participants *expected the WEpods would stop in all possible instances* (according to them it should be programmed to do that). One participant mentioned he was not completely sure, but he claimed the WEpods were safer than vehicles given its faster reaction time compared to human drivers. Another participant wondered if the vehicle could perceive objects behind obstacles (e.g., an intersection with trees obstructing the view).

All the eight participants wanted the vehicle to have *the same characteristics as a traditional motor vehicle,* lights for turning movements and noise to communicate with other road users, for them to be aware of the presence of the WEpods. Two of the participants mentioned it could be an additional distraction to have additional information than the minimum needed, for instance reading text on the vehicle. Furthermore, three out of the eight participants did not mind that the vehicle did not make any noise, one of them stated that people should be always aware of their surroundings. The remaining five participants claimed it would be practical if the vehicle produces *soft noises when it started moving and braking,* also when it is moving to make its location known. Finally, all the eight participants would have liked the WEpods to have a higher speed (considering the time could take for the WEpods to travel from the train station to the University) but they were aware of the repercussions that this could bring to road safety.

5.3 Self-administered survey

The results of the two above-mentioned research methods gave direction to the research about the general thoughts of the VRUs and the aspects that appeared to explain and influence VRU's perception of safety and behaviour. This information was used as input for the completion of the online survey (see survey questions in Appendix D), the relation of the variables and the type of test used for the analyses are shown in Appendix G. Additionally, to be able to give answers to the eight sub-research questions, this research collected data regarding incidents or near misses of VRUs inside the campus, this information was used to analyse if these events had any impact on their safety perception towards traditional motor vehicles and the WEpods. Finally, the respondents answered the survey from their point of view as a pedestrian and as a cyclist, all the hypotheses were analysed if there were differences between cyclists and pedestrians.

Figure 10 illustrates the percentage of walking and cycling for exercising and commuting. From the 190 participants who answered how frequently they walk inside the campus for commuting, just over a half (50.5%) of the respondents claimed to walk inside the campus very frequently; 5 or more days per week (32.6%) and 3-4 days per week (17.9%). The other half of the respondents (49.5%) walk infrequently inside the campus for commuting; 1-2 days per week (28.9%) and never (20.5%). Most the respondents do not walk at all (69.9% - 0 days per week) or cycle (72.9% - 0 days per week) on campus for exercise purposes. In contrast, the bicycle is used more frequently. From the 189 participants who answered how frequent they cycle on campus for commuting, almost four-fifth (79.3%) of the respondents claimed to cycle inside the campus very frequently; 5 or more days per week (60.8%) and 3-4 days per week (18.5%). The other one-fifth of the respondents (20.7%) cycle very infrequently on campus for commuting, 1-2 days per week (8.5%) or never (12.2%).

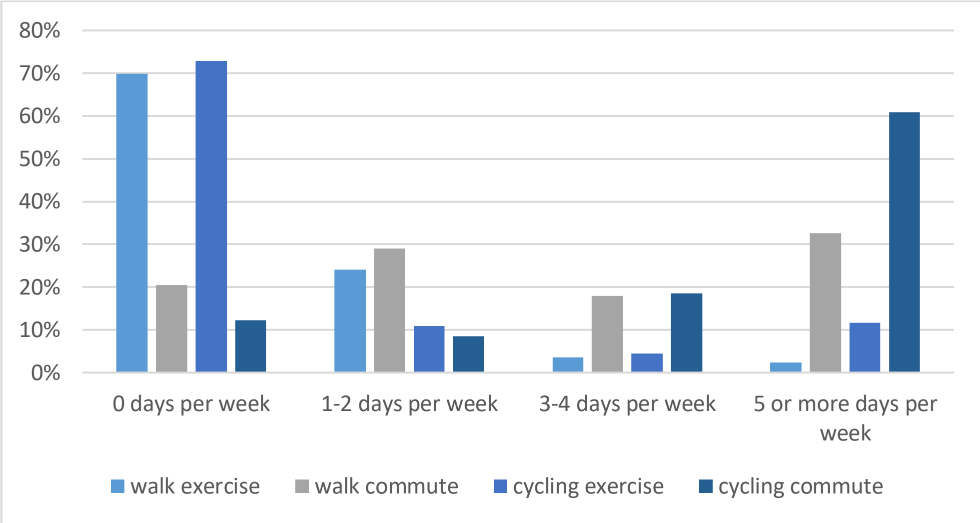


Figure 10 Frequency of exercising and commuting of VRUs on campus

5.3.1 VRUs interacting with traditional motor vehicles vs. the WEpods

Perceived safety and crossing behaviour traditional motor vehicles vs. the WEpods

In the first part of the survey, the participants were asked to rate their perceived safety when sharing the road with vehicles, at unsignalised intersections on the campus and their reported crossing behaviour in their current interactions with traditional motor vehicles. In this section of the survey, the participants were unaware that this research was about automated vehicles to avoid bias or change of perception. Subsequently, the same questions were done rating their perceived safety and crossing behaviour interacting with the WEpods. The results of the comparison of these two scenarios (traditional motor vehicles vs. the WEpods) for the three variables (share the road, unsignalised intersections, and crossing behaviour) are displayed in Table 6.

Table 6 Perceived safety and reported crossing behaviour of VRUs when interacting with traditional motor vehicles (V) compared to interacting with the WEpods (W)

Variable to evaluate ***(survey questions)***	**Description**
Pedestrians sharing the road *(V: 6 - W: 31 and 37)*	Pedestrians felt significantly safer sharing the road in general with the WEpods ($M = 3.73$) than sharing the road with traditional motor vehicles ($M = 3.21$), a mean increase of 0.52, $z = 5.54$, $p < 0.001$ (Wilcoxon signed − rank test).
Cyclists sharing the road *(V: 6 - W: 31 and 37)*	Cyclists felt significantly safer sharing the road in general with the WEpods ($M = 3.78$) than sharing the road with traditional motor vehicles ($M = 3.61$), a mean increase of 0.17, $z = 1.99$, $p = 0.046$ (Wilcoxon signed − rank test).
Pedestrians at unsignalised intersections *(V: 9 - W: 34 and 40)*	There was no significant difference in the perceived safety of pedestrians interacting at unsignalised intersections with traditional motor vehicles compared to interacting with the WEpods, $p = 0.246$ (Wilcoxon signed − rank test).

Cyclists at unsignalised intersections *(V: 9 - W: 34 and 40)*	Cyclists felt significantly less safe at unsignalised intersections with the WEpods $(M = 3.60)$ than sharing the road with traditional motor vehicles $(M = 3.82)$, a mean increase of 0.22, $z = -2.84,\ p = 0.005$ (Wilcoxon signed − rank test).
Pedestrians crossing behaviour *(V: 7 - W: 32 and 38)*	Pedestrians choose more often crossing facilities (i.e., they felt less safe) in the presence of the WEpods than in the presence of traditional motor vehicles, $p = 0.028$ (Marginal homogeneity test).
Cyclists crossing behaviour *(V: 8 - W: 33 and 39)*	There was no significant difference in the cyclists´ crossing behaviour interacting with traditional motor vehicles compared to interacting with the WEpods, $p = 0.078$ (Marginal homogeneity test).

To illustrate one of the above-mentioned results, Figure 11 shows data on the differences in perceived safety of *pedestrians sharing the road* with the two types of vehicles (traditional motor vehicles and the WEpods). As it is observed from the graph, the number of pedestrians who felt less safe interacting with traditional motor vehicles ("Not at all safe": 13 respondents and "Slightly safe": 53 respondents), was higher than the number of pedestrians who felt less safe interacting with the WEpods ("Not at all safe": 3 respondents and "Slightly safe": 18 respondents). On the contrary, the number of pedestrians who felt safer interacting with the WEpods ("Somewhat safe": 44 respondents, "Very safe": 93 respondents, and "Extremely safe": 36 respondents), was higher than the number of pedestrians who felt safer interacting with the traditional motor vehicles ("Somewhat safe": 30 respondents, "Very safe": 77 respondents, and "Extremely safe": 21 respondents).

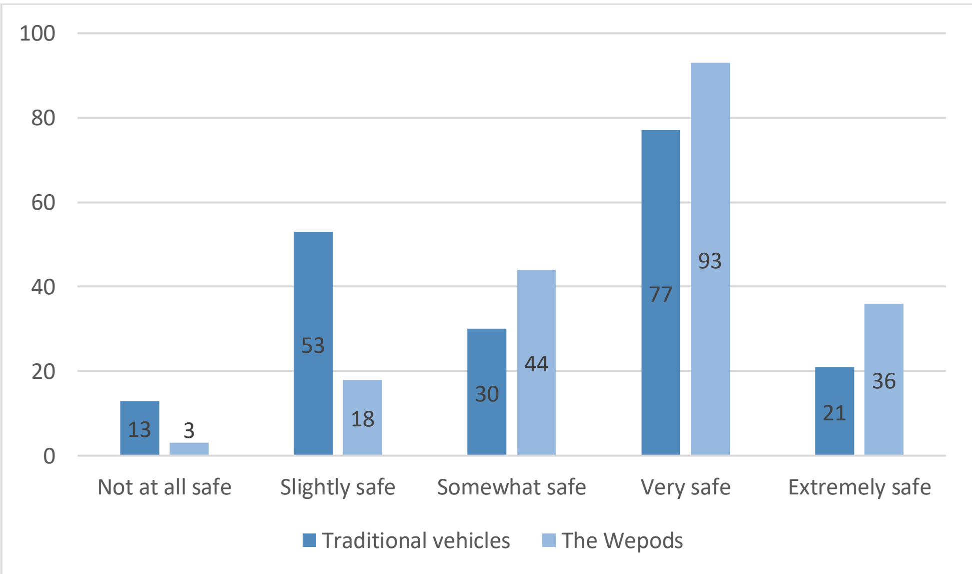


Figure 11 Comparison of the perceived safety of pedestrians sharing the road in general with traditional motor vehicles and with the WEpods

In a further analysis, it was calculated that from the 194 participants (2 were filtered out for missing values); 94 participants reported to feel safer interacting with the WEpods than with the traditional motor vehicles (e.g., pedestrians who reported feeling "slightly safe" with the traditional vehicles and then they reported feeling "Very safe" with the WEpods). Moreover, 59 participants responded they felt equally safe with both vehicles (e.g., pedestrians who reported feeling “Somewhat safe” with the traditional vehicles and then they reported also feeling “Somewhat safe” with the WEpods). Finally, 41 respondents reported to feel safer, in general, sharing the road with traditional motor vehicles than with the WEpods (e.g., pedestrians who reported feeling “Somewhat safe” with the traditional vehicles and then they reported feeling “Not at all safe” with the WEpods).

Furthermore, Figure 12 shows data on the differences in perceived safety of *cyclists interacting at unsignalised intersections* with the two types of vehicles (traditional motor vehicles and the WEpods). As it is observed from the graph, the number of cyclists who felt less safe interacting with traditional motor vehicles (“Not at all safe”: 2 respondents, “Slightly safe”: 23 respondents and “Somewhat safe”: 29 respondents), was lower than the number of pedestrians who felt less safe interacting with the WEpods (“Not at all safe”: 4 respondents, “Slightly safe”: 25 respondents and “Somewhat safe”: 47 respondents). On the contrary, the number of cyclists who felt safer interacting with the WEpods (“Very safe”: 86 respondents, and “Extremely safe”: 32 respondents), was lower than the number of pedestrians who felt safer interacting with the traditional motor vehicles (“Very safe”: 94 respondents, and “Extremely safe”: 46 respondents).

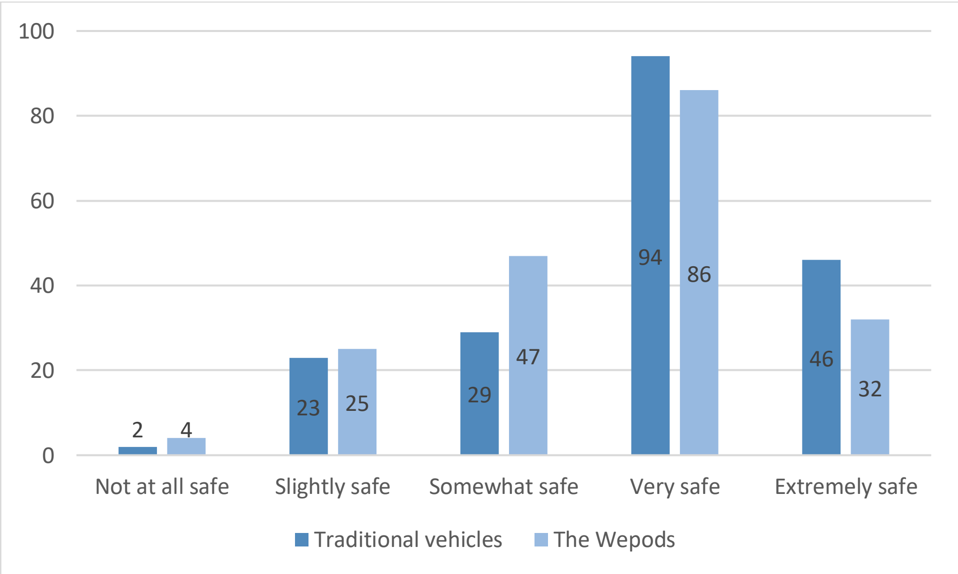


Figure 12 Comparison of perceived safety of cyclists interacting at unsignalised intersections with traditional motor vehicles and with the WEpods

In a further analysis, it was found that from the 194 participants (2 were filtered out for missing values); 36 participants reported to feel safer interacting with the WEpods than with traditional motor vehicles (e.g., cyclists who reported feeling “slightly safe” with the traditional vehicles and then they reported feeling “Very safe” with the WEpods). Moreover, 94 participants responded they felt equally safe with both vehicles (e.g., cyclists who reported feeling “Somewhat safe” with the traditional vehicles and then they reported also feeling “Somewhat safe” with the WEpods). Finally, 64 respondents reported to feel safer interacting at unsignalised intersections with traditional motor vehicles than interacting with the WEpods (e.g., cyclists who reported feeling "Somewhat safe" with the traditional vehicles and then they reported feeling "Not at all safe" with the WEpods).

Furthermore, regarding *pedestrian crossing behaviour* an analysis showed that 37 pedestrians preferred safer crossing behaviour (this could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the automated vehicles), 17 respondents preferred less safe crossing behaviour (this could be interpreted as that they felt safer to cross the road in a convenient place in the presence of the automated vehicles) and 140 respondents have the same preference in their interaction with both types of vehicles.

It was concluded that this difference in the perceived safety is related to the proposed situation given to the respondents. *In general, pedestrians and cyclists felt significantly safer when sharing the road with the WEpods (max. speed of* $15\ km/h$*) than with traditional motor vehicles (max. speed of* $30\ km/h$*). However, cyclists reported feeling less safe with the automated vehicles when it was asked about their perceived safety at unsignalised intersections. Similarly, pedestrians reported a safer crossing behaviour, choosing more often dedicated crossing facilities in the presence of the WEpods in comparison with the traditional motor vehicles.*

N.B.: It is important to consider that the reason why in general VRUs feel safer sharing the road with the WEpods could be related to its lower speed in comparison with traditional motor vehicles, rather than the fact of being an automated vehicle. However, being in line with this premise it was expected to have a similar outcome in specific cases of interaction (interacting at unsignalised intersections and crossing behaviour), which was not the case as shown in the results of the present research. As mentioned by authors such as [99] and [113], the speed is indeed an important factor in the perceived safety and behaviour of VRUs. However, the above-mentioned finding can be interpreted as an indicator that the speed in not the only factor involved the perception of safety and behaviour of VRUs. The next sections will describe the effect of other factors influencing the perceptions and behaviour of VRUs.

Interaction with human drivers

The interaction (i.e., eye contact and signals) with a human driver is important for most of the VRUs. From the 196 respondents, a significant proportion (54.1% - 106 respondents) of respondents most of the time base their actions on cues from the drivers. Only a small minority, 3 participants (1.5%), stated to never base their actions on driver cues. Finally, the proportion of respondents that rarely and always look at the driver are fairly similar; 23% (45 participants) and 21.4% (42 participants) respectively. *This means that a very large majority of the sample* (75.5%) *always or most of the times base their actions on a driver´s eye contact and gestures.* The outcomes of the safety perception and reported crossing behaviour of VRUs who make and do not make eye-contact (based on survey *question 10*) with vehicles´ drivers are shown in Table 7.

Table 7 Perceived safety and reported crossing behaviour of VRUs who interact with a human driver (I) compared to VRUs´ who do not interact with a human driver (NI)

Variable to evaluate *(survey questions)*	**Description**
Level of concern of pedestrians *(I: 30 – NI: 36)*	There was no significant difference for pedestrians who interact and do not interact with human drivers, $p = 0.259$ (Mann – Whitney test).
Level of concern of cyclists *(I: 30 – NI: 36)*	The cyclists who never/rarely interact with human drivers ($M = 4.19$) felt significantly less concerned than those who always/mostly interact with human drivers ($M = 3.80$) $U = 4294.5$, $z = 2.28$, $p = 0.023$ (Mann – Whitney test).
Pedestrians sharing the road *(I: 31 – NI: 37)*	There was no significant difference for pedestrians who interact and do not interact with human drivers, $p = 0.415$ (Mann – Whitney test).
Cyclists sharing the road *(I: 31 – NI: 37)*	There was no significant difference for cyclists who interact and do not interact with human drivers, $p = 0.986$ (Mann – Whitney test).
Pedestrians at unsignalised intersections *(I: 34 – NI: 40)*	There was no significant difference for pedestrians who interact and do not interact with human drivers, $p = 0.331$ (Mann – Whitney test).
Cyclists at unsignalised intersections *(I:34 - NI: 40)*	There was no significant difference for cyclists who interact and do not interact with human drivers, $p = 0.792$ (Mann – Whitney test).
Pedestrians crossing behaviour *(I: 32 - NI: 38)*	Pedestrians who never/rarely interact with human drivers ($M = 1.19$) preferred riskier crossing behaviour (i.e., they felt safer), than those who always/mostly interact with human drivers ($M = 1.38$), $\chi^2(1) = 6.09, p = 0.014$ (Chi – square test). There was a small effect association between the two variables, $\varphi = -0.177$, $p = 0.014$[1].
Cyclists crossing behaviour *(I: 33 - NI: 39)*	Cyclists who never/rarely interact with human drivers ($M = 1.19$) preferred riskier crossing behaviour (i.e., they felt safer), than those who always/mostly interact with human drivers ($M = 1.37$), $\chi^2(1) = 5.35, p = 0.021$ (Chi – square test). There was a small effect association between the two variables, $\varphi = -0.166$, $p = 0.021$.

To illustrate one of the above-mentioned results, Figure 13 shows the differences in the *level of concern of cyclists* who (always/mostly) interacted and (rarely/never) interact with human drivers, based on the percentage of people for each case. It can be observed that most of the cyclists are not concerned with the WEpods. Nevertheless, the biggest share (52%) of cyclists who never/rarely interact with the human drivers were "Not at all concerned". Whereas the 62% of the respondents who always/mostly interact with human drivers felt "Slightly concerned" (34%) and "Somewhat concerned" (28%).

[1] Phi ϕ and Cramer's V are measures of the strength of association (size effect) between two categorical variables. However, Phi is used with 2 × 2 contingency tables Cramer's V is preferred when the two categorical variables contains more than two levels [139]. The interpretations of these values were done according to [147].

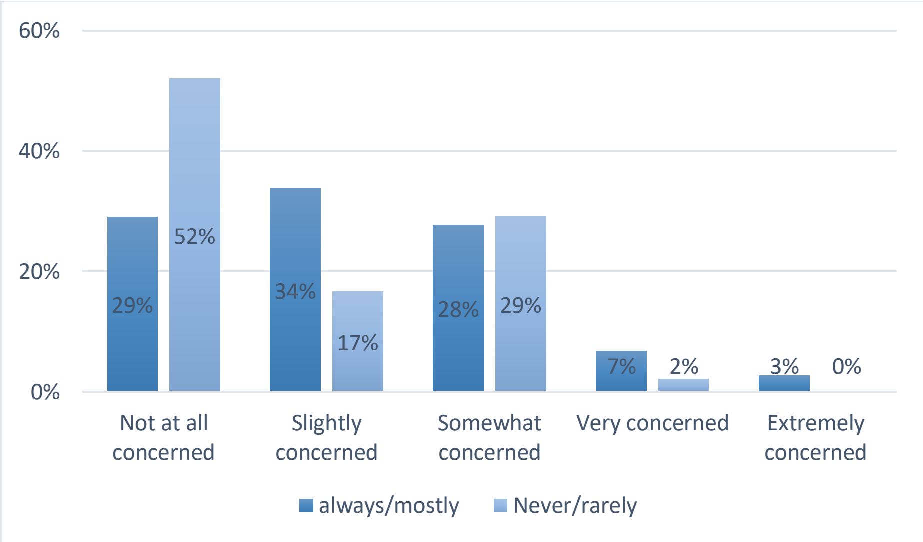


Figure 13 Comparison of level of concerned of cyclists who interact and do not interact with human drivers

5.3.2 VRUs´ perception of safety interacting with the WEpods

Stated vs. revealed preferences

The participants were asked if they had previously interacted with the WEpods. Based on this, the survey was divided into stated preference questions (for those respondents who had not interacted with the vehicle) or similar revealed preference questions (if they already interacted with the WEpods), regarding the perceived safety and their crossing behaviour with the automated vehicles. From the 196 respondents, 39 respondents (19.9%) responded they had interacted with the WEpods, from which 28 people (14.3%) interacted as cyclists and the other 11 respondents (5.6%) interacted as pedestrians. For this analysis, the safety perception of the respondents who interacted with the WEpods (39 participants) was compared with the safety perception the respondents who did not interact with the vehicle (157 participants). The results are presented in Table 8.

Table 8 Perceived safety and reported crossing behaviour of VRUs´ who had interacted (S) compared to VRUs´ who had not interacted (R) with the WEpods

Variable to evaluate *(survey questions)*	**Description**
Level of concern of pedestrians *(S: 30 - R: 36)*	Pedestrians who had interacted ($M = 4.45$) felt less concerned than those who had not interacted with the WEpods ($M = 3.92$) $U = 3903.5$, $z = 3.21,\ p = 0.001$ (Mann − Whitney test).
Level of concern of cyclists *(S: 30 - R: 36)*	There was no significant difference for cyclists who had and had not interacted with the WEpods, $p = 0.051$ (close to significant, Mann − Whitney test).
Pedestrians sharing the road *(S: 31 - R: 37)*	Pedestrians who had interacted ($M = 4.11$) felt safer sharing the road than those who had not interacted with the WEpods ($M = 3.63$) $U = 3790.5$, $z = 2.85,\ p = 0.004$ (Mann − Whitney test).
Cyclists sharing the road *(S: 31 - R: 37)*	Cyclists who had interacted ($M = 4.08$) felt safer sharing the road than those who had not interacted with the WEpods ($M = 3.69$) $U = 3739$, $z = 2.27,\ p = 0.023$ (Mann − Whitney test).

Pedestrians at unsignalised intersections *(S: 34 - R: 40)*	There was no significant difference for pedestrians who had and had not interacted with the WEpods, $\mathrm{p} = 0.841$ (Mann − Whitney test).
Cyclists at unsignalised intersections *(S: 34 - R: 40)*	There was no significant difference for cyclists who had and had not interacted with the WEpods, $\mathrm{p} = 0.755$ (Mann − Whitney test).
Pedestrians crossing behaviour *(S: 32 - R: 38)*	There was no significant difference for pedestrians who had and had not interacted with the WEpods, $\mathrm{p} = 0.715$ (Chi − square test).
Cyclists crossing behaviour *(S: 33 - R: 39)*	There was no significant difference for cyclists who had and had not interacted with the WEpods, $\mathrm{p} = 0.985$ (Chi − square test).

To illustrate one of the above-mentioned results, Figure 14 shows the differences in the *level of concern of pedestrians* who had and had not interacted with the WEpods, based on the percentage of people who selected each option. The biggest share (63%) of pedestrians who had interacted were not at all concerned. While, for the pedestrians who had not interacted, a significant proportion (57%) of respondents were "Slightly concerned" (26%) and "Somewhat concerned" (31%).

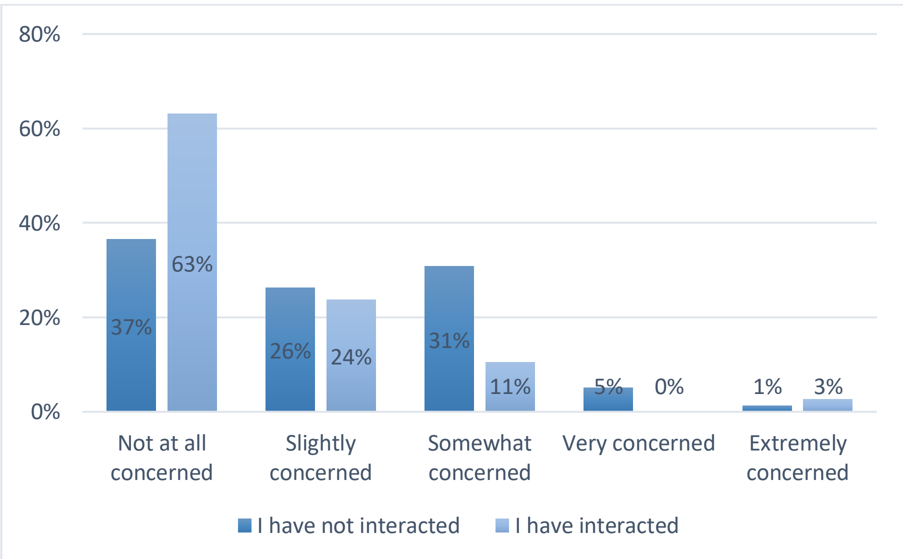


Figure 14 Comparison of the level of concern of pedestrians who had and had not interacted with the WEpods

Knowledge of the technology and the WEpods

The safety perception of the respondents depends on their familiarity with the technology in general and with the WEpods. The three variables used in this section to evaluate their effect are: knowledge of the automated technology, awareness (if they had seen it) and knowledge of the WEpods (if they know its characteristics). A three-way log-linear analysis was performed to determine the association between these three variables. This displayed two two-way correlations, (knowledge of the WEpods/knowledge of the automated technology) and (knowledge of the WEpods/awareness of the WEpods). The model had a likelihood ratio of $\chi^2(2) = 1.45, p = 0.485, (p > 0.05$ indicates that the model was a good fit to the observed data) (see Appendix G - Table 15). Figure 15 illustrates that a large majority of the respondents (91%)

have at least a minimum of knowledge of the automated technology (follow its development, familiar with the idea and have heard a few times about it) and only 9% have never heard of it.

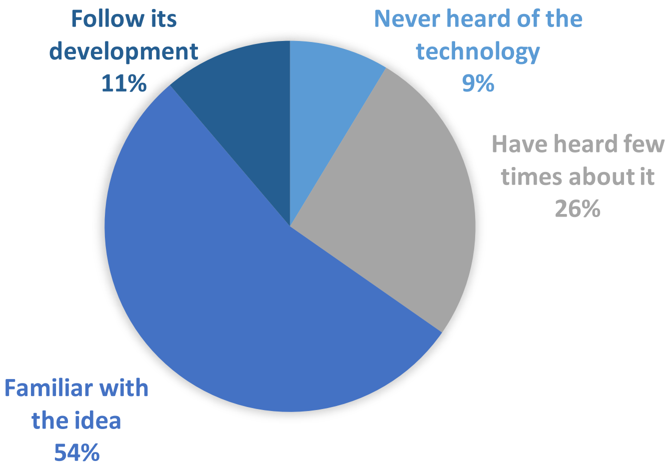


Figure 15 Knowledge of the technology

Moreover, a significant proportion (68.4% - 134 people) have seen the WEpods at least once on campus compared to the proportion (31.6%) who had never seen it. Two-fifths of the respondents (40.4% - 80 people) demonstrated a fair to a good prior understanding of the WEpods´ operations compared to the three-fifths of the respondents (59.6% - 118 people) who did not have prior knowledge. The perceived safety and reported crossing behaviour of VRUs for these three variables (Familiarity with the technology, awareness of the presence of the WEpods and general knowledge of the vehicle) are described in that order in Table 9.

Table 9 Safety perception and reported crossing behaviour of VRUs according to their familiarity (F) with the technology, awareness (AW) and knowledge (K) of the WEpods

Variable to evaluate *(survey questions)*	Description
Level of concern of pedestrians *(30, 36 - F: 25, AW: 28 and K: 26)*	***F***: The mean rank scores showed statistically significant differences between the four groups of knowledge of the technology, $\chi^2(3) = 11.03, p = 0.012$ (Kruskal – Wallis H test). Post hoc: There was no statistically significant difference in the pairwise comparisons [2].
	AW: There was no significant difference for pedestrians who had and had not seen the WEpods, $p = 0.058$ (Mann – Whitney test).
	K: Pedestrians who had a prior knowledge of the WEpods $(\text{mean rank} = 110.23)$ felt significantly less concerned than those who did not have this knowledge $(\text{mean rank} = 88.57), U = 5578.5,\ z = 2.80,\ p = 0.005$ (Mann- Whitney test).
Level of concern of cyclists	***F***: The mean rank scores showed statistically significant differences between the four groups of knowledge of the technology, $\chi^2(3) = 13.93, p = 0.003$ (Kruskal – Wallis H test). Post hoc: respondents in the group "never

[2] It is possible to have a statistically significant Kruskal-Wallis H test but not statistically significant pairwise comparison [148].

(30, 36 - F: 25, AW: 28 and K: 26)	heard of it" $(\text{mean rank} = 70.18)$ felt significantly more concerned than those in "follow its development" $(\text{mean rank} = 119.23)$, $p = 0.030$[3].
	$\boldsymbol{AW}$: Cyclists who had seen the WEpods $(\text{mean rank} = 105.32)$ were significantly less concerned than those who had not seen them $(\text{mean rank} = 83.77)$ $U = 5067.5,\ z = 2.59,\ p = 0.01$ (Mann − Whitney test).
	$\boldsymbol{K}$: Cyclists who had a prior knowledge of the WEpods $(\text{mean rank} = 112.72)$ felt significantly less concerned than those who did not have this knowledge $(\text{mean rank} = 88.69)$, $U = 5778,\ z = 3.06,\ p = 0.002$ (Mann- Whitney test).
Pedestrians sharing the road *(31, 37 - F: 25, AW: 28 and K: 26)*	$\boldsymbol{F}$: The mean rank scores showed statistically significant differences between the four groups of knowledge of the technology, $\chi^2(3) = 11.72, p = 0.008$ (Kruskal − Wallis H test). Post hoc: There was no statistically significant difference in the pairwise comparisons.
	$\boldsymbol{AW}$: There was no significant difference for pedestrians who had and had not seen the WEpods, $p = 0.071$ (Mann − Whitney test).
	$\boldsymbol{K}$: Pedestrians who had a prior knowledge of the WEpods $(M = 3.91)$ felt significantly safer than those who did not have this knowledge $(M = 3.60)$ $U = 5464,\ z = 2.52,\ p = 0.012$ (Mann − Whitney test).
Cyclists sharing the road *(31, 37 - F: 25, AW: 28 and K: 26)*	$\boldsymbol{F}$: The mean rank scores showed statistically significances different between the four groups of knowledge of the technology $\chi^2(3) = 18.27, p < 0.001$ (Kruskal − Wallis H test). Post hoc: respondents in the group "I never heard of it" $(\text{mean rank} = 70.26)$ felt significantly less safe than those in the groups "follow its development" $(\text{mean rank} = 122.11)$, $p = 0.016$ and "familiar with the idea" $(\text{mean rank} = 107.20)$, $p = 0.048$. Furthermore, respondents in the group "have heard a few times" $(\text{mean rank} = 79.65)$ felt significantly less safe than those in the groups "familiar with the idea", $p = 0.011$ and "follow its development", $p = 0.015$.
	$\boldsymbol{AW}$: There was no significant difference for cyclists who had and had not seen the WEpods, $p = 0.135$ (Mann − Whitney test).
	$\boldsymbol{K}$: Cyclists who had a prior knowledge of the WEpods $(M = 4.01)$ felt significantly safer than those who did not have this knowledge $(M = 3.59)$ $U = 5775.5,\ z = 3.09,\ p = 0.002$ (Mann − Whitney test).
Pedestrians at unsignalised intersections *(34, 40 - F: 25, AW: 28 and K: 26)*	$\boldsymbol{F}$: The mean rank scores showed statistically significant differences between the four groups of knowledge of the technology $\chi^2(3) = 8.67, p = 0.034$ (Kruskal − Wallis H test). Post hoc: There was no statistically significant difference in the pairwise comparisons.
	$\boldsymbol{AW}$: There was no significant difference for pedestrians who had and had not seen the WEpods, $p = 0.525$ (Mann − Whitney test).
	$\boldsymbol{K}$: There was no significant difference for pedestrians who had and did not have prior knowledge of the WEpods, $p = 0.056$ (Mann − Whitney test).
Cyclists at unsignalised intersections	$\boldsymbol{F}$: The mean rank scores showed statistically significant differences between the four groups, of knowledge of the technology $\chi^2(3) = 19.90, p < 0.001$ (Kruskal − Wallis H test). Post hoc: respondents in the group "have heard a few times" $(\text{mean rank} = 72.20)$ felt significantly less safe than

[3] Pairwise comparison is done with Bonferroni correction, using an alpha value equal to 0.05 is not appropriate for the set of all comparisons, this inflates the Type I error rate (incorrect rejection of a true null hypothesis). Hence, this critical value will be divided by the number of tests that will be conducted [141].

(34, 40 - F: 25, AW: 28 and K: 26)	those in the groups "follow its development" $(\text{mean rank} = 124.39),\ p = 0.001$ and "familiar with the idea" $(\text{mean rank} = 105.99),\ p = 0.001$.
	$\boldsymbol{AW}$: There was no significant difference for cyclists who had and had not seen the WEpods, $p = 0.627$ (Mann − Whitney test).
	$\boldsymbol{K}$: Cyclists who had a prior knowledge of the WEpods $(M = 3.79)$ felt significantly safer than those who did not have this knowledge $(M = 3.49)$ $U = 5331,\ z = 1.99,\ p = 0.046$ (Mann − Whitney test).
Pedestrians crossing behaviour *(32, 38 - F: 25, AW: 28 and K: 26)*	$\boldsymbol{F}$: There was no significant difference between the four groups of knowledge of the technology, $p = 0.266$ (Chi − square test).
	$\boldsymbol{AW}$: There was no significant difference for pedestrians who had and had not seen the WEpods, $p = 0.213$ (Chi − square test).
	$\boldsymbol{K}$: Pedestrians who had prior knowledge of the WEpods $(M = 1.80)$ preferred riskier crossing behaviour (i.e., they felt safer) than those who did not have this knowledge $(M = 2.34)$, $\chi^2(3) = 13.40, p = 0.004$ (Chi − square test). There was a moderately to a strong association between these two variables, $V = 0.262,\ p = 0.004$.
Cyclists crossing behaviour *(33, 39 - F: 25, AW: 28 and K: 26)*	$\boldsymbol{F}$: There was no significant difference between the four groups of knowledge of the technology, $p = 0.289$ (Chi − square test).
	$\boldsymbol{AW}$: Cyclists who had not seen the WEpods $(M = 1.44)$ preferred safer crossing behaviour (i.e., they felt less safe) than those who had seen the WEpods on campus $(M = 1.27)$, $\chi^2(1) = 9.59, p = 0.022$ (Chi − square test). There was a small effect association between the two variables, $V = 0.222,\ p = 0.022$.
	$\boldsymbol{K}$: There was no significant difference for cyclists who had and did not have prior knowledge of the WEpods, $p = 0.136$ (Chi − square test).

Required information of the WEpods

The awareness of the steward and the trust in the technology (i.e., to expect the WEpods will stop in all possible instances even when traffic rules are violated) are two features that influence the perceived safety and reported crossing behaviour of VRUs in the surroundings of the automated vehicles. From the former variable, it was found that *most of the VRUs were not aware of the presence of the steward* (11.7% - WEpods do not have a steward and 51.5% - I don't know), in contrast to the answer of 72 respondents (36.7%) who knew it had a steward. For the latter variable, it was observed *that a very large majority (81.1% - 159 respondents) answered that they trust that the WEpods will always stop*, the other percentage of participants (17.9% - 35 respondents) did not expect the vehicle to stop in all possible instances. The outcomes of the safety perception and reported crossing behaviour of VRUs regarding their awareness of the steward and trust in the technology are shown in Table 10.

Table 10 Safety perception and reported crossing behaviour of VRUs according to their awareness of the steward (AS) and their trust in technology (T)

Variable to evaluate *(survey questions)*	**Description**
Level of concern of pedestrians *(30, 36 - AS: 41 and T: 42)*	$\boldsymbol{AS}$: The mean rank score of the level of concern of pedestrians were statistically significant different between the three groups of awareness of the steward $\chi^2(2) = 14.22, p = 0.001$ (Kruskal − Wallis H test). <u>Post hoc:</u> respondents in the group "Yes, it has a steward"

	$(\text{mean rank} = 116.17)$ felt less concerned than those in "I do not know" $(\text{mean rank} = 86.38)$, $p = 0.001$.
	T: Pedestrians who expected the WEpods to stop $(\text{mean rank} = 101.08)$ were less concerned that those who did not expect it to stop $(\text{mean rank} = 75.22)$ $U = 3409.5,\ z = 2.61,\ p = 0.009$ (Mann – Whitney test).
Level of concern of cyclists *(30, 36 - AS: 41 and T: 42)*	***AS***: The mean rank score of the level of concern of cyclists were statistically significant different between the three groups of awareness of the steward $\chi^2(2) = 14.62, p = 0.001$ (Kruskal – Wallis H test). <u>Post hoc:</u> respondents in the group "Yes, it has a steward" $(\text{mean rank} = 117.9)$ felt less concerned than those in "I do not know" - ***K*** $(\text{mean rank} = 87.25)$, $p = 0.001$.
	T: Cyclists who expected the WEpods to stop $(\text{mean rank} = 101.92)$ were less concerned than those who did not expect it to stop $(\text{mean rank} = 77.41)$ $U = 3485,\ z = 2.45,\ p = 0.014$ (Mann – Whitney test).
Pedestrians sharing the road *(31, 37 - AS: 41 and T: 42)*	***AS***: There was no significant difference in the perceived safety of pedestrians between the three groups of awareness of the steward, $p = 0.858$ (Kruskal – Wallis H test).
	T: There was no significant difference in the perceived safety of pedestrians who expected the vehicle to stop and those who did not expect it, $p = 0.056$ (Kruskal – Wallis H test).
Cyclists sharing the road *(31, 37- AS: 41 and T: 42)*	***AS***: There was no significant difference in the perceived safety of cyclists between the three groups of awareness of the steward, $p = 0.304$ (Kruskal – Wallis H test).
	T: There was no significant difference in the perceived safety of cyclists who expected the vehicle to stop and those who did not expect it, $p = 0.226$ (Kruskal – Wallis H test).
Pedestrians interacting at unsignalised intersections *(34, 40 - AS: 41 and T: 42)*	***AS***: There was no significant difference in the perceived safety of pedestrians between the three groups of awareness of the steward, $p = 0.074$ (Kruskal – Wallis H test).
	T: There was no significant difference in the perceived safety of pedestrians who expected the vehicle to stop and those who did not expect it, $p = 0.414$ (Kruskal – Wallis H test).
Cyclists interacting at unsignalised intersections *(34, 40 - AS: 41 and T: 42)*	***AS***: There was no significant difference in the perceived safety of cyclists between the three groups of awareness of the steward, $p = 0.111$ (Kruskal – Wallis H test).
	T: There was no significant difference in the perceived safety of cyclists who expected the vehicle to stop and those who did not expect it, $p = 0.175$ (Kruskal – Wallis H test).
Pedestrians crossing behaviour *(32, 38 - AS: 41 and T: 42)*	***AS***: There was a statistically significant association between respondents who stated: "No, it does not have a steward" $(M = 1.35)$, "I do not know" $(M = 1.41)$ and "Yes, it has a steward" $(M = 1.22)$, $\chi^2(2) = 6.67, p = 0.036$ (Chi – square test). There was a small to moderate effect association between these two variables, $V = 0.185,\ p = 0.036$. <u>Post-hoc:</u> Pedestrians who were uncertain if the WEpods had a steward preferred safer crossing behaviour (i.e., they felt less safe) than those who knew the WEpods have a steward.

	T: There was no significant difference in the crossing behaviour of pedestrians who expected the vehicle to stop and those who did not expect it, $\mathrm{p} = 0.632$ $(\mathrm{Chi-square\ test})$.
Cyclists crossing behaviour *(33, 39 - AS: 41 and T: 42)*	***AS***: There was a statistically significant association between respondents who stated: "No, it does not have a steward" $(\mathrm{M} = 1.30)$, "I do not know" $(\mathrm{M} = 1.43)$ and "Yes, it has a steward" $(\mathrm{M} = 1.18)$, $\chi^2(2) = 11.27, \mathrm{p} = 0.004$ $(\mathrm{Chi-square\ test})$. There was a moderate effect association between these two variables, $\mathrm{V} = 0.240$, $\mathrm{p} = 0.004$. Post-hoc: Cyclists who were uncertain if the WEpods have a steward preferred safer crossing behaviour (i.e., they felt less safe) than those who knew the WEpods have a steward.
	T: There was no significant difference in the crossing behaviour of cyclists who expected the vehicle to stop and those who did not expect it, $\mathrm{p} = 0.762$ $(\mathrm{Chi-square\ test})$.

Furthermore, VRUs were asked what types of information they wanted to receive in their interaction with the WEpods (this topic is further discussed in section 6.2). It was found that the most important indication was whether the vehicle was turning (58.2% with visual - lights) and the respondents did not want to receive any notification regarding the speed of the vehicle (46.9% - none). Most of the participants chose visual - light, to be informed if the automated vehicle was turning (58.2%), if it was stopping (48%), and if it had detected them (30.6%). To be notified whether the vehicle was going to start moving, the respondents preferred the combination of two types of indications auditory - tones and visual – lights (32.1%).

Demographic data

As it was described in the literature review; the perceived safety and crossing behaviour varies for different demographic groups. This section analysed the effects of the VRUs´ characteristics, such as age group (adolescence, early adulthood and mature adulthood), cycling experience (beginner, novice, intermediate, advanced and expert), occupation (Bachelor/Master degree students, PhD or higher degree, Working full/part-time job and unemployed), gender (male and female) and nationality (Dutch and non-Dutch) in their interaction with the WEpods. Firstly, the respondents were divided into three groups according to the stages of development of psychology described by [142]: the “adolescence: 12-20 years” (27% - 53 respondents), “early adulthood: 20-30 years” (56.6% - 111 respondents) and “mature adulthood: 30-65 years” (16.3% - 32 respondents).

Regarding the cycling experience, almost a half of the respondents (46.9% - 92 respondents) considered themselves as experts, followed by less than a third of the respondents (31.6% - 62 respondents) who stated having an advanced level, nearly a fifth of the participants (16.8% - 33 respondents) classified themselves as having an intermediate level and the remainder of the participants (4.5% - 9 respondents) considered themselves a novice or beginners. For the occupation of the respondents, the majority (81.6% - 160 respondents) were Bachelor/Mater degree students, followed by 26 respondents (13.3%) working a full/part-time job. The remaining minority of the participants were PhD or had a higher degree (4.1% - 8 respondents) and were unemployed (1.0% - 2 respondents), they were grouped in two groups (students and workers), excluding the two people who were unemployed. Finally, there was almost an equal proportion of gender distribution (48.5% - females and 51.5% - males). As expected the majority of the respondents were Dutch (64.3% - 126 respondents) and the rest were non-Dutch (35.7% - 70 people).

A log-linear analysis was performed to determine the associations between the variables. This analysis displayed numerous correlations, (cycling experience / occupation / nationality), (occupation /age group / nationality), (cycling experience / occupation / gender), (occupation / age group / gender), (cycling experience / gender / nationality), (nationality / age group / gender), (cycling experience / age group). One of the most important correlation was (cycling experience / gender / nationality) as shown in Table 11. The model had a likelihood ratio of $\chi^2(48) = 4.68, p = 1.00$ ($p > 0.05$, indicated that the model was a good fit to the observed data). The results of the safety perception and reported crossing behaviour of VRUs according to their demographic data are shown in Table 11.

Table 11 Safety perception and reported crossing behaviour according to VRUs demographic characteristics - gender (G), age (A), nationality (N), cycling experience (C) and occupation (O)

Variable to evaluate *(survey questions)*	**Description**
Level of concern of pedestrians *(30, 36 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	$\boldsymbol{G}$: Males $(\text{mean rank} = 108.28)$ felt significantly less concerned than females $(\text{mean rank} = 85.80)$ with the automated vehicle, $\text{U} = 5785$, $\text{z} = 2.95$, $\text{p} = 0.003$ (Mann – Whitney test).
	$\boldsymbol{A}$: There was no significant difference in the level of concern between pedestrians within different age groups, $\text{p} = 0.184$ (Kruskal – Wallis test).
	$\boldsymbol{N}$: Dutch $(\text{mean rank} = 108.07)$ felt significantly less concerned than non-Dutch $(\text{mean rank} = 77.92)$ with the automated vehicle, $\text{U} = 2952.5$, $\text{z} = -3.78$, $\text{p} < 0.001$ (Mann – Whitney test).
	$\boldsymbol{C}$: Statistically significant different between the four groups of experience $\chi^2(3) = 14.77, \text{p} = 0.002$ (Kruskal – Wallis test). Post-hoc: people in the intermediate level $(\text{mean rank} = 70.14)$ felt more concerned than people in the other two groups; advanced $(\text{mean rank} = 105.30)$, $\text{p} = 0.013$, and expert $(\text{mean rank} = 105.11)$, $\text{p} = 0.007$.
	$\boldsymbol{O}$: There was no significant difference in the level of concern between pedestrians that were students and workers, $\text{p} = 0.291$ (Mann – Whitney test).
Level of concern of cyclists *(30, 36 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	$\boldsymbol{G}$: Males $(\text{mean rank} = 109.41)$ felt significantly less concerned than females $(\text{mean rank} = 86.91)$, $\text{U} = 5899$, $\text{z} = 2.91$, $\text{p} = 0.004$ (Mann – Whitney test).
	$\boldsymbol{A}$: There was no significant difference in the level of concern between cyclists within different age groups, $\text{p} = 0.129$ (Kruskal – Wallis test).
	$\boldsymbol{N}$: Dutch $(\text{mean rank} = 114.47)$ felt significantly less concerned than non-Dutch $(\text{mean rank} = 69.75)$ with the automated vehicle, $\text{U} = 2397.5$, $\text{z} = -5.54$, $\text{p} < 0.001$ (Mann – Whitney test).
	$\boldsymbol{C}$: Statistically significantly different between the four groups of experience $\chi^2(3) = 22.07, \text{p} < 0.001$ (Kruskal – Wallis test). Post-

	<u>hoc:</u> people in the intermediate level $(\text{mean rank} = 64.73)$ felt more concerned than people in the other two groups; advanced $(\text{mean rank} = 104.70)$, $p = 0.004$, and expert $(\text{mean rank} = 110.05)$, $p < 0.001$.
	O: There was no significant difference in the level of concern between cyclists that were students and workers, $p = 0.970$ (Mann – Whitney test).
Pedestrians sharing the road *(31, 37 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: Males $(M = 3.92)$ felt safer sharing the road in general than females $(M = 3.52)$, $U = 5900.5$, $z = 3.30$, $p = 0.001$ (Mann – Whitney test).
	A: There was no significant difference in the perceived safety of pedestrians within different age groups, $p = 0.526$ (Kruskal – Wallis test).
	N: There was no significant difference in the perceived safety of Dutch and non-Dutch pedestrians, $p = 0.065$ (Mann – Whitney test).
	C: There was no significant difference in the perceived safety of pedestrians within the four groups of experience, $p = 0.065$ (Kruskal – Wallis test).
	O: There was no significant difference in the perceived safety of pedestrians that were students and workers, $p = 0.605$ (Mann – Whitney test).
Cyclists sharing the road *(31, 37 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: Males $(M = 3.91)$ felt safer sharing the road in general than females $(M = 3.61)$, $U = 5839.5$, $z = 2.79$, $p = 0.005$ (Mann – Whitney test).
	A: There was no significant difference in the perceived safety of cyclists within different age groups, $p = 0.677$ (Kruskal – Wallis test).
	N: Dutch $(M = 3.87)$ felt safer sharing the road in general than non-Dutch $(M = 3.57)$, $U = 3684.5$, $z = -2.03$, $p = 0.043$ (Mann – Whitney test).
	C: Statistically significantly different between the four groups of experience $\chi^2(3) = 11.14$, $p = 0.011$ (Kruskal – Wallis test). <u>Post-hoc:</u> people in the intermediate level $(\text{mean rank} = 74.77)$ felt less safe than people in the other two groups; advanced $(\text{mean rank} = 105.76)$, $p = 0.042$, and expert $(\text{mean rank} = 104.71)$, $p = 0.034$.
	O: There was no significant difference in the perceived safety of cyclists that were students and workers, $p = 0.636$ (Mann – Whitney test).
Pedestrians interacting at unsignalised intersections *(34, 40 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: Males $(M = 3.78)$ felt safer at unsignalised intersections than females $(M = 3.51)$, $U = 5537.5$, $z = 2.15$, $p = 0.031$ (Mann-Whitney test).
	A: There was no significant difference in the perceived safety of pedestrians within different age groups, $p = 0.441$ (Kruskal – Wallis test).
	N: Dutch $(M = 3.77)$ felt safer at unsignalised intersections than non-Dutch $(M = 3.43)$, $U = 3427.5$, $z = -2.62$, $p = 0.009$ (Mann-Whitney test).
	C: Statistically significantly different between the four groups of experience $\chi^2(3) = 8.06$, $p = 0.045$ (Kruskal – Wallis test). <u>Post-hoc:</u> there was no statistically significant difference in the pairwise comparison.

	O: There was no significant difference in the perceived safety of pedestrians that were students and workers, $p = 0.549$ (Mann – Whitney test).
Cyclists interacting at unsignalised intersections *(34, 40 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: There was no significant difference in the perceived safety of cyclists between genders, $p = 0.178$ (Mann – Whitney test).
	A: There was no significant difference in the perceived safety of cyclists within different age groups, $p = 0.353$ (Kruskal – Wallis test).
	N: Dutch ($M = 3.78$) felt safer at unsignalised intersections than for non-Dutch ($M = 3.31$), $U = 3243$, $z = -3.17$, $p = 0.002$ (Mann-Whitney test).
	C: Statistically significantly different between the four groups of experience $\chi^2(3) = 8.83, p = 0.032$ (Kruskal – Wallis test). <u>Post-hoc:</u> people in the intermediate level (mean rank = 77.17) felt less safe than people in the expert level (mean rank = 106.99), $p = 0.036$.
	O: There was no significant difference in the perceived safety of cyclists that were students and workers, $p = 0.835$ (Mann – Whitney test).
Pedestrians crossing behaviour *(32, 38 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: There was no significant difference in the crossing behaviour of pedestrians between genders, $p = 0.061$ (Chi – square test).
	A: Statistically significant association between adolescence ($M = 1.25$), early adulthood ($M = 1.41$) and mature adulthood ($M = 1.22$), $\chi^2(2) = 6.58, p = 0.037$ (Chi – square test). Small to moderate effect association between the two variables, $V = 0.184$, $p = 0.036$. <u>Post hoc:</u> pedestrians in their early adulthood preferred safer crossing behaviour (i.e., they felt less safe) than those in the other two age groups; adolescence and mature adulthood.
	N: Dutch ($M = 1.76$) preferred riskier crossing behaviour (i.e., they felt safer) than Non-Dutch ($M = 2.77$), $\chi^2(3) = 28.39, p < 0.001$ (Chi – square test). Large effect association between the variables, $V = 0.382$, $p < 0.001$.
	C: Statistically significant association between the cycling experience levels: beginner/novice ($M = 1.56$), intermediate - ***I*** ($M = 1.61$), advanced ($M = 1.26$) and expert ($M = 1.26$), $\chi^2(3) = 16.61$, $p = 0.001$ (Chi – square test). Large effect association between both variables, $V = 0.292$, $p = 0.001$. <u>Post-hoc:</u> VRUs with intermediate level - ***I*** preferred safer crossing behaviour than the people in the expert and advanced groups.
	O: There was no significant difference in the crossing behaviour between pedestrians that were students and workers, $p = 0.168$ (Chi – square test).
Cyclists crossing behaviour *(33, 39 - G: 45, A: 44, N: 46, C: 5 and O: 47)*	***G***: There was no significant difference in the crossing behaviour of cyclists between genders, $p = 0.653$ (Chi – square test).
	A: There was no significant difference in the crossing behaviour between cyclists within different age groups, $p = 0.086$ (Chi – square test).
	N: Dutch ($M = 1.70$) preferred riskier crossing behaviour (i.e., they felt safer) than non-Dutch ($M = 2.66$), $\chi^2(3) = 25.36, p < 0.001$ (Chi – square test). Large effect association between both variables, $V = 0.361$, $p < 0.001$.

	C: Statistically significant association between the experience levels: beginner/novice $(\mathrm{M} = 1.44)$, intermediate $(\mathrm{M} = 1.64)$, advanced $(\mathrm{M} = 1.26)$ and expert $(\mathrm{M} = 1.24)$, with the pedestrians crossing behaviour, $\chi^2(3) = 19.37, \mathrm{p} < 0.001$ (Chi − square test). Large effect association between the two variables, $\mathrm{V} = 0.315,\ \mathrm{p} < 0.001$. Post-hoc: VRUs with intermediate level preferred safer crossing behaviour than the people in the expert group.
	O: There was no significant difference in the crossing behaviour between cyclists that were students and workers, $\mathrm{p} = 0.124$ (Chi − square test).

Perceived safety and reported crossing behaviour of VRUs involved in incidents or near misses

Events as incidents and near misses can change the safety perception and behaviour of the VRUs involved in these events. On one hand, a total of 24 pedestrians (12.2% of the 196 respondents) had been involved in an incident on campus. Most of these incidents (91.6% - 22 cases) were a near miss (almost collision) and only two pedestrians (8.3%) had an incident with minor injuries. A total of 23 cases (95.8%) were pedestrian - cyclist incidents and only one (4.2%) was a pedestrian - motor vehicle incident. The incident registered with a motor vehicle was less than 6 months ago at an unsignalised intersection, it was caused by speeding. As a consequence, this participant stated that this event changed her previous safety perception to be currently more afraid of other road users.

On the other hand, 54 cyclists (27.6% of the 196 respondents) have been involved in an incident on campus. Of this incidents, over three quarters (77.8% - 42 cyclists) were near collisions, nine cyclists (16.7%) were involved in incidents with minor injuries and one cyclist (1.8%) suffered a serious incident at unsignalised intersections, the other two cyclists (3.7%) did not give details. A significant proportion (37 cases - 68.5%) of these events were cyclists - cyclist incidents, followed by nine (16.7%) cyclists – motor vehicle incident, six (11.1%) cyclist - pedestrian incidents, one (1.8%) cyclists - moped and only one cyclist (1.8%) had a near miss with a bus. Regarding the nine reported incidents involving a motor vehicle, three of these were incidents with minor injuries at unsignalised intersections and the other six were near misses (four at unsignalised intersections, one in a straight section of the road, and the last one in a roundabout - exit Mansholtlaan). Different causes of the incidents with motor vehicles were mentioned, amongst them are the violation of traffic rules, reckless behaviour, distraction and even road design defects. Finally, concerning the consequences of the incident with a vehicle, five out of the nine cyclists claimed that the accident did not affect them, three respondents said they felt afraid of other road users and the last one said he felt somehow afraid and avoided the roundabout where he had the near collision. The participant who had the near miss with a bus claimed that this incident did not change his perceived safety towards vehicles after the event.

A total of 61 VRUs were involved in incidents and near misses on campus, of which 17 were involved as both as a cyclist as a pedestrian. The difference in safety perception and reported crossing behaviour while *interacting with traditional motor vehicles* was analysed, between VRUs who had and did not have incidents. VRUs who did not have an incident with other road users $(M = 3.33)$ felt significantly safer as pedestrians sharing the road in general than those who had an incident $(M = 2.90)$ $U = 3258.5$, $z = -2.73$, $p = 0.018$ $(Mann - Whitney\ test)$, there was no significant difference in safety perception of cyclists sharing the road in general $(p = 0.516)$. VRUs who did not have an incident with other road users $(M = 3.71)$ felt significantly safer as pedestrians at unsignalised intersections than those who had an incident $(M = 3.23)$ $U = 3102$, $z = -2.84$, $p = 0.004$ $(\text{Mann} - \text{Whitney test})$ and VRUs who did not have an incident with other road users $(M = 3.92)$ felt significantly safer as cyclists at unsignalised intersections than those who had an incident $(M = 3.62)$ $U = 3415.5$, $z = -1.97$, $p = 0.049$ $(\text{Mann} - \text{Whitney test})$. Finally, there was no significant difference in the reported crossing behaviour of VRUs as a cyclist, $p = 0.944$ $(\text{Chi} - \text{square test})$, or as a pedestrian, $p = 0.916$ $(\text{Chi} - \text{square test})$, between VRUs who had and did not have an incident or near miss.

Similarly, it was analysed if there were differences in the safety perception and reported crossing behaviour when *interacting with the WEpods* between VRUs who had and did not have incidents. It was identified that VRUs who did not have an incident with other road users $(M = 3.85)$ felt significantly safer as pedestrians sharing the road than those who had an incident $(M = 3.46)$ $U = 3252$, $z = -2.37$, $p = 0.018$ $(\text{Mann} - \text{Whitney test})$, there was no significant difference in safety perception of cyclists sharing the road $(p = 0.163)$. VRUs who did not have an incident with another road user $(M = 3.72)$ felt significantly safer as cyclists at unsignalised intersections than those who had an incident $(M = 3.38)$, $U = 3368$, $z = -2.08$, $p = 0.037$ $(\text{Mann} - \text{Whitney test})$, there was no significant difference in safety perception of pedestrians at unsignalised intersections, $(p = 0.179)$. Finally, VRUs who had an incident $(M = 1.92)$ prefer safer crossing behaviour as cyclists (i.e., they felt less safe) than those who did not have an incident $(M = 2.10)$, $p = 0.003$ $(\text{Chi} - \text{square test})$. There was no significant difference in the reported crossing behaviour of VRUs as pedestrians, $p = 0.289$, $(\text{Chi} - \text{square test})$, between VRUs who had and did not have an incident or near miss.

6. CONCLUSIONS & DISCUSSION

This chapter comprises the conclusions and discussion of the present research. First, the relevance of the main findings of this research is highlighted, considering the research gaps found in the literature regarding the interaction of VRUs with automated vehicles. It continues with the comparison of the outcomes of this study with other studies related to the current interaction of VRUs with traditional motor vehicles, and with the limited research carried out on the interaction of VRUs with automated vehicles. Finally, after having discussed the answers to the eight sub-research questions, the main research question is answered.

6.1 Main findings

6.1.1 Problem and research gap

It is mentioned by [143] that the biggest challenge for autonomous vehicles is the so so-called "corner cases", which are abnormal situations that rarely occur. Following this reasoning, the logical first wave of self-driving vehicles should be shuttles or buses. These types of vehicles have an advantage that they drive in predefined routes, and ideally, in a restrictive well-defined environment, these corner cases could be avoided. Unfortunately, unexpected situations could happen anywhere, even with well-known and well-mapped routes, especially in urban environments when the unpredicted behaviour of pedestrians and cyclists could become a challenge. For this reason, it is important to consider that the effective introduction of this technology not only relies on the technological developments. For example, human factors also play an important role in the further development of this technology.

Some authors such as [11], [12], [13] and [144], have shown certain reservation and even criticism regarding the potential of self-driving vehicles to improve road safety. For instance, [144] exemplified this with the "Self-driving cars and the child–ball problem" that refers to how a human driver that sees a ball roll onto a road, expects a child to follow it, which would not be the same inferential thinking as could be done by a self-driving vehicle. However, programming the vehicle to anticipate on the child is the easiest solution. The problem becomes more pronounced when the unexpected behaviour of children or other road users such as pedestrians or cyclists occurs more often. Additionally, it was expressed by [144] how the current vision of further self-driving scenarios focus on how car travel will be safer through the control of the vehicle to vehicle interaction. However, this vision completely excludes the presence of pedestrians and cyclists, and it is stressed that in the case of interaction with VRUs the vehicle should be programmed to behave "differently".

A clear real example of not taking into consideration the needs and opinions of VRUs in the surroundings of automated vehicles were the pods in Appelscha, in the north of the Netherlands. The vehicles were operating on cycle paths possibly creating unsafe situations and discomfort for the cyclists. As a result of the complaints of road users, the pods´ operations were disrupted [145]. This absence of consideration towards the VRUs in future automated environments was also noticed in the literature review in the current research. The existing studies that emphasise societal acceptance, are mostly from the general public's acceptance, the perspective of driver's willingness to buy the technology and in the citizen's reception of these vehicles as new transport systems. Nonetheless, limited research is done regarding the perceived safety, acceptance, behaviour and awareness of the vulnerable road users that will be present in the surroundings of these vehicles.

6.1.2 Findings of the present research

In the present research, the differences in perceived safety, the reported crossing behaviour and factors that are potentially involved in the acceptance of VRUs towards the WEpods (automated shuttles) were investigated. Two qualitative methods were used, face-to-face interviews and focus groups with participants who had seen the WEpods at least once. The interpretation of the results of both qualitative methods (face-to-face interviews and focus group) led the researcher to think that there was no significant difference in the perceived safety of the VRUs sharing the road, interacting at unsignalised intersections, nor in their reported crossing behaviour with traditional motor vehicles as compared to interacting with the WEpods.

VRUs reported that they wanted to be notified of the WEpods operation (preferably with lights and sounds). This could be interpreted as a replacement for the actual interaction with human drivers, that was found to have a notable importance for most VRUs as they mentioned this aspect during the interviews and the discussion. A significant number of participants were not aware of the presence of the steward inside the WEpods. Nevertheless, it was found that the awareness of its presence increases their perceived safety. Finally, in these two research approaches, it was found that there is a noteworthy confidence in the technology that drives the vehicles, which makes VRUs think that the vehicle will always stop in all possible instances, even when traffic rules are violated. The results of these two methods are now compared with the outcomes obtained from the survey. In this section, the answers to these questions are first translated into conclusions individually, by each hypothesis, and then are jointly analysed to obtain a general conclusion.

Perceived safety and reported crossing behaviour of VRUs towards the WEpods

The first four questions were related to the interaction of VRUs with traditional motor vehicles in comparison with the WEpods:

a. Do VRUs perceive road safety different when they share the road (in general) with traditional motor vehicles compared to sharing the road with the WEpods?

The qualitative methods showed that VRUs would not change their current behaviour in the presence of automated vehicles, the main reasons were their trust in the technology and the low speed of the WEpods. In addition, the results of the survey revealed that in general, and in comparison, with traditional motor vehicles (max. speed of $30\ \mathrm{km/h}$), both cyclists and pedestrians reported feeling safer when sharing the road with the WEpods (max. speed of $15\ \mathrm{km/h}$).

b. Do VRUs perceive road safety different when they interact with traditional motor vehicles compared to interacting with the WEpods at unsignalised intersections?

The face-to-face interviews showed that some respondents at unsignalised intersections were more distressed by other cyclists than by traditional motor vehicles. Furthermore, in the focus group it was mentioned that given the layout of the intersections, they look with more precautions to motor vehicles and cyclists coming from all directions. This means that they were more concerned with other modes than with traditional motor vehicles, and they usually take more precautions in this type of road layout than in other road sections. In general, they mentioned that they will not change their current behaviour interacting with traditional motor vehicles. In the survey, cyclists reported feeling significantly safer interacting at unsignalised intersections with traditional motor vehicles than interacting with the WEpods. On the other hand, pedestrians did not report a significant difference in their perceived safety interacting with both types of vehicles at unsignalised intersections.

c. Do VRUs report a different crossing behaviour in interacting with traditional motor vehicles compared to interacting with the WEpods?

In the qualitative methods, it was found that VRUs would not change their current crossing behaviour in the presence of the WEpods, except for those who had interacted with the WEpods who indicated a riskier crossing behaviour. The results of the survey showed that pedestrians will display safer crossing behaviour, choosing more often dedicated crossing facilities in the presence of the WEpods in comparison with the traditional motor vehicles. This finding can be interpreted as an indicator that they felt less safe interacting with the WEpods. On the other hand, cyclists did not report a significant difference in their crossing behaviour interacting with both types of vehicles.

d. Do the VRUs that base their actions on eye contact or signals received from a human driver report a different crossing behaviour and perceived safety in their new interaction with the WEpods, compared to those who do not use these cues?

The relevance of the actual interaction with human drivers for VRUs was first noted using the qualitative methods. It was especially important for them to see if the driver had noticed them. Furthermore, it was observed that the respondents who did not interact with human drivers (e.g., reported to look at the approaching motor vehicle speed) were somehow less concerned regarding their interactions with the WEpods than those who based their actions on driver's cues. This premise was corroborated with the results of the survey. Particularly for their crossing behaviour, the actual interaction with human drivers for both cyclists and pedestrians played an important role, VRUs who interacted with the human driver indicated a safer crossing behaviour conditions and reported that they would walk to zebras in the presence of the WEpods than VRUs who did not report to use cues from the driver. This preference to opt for safer crossing conditions (i.e., walk to zebras and wait longer to cross), could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the WEpods. This tendency was also observed in the level of concern of cyclists: those who did not report to use cues to interact with human drivers felt less concerned with the WEpods than those who reported interacting with them.

VRUs´ perception of safety interacting with the WEpods

Several parameters are assumed to play an important role in the perceived safety and reported crossing behaviour of VRUs in their interactions with the WEpods. It was already mentioned that the future absence of VRUs – human driver interaction cues will be one important factor that could negatively affect the perceived safety and hence should be addressed. Furthermore, other factors that could influence positive or negative this perception were examined. On the one hand, external factors such as characteristics of the WEpods or the technology in general that generated trust amongst the VRUs could be intrinsically related to the fact of actually having interacted with the vehicle. On the other hand, individual characteristics of the VRUs, such as their age or other demographic variables could also have an impact on their perceived safety of VRUs interacting with the WEpods. This section answers how those factors could have an influence on the perceived safety:

e. Do VRUs that have already interacted with the WEpods (revealed preference) report a different crossing behaviour and perceived safety, compared to those who have not interacted yet with these vehicles (stated preference)?

Both qualitative methods were carried out with respondents who had seen or interacted with the WEpods, which could explain why the outcome of these two methods indicated a tendency to perceive WEpods as safe or even safer than traditional motor vehicles. This idea was verified with the outcomes of the survey; VRUs who had interacted with the WEpods felt, in general, safer sharing the road with the WEpods than those who had not interacted. Similarly, pedestrians who had interacted reported feeling less concerned than those who had not interacted with the WEpods.

f. Do VRUs who have knowledge of the WEpods and its automated technology report a different crossing behaviour and perceived safety, compared to those who do not have this knowledge?

As previously mentioned, most of the participants that were part of the study using qualitative methods had seen and were familiar with the general concept of automated vehicles (based on their knowledge on news such as the Google cars). This led the researcher to believe that this previous knowledge could also be the cause why these two methods indicated a tendency to perceive WEpods as safe or even safer than traditional motor vehicles. The results of the survey showed that VRUs who had good knowledge of the automated technology in general and the WEpods themselves were less concerned and felt safer, in general, sharing the road and interacting with them at unsignalised intersections. Additionally, pedestrians with knowledge of the WEpods indicated to display a riskier crossing behaviour, which can be interpreted as that they felt safer than those who do not have this knowledge. Moreover, the cyclists who had not seen the WEpods felt more concerned and preferred safer crossing behaviour (this could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the automated vehicles) than those who had seen it on campus.

g. What information do VRUs require from the WEpods to feel safe when interacting with them?

In the qualitative methods, it was found that respondents were concerned about the unclear driving direction of the WEpods due to its shape. They found it especially important to know when the vehicles were standing still. Additionally, some participants were not aware that the WEpods would follow the same traffic rules as traditional motor vehicles (VRUs will still have priority over the WEpods). Although most of the participants did not know the vehicles had a steward, most of them had enough trust in the vehicle (due to its sensors and the fact that is already operating on the roads).

The outcomes of the survey showed that VRUs who were uncertain if the WEpods had a steward were more concerned and preferred safer crossing behaviour (this could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the automated vehicles) than those who knew the WEpods had a steward. Moreover, the VRUs who expected the pods always to stop in emergency cases, were less concerned when interacting with the WEpods than those who did not expect them to stop. This could mean that informing VRUs about these features of the WEpods could increase their safety perception towards the automated vehicles. Furthermore, it was found that most of the respondents preferred visual (lights) or the combination of two types of indications auditory (tones) and visual (lights) to know the intentions of the WEpods.

h. How do the VRUs´ demographic data relate to the crossing behaviour and perceived safety when interacting with the WEpods?

The face-to-face interviews pointed out that there was a difference in the reported crossing behaviour for different age groups. The outcomes of the survey indicated that VRUs that were Dutch, males, and with a high level of cycling experience, felt less concerned and safer sharing the road and interacting at unsignalised intersections with the WEpods than their counterpart; VRUs that were non-Dutch, females and low cycling experience level, respectively. Furthermore, cyclists that were Dutch, and with a high cycling experience level, felt safer at unsignalised intersections and preferred riskier cycling crossing behaviour (this could be interpreted as that they felt safer to cross the road in a convenient place in the presence of the automated vehicles), than their counterpart; cyclists that were non-Dutch, and with low cycling experience level, respectively.

Male pedestrians felt also safer sharing the road in general than female pedestrians. Finally, it was found in the survey that pedestrians that were Dutch, in their early adulthood (20-30 years) stage reported safer pedestrian crossing behaviour (this could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the automated vehicles) than their counterpart; pedestrians that were non-Dutch and VRUs in the other two age groups, respectively.

6.2 Discussion

It was concluded in the current research that in general, pedestrians and cyclists felt significantly safer when sharing the road with the WEpods (max. speed of $15\ km/h$) than with traditional motor vehicles (max. speed of $30\ km/h$). However, it is important to consider that a possible reason why VRUs feel safer with the WEpods could be related to its lower speed in comparison with traditional motor vehicles, rather than the fact of being an automated vehicle. Regrettably, as mentioned before, there are few available studies with the same aim of the present study. For this reason, we refer here to the study made by [48], who concluded that pedestrians preferred to share road space with automated vehicles when their presence to the drivers was ensured, with low vehicular traffic, pedestrian-only facilities and high pedestrian traffic. The campus met these conditions, which could partly explain why in general VRUs feel safe(r) sharing the road with the WEpods. Furthermore, in the surveys carried out by [116] and [117] (mentioned in section 2.2.1), it was concluded that most respondents in China, India, Australia and U.S. had, in general, a very positive initial opinion of the technology. This study also supports the idea that respondents have in general a positive attitude towards automated vehicles.

The current research also demonstrated that when it comes to specific situations such as interacting at unsignalised intersections and crossing behaviour, cyclists reported to feel less safe and pedestrians more often indicated a preference to cross at a pedestrian dedicated facility when interacting with the WEpods compared to traditional motor vehicles. For that reason, special emphasis is given here to the results obtained in the stated preference survey carried out by [32], and specifically in the scenario of road type 1 (quiet residential street - low traffic and few vehicles) that is comparable to the conditions of the current research. In this study, it was shown that the option "unsignalised intersections, shared lanes for bikes and vehicles" ranked as the first option for intersection preference in both current and future scenarios. However, it had a significant drop (67.4% - current and 41.6% - autonomous), with an increased preference for separation in driverless conditions. Regarding crossing behaviour, [32] showed that the option "jaywalk, with no crossing facilities and no oncoming traffic" also ranked first in both scenarios (92.6% - current - and 83% - autonomous). However, it was noticed an increase in the preference for a dedicated crossing facility increased by 5.23% to 10.2% with autonomous vehicles. Finally, [32] concluded that with hypothetical future scenarios with autonomous vehicles, the preferences for segregated and controlled environments will significantly increase as compared to the scenario without autonomous vehicles. This shows that these results are in line with the outcomes of the present research, both regarding the interaction at unsignalised intersections and the reported crossing behaviour.

This reduction in the perceived safety interacting with automated vehicles could also be perceived on the results of the surveys made by [116] and [117]. Even though, people from six different countries (the U.S., the U.K., Australia, China, India and Japan), were most likely to had heard of the technology and had a positive initial opinion of the technology, they expressed they were moderately or very concerned regarding the technology, which could not drive as well as human drivers or could get confused by unexpected situations or have system failures. Additionally, in the survey carried out by [115], one of the reasons given to the current lack of trust towards the automated technology is because they had not seen the technology working yet, so the road safety should not only be assessed by experts, it should be demonstrated and determined by the public in general [118]. This statement supports the results of the present study regarding stated versus revealed preferences, VRUs who had interacted with the WEpods described the vehicle as steady and with a passive driving style, for that reason they felt less concerned and safer when sharing the road than those who had not interacted with the vehicle yet. It was also mentioned by [32] that respondents that were unfamiliar with the technology were more likely (0.8 times) to select protected facilities than those who were familiar.

The importance for VRUs of the actual interaction (e.g., eye contact) with human drivers, that was indicated in this research, can also be found in the literature in the study made by [73], who mentioned that different means of communication driver-pedestrians are used in their interaction such as flashing lights, eye-contact, hand waving, etc. Moreover, the present research found that VRUs who interact with human drivers preferred more often safer crossing behaviour such as walk to zebras in the presence of the WEpods than VRUs who do not interact with human drivers, which could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the automated vehicles. This finding can be compared to the results of [120], who found that there was a reduction in the pedestrians´ willingness to cross (used as an indicator of perceived safety) in the cases where the driver was not paying attention (reading a newspaper or sleeping); the lack of feedback demotivates them to cross. To tackle this problem different research has been done specifically on the vehicle-to-pedestrian communications with external vehicles' interfaces, to communicate the vehicle´ intentions to its surroundings [35]. The experiments made by [36] concluded that the visual (more used in frequent interaction) interface was easy to interpret by pedestrians, improved comfort making it a calmer experience, and could increase safety perception.

In the present research, VRUs were asked what types of information they wanted to receive in their interaction with the WEpods, the results are illustrated in Figure 16. It was found that the most important indication for VRUs was to know whether the vehicle was turning (58.2% with visual - lights) and the respondents did not want to receive any notification regarding how fast the vehicle was driving (46.9% - none). This lack of interest of the VRUs in the speed of the vehicle could be a reason why [37], which displayed visual signals indicating when to cross the road and its speed concluded that having a display was an effective as not having any display at all. While the study of [36] found more positive results of the pedestrians towards interfaces, displaying another type of information ("I am in automated mode", "I am about to yield", "I am waiting" and "I am about to drive").

Furthermore, in the current research, the indication with visual - lights was the most chosen by the participants, to be informed if the vehicle was turning (58.2%), if it was stopping (48%), and if it had detected them (30.6%). To be notified whether the vehicle was going to start moving, the respondents preferred the combination of two types of indications *auditory - tones* and *visual – lights* (32.1%). As can be observed, the option *auditory - words* was the least popular option amongst the respondents (chosen by less than 3% of the participants). These results can be compared with the graph of Citymobil2 in the EPFL campus in Lausanne (that is the most similar scenario to the one in Wageningen UR with the same type of vehicle EZ-10) illustrated in

Figure 17. Most of the participants preferred *visual - lights* as feedback if the vehicle is stopping, if it is turning, and if it had detected them. To know if the vehicle is going to start moving they prefer auditory signals**.** Similarly, to the result of the present study, the least important information and type of indication were the speed and auditory (spoken words), respectively.

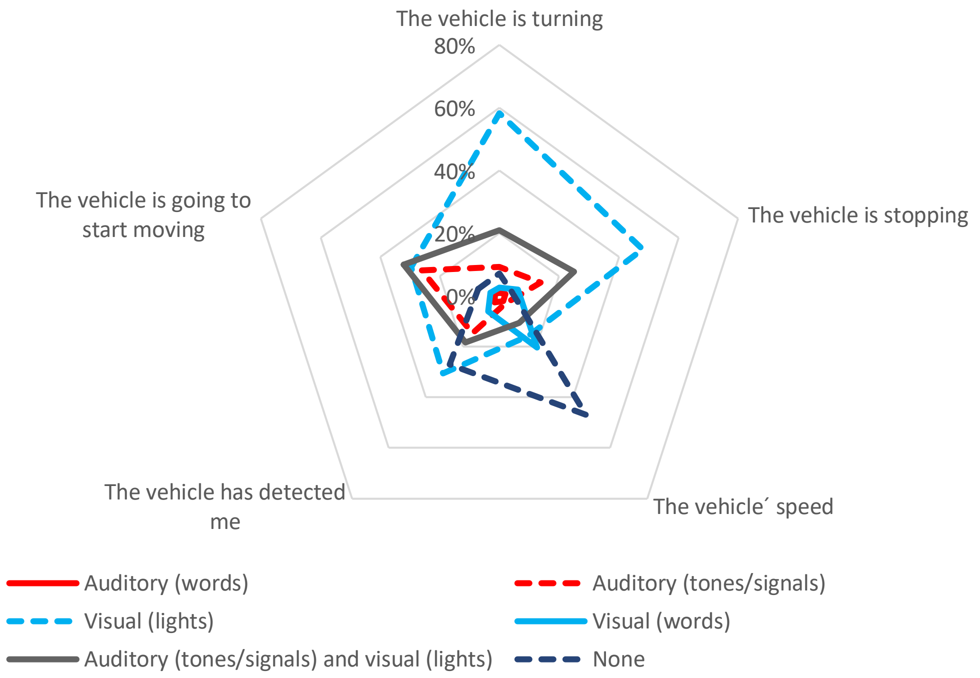


Figure 16 Types of indications of intentions that VRUs want to receive from the operations of the WEpods

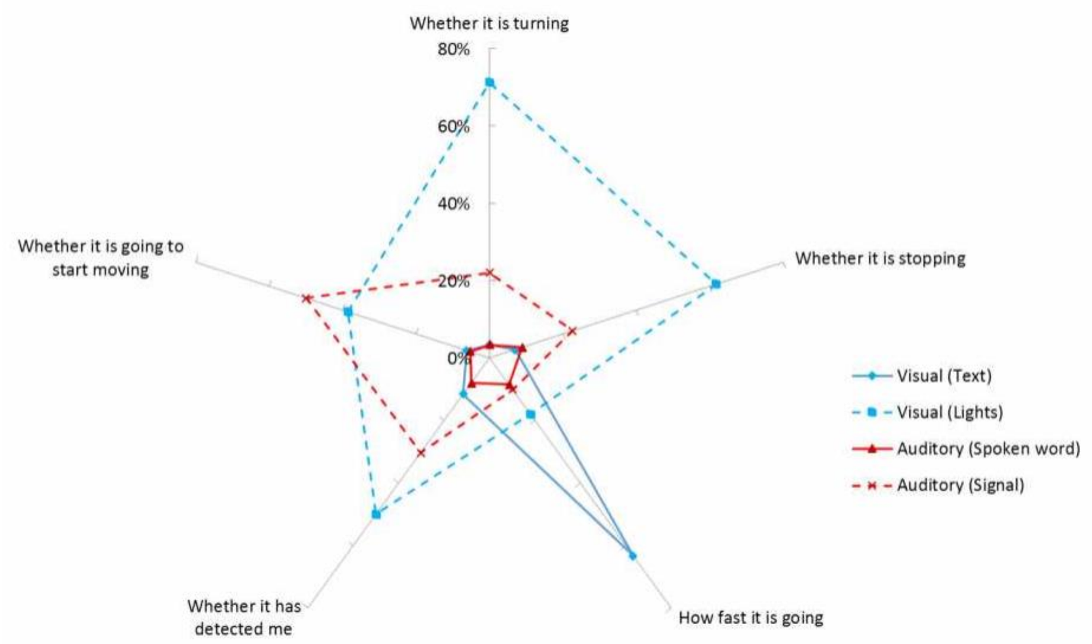


Figure 17 Types of indications of intention VRUs want to receive from the operations of the EZ10 vehicle in Lausanne (Switzerland) according to Citymobil2 [33]

The current research also found differences in safety perception depending on individual characteristics, such as demographic data. Especially, VRUs that were Dutch, males, and with a high level of cycling experiences were respondents who felt safer with the technology than VRUs with other characteristics. There were some similarities with the few studies regarding automated vehicles. For instance, the survey of [116] found that females expressed higher levels of concern with self-driving vehicles than males. Moreover, [32] found that relative to the odds of experienced cyclists, the odds to select more protected facilities were greater for intermediate cyclists (1.42 times) and novice cyclists (2.61 times). Furthermore, the current thesis indicated that pedestrians in their early adulthood stage (20-30 years) preferred safer crossing behaviour which could be interpreted as that they felt less safe to cross the road not using dedicated locations in the presence of the WEpods than pedestrians in other age groups. This can be compared to the result of [32] who indicated that every age category (31 to 45 years, 46 to 60 years and more than 60) was less likely to select protected facilities than the reference group (people under 30) in the presence of autonomous vehicles. These findings are not in line with previous studies with traditional motor vehicles [63] [64], either with the common perception that younger road users are less risk-averse than older ones. Hence, this result could be partly explained by the associations between the variables age group and cycling experience; VRUs in their mature adulthood stage - 30-65 years, have more cycling experience $(\text{mean rank} = 128.55)$ than VRUs in their early adulthood stage - 20-30 years $(\text{mean rank} = 86.6)$.

Some parameters that were found in the literature that are related to the current interaction between VRUs with traditional motor vehicles are reviewed, to analyse how other variables could influence the results of this thesis. For instance, female pedestrians had always been considered to take a lower risk in crossing behaviour [68] and feel less comfortable sharing the space [48], similarly to female cyclists than preferred to use routes with maximum separation from motorised traffic [97] [98] [99]. Furthermore, [96] concluded that cyclists who had been cycling regularly for more than two years expressed to be less concerned with traffic compared to cyclists who had cycled for less time. These results can be interpreted for the present research; the differences in perceived safety for the variables of gender and cycling experience are not only the result of the presence of automated vehicles, these relations already existed in the interaction with traditional motor vehicles.

Another important finding that can be compared with the current literature is the results of incidents or near crashes. The current research showed a difference in safety perception between road users; VRUs who had incidents or near misses felt less safe sharing the road as pedestrians and as cyclists at unsignalised intersections and preferred safer crossing behaviour than those who did not have near misses. This is explained by [101], who concluded that near collisions that occur more frequently may be a significant cause for levels of people´s fear associated with bicycle riding, even more than actual collisions.

6.3 Conclusion

After discussing all the eight research questions, the main research question is reviewed:

How is road safety perceived by vulnerable road users, such as pedestrians and cyclists, when they interact with the WEpods during its test phase?

The results of the current research indicated that in general pedestrians and cyclists reported feeling significantly safer when sharing the road with the WEpods (max. speed of 15 km/h) than with traditional motor vehicles (max. speed of 30 km/h). However, cyclists reported feeling less safe interacting with the automated vehicles at unsignalised intersections. Similarly, pedestrians expressed their preference for a safer crossing behaviour, choosing more often dedicated crossing facilities in the presence of the WEpods than in the presence of the traditional motor vehicles.

Furthermore, the VRUs´ safety perception was positively affected by the WEpods´ low speed, having an actual experience with the WEpods, the knowledge and confidence in the automated technology and in the WEpods themselves. In order to increase the perceived safety amongst cyclists and pedestrians, it is important to inform VRUs about the presence and function of the steward inside the WEpods, the traffic rules that apply to the automated vehicles, especially the fact that VRUs will still have priority over this new mode of transport. The present study corroborates the importance for the VRUs of the current interaction (e.g., eye contact and gestures) with human drivers, especially in their reported crossing behaviour. VRUs who do not depend on cues given by human drivers felt safer interacting with the WEpods than those who depend on this interaction. To tackle this problem and increase safety perception, indications of intentions from the WEpods are needed, VRUs preferred visual - lights to be informed if the automated vehicle was stopping, turning and whether it had detected them, and a combination of auditory - tones and visual - lights to be notified when the vehicle was going to start moving. Finally, the perceived safety did not only depend on external factors above-mentioned but also relied on VRUs´ individual characteristics, such as their gender and other demographic variables.

The findings of the current research appear to point at a prudent attitude of VRUs in their interaction with automated vehicles. Nevertheless, this conservative mindset could be balanced by informing VRUs about both the features (e.g., the presence of a steward on board) and the limitations (e.g., the technology unable to respond to unexpected conditions) of the WEpods. This information along with an appropriate communication of intentions of the vehicle to its surroundings are relevant to achieve a safe interaction between VRUs and automated vehicles.

7. RECOMMENDATION FOR FUTURE RESEARCH

The present study had some limitations, which should be considered in future studies. The most important to discuss is the respondents´ comprehension and interpretation of the survey questions that are related to both, the phrasing of the different questions in the survey and the fact that not many people have experienced the WEpods. The options of unsignalised intersections and crossing behaviour had pictures to exemplify and converge the participant's attention into the same situations. However, the option of shared road space only had the definition of the term, which could lead to a wide range of interpretations. For that reason, the interpretation of the current results is done from a general to a specific situation; concluding then that in general, and in comparison, with traditional motor vehicles VRUs felt safer sharing the road with automated vehicles. Nevertheless, cyclists felt less safe at unsignalised intersections interacting with the WEpods and equally, pedestrians preferred safer crossing behaviour, choosing more often dedicated crossing facilities in the presence of the pods.

In the survey, the comparison between the two types of vehicles was carried out considering different speeds, the WEpods with $15\ km/h$ and traditional motor vehicles with $30\ km/h$. Even though the speed difference was in favour of the WEpods to be chosen as a safer option than the traditional motor vehicles, the outcome of the present study showed the opposite result; cyclists reported to feel less safe interacting at unsignalised intersections with the automated vehicles and pedestrians more often opted for crossing facilities in the presence of the WEpods than in the presence of traditional motor vehicles. However, it is highly recommended to do further research considering equal speed conditions. Furthermore, the current research compares different types of vehicles (regarding its size), the WEpods that are shuttles or mini buses and the traditional motor vehicles. According to [68], the number of attempts to cross roads was reduced if the approaching vehicle was a large bus and [80] concluded that middle-aged pedestrians, looked at vehicles more often before crossing with buses rather than with cars. The results of those studies proved a change in the safety perception and reported crossing behaviour related to the size of the vehicle. Ideally, further research should compare the differences in perceived safety and behaviour of VRUs interacting with traditional motor vehicles and automated vehicles under equal speed and size vehicle conditions.

Speed and volume of the traffic were assumed constant in this study. However, these are conditions that affect crossing strategies [77], compliance with traffic signals [78] and the risk encountered by pedestrian and cyclist on the road [105] [111]. Even though, the WEpods will not exceed the $25\ km/h$ (in their route to the train station), it will be interesting to observe how the change in speed of the traffic (maximum speed of $50\ km/h$) in the environment in which the WEpods will be operating, could generate variations in the perceived safety and crossing behaviour of VRUs in the surrounding of the route. Furthermore, not only the conditions of the traffic but also the number of pedestrians and cyclists affect their behaviour. In the study of [82], pedestrians reported greater likelihood in crossing the road when other pedestrians were crossing the road. Similarly, [68] proved that the waiting times to cross the street were shown to reduce as the number of pedestrians increased. Moreover, the theory of "safety in numbers" explained how drivers adapt their scanning routine with high levels of cycling, thus the risk faced by each cyclist declines as the number of cyclists increases [105] [106]. These results could be generalised for the present thesis; respondents are influenced by the environment of a campus crowded with VRUs, where motor vehicles are perceived as guests. It is suggested to do further studies of comparisons, considering different environments for the VRUs, for instance on its way to the train station. Finally, it is important to highlight the fact that VRUs can change their behaviour depending on their social and psychological characteristics rather than to characteristics of the external environment [70], so these intrinsic factors will inevitably influence the results of further studies.

Another factor that might have influenced the results of the current research is the familiarity of the respondents with the environment (in this case the campus). According to [68], the familiarity with the environment is related to higher risk taking and less waiting time to cross the road. For this reason, it is highly recommended to carry out the same investigation with the WEpods driving to the train station, it could be possible to evidence different crossing behaviour and perception of safety. Furthermore, a further study in the route of the WEpods towards the train station including new types of interaction, for instance, the presence of signalised intersections. The study of [111] concluded that the variation in the type of design affects cyclist's safety; at intersections where cyclists had the priority, one-way bicycle paths were safer than two-way bicycle paths. Therefore, interesting results could come up considering another study area.

Additionally, considering that the WEpods will not be operating in a foreseeable future in bad weather conditions, studies related to this parameter will not be needed. However, other limitations of the automated technology should be considered, for instance, the detection of occluded pedestrians [28]. The document of [112] determined that cycling in proximity to an intersection increased the risk of an incident fourfold, and in an intersection with visual occlusions such as buildings and hedges, the risk would be twelvefold. It could be interesting to carry out some studies to measure differences in the perceived safety and crossing behaviour of pedestrians interacting with automated vehicles with different degrees of occlusion. Finally, considering that one limitation of the current research is that it is based on a stated preference survey which can differ from the actual behaviour of the road users, it is recommended to carry out further field studies to measure actual behaviour of VRUs. For instance, to compile the data from cameras inside and outside the WEpods to monitor conflicts and to analyse other road users´ behaviour. These field studies could corroborate the results obtained in the present investigation and give more indications on the real causes why VRUs feel less safe interacting with the WEpods in specific situations. It could also be considered the possibility to do a follow-up study, to track the change of perception and behaviour after some time when respondents are more familiarised and completely adapted to the vehicle and the technology in general.

8. REFERENCES

[1] Netherlands Institute for Transport Policy Analysis, “Paths to a self-driving future,” Ministry of Infrastructure and the Environment, The Hague, the Netherlands, 2017.

[2] C. Reid, “Roads Were Not Built For Cars,” Why is cycling popular in the Netherlands: infrastructure or 100+ years of history?, 08 December 2012. [Online]. Available: http://www.roadswerenotbuiltforcars.com/netherlands/. [Accessed 22 May 2016].

[3] V&W, “The Dutch Bicycle Master Plan,” Ministry of Transport, Public Works and Water Management - V&W, The Hague, the Netherlands, 1999.

[4] NL Cycling, “Amsterdam children fighting cars in 1972,” Bicycle Dutch , 12 December 2013. [Online]. Available: https://bicycledutch.wordpress.com/2013/12/12/amsterdam-children-fighting-cars-in-1972/. [Accessed 22 May 2016].

[5] J. Pucher and L. Dijkstra, “Making Walking and Cycling Safer: Lessons from Europe,” *Transportation Quarterly,* vol. 54, no. 3, pp. 25 - 50, 2000.

[6] J. Pucher and R. Buehler, “Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany,” *Transport Reviews,* vol. 28, no. 4, pp. 495 - 528, 2008.

[7] W. Vlakveld, “Transition of control in highly automated vehicles A literature review,” SWOV Institute for Road Safety Research, The Hague, the Netherlands, 2015.

[8] I. van de Poel, “Value Sensitive Design,” CityMobil2, 2015. [Online]. Available: http://wepods.nl/artikelen/value-sensitive-design. [Accessed 17 May 2016].

[9] M. Boele, C. Duivenvoorden, A. Hoekstra and S. de Craen, “Procedure en criteria voor de veiligheid van praktijkproeven op de openbare weg met (deels) zelfrijdende voertuigen,” SWOV Institute for Road Safety Research, The Hague, the Netherlands, 2015.

[10] W. Oosterbaan, “The future does not have a driver,” *nrc.nl,* p. http://vorige.nrc.nl//international/Features/article2219438.ece/The_future_does_not_have_a_driver, 21 04 2009.

[11] M. Sivak and B. Schoettle, “Road safety with self-driving vehicles: General limitations and road sharing with conventional vehicles,” The University of Michigan, Transportation Research Institute, Michigan, The United States, 2015.

[12] M. Hagenzieker, “On traffic safety and human behaviour in traffic: "That bollard could have been a child",” in *Inaugural speech*, Delft, the Netherlands, 2015.

[13] S. Shladover, “The truth about "Self-driving" cars,” *Scientifi c American,* vol. 314, no. 6, pp. 52 - 57, 2016.

[14] G. Savino, J. Brown, M. Rizzi, M. Pierini and M. Fitzharris, “Triggering algorithm based on Inevitable collision states for Autonomous Emergency Braking (AEB) in motorcycle-to-car crashes,” in *2015 IEEE Intelligent Vehicles Symposium (IV)*, Seoul, Korea, 2015.

[15] S. Ferguson, E. Teoh and A. McCartt, “Progress in teenage crash risk during the last decade,” *Journal of Safety Research,* vol. 38, pp. 137 - 145, 2007.

[16] D. Yadron and D. Tynan, “Tesla driver dies in first fatal crash while using autopilot mode,” *the Guardian,* 1 July 2016.

[17] K. Bussemaker, “Sensing requirements for an automated vehicle for highway and rural environments,” Delft University of Technology, Delft, the Netherlands, 2014.

[18] D. Milakis, M. Snelder, B. van Arem, G. Van Wee and G. Homem De Almeida Rodriguez Correia, “Exploring plausible futures of automated vehicles in the Netherlands: Results from a scenario analysis,” in *Automated Vehicle Symposium 2015*, Michigan, the United States, 2015.

[19] CityMobil2, “News & events,” CityMobil2, 2015. [Online]. Available: http://www.citymobil2.eu/en/News-Events/News/EasyMile-EZ10-from-CityMobil2-to-WEpods/?sw=wepods. [Accessed 17 May 2016].

[20] WEpods, “WEpods.com,” Crowded, 01 June 2016. [Online]. Available: http://wepods.com/. [Accessed 07 September 2016].

[21] WEpods, “WEpods.com,” 2016. [Online]. Available: http://wepods.nl/wepods-brengt-zelfrijdend-vervoer-dichtbij/. [Accessed 25 April 2017].

[22] R. Möhring, “Design of the WEpod track: Evaluation report,” Delft University of Technology, Delft, the Netherlands, 2015.

[23] K. Zeeb, A. Buchner and M. Schrauf, “Is take-over time all that matters? The impact of visual-cognitive load on driver take-over quality after conditionally automated driving,” *Accident Analysis & Prevention,* vol. 92, pp. 230 - 239, 2016.

[24] M. Cunningham and M. Regan, “Driver inattention, distraction and autonomous vehicles,” in *4th International Conference on Driver Distraction and Inattention*, Sydney, Australia, 2015.

[25] B. Seppelt and J. Leeb, “Modeling driver response to imperfect vehicle control automation,” *Procedia Manufacturing,* vol. 3, pp. 2621 - 2628, 2015.

[26] J. Weyer, R. Fink and F. Adelt, “Human–machine cooperation in smart cars. An empirical investigation of the loss-of-control thesis,” *Safety Science,* vol. 72, pp. 199 - 208, 2015.

[27] B. van Arem, C. van Driel and R. Visser, “The Impact of Cooperative Adaptive Cruise Control on Traffic-Flow Characteristics,” *IEEE Transactions on Intelligent Transportation Systems,* vol. 7, no. 4, pp. 429 - 436, 2006.

[28] P. Dollár, C. Wojek, B. Schiele and P. Perona, “Pedestrian Detection: An Evaluation of the State of the Art,” *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 34, no. 4, pp. 743 - 761, 2012.

[29] D. Fagnant and K. Kockelman, “Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations,” *Transportation Research Part A: Policy and Practice,* vol. 77, pp. 167 - 181, 2015.

[30] R. Madigan, T. Louw, M. Dziennus, T. Graindorge, E. Ortega, M. Graindorge and N. Merat, “Acceptance of Automated Road Transport Systems (ARTS): an adaptation of the UTAUT model,” *Transportation Research Procedia,* vol. 14, pp. 2217 - 2226, 2016.

[31] M. Kyriakidis, R. Happee and J. de Winter, “Public opinion on automated driving: Results of an international questionnaire among 5000 respondents,” *Transportation Research Part F,* vol. 32, pp. 127 - 140, 2015.

[32] M. Blau, “Driverless Vehicles’ Potential Influence on Cyclist and Pedestrian Facility Preferences (Master Thesis).,” The Ohio State University, Cleveland, the United States, 2015.

[33] N. Merat, R. Madigan, T. Louw, M. Dziennus and A. Schieben, “What do Vulnerable Road Users think about ARTS?,” in *CityMobil2 final conference*, Donostia / San Sebastián, Spain, 2016.

[34] Citymobil2, “CityMobil2 final publication: Experience and recommendations,” Citymobil2, Florence, Italy, 2016.

[35] A. Habibovic, J. Andersson, M. Nilsson, V. Malmsten Lundgren and J. Nilsson, “Evaluating Interactions with Non-existing Automated Vehicles: Three Wizard of Oz Approaches,” in *2016 IEEE Intelligent Vehicles Symposium (IV)*, Gothenburg, Sweden, 2016.

[36] A. Habibovic, V. Malmsten Lundgren, J. Andersson, M. Klingegård, T. Lagström, A. Sirkka, J. Fagerlönn, C. Edgren, R. Fredriksson, S. Krupenia, D. Saluäär and P. Larsson, “Communicating the intent of automated vehicles to their surroundings,” unpublished, 2016.

[37] M. Clamann, M. Aubert and M. Cummings, “Evaluation of Vehicle-to-Pedestrian Communication Displays for Autonomous Vehicles,” in *Transportation Research Board 96th Annual Meeting*, Washington DC, the United States, 2017.

[38] L. Vissers, S. van der Kint, I. van Schagen and M. Hagenzieker, “Safe interaction between cyclists, pedestrians and automated vehicles,” SWOV Institute for Road Safety Research, the Hague, the Netherlands, 2016.

[39] SWOV, “Vulnerable road users,” SWOV Institute for Road Safety Research, Leidschendam, the Netherlands, 2012.

[40] J. Lutin, A. Kornhauser and E. Lerner-Lam, “The revolutionary development of self-driving vehicles and implications for the transportation engineering profession,” *Institute of Transportation Engineers - ITE Journal,* vol. 83, no. 7, pp. 28 - 32, 2013.

[41] J. Parkin, B. Clark, W. Clayton, M. Ricci and G. Parkhurst, “Understanding interactions between autonomous vehicles and other road users: A literature review,” University of the West of England - UWE, Bristol, the United Kingdom, 2016.

[42] CBS, “Overledenen; doden door verkeersongeval in Nederland, wijze van deelname,” Central Bureau voor de Statistiek, 21 April 2016. [Online]. Available: http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=71936NED&D1=a&D2=0&D3=a&D4=a&HDR=T&STB=G1,G2,G3&VW=T. [Accessed 31 May 2016].

[43] SWOV, “Werkelijke aantal doden en ernstig verkeersgewonden naar vervoerswijze en leeftijd (Actual number of fatalities and serious road injuries by mode of transport and age),” SWOV Institute for Road Safety Research, [Online]. Available: https://www.swov.nl/NL/Research/cijfers/Cijfers_Ongevallen.htm. [Accessed 22 May 2016].

[44] SWOV, “Cijfers - slachtoffers, bestuurders en ongevallen (Figures - victims, drivers and accidents),” SWOV Institute for Road Safety Research, [Online]. Available: https://www.swov.nl/NL/Research/cijfers/Cijfers_Ongevallen.htm. [Accessed 22 May 2016].

[45] K. Duivenvoorden, C. Goldenbeld, W. Weijermars, N. Bos, J. de Groot-Mesken and H. Stipdonk, "Monitor Beleidsimpuls Verkeersveiligheid 2015 Onderzoeksverantwoording R-2015-20A (Monitor Traffic Safety Administration Pulse 2015 Research Accountability)," SWOV Institute for Road Safety Research, the Hague, the Netherlands, 2015.

[46] SWOV, "Pedestrian safety," SWOV Institute for Road Safety Research, Leidschendam, the Netherlands, 2012.

[47] J. Pucher and L. Dijkstra, "Promoting safe walking and cycling to improve public health: Lessons from the Netherlands and Germany," *Public Health Matters,* vol. 93, no. 9, pp. 1509 - 1516, 2003.

[48] I. Kaparias, M. Bell, A. Miri, C. Chan and B. Mount, "Analysing the perceptions of pedestrians and drivers to shared space," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 15, no. 3, pp. 297 - 310, 2012.

[49] E. Papadimitriou, G. Yannis and J. Golias, "A critical assessment of pedestrian behaviour models," *Transportation Research Part F,* vol. 12, pp. 242 - 255, 2009.

[50] M. M. Ishaque and R. B. Noland, "Behavioural issues in pedestrian speed Choice and street crossing behaviour: A Review," *Transport Reviews,* vol. 28, no. 1, pp. 61 - 85, 2008.

[51] G. Yannis, E. Papadimitriou and . A. Theofilatos, "Pedestrian gap acceptance for mid-block street crossing," *Transportation Planning and Technology,* vol. 36, no. 5, pp. 450 - 462, 2013.

[52] B. Kadali and V. Perumal, "Pedestrians' gap acceptance behavior at mid block," *International Journal of Engineering and Technology,* vol. 4, no. 2, pp. 158 - 161, 2012.

[53] A. Dommes, V. Cavallo, J. Dubuisson, I. Tournier and F. Vienne, "Crossing a two-way street: comparison of young and old pedestrians," *Journal of Safety Research,* vol. 50, pp. 27 - 34, 2014.

[54] R. Lobjois and V. Cavallo, "Age-related differences in street-crossing decisions: The effects of vehicle speed and time constraints on gap selection in an estimation task," *Accident Analysis and Prevention,* vol. 39, pp. 934 - 943, 2007.

[55] S. Chandra, R. Rastogi and V. Das, "Descriptive and parametric analysis of pedestrian gap acceptance in mixed traffic conditions," *KSCE Journal of Civil Engineering,* vol. 18, no. 1, pp. 284 - 293, 2014.

[56] D. Pawar and G. Patil, "Pedestrian temporal and spatial gap acceptance at mid-block street crossing in developing world," *Journal of Safety Research,* vol. 52, pp. 39 - 46, 2015.

[57] C. Cherry, B. Donlon, X. Yan, S. Moore and J. Xiong, "Illegal mid-block pedestrian crossings in China: gap acceptance, conflict," *International Journal of Injury Control and Safety Promotion,* vol. 19, no. 4, pp. 320 - 330, 2012.

[58] T. Petzoldt, "On the relationship between pedestrian gap acceptance and time to arrival estimates," *Accident Analysis & Prevention,* vol. 72, pp. 127 - 133, 2014.

[59] B. Raghuram Kadali and P. Vedagiri, "Effect of vehicular lanes on pedestrian gap acceptance behaviour," *Social and Behavioral Sciences,* vol. 104, pp. 678 - 687, 2013.

[60] P. Koh and Y. Wong, "Gap acceptance of violators at signalised pedestrian crossings," *Accident Analysis & Prevention,* vol. 62, pp. 178 - 185, 2014.

[61] S. Hoogendoorn, and P. Bovy, "Nonlocal continuous-space microscopic simulation of pedestrian flows with local choice behavior," *Transportation Research Record,* vol. 1776, pp. 201 - 210, 2001.

[62] M. Brosseau, S. Zangenehpour, N. Saunier and L. Miranda-Moreno, "The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: A case study in Montreal," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 21, pp. 159 - 172, 2013.

[63] I. Bernhoft and G. Carstensen, "Preferences and behaviour of pedestrians and cyclists by age and gender," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 11, no. 2, pp. 83 - 95, 2008.

[64] E. Moyano, "Theory of planned behavior and pedestrians' intentions to violate traffic regulations," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 5, no. 3, pp. 169 - 175, 2002.

[65] E. Avineri, D. Shinar and Y. Susilo, "Pedestrians' behaviour in cross walks: The effects of fear of falling and age," *Accident Analysis & Prevention,* vol. 44, no. 1, pp. 30 - 34, 2012.

[66] D. Yagil, "Beliefs, motives and situational factors related to pedestrians' self-reported behavior at signal-controlled crossings," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 3, no. 1, pp. 1 - 13, 2000.

[67] C. Holland and R. Hill, "The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations," *Accident Analysis and Prevention,* vol. 39, pp. 224 - 237, 2007.

[68] M. Hamed, "Analysis of pedestrians' behavior at pedestrian crossings," *Safety Science,* vol. 38, no. 1, pp. 63 - 82, 2001.

[69] J. Cinnamon, N. Schuurman and M. Hameed, "Pedestrian Injury and Human Behaviour: Observing Road-Rule Violations at High-Incident Intersections," *PLOS ONE,* vol. 6, no. 6, pp. 1-10, 2011.

[70] H. Guo, W. Wang, W. Guo, X. Jiang and H. Bubb, "Reliability analysis of pedestrian safety crossing in urban traffic environment," *Safety Science,* vol. 50, no. 4, pp. 968 - 973, 2012.

[71] B. Kadali and P. Vedagiri, "Modelling pedestrian road crossing behaviour under mixed traffic condition," *European Transport,* no. 55, pp. 1-17, 2013.

[72] D. Evans and P. Norman, "Understanding pedestrians' road crossing decisions: An application of the theory of planned behaviour," *Health Education Research,* vol. 13, no. 4, pp. 481 - 489, 1998.

[73] M. Susha, "Pedestrian and driver encounters, communication and decision strategies," Department of Psychology, University in Olomouc, Olomouc, Czech Republic, 2014.

[74] S. Das, C. Manski and M. Manuszak, "Walk or wait? An empirical analysis of street crossing decisions," *Journal of Applied Econometrics,* vol. 20, no. 4, pp. 529 - 548, 2005.

[75] M. Brewer, K. Fitzpatrick, J. Whitacre and D. Lord, "Exploration of Pedestrian Gap-Acceptance Behavior at Selected Locations," *Transportation Research Record: Journal of the Transportation Research board,* no. 1982, pp. 132 - 140, 2006.

[76] G. Tiwari, S. Bangdiwala, A. Saraswat and S. Gaurav, “Survival analysis: Pedestrian risk exposure at signalized intersections,” *Transportation Research Part F,* vol. 10, no. 2, pp. 77 - 89, 2007.

[77] J. Hine and J. Russell, “Traffic barriers and pedestrian crossing behaviour,” *Journal of Transport Geography,* vol. 1, no. 4, pp. 230 - 239, 1993.

[78] D. Eustace, “Pedestrian reaction to crossing signal delay,” *Journal of Transportation Research Forum,* vol. 40, no. 1, pp. 117 - 128, 2001.

[79] P. Gårder, “The impact of speed and other variables on pedestrian safety in Maine,” *Accident Analysis & Prevention,* vol. 36, no. 4, pp. 533 - 542, 2004.

[80] X. Zhuang and C. Wu, “Pedestrians’ crossing behaviors and safety at unmarked roadway in China,” *Accident Analysis & Prevention,* vol. 43, no. 6, pp. 1927 - 1936, 2011.

[81] S. Moody and S. Melia, “Shared space – research, policy and problems.,” *Proceedings of the Institution of Civil Engineers - Transport,* vol. 167, no. 6, pp. 384 - 392, 2014.

[82] R. Zhou, W. Horrey and R. Yu, “The effect of conformity tendency on pedestrians’ road-crossing intentions in China: An application of the theory of planned behavior,” *Accident Analysis & Prevention,* vol. 41, no. 3, pp. 491 - 497, 2009.

[83] T. Rosenbloom, “Crossing at a red light: Behaviour of individuals and groups,” *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 12, no. 5, pp. 389 - 394, 2009.

[84] H. Guo, Z. Gao, X. Yang and X. Jiang, “Modeling pedestrian violation behavior at signalized crosswalks in China: A hazards-based duration approach,” *Traffic Injury Prevention,* vol. 12, no. 1, pp. 96 - 103, 2011.

[85] R. van Houten, R. Ellis and J. Kim, “Effects of Various Minimum Green Times on Percentage of Pedestrians Waiting for Midblock "Walk" Signal,” *Transportation Research Record,* vol. 2002, pp. 78 - 83, 2007.

[86] W. Wang, H. Guo, Z. Gao and H. Bubb, “Individual differences of pedestrian behaviour in midblock crosswalk and intersection,” *International Journal of Crashworthiness,* vol. 16, no. 1, pp. 1 - 9, 2011.

[87] B. de Lavalette, C. Tijus, S. Poitrenaud, C. Leproux, J. Bergeron and J. Thouez, “Pedestrian crossing decision-making: A situational and behavioral approach,” *Safety Science,* vol. 47, no. 9, pp. 1248 - 1253, 2009.

[88] Y. Li and G. Fernie, “Pedestrian behavior and safety on a two-stage crossing with a center refuge island and the effect of winter weather on pedestrian compliance rate,” *Accident Analysis & Prevention,* vol. 42, no. 4, pp. 1156 - 1163, 2010.

[89] P. Schepers, H. Stipdonk, R. Methorst and J. Olivier, “Bicycle fatalities: Trends in crashes with and without motor vehicles in The Netherlands,” *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. unpublished.

[90] P. Schepers, N. Agerholm, E. Amoros, R. Benington, T. Bjørnskau, S. Dhondt, B. de Geus, C. Hagemeister, B. Loo and A. Niska, “An international review of the frequency of single-bicycle crashes (SBCs) and their relation to bicycle modal share,” *Injury Prevention,* vol. 21, pp. 138 - 143, 2014.

[91] M. Wardlaw, "Assessing the actual risks faced by cyclists," *Traffic Engineering & Control,* vol. 43, no. 11, pp. 420 - 424, 2002.

[92] P. G. Furth, "Bicycling infrastructure for mass cycling: A transatlantic comparison," in *City Cycling*, J. Pucher and R. Buehler, Eds., Cambridge, Massachusetts Institute of Technology, 2012, pp. 105 - 108.

[93] SWOV, "Background of the five Sustainable Safety principles," SWOV Institute for Road Safety Research, Leidschendam, the Netherlands, 2012.

[94] CROW, Design manual for bicycle traffic, CROW, 2007.

[95] J. Hunt and J. Abraham, "Influences on bicycle use," *Transportation,* vol. 34, no. 4, pp. 453 - 470, 2007.

[96] J. O'Connor and T. Brown, "Riding with the sharks: Serious leisure cyclist's perceptions of sharing the road with motorists," *Journal of Science and Medicine in Sport,* vol. 13, no. 1, pp. 53 - 58, 2010.

[97] J. Garrard, G. Rose and S. Lo, "Promoting transportation cycling for women: The role of bicycle infrastructure," *Preventive Medicine,* vol. 46, no. 1, pp. 55 - 59, 2008.

[98] J. Garrard, "Healthy revolutions: promoting cycling among women," *Health promotion journal of Australia,* vol. 14, no. 3, pp. 213 - 215, 2003.

[99] J. Dill and N. McNeil, "Four types of cyclists? examining a typology to better understand bicycling behavior and potential," in *92nd Annual Meeting of the Transportation Research Board*, Washington, D.C., the United States, 2012.

[100] E. Lehtonen, V. Havia, A. Kovanen, M. Leminen and E. Saure, "Evaluating bicyclists' risk perception using video clips: Comparison of frequent and infrequent city cyclists," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 41, pp. 195 - 203, 2016.

[101] E. Fishman, S. Washington and N. Haworth, "Understanding the fear of bicycle riding in Australia," *Australasian College of Road Safety,* vol. 23, no. 3, pp. 19 - 27, 2012.

[102] B. Caulfield, E. Brick and O. McCarthy, "Determining bicycle infrastructure preferences – A case study of Dublin," *Transportation Research Part D: Transport and Environment,* vol. 17, no. 5, pp. 413 - 417, 2012.

[103] E. Heinen, K. Maat and B. van Wee, "The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances," *Transportation Research Part D: Transport and Environment,* vol. 16, no. 2, pp. 102 - 109, 2011.

[104] M. Johnson, S. Newstead, J. Charlton and J. Oxley, "Riding through red lights: The rate, characteristics and risk factors of non-compliant urban commuter cyclists," *Accident Analysis & Prevention,* vol. 43, no. 1, pp. 323 - 328, 2011.

[105] R. Elvik, "The non-linearity of risk and the promotion of environmentally sustainable transport," *Accident Analysis & Prevention,* vol. 41, no. 4, pp. 849 - 855, 2009.

[106] P. Schepers, D. Twisk, E. Fishman, A. Fyhri and A. Jensen, "The Dutch road to a high level of cycling safety," in *International Cycling Safety Conference 2014*, Göteborg, Sweden, 2014.

[107] A. Billot-Grasset, E. Amoros and M. Hours, "How cyclist behavior affects bicycle accident configurations?," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 41, pp. 261 - 276, 2016.

[108] C. Reynolds, M. Harris, K. Teschke, P. Cripton and M. Winters, "Impact of Transportation Infrastructure on Bicycling Injuries and Crashes: a Review of the Literature," *Environmental Health,* vol. 8, no. 47, pp. 1 - 17, 2009.

[109] New York City Department of Transportation, "Making Safer Streets," NYCDOT, New York, the United States, 2013.

[110] A. Welleman and A. Dijkstra, "Safety aspects of urban bicycle tracks," SWOV Institute for Road Safety Research, Leidschendam, the Netherlands, 1988.

[111] J. Schepers, P. Kroeze, W. Sweers and J. Wüst, "Road factors and bicycle–motor vehicle crashes at unsignalized priority intersections," *Accident Analysis & Prevention,* vol. 43, no. 3, pp. 853 - 861, 2010.

[112] M. Dozza and J. Werneke, "Introducing naturalistic cycling data: What factors influence bicyclists' safety in the real world?," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 24, pp. 83 - 91, 2014.

[113] P. Jacobsen, F. Racioppi and H. Rutter, "Who owns the roads? How motorised traffic discourages walking and bicycling," *Injury prevention,* vol. 15, no. 6, pp. 369 - 373, 2009.

[114] J. Broach, J. Dill and J. Gliebe, "Where do cyclists ride? A route choice model developed with revealed preference GPS data," *Transportation Research Part A: Policy and Practice,* vol. 46, no. 10, pp. 1730 - 1740, 2012.

[115] IEEE, "News releases," IEEE, 15 October 2015. [Online]. Available: https://www.ieee.org/about/news/2015/15october_2015.html. [Accessed 12 May 2016].

[116] B. Schoettle and M. Sivak, "A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the U.S., the U.K., and Australia," The University of Michigan, Transportation Research Institute, Michigan, the United States, 2014.

[117] S. B. and M. Sivak, "Public Opinion about Self-Driving Vehicles in China, India, Japan, the U.S., the U.K., and Australia," The University of Michigan, Sustainable Worldwide Transportation, Michigan, the United States, 2014.

[118] KPMG, "Self-Driving Cars: Are We Ready?," KPMG LLP, Delaware, the United States, 2013.

[119] CityMobil2, "Seven European towns and cities to demonstrate automated transport in 2014 and 2015," EU's Seventh Framework Programme, May 2014. [Online]. Available: http://www.citymobil2.eu/en/upload/Dissemination_materials/CityMobil2%20press%20release_May2014_final.pdf. [Accessed 08 May 2016].

[120] V. Lundgren, A. Habibovic, J. Andersson, T. Lagström, M. Nilsson, A. Sirkka, J. Fagerlönn, R. Fredriksson, C. Edgren, S. Krupenia and D. Saluäär, "Will There Be New Communication Needs When Introducing Automated Vehicles to the Urban Context?," *Advances in Human Aspects of Transportation,* vol. 484, pp. 485 - 497, 2017.

[121] R. Happee, "Driverless shuttles in the Netherlands," WEpods, Berlin, Germany, 2016.

[122] R. Leuvenink, “WEpods,” Youngwise, 2016. [Online]. Available: http://wepods.nl/weki/technologie. [Accessed 08 May 2016].

[123] European Commission, “ITS Action Plan,” European Commission, Amsterdam, the Netherlands, 2011.

[124] D. Doody, P. Kearney, J. Barry, R. Moles and B. O’Regan, “Evaluation of the Q-method as a method of public participation in the selection of sustainable development indicators,” *Ecological Indicators,* vol. 9, pp. 1129 - 1137, 2009.

[125] T. Grosvenor, “Qualitative Research in the Transport Sector,” in *Transport Surveys: Raising the Standard*, Grainau, Germany, 2000.

[126] R. Hicks, “A Comparison of Stated and Revealed Preference Methods for Fisheries Management,” in *2002 Annual meeting, July 28-31*, Long Beach, the United States, 2002.

[127] N. Tilahun, D. Levinson and K. Krizek, “Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey,” *Transportation Research Part A,* vol. 41, pp. 287 - 301, 2007.

[128] M. Wardman, “A comparison of revealed preference and stated preference models of travel behaviour,” *Journal of transport economics and policy,* vol. 22, no. 1, pp. 71 - 91, 1988.

[129] L. La Paix and K. Geurs, “Train Station Access and Train Use: A Joint Stated and Revealed Preference Choice Modelling study,” in *Accessibility, Equity and Efficiency. Challenges for transport and public services*, Northampton, the United States, Edward Elgar, 2016, pp. 144 - 159.

[130] M. Batarce, J. Muñoz, J. d. D. Ortúzar, S. Raveau, C. Mojica and R. Ríos, “Use of Mixed Stated and Revealed Preference Data for Crowding Valuation on Public Transport in Santiago, Chile,” *Transportation Research Record: Journal of the Transportation Research Board,* vol. 2535, pp. 73 - 78, 2015.

[131] A. Pirdavani, T. Brijs, T. Bellemans and G. Wets, “Traffic safety perception and its potential impact on travel demand choices,” in *17th International Conference Road Safety On Five Continents (RS5C 2016)*, Rio de Janeiro, Brazil, 2016.

[132] J. C. F. de Winter, D. Dodou and P. A. Wieringa, “Exploratory factor analysis with small sample sizes,” *Multivariate Behavioral Research,* vol. 44, pp. 147 - 181, 2009.

[133] A. Comrey and H. Lee, A first course in factor analysis, Psychology Press, 2013.

[134] Raosoft. Inc, “Sample size calculator,” Raosoft, 2004. [Online]. Available: http://www.raosoft.com/samplesize.html. [Accessed 02 May 2017].

[135] Wageningen University and Research, “Facts and figures,” Wageningen University and Research, 2015. [Online]. Available: http://www.wur.nl/en/wageningen-university/About-Wageningen-University/Facts-and-figures-1.htm. [Accessed 02 May 2017].

[136] Wageningen University and Research, “Annual report 2014,” Wageningen UR, Wageningen, the Netherlands, 2014.

[137] K. Grace-Martin, “The Analysis Factor,” Ghement Statistical Consulting Company Ltd., 2016. [Online]. Available: http://www.theanalysisfactor.com/missing-data-mechanism/. [Accessed 10 October 2016].

[138] UCLA: Statistical Consulting Group., “Introduction to SAS,” Institute for Digital Research and Education - IDRE, February 2011. [Online]. Available: http://www.ats.ucla.edu/stat/mult_pkg/whatstat/. [Accessed 16 September 2016].

[139] D. Sheskin, Handbook of parametric and nonparametric statistical procedures, Florida, the United States: Chapman & Hall/CRC, 2000.

[140] A. Field, Discovering Statistics Using SPSS, 3rd Edition, California, the United States: SAGE Publications., 2009.

[141] Statistics.laerd.com, “Laerd Statistics,” Lund research Ltd, 2015. [Online]. Available: https://statistics.laerd.com/premium/spss/kwht/kruskal-wallis-test-in-spss-13.php. [Accessed 21 October 2016].

[142] A. Sharma, “Stages of Development of Psychology of People at Different Ages from Infancy to Old Age,” PsychologyDiscussion.Net, 2016. [Online]. Available: http://www.psychologydiscussion.net/psychology/stages-of-development-of-psychology-of-people-at-different-ages-from-infancy-to-old-age/732. [Accessed 31 October 2016].

[143] A. Hars, “Baidu expects autonomous buses to become first wave of self-driving vehicles,” WordPress, 31 January 2016. [Online]. Available: http://www.driverless-future.com/. [Accessed 27 November 2016].

[144] J. Adams, “Self-driving cars and the child–ball problem: why autonomous vehicles are not the answer,” London Essays, 6 July 2015. [Online]. Available: http://essays.centreforlondon.org/issues/technology/self-driving-cars-and-the-child-ball-problem-why-autonomous-vehicles-are-not-the-answer/. [Accessed 22 November 2016].

[145] SDC360.com, “‘Pods’ in Appelscha weer de weg op na tijdelijke onderbreking,” Promedia, 22 September 2016. [Online]. Available: http://www.sdc360.com/nl/tests/2016/09/22/pods-in-appelscha-weer-de-weg-op-na-tijdelijke-onderbreking/. [Accessed 30 November 2016].

[146] Continental AG, “eHorizon – New intelligence in vehicle navigation,” Continental AG, 2016. [Online]. Available: http://www.continental-automotive.com/www/automotive_de_en/themes/passenger_cars/interior/multimedia/ehorizon_en.html. [Accessed 21 November 2016].

[147] C. Zaiontz, “Real Statistics Using Excel,” WordPress, 2013. [Online]. Available: http://www.real-statistics.com/chi-square-and-f-distributions/effect-size-chi-square/. [Accessed 26 October 2016].

[148] Statistics.laerd.com, “Laerd Statistics,” Lund research Ltd, 2015. [Online]. Available: https://statistics.laerd.com/. [Accessed 21 October 2016].

APPENDICES

APPENDIX A – CITYMOBIL2 RESULTS

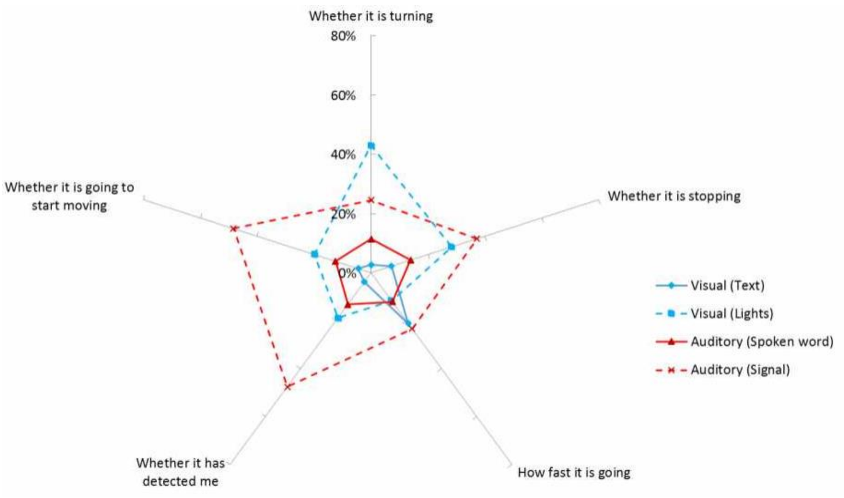


Figure 18 Types of indications of intentions that VRUs want to receive in La Rochelle [33]

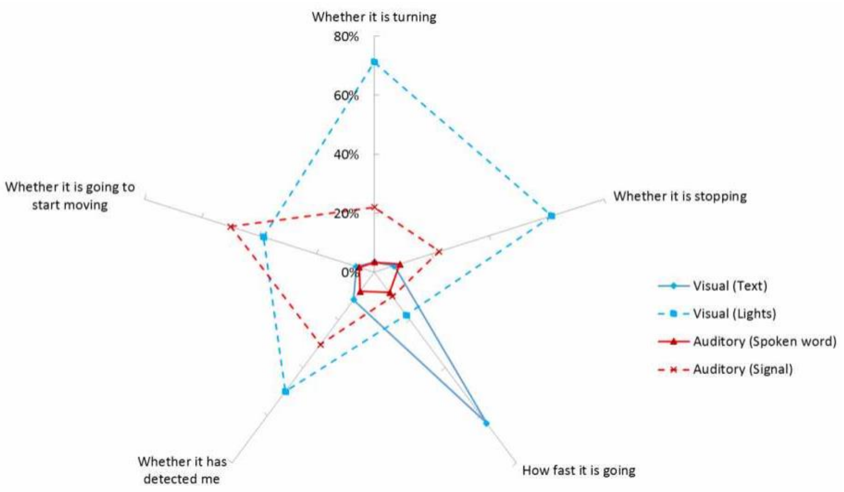


Figure 19 Types of indications of intentions that VRUs want to receive in Lausanne [33]

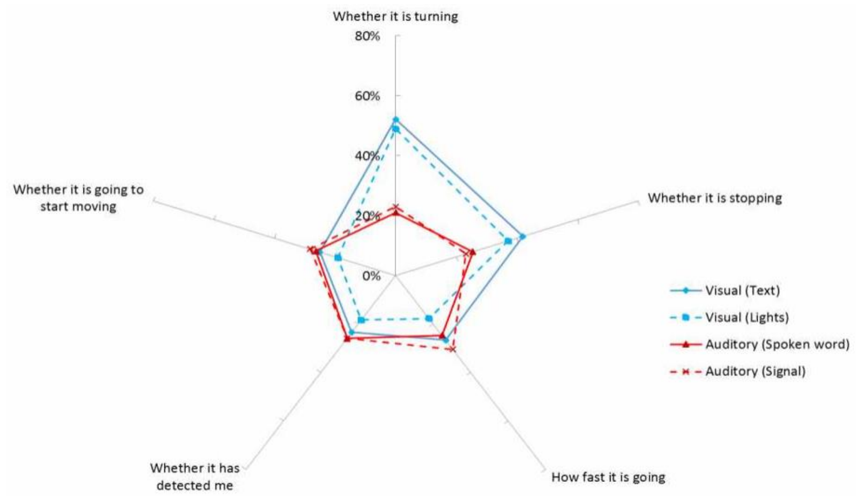


Figure 20 Types of indications of intentions that VRUs want to receive in Trikala [33]

APPENDIX B – THE TECHNOLOGY OF THE WEPODS

The WEpods equipment

Additional technical equipment, added by the WEpods consortium to the WEpods [121]:

- D-DPS/RTK + INS + Odometry (sensors to measure wheel speed and steering angles and thus determine the distance travelled) + landmark positioning
- 8 cameras + 8 radars + 8 ultrasonics
- 6 multilayer lasers
- 11 computers
- An interior camera
- An interior + exterior intercom
- 2x4G + 3G + Wi-Fi-P communication
- 20 kWh batteries
- Heater, belts, roller chair fixation, wiper, a third brake light, interior covers, a steward seat
- A supervisor system and user App and infotainment

Sensors in the WEpods:

The RADAR *(RAdio Detection And Ranging)* sensors work by emitting high-frequency radio signals and measuring the reflection of that signal coming from any present obstacle within the sensor's field of view (FoV). RADAR sensors are also able to directly detect the relative velocity, distance and detection angle of a detected object. The process of operation of the RADAR is: pulse transmission, pulse reflection on object and pulse return to the sensor. The 77-81 GHz frequency band provides superior range, resolution and accuracy due to its shorter wavelength compared to 24 GHz, which makes it more suitable for applications such as pedestrian detection [17].

The LIDAR (*LIght Detection And Ranging*) sensor (laser scanner) is an active optical ranging sensor, its process of operation of the laser scanner is similar to the RADAR. Some of the applications are obstacle detection, pedestrian and vehicle detection, lane recognition, and determination of the exact position of the vehicle. It emits light pulses at a high frequency using a laser. If the emitted light hits an object, the reflected light is measured and used to calculate the distance between the sensor and the object, detection angle and it creates a 3D point cloud that is translated into detections. Additionally, the WEpods use 4 SICK lasers, single layer for detection. Finally, the *Ultrasonic sensors* operate by emitting a high-frequency audio signal, which will be reflected by any object in front of the sensor (similar to RADAR) [17]. This reflected signal is detected, and the time is used to calculate the distance to the object. it is able to detect extremely close objects but presents problems of interference with other ultrasonic sensors and its vulnerability to the wind might need attention.

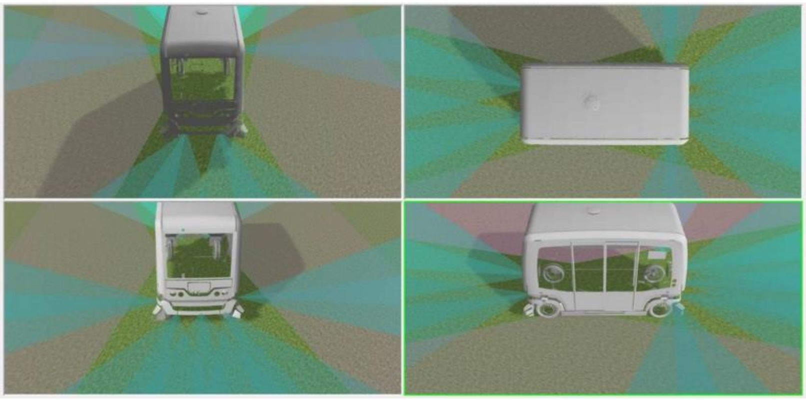


Figure 21 Environmental sensing 5x360° view- 4 physical principles [121]

Navigation of the WEpods:

The combination of subsystems for the absolute position are [122]:

Global navigation Satellite System:

- High-precision GPS sensor for satellite navigation (absolute positioning and orientation (dual-antenna)
- Multi-GNSS (Global Navigation Satellite System) for improved availability (GPS+GLONASS (GLObal NAvigation Satellite System))
- Network-based RTK (Real-Time Kinematic) for cm-accuracy.

The Inertial Navigation System to measure the acceleration of the vehicle in all directions:

- Bridge short GNSS-RTK (Real Time Kinematic) interruptions.
- Data fusion and higher update rate.

Vehicle Odometry; sensors to measure wheel speed and steering angles and thus determine the distance travelled:

- Limit INS (Inertial Navigation System) drift in the case of poor GNSS reception.

According to [121] the *relative positioning* of the WEpods is given by the IBEO laser-based localisation:

- 6 Multi-layer LIDARs (LUX)
- LIDAR odometry
- Fusion with another localisation system
- Simultaneous object detection

Finally, the E-horizon (integration of topographical and digital data with sensor data for predictive control [146]) is done by Adaris V-2 [121].

APPENDIX C – OPERATIONALISATION OF SUB-RESEARCH QUESTIONS AND HYPOTHESES

Table 12 Operationalisation of questions and Hypotheses

Step 1	Step 2		Step 3
Sub-research question	Questions in the survey		Hypotheses
	Traditional motor vehicles	The WEpods	
Do VRUs perceive road safety different when they *share the road* (in general) with traditional motor vehicles compared to sharing the road with the WEpods?	6	31, 37	H_0^a: There is no statistically significant difference in the perceived safety of VRUs *sharing the road* in general with traditional motor vehicles compared to sharing the road with the WEpods. VRUs will report feeling equally safe sharing the road with traditional motor vehicles as with the WEpods.
Do VRUs perceive road safety different when they interact with traditional motor vehicles compared to interacting with the WEpods at *unsignalised intersections*?	9	34, 40	H_0^b: There is no statistically significant difference in the perceived safety of VRUs interacting with traditional motor vehicles compared to interacting with the WEpods at *unsignalised intersections*. VRUs will report feeling equally safe with traditional motor vehicles as with the WEpods at unsignalised intersections.
Do VRUs report a different *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods?	7,8	32, 33, 38,39	H_0^c: There is no statistically significant difference in the VRUs *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods. VRUs will report the same crossing behaviour when interacting with the WEpods as with traditional motor vehicles.
Do the VRUs that base their actions on *eye contact or signals received* from a human driver report a different crossing behaviour and perceived safety in their new interaction with the WEpods, compared to those who do not use these cues?	10	30, 36 / 31, 37 / 32, 33, 38, 39 / 34, 40	H_0^d: There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that base their actions on *eye contact or signals* received from human drivers compared to those who do not use these cues. Both type of VRUs will report feeling equally safe with the WEpods.
Do VRUs that *have already interacted* with the WEpods (revealed preference) report a different crossing behaviour and perceived safety, compared to those who *have not interacted* yet with these vehicles (stated preference)?		30, 36 /31, 37/ 32, 33, 38, 39 / 34, 40	H_0^e: There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who *have already interacted* with the WEpods, compared to those who have not interacted with the automated vehicles. Both type of VRUs will report feeling equally safe with the WEpods.

<table>
<tr><td>Do VRUs who have knowledge of the WEpods and its automated technology report a different crossing behaviour and perceived safety, compared to those who do not have this knowledge?</td><td></td><td>25 – 29 / 30, 36 / 31, 37 / 32, 33, 38, 39 / 34, 40</td><td>$\boldsymbol{H_0^f}$: There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who have knowledge of the WEpods and its automated technology, compared to those who do not have this knowledge. VRUs will report feeling equally safe, regardless of their knowledge of the WEpods and its automated technology.</td></tr>
<tr><td>What information do VRUs require from the WEpods to feel safe when interacting with them?</td><td></td><td>35, 41, 42, 43 / 30, 36 / 31, 37 / 32, 38, 33, 39 / 34, 40</td><td>$\boldsymbol{H_0^g}$: There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that consider that the vehicles will always stop and that it has a steward compared to the VRUs that do not know this information. Both type of VRUs will report feeling equally safe with the WEpods.</td></tr>
<tr><td rowspan="2">How do the VRUs´ demographic data relate to the crossing behaviour and perceived safety when interacting with the WEpods?</td><td colspan="2">5, 44, 45, 46, 47</td><td rowspan="2">$\boldsymbol{H_0^h}$: There is no statistically significant difference in the perceived safety and crossing behaviour within different VRUs´ demographic groups (age, gender, occupation, nationality and cycling experience). All groups of VRUs will report feeling equally safe interacting with the WEpods.</td></tr>
<tr><td>6 / 7, 8 / 9</td><td>30, 36 / 31, 37/ 32, 33, 38, 39 / 34, 40</td></tr>
</table>

APPENDIX D – SELF-ADMINISTERED SURVEY

Survey link: https://docs.google.com/forms/d/e/1FAIpQLScfh2yxLw68B7XkFvZUcYBKWRUyF6JWiiZL-aWD5A7LcGPg5g/viewform

Survey for pedestrians and cyclists

Purpose: The purpose of this study is to understand the opinions of pedestrians and cyclists towards road safety in urban environments. This study will include an interview with questions about your acceptance, awareness and perception of the safety of urban environments. It is expected to take approximately 8-10 MINUTES of your time to complete this survey.

Please note that you must be above 18 years old to participate in this voluntary interview. If you wish to decline or withdraw at any time, you may do so without any consequences. If you agree to participate in this study, you are not likely to experience any risk or unique discomfort from answering these questions.

Confidentiality: Once the surveys are completed, the researcher will analyse the data for statistical summaries only. The data will be used only for the purpose of this study. Data will be printed and stored securely without any names associated. Therefore, no names need to be written on the survey form. This is in order to ensure anonymity (privacy/confidentiality). Please do not discuss the content of the survey with other people, as they might also be invited to participate in this study.

As the main investigator in this study, I will be pleased to answer any questions that you may have concerning the study. If you have any questions during, between, or after your participation in the interview, please send an email to:

P.K.RodriguezCabezas@student.tudelft.nl

Thanks in advance,

Paola Rodríguez

*Required

1. I have read and understood the above information. I declare that I am above 18 years old, and give my consent to voluntarily participate in this study. * Mark only one oval.

◯ I accept.

Mode of transportation

2. What mode of transportation do you mostly use for your internal trips on Wageningen UR campus (including exercise, commuting, leisure, etc.)? Mark only one oval.

- Walk.
- Bicycle.
- Motorbike or moped.
- Bus.
- Car.
- Bicycle and bus (same trip).
- Bicycle and car (same trip).
- Car and bus (same trip).
- I never travel inside the campus.
- Other: ....

3. How often do you WALK on the campus for the following reasons? Mark only one oval per row.

	0 days per days per week	1-2 days per week	3-4 days per week	5 or more week
Exercise.				
Commute (e.g., to study or work).				

4. How often do you CYCLE on the campus for the following reasons? Mark only one oval per row.

	0 days per days per week	1-2 days per week	3-4 days per week	5 or more week
Exercise.				
Commute (e.g., to study or work).				

5. Please rate on a scale from "beginner" to "expert" your skills as a CYCLIST? Mark only one oval per row.

	Beginner	Novice	Intermediate	Advanced	Expert
My level as a cyclist is					

Interaction with vehicles

6. Please rate on a scale from "strongly disagree" to "strongly agree", the idea of sharing space with few and slow vehicles (max. speed of 30 km/h).

Shared space: Street or area where pedestrians, cyclists and vehicles mix and share the space together.
Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
As a pedestrian, I feel safe when sharing space with vehicles.					
As a cyclist, I feel safe when sharing space with vehicles.					

Crossing behaviour

---

7. As a PEDESTRIAN on the campus, how do you usually cross the road with few and slow vehicles?

Mark only one oval.

- I wait in a convenient place to cross until there is an acceptable gap between cars.
- I wait in a convenient place to cross until there is no traffic coming.
- I walk to a crossing facility (e.g., zebra) and immediately cross.
- I walk to a crossing facility (e.g., zebra) and wait for the vehicles to stop.

8. As a CYCLIST on the campus, how do you usually cross the road with few and slow vehicles?

Mark only one oval.

- II wait in a convenient place to cross until there is an acceptable gap between cars.
- I wait in a convenient place to cross until there is no traffic coming.
- I ride to a crossing facility (e.g., bicycle traffic light) and immediately cross.
- I ride to a crossing facility (e.g., bicycle traffic light) and wait for the vehicles to stop.

Unsignalised intersections

Currently, on the campus, there are unsignalised intersections (intersections with no traffic light) as the ones shown below.

Stop sign-controlled (Bornsesteeg/Droevendaalsesteeg)

Yield sign-controlled (Bornsesteeg/Akkermaalsbos-Bronland)

9. Please rate on a scale from "strongly disagree" to "strongly agree", how do you feel about your interaction with few and slow vehicles in these types of intersections? Mark only one oval per row.

	Strongly	Disagree Strongly disagree	Neither agree nor disagree	Agree agree	
As a pedestrian, I feel safe on these intersections.	⬭	⬭	⬭	⬭	⬭
As a cyclist, I feel safe on these intersections.	⬭	⬭	⬭	⬭	⬭

Interaction with vehicles' driver

10. In your interaction as a cyclist or pedestrian with a vehicle´s driver, how often do you base your actions (e.g., stop or keep going) on eye contact or signals that are given by the driver? Mark only one oval.

- ⬭ I always base my actions on a driver´s eye contact and gestures.
- ⬭ I most of the times base my actions on a driver´s eye contact and gestures.
- ⬭ I rarely base my actions on a driver´s eye contact and gestures.
- ⬭ I never base my actions on driver´s eye contact and gestures.

Pedestrians

11. As a pedestrian have you ever had an incident or near miss with other road users on the Wageningen UR campus?

Mark only one oval.

- ⬭ Yes. Skip to question 12.
- ⬭ No. Skip to question 18.

Details of the incident or near miss

12. How do you classify the severity of the event?
Mark only one oval.

- ⬭ Serious incident (major injuries and property damage).
- ⬭ Incident (minor injuries or property damage).
- ⬭ Near miss (almost collision).

13. With whom did you have the incident or near miss? Mark only one oval.

- With a pedestrian.
- With a cyclist.
- With a motorbike or moped.
- With a car.
- With a bus.
- Other

14. How long ago was the incident or near miss? Mark only one oval.

- Less than 6 months ago.
- 6 months to 1 year ago.
- 1 year to 3 years ago.
- 3 year to 5 years ago.
- More than 5 years ago.

15. Where did you have the incident or near miss? Mark only one oval.

- In a straight section of the road.
- In a curve.
- In an unsignalised intersection.
- In an intersection with traffic lights.

16. What was the cause of the incident or near miss (caused by you or by the other party)? Mark only one oval.

- Distraction (e.g., talking on the mobile phone).
- Speeding.
- Reckless behaviour.
- Violation of traffic rules.
- Wrong way driving.
- Bad weather conditions.
- Poor visibility.
- Inadequate signalization.
- Road design defects.
- Obstruction on the road.
- Bad maintenance of the road (e.g., potholes).
- Mechanical fault.
- Other:

17. Has your perception of safety changed after the incident or near miss? Mark only one oval.

- No, it did not affect me.
- Yes, I feel afraid of other road users.
- Yes, I feel afraid and I have taken some measures (e.g., avoid some places).

Cyclists

18. As a cyclist have you ever had an incident or near miss with other road users on the Wageningen UR campus?

Mark only one oval.

- Yes. Skip to question 19.
- No. Skip to question 25.

Details of the incident or near miss

19. How do you classify the severity of the event? Mark only one oval.

- Serious incident (major injuries and property damage).
- Incident (minor injuries or property damage).
- Near miss (almost collision).

20. With whom did you have the incident or near miss? Mark only one oval.

- With a pedestrian.
- With a cyclist.
- With a motorbike or moped.
- With a car.
- With a bus.
- Other:

21. How long ago was the incident or near miss? Mark only one oval.

- Less than 6 months ago.
- 6 months to 1 year ago.
- 1 year to 3 years ago.
- 3 year to 5 years ago.
- More than 5 years ago.

22. Where did you have the incident or near miss?
Mark only one oval.

- In a straight section of the road.
- In a curve.
- In an unsignalised intersection.
- In an intersection with traffic lights.
- Other: ....

23. What was the cause of the incident or near miss (caused by you or by the other party)?
Mark only one oval.

- Distraction (e.g., talking on the mobile phone).
- Speeding.
- Reckless behaviour.
- Violation of traffic rules.
- Wrong way driving.
- Bad weather conditions.
- Poor visibility.
- Inadequate signalization.
- Road design defects.
- Obstruction on the road.
- Bad maintenance of the road (e.g., potholes).
- Mechanical fault.
- Other: ....

24. Has your perception of safety changed after the incident or near miss? Mark only one oval.

- No, it did not affect me.
- Yes, I feel afraid of other road users.
- Yes, I feel afraid and I have taken some measures (e.g., avoid some places).

Self-driving vehicles

25. How familiar are you with the concept of self-driving vehicles? Mark only one oval.

- I have never heard of it.
- I have heard a few times about it.
- I am familiar with the idea.
- I follow the development of the technology.
- I study or work in a field directly related to it.

26. Are you familiar with the WEpods? Mark only one oval.

- Yes.
- No.

27. If you answered the previous question with YES, then explain in few words what are the WEpods?

Background information

The WEpods are driverless vehicles (also called autonomous vehicles or self-driving vehicles) that drive in mixed traffic (manual vehicles, cyclists, pedestrians). The WEpods have sensors and cameras, to estimate the position and speed of relevant objects in the area nearby the WEpods. Furthermore, the WEpod knows its route and is able to navigate itself based on a combination of different systems (e.g., GPS). The vehicle has permanent human supervision from the control room.

The WEpods are already being tested on the campus of Wageningen UR. If this test phase is successful, then the route will be gradually expanded to the Ede-Wageningen railway station.

Rules of the road:

When sharing the road with pedestrians and cyclists, the WEpods will follow established rules of the road, they will participate in traffic just as drivers do today. The maximum speed of operation for the WEpods on the campus area is 15 km/h.

The WEpod - EZ-10 vehicle

28. How many times have you seen the WEpods operating in the vicinity?
    Mark only one oval.

- ⬭ I have never seen them operating. Skip to question 36.
- ⬭ I have seen them operating once or twice. Skip to question 29.
- ⬭ I have seen them operating several times. Skip to question 29.
- ⬭ I have seen them operating very frequently. Skip to question 29.

Interaction with the WEpods

29. Have you interacted with the WEpods?

Interact: come across or share space with the WEpods. Mark only one oval.

- ◯ Yes, I have mostly interacted as a cyclist. Skip to question 30.
- ◯ Yes, I have mostly interacted as a pedestrian. Skip to question 30.
- ◯ No, I have not interacted with the WEpods. Skip to question 36.

Preferences and opinions

30. Please rate on a scale from "not at all concerned" to "extremely concerned", how concerned were you about your personal safety in your interaction with the WEpods? Mark only one oval per row.

	Not at all concerned	Slightly concerned	Somewhat concerned	Very concerned	Extremely concerned
As a pedestrian, walking in their vicinity.	◯	◯	◯	◯	◯
As a cyclist, riding in their vicinity.	◯	◯	◯	◯	◯

31. Please rate on a scale from "strongly disagree" to "strongly agree", the idea of sharing space with the WEpods (max. speed of 15 km/h). Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
As a pedestrian, I feel safe when sharing space with them.	◯	◯	◯	◯	◯
As a cyclist, I feel safe when sharing space with them.	◯	◯	◯	◯	◯

Crossing behaviour

32. How do you cross the road as a PEDESTRIAN walking in the vicinity of the WEpods? Mark only one oval.

- ◯ I wait in a convenient place to cross until there is an acceptable gap between cars.
- ◯ I wait in a convenient place to cross until there is no traffic coming.
- ◯ I walk to a crossing facility (e.g., zebra) and immediately cross.
- ◯ I walk to a crossing facility (e.g., zebra) and wait for the vehicles to stop.

33. How do you cross the road as a CYCLIST riding in the vicinity of the WEpods? Mark only one oval.

- II wait in a convenient place to cross until there is an acceptable gap between cars.
- I wait in a convenient place to cross until there is no traffic coming.
- I ride to a crossing facility (e.g., bicycle traffic light) and immediately cross.
- I ride to a crossing facility (e.g., bicycle traffic light) and wait for the vehicles to stop.

Unsignalised intersections

Currently, on the campus, there are unsignalised intersections (intersections with no traffic light) as the ones shown bellow (red arrows show the WEpods' route).

Stop sign-controlled (Bornsesteeg/Droevendaalsesteeg)

Yield sign-controlled (Bornsesteeg/Akkermaalsbos-Bronland)

34. Please rate on a scale from "strongly disagree" to "strongly agree", how do you feel in your interaction with the WEpods in these types of intersections? Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
As a pedestrian, I feel safe on these intersections with them.	⬭	⬭	⬭	⬭	⬭
As a cyclist, I feel safe on these intersections with them.	⬭	⬭	⬭	⬭	⬭

Driving style

35. How do you describe the driving style of the WEpods? Mark only one oval per row.

	Very passive	Passive	Neither passive nor aggressive	Aggressive	Very aggresive
I consider the WEpods to be	⬭	⬭	⬭	⬭	⬭

Skip to question 41.

Preferences and opinions

36. Please rate on a scale from "not at all concerned" to "extremely concerned", how concerned would you be about your personal safety in your interaction with the WEpods? Mark only one oval per row.

	Not at all concerned	Slightly concerned	Somewhat concerned	Very concerned	Extremely concerned
As a pedestrian, walking in their vicinity.	⬭	⬭	⬭	⬭	⬭
As a cyclist, riding in their vicinity.	⬭	⬭	⬭	⬭	⬭

37. Please rate on a scale from "strongly disagree" to "strongly agree", the idea of sharing space with the WEpods (max. speed of 15 km/h). Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
As a pedestrian, I would feel safe when sharing space with them.	⬭	⬭	⬭	⬭	⬭
As a cyclist, I would feel safe when sharing space with them.	⬭	⬭	⬭	⬭	⬭

Crossing behaviour

---

38. How would you cross the road as a PEDESTRIAN walking in the vicinity of the WEpods? Mark only one oval.

⬭ I would wait in a convenient place to cross until there is an acceptable gap between cars.
⬭ I would wait in a convenient place to cross until there is no traffic coming.
⬭ I would walk to a crossing facility (e.g., zebra) and immediately cross.
⬭ I would walk to a crossing facility (e.g., zebra), and wait for the vehicles to stop.

39. How would you cross the road as a CYCLIST riding in the vicinity of the WEpods? Mark only one oval.

⬭ II would wait in a convenient place to cross until there is an acceptable gap between cars.
⬭ I would wait in a convenient place to cross until there is no traffic coming.
⬭ I would ride to a crossing facility (e.g., bicycle traffic light) and immediately cross.
⬭ I would ride to a crossing facility (e.g., bicycle traffic light) and wait for the vehicles to stop.

Unsignalised intersections

Currently, on the campus, there are unsignalised intersections (intersections with no traffic light) as the ones shown below (red arrows show the WEpods´ route).

Stop sign-controlled (Bornsesteeg/Droevendaalsesteeg)

Yield sign-controlled (Bornsesteeg/Akkermaalsbos-Bronland)

40. Please rate on a scale from "strongly disagree" to "strongly agree", how would you feel in your interaction with the WEpods in these types of intersections? Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
As a pedestrian, I would feel safe on these intersections with them.	◯	◯	◯	◯	◯
As a cyclist, I would feel safe on these intersections with them.	◯	◯	◯	◯	◯

What do you know about the WEpods?

41. Do the WEpods have a steward?

Steward: A person that is employed to oversee the operations of self-driving vehicles. If needed the steward can intervene in its operation. Mark only one oval.

- ◯ Yes, it has a steward.
- ◯ No, it does not have a steward.
- ◯ I do not know.

42. Do you expect the WEpods to stop in all possible instances, even though when other traffic participants violate traffic rules? Mark only one oval.

- ◯ Yes, I expect it to stop in all possible instances.
- ◯ No, I do not expect it to stop.

43. How would you like to receive these indications from the WEpods? Mark only one oval per row.

	Auditory (words)	Auditory (tones/signals)	Visual (lights)	Visual (words)	Auditory (tones/signals) and visual (lights)	None
If it is stopping	◯	◯	◯	◯	◯	◯
If it is going to start moving	◯	◯	◯	◯	◯	◯
If it is turning	◯	◯	◯	◯	◯	◯
If it has detected me	◯	◯	◯	◯	◯	◯
How fast it is riding	◯	◯	◯	◯	◯	◯

Personal information

44. Which year were you born? *
45. What is your gender? * Mark only one oval.

- ◯ Female.
- ◯ Male.

46. What is your nationality? *

....

47. What is your current occupation? * Mark only one oval.

- Bachelor´s degree or Master´s degree student.
- PhD or higher degree.
- Working in full time/part time job.
- Currently unemployed.

APPENDIX E – FACE-TO-FACE-INTERVIEWS

INFORMED CONSENT FORM

Delft University of Technology - Stevinweg 1, 2628 CN Delft - 015 278 9802
Faculty of Civil Engineering and Geosciences CiTG
Transport and Planning T&P

Title of study: Perceived safety of pedestrians and cyclists in urban environments.

Purpose: The purpose of this study is to understand the opinions of **pedestrians** and **cyclists** towards road safety in urban environments. This study will include an interview with questions about your acceptance, awareness and perception of the safety of urban environments. The entire interview should take about **10 to 13 minutes** to complete.

Please note that you must be above 18 years old to participate in this voluntary interview. If you wish to decline or withdraw at any time, you may do so without any consequences. If you agree to participate in this study, you are not likely to experience any risk or unique discomfort from answering these questions. You will not receive any payment or get any personal benefit or reward from this research. You must complete this informed consent form before participating in this interview.

Once the interviews are completed, the researcher will analyse the data for statistical summaries only. The data will be used only for the purpose of this study. Data will be printed and stored securely without any names associated. Therefore, no names need to be written on the interview form. This is in order to ensure anonymity (privacy/confidentiality).

As the main investigator in this study, I will be pleased to answer any questions that you may have concerning the study. If you have any questions during, between, or after your participation in the interview, please send an email to: P.K.RodriguezCabezas@student.tudelft.nl. Please do not discuss the content of the interview with other people, as they might also be invited to participate in this study.

The results of this study are expected to contribute to the scientific knowledge regarding the safety of pedestrians and cyclists.

Confidentiality: Any information that you provide will be kept strictly private, confidential, and anonymous. Your name will not be attached to your answers in any way. Results from this study will be presented as statistical summaries, but no information will be presented to individual participants/respondents.

I have read and understood the above information. I have been invited by the interviewer and was informed about the general nature of this study. I declare that I am above 18 years old, and give my consent to voluntarily participate in this study.

If you agree, please sign this informed consent:

____

Name: __________________________________
Date: ___________________________________

____
Paola K. Rodriguez
Principal Investigator
Thesis Research Study
P.K.RodriguezCabezas@student.tudelft.nl
+31 6 18800478

Face-to-face interviews for pedestrians and cyclists

1. Do you walk or cycle more on the Wageningen University campus?

☐ Walk. ☐ Bicycle.

2. If you answered *question 1* with "Bicycle": How long have you been riding a bike?

____

3. Are you concerned about your personal safety when you are **sharing space**[4] with **vehicles** (max. speed of 30 km/h)? If so, why?

____

____

Currently, on the campus, there are unsignalised intersections (intersections with no traffic light), where vehicles have to give priority to bicyclists and pedestrians as the ones shown **Fig. 1and 2**.

4. Are you concerned about your personal safety in your interaction with **vehicles** in unsignalised intersections? If so, why?

____

____

5. If you answered *question 1* with "Walk": As a **pedestrian** in urban areas in general, what is the way you usually cross the road with slow traffic and few vehicles (e.g., wait at the most convenient place or walk to crossing facility)?

____

____

6. If you answered *question 1* with "Bicycle": As a **cyclist** in urban areas in general, what is the way you usually cross the road with slow traffic and few vehicles (e.g., wait at the most convenient place or walk to crossing facility)?

____

____

7. In your interaction as a **cyclist** or **pedestrian** with a vehicle´s driver, how often do you base your actions (e.g., stop or keep going) on eye contact or signals given by the driver?

____

____

8. How familiar are you with the concept of self-driving vehicles?

____

____

Show information of the WEpods

---

[4]**Shared space:** Street or area where pedestrians, cyclists and vehicles mix and share the space together.

9. How many times have you seen before **the WEpods** operating in the vicinity?

____

____

10. What mode of transportation were you using when you interacted with **the WEpods**?

☐ Walk. ☐ Bicycle.

11. Are you concerned about your personal safety when you are **sharing space**[5] with **the WEpods** (max. speed of 15 km/h)? If so, why?

____

____

12. Who do you think has the priority at unsignalised intersections, bicyclists and pedestrians or the WEpods?

____

____

Currently, on the campus, there are unsignalised intersections, where the WEpods have to give priority to bicyclists and pedestrians as the ones shown in **Fig. 3** and **4** (red arrows show **the WEpods'** route).

13. Have you interacted with the WEpods in these intersections?

☐ Yes. ☐ No.

14. If you answered *question 12* with "Yes": Were you concerned about your personal safety in your interaction with **the WEpods** in these intersections? If so, why?

____

____

15. Have you crossed the road in the presence of **the WEpods**?

☐ Yes. ☐ No.

16. If you answered *question 14* with "Yes": How did you cross the road as a **pedestrian** walking in the vicinity of **the WEpods**?

____

____

17. If you answered question 14 with "Yes": How did you cross the road as a **cyclist** riding in the vicinity of **the WEpods**?

____

____

[5]**Shared space:** Street or area where pedestrians, cyclists and vehicles mix and share the space together.

18. Do you expect **the WEpods** to stop in all possible instances, even though when other traffic participants violate traffic rules?

____

____

19. How do you describe the driving style of **the WEpods** (e.g., passive or aggressive)?

____

____

20. Is the driving direction of **the WEpods** clear? If not why not?

____

21. Do you feel safe with the features of **the WEpods** (e.g., visibility, lack of noise and speed)?

____

____

22. Would you change any current feature on **the WEpods** (e.g., colour, noise and speed)?

____

____

23. Do you know if **the WEpods** have a steward[6]?

____

24. How important is it for you to be notified about **the WEpods** operations (e.g., stopping, start moving, turning, if it has detected me and speed)?

____

____

25. How would you like to receive these indications from **the WEpods** (e.g., auditory- words, signals visual – words, lights)?

____

____

Personal Information

26. Which year were you born? ________________.
27. What is your gender? ☐ Female. ☐ Male.
28. What is your nationality? ___________________.
29. What is your current occupation? ____.

[6] **Steward:** A person that is employed to oversee the operations of self-driving vehicles. If needed the steward can intervene in its operation.

Unsignalised Intersections

Fig. 1 Bornsesteeg/Droevendaalsesteeg

Fig. 2 Bornsesteeg/Akkermaalsbos-Bronland

Fig. 3 Bornsesteeg/Droevendaalsesteeg

Fig. 4 Bornsesteeg/Akkermaalsbos-Bronland

Background information:

The WEpods are driverless vehicles (also called autonomous vehicles or self-driving vehicles) that drive in mixed traffic (manual vehicles, cyclists and pedestrians) without an onboard driver. The WEpods have sensors and cameras, to estimate the position and speed of relevant objects in the area nearby the WEpods. Furthermore, the WEpod knows its route and is able to navigate itself based on a combination of different systems (e.g., GPS). The vehicle has permanent human supervision from the control room.

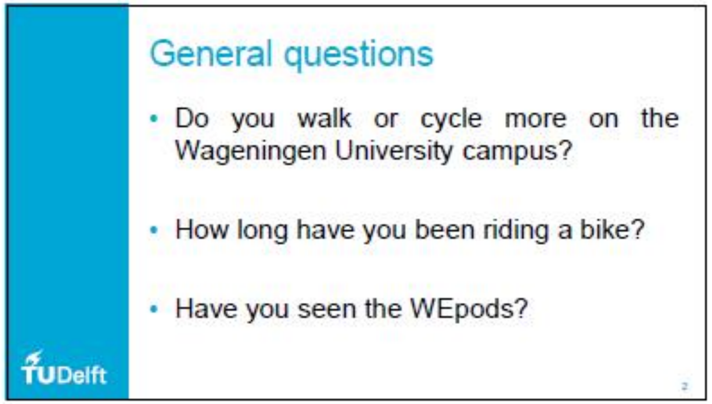
The WEpods are already being tested on the campus of Wageningen UR. If this test phase is successful, then the route will be gradually expanded to the Ede-Wageningen railway station.

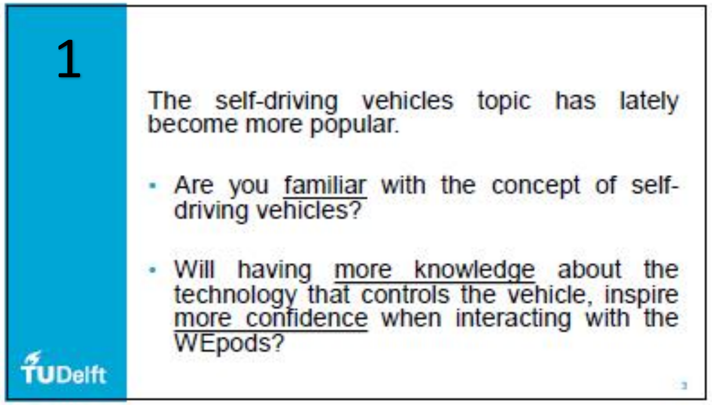
Fig. 3 The WEpod - EZ-10 vehicle.

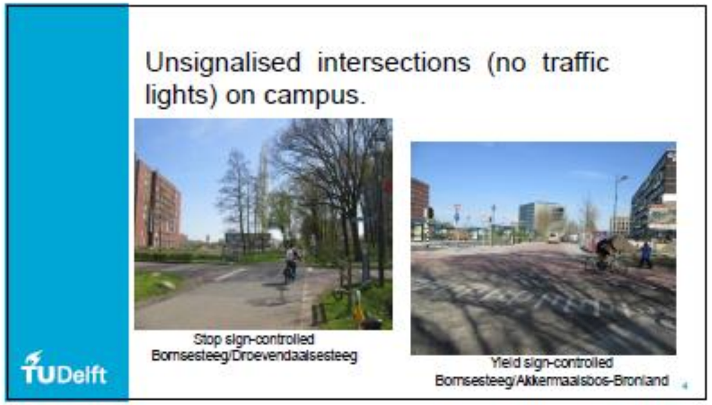
Rules of the road:

When sharing the road with pedestrians and cyclists, the WEpods will follow established rules of the road, they will participate in traffic just as drivers do today. The maximum speed of operation for the WEpods on the campus area is **15 km/h**.

APPENDIX F – FOCUS GROUP







2

What traffic rules should apply to the WEpods in these intersections?

Bornsesteeg/Droevendaalsesteeg

Bornsesteeg/Akkermaalsbos-Bronland

3

Behaviour with few and slow (30 km/h) traditional vehicles on campus.

- Are you concerned about your personal safety when you are sharing space with vehicles on campus? If so, why?
- Are you concerned about your personal safety in your interaction with vehicles in unsignalised intersections (no traffic lights)? If so, why?
- What is the way you usually cross the road on campus?

4

New technology may influence change in people´s behaviour.

- Would you change your behaviour when sharing space with the WEpods as with traditional vehicles?
- Would you change your behaviour in unsignalised intersection (not traffic lights) with the self-driving vehicles?
- Would you change your crossing road behaviour in the presence of the self-driving vehicles?

5

Some people base their actions (e.g., stop or keep going) on eye contact and gestures with a driver. With self-driving vehicles such as the WEpods this interaction will be absent.

- Will this affect the perception of safety of you as a vulnerable road user? Why?

6

- Do you know if the WEpods have a steward (a person that is employed to oversee the operations of self-driving vehicles and can intervene in its operation)?

9

6

For safety reasons and current laws, a steward is always present inside the WEpods.

- Would your perception of safety be affected towards these vehicles by knowing that the WEpods have a steward? Why?

10

7

- Is the driving direction of the WEpods clear? If not, why not?
- Do you expect the WEpods to stop in all possible instances, even though when other traffic participants violate traffic rules?
- Do you feel safe with the features of the WEpods (e.g., visibility, lack of noise and speed)?

11

8

Traditional vehicles give indications to other road users through lights and honks.

- Would this be equally important for your perception of safety towards the WEpods?
- Would you feel safer if you receive additional information from the manoeuvres of the WEpods?

12

APPENDIX G - STATISTICAL TESTS

Table 13 Description and assumptions of the statistical tests [139] [141]

Statistical test	Description	Assumptions
Mann-Whitney U test	The non-parametric equivalent of the independent t-test. It ranks each score of the dependent variable according to its size, irrespective of the group it is in. The ranks for each independent group are averaged. If one group tends to have higher values than the other group, this will have a higher mean rank (and vice versa for lower scores).	1. One dependent variable that is measured at continuous or ordinal level.
		2. One independent variable that consists of two categorical, independent groups.
		3. Independence of observations: there is no relationship between the observations in each group of the independent variable or between the groups themselves.
		4. Determine whether the distribution of scores for both groups of the independent variable have the same shape (test determines whether there are differences in the "medians" of the 2 groups) or a different shape (test determines whether there are differences in the distribution of the 2 groups).
Kruskal-Wallis	The non-parametrical alternative to the one-way ANOVA. Like the Mann– Whitney U test, this is based on ranked data (scores from lowest to highest), ignoring the group to which the score belongs, the lowest score is ranked 1, the next value is ranked 2 and so on. Then the scores are put back and add up into their groups giving the ranks for each group.	1. The dependent variable should be measured at continuous or ordinal level.
		2. The independent variable should consist of two or more categorical, independent groups.
		3. Independence of observations: there is no relationship between the observations in each group of the independent variable or between the groups themselves.
		4. Determine whether the distribution of the groups of the independent variable have the same shape (test compare the medians of the dependent variable) or a different shape (test can only be used to compare mean ranks).
Chi-square test	To investigate whether there is a relationship between two categorical variables. It does this by comparing the observed frequencies in the cells to the frequencies that would be expected if there was no association between the two nominal variables.	1. The two variables should be measured at an ordinal or nominal level.
		2. Independence of observations: the two variables should consist of two or more categorical, independent groups.
		3. No more than 20% of the cells in expected counts are less than five.
Wilcoxon signed ranks test	The non-parametric test equivalent to the dependent t-test. It is used in conditions in which there are two sets of scores to compare, but these scores are from the same participants.	1. The dependent variable should be measured at the ordinal or continuous level.
		2. The independent variable should consist of two categorical, "related groups" or "matched pairs".
		3. The distribution of the differences between the two related groups needs to be symmetrical in shape.
Marginal homogeneity test	It is a score-type test and is an extension of McNemar's test to the situation where responses are allowed more	1. One categorical dependent variable with more than two categories and one categorical independent variable with more than two related groups.

	than two response categories. It is used to assess marginal homogeneity in independent matched-pair data.	2. The two groups of your dependent variable must be mutually exclusive (a participant can only be in one group).
		3. The participants are a random sample from the population of interest.
Jonckheere-Terpstra test	It is a rank-based nonparametric test (similar to Kruskal-Wallis H test) that can determine if there is a statistically significant trend between an ordinal independent variable and a continuous or ordinal dependent variable.	1. Dependent variable should be measured at the ordinal or continuous level.
		2. The independent variable should have two or more ordinal, independent groups.
		3. Independence of observations.
		4. Determine whether the distribution of scores for both groups of the independent variable have the same shape (test determines whether there are differences in the medians of the 2 groups) or a different shape.
		5. Predict, a priori, the order of the groups of the independent variable.
		6. Predict, "a priori", the direction of the alternative hypothesis.
Log-linear Analysis	It is similar to chi-square tests, however, assume multiplicative relationships between three or more nominal and ordinal variables. It aims to find the simplest model that fits the data without being fully saturated.	1. Two or more categorical variables (can be either a nominal variable or an ordinal variable).
		2. The residuals are approximately normally distributed.
		3. All the expected counts should be greater than one, and 80% of the cells should be greater than five and no outliers.

Table 14 Type of variables and statistical tests for the data analysis in SPSS

H_0		Dependent variables		Independent variables	Statistical test
H_0^a There is no statistically significant difference in the perceived safety of VRUs *sharing the road* in general with traditional motor vehicles compared to sharing the road with the WEpods. ***(Null hypothesis rejected)***	**Ordinal Variable**	• Perceived safety sharing the road.	**1 IV with 2 levels (dependent/matched groups).**	Perceived safety sharing the road (traditional motor vehicles/the WEpods).	Wilcoxon signed-ranks test.
H_0^b There is no statistically significant difference in the perceived safety of VRUs interacting with traditional vehicles compared to interacting with the WEpods at *unsignalised intersections*. ***(Null hypothesis rejected)***	**Ordinal Variable**	• Perceived safety at unsignalised intersections.	**1 IV with 2 levels (dependent/matched groups).**	Perceived safety at unsignalised intersections (traditional motor vehicles/the WEpods).	Wilcoxon signed-ranks test.
H_0^c There is no statistically significant difference in the VRUs *crossing behaviour* in interacting with traditional motor vehicles compared to interacting with the WEpods. ***(Null hypothesis rejected)***	**Categorical variable**	• Crossing behaviour.	**1 IV with 2 levels (dependent/matched groups).**	Crossing behaviour (traditional motor vehicles/the WEpods).	Marginal homogeneity test.

H_0^d There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that base their actions on _eye contact or signals_ received from human drivers compared to those who do not use these cues. ***(Null hypothesis rejected)***	**Ordinal Variables**	• The level of concern interacting with the WEpods. • Perceived safety sharing the road with the WEpods. • Perceived safety at unsignalised intersections with the WEpods.	**1 IV with 2 levels (independent groups).**	Perceived safety (always/mostly Vs. rarely/never interact with human drivers).	Mann-Whitney test.
	Categorical variable	• Crossing behaviour with the WEpods.	**1 IV with 2 levels (independent groups).**	Crossing behaviour with the WEpods (always/mostly Vs. rarely/never interact with human drivers).	Chi-square test of association (2 x 2).
H_0^e There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who _have already interacted_ with the WEpods, compared to those who have not interacted with the automated vehicles. ***(Null hypothesis rejected)***	**Ordinal Variables**	• The level of concern interacting with the WEpods. • Perceived safety sharing the road with the WEpods. • Perceived safety at unsignalised intersections with the WEpods.	**1 IV with 2 levels (independent groups).**	Perceived safety (stated preference Vs. revealed preference).	Mann-Whitney test.
	Categorical variable	• Crossing behaviour with the WEpods.	**1 IV with 2 levels (independent groups).**	Crossing behaviour with the WEpods (stated preference Vs. revealed preference).	Chi-square test of independence (R x N).

H_0^f There is no statistically significant difference in the perceived safety and crossing behaviour of VRUs who have <u>*knowledge of the WEpods and its automated technology*</u>, compared to those who do not have this knowledge. ***(Null hypothesis rejected)***	**Ordinal Variables**	• The level of concern interacting with the WEpods. • Perceived safety sharing the road with the WEpods. • Perceived safety at unsignalised intersections with the WEpods.	**1 IV with 2 or more levels (independent groups).**	General knowledge of the automated technology (from “never heard of it” to “I follow the development of the technology”).	Kruskal-Wallis H test / Jonckheere-Terpstra test.
			1 IV with 2 levels (independent groups).	General knowledge of the WEpods (yes/no).	Mann- Whitney test.
				Sighting the WEpods (never/at least once).	Mann- Whitney test.
	Categorical variable	• Crossing behaviour with the WEpods.	**1 IV with 2 or more levels (independent groups).**	General knowledge of the automated technology (“never heard” to “study field related”).	Chi-square test of independence (R x N).
			1 IV with 2 levels (independent groups).	General knowledge of the WEpods (yes/no).	Chi-square test of independence (R x N).
				Sighting the WEpods (never/at least once).	Chi-square test of independence (R x N).

H_0^g There is no statistically significant difference in the perceived safety and crossing behaviour of the VRUs that consider that the *vehicles will always stop* and that it has a *steward* compared to the VRUs that do not know this information. ***(Null hypothesis rejected)***	**Ordinal Variables**	• The level of concern interacting with the WEpods. • Perceived safety sharing the road with the WEpods. • Perceived safety at unsignalised intersections with the WEpods.	**1 IV with 2 levels (independent groups).**	Expected to stop (yes/no).	Mann- Whitney test.
			1 IV with 2 or more levels (independent groups).	Knowledge of steward (yes/no/I don't know).	Kruskal-Wallis H test / Jonckheere-Terpstra test.
				Driving style (very passive to very aggressive).	Kruskal-Wallis H test.
	Categorical variable	• Crossing behaviour with the WEpods.	**1 IV with 2 levels (independent groups).**	Expected to stop (yes/no).	Chi-square test of association (2 x 2).
			1 IV with 2 or more levels (independent groups).	Knowledge of steward (yes/no/I don't know).	Chi-square test of independence (R x N).
				Driving style (very passive to very aggressive).	Chi-square test of independence (R x N).
H_0^h There is no statistically significant difference in the perceived safety and crossing behaviour within different *VRUs´ demographic groups* (age, gender, occupation, nationality and cycling experience). ***(Null hypothesis rejected)***	**Ordinal Variables**	• The level of concern interacting with the WEpods. • Perceived safety sharing the road with the WEpods. • Perceived safety at unsignalised intersections with the WEpods.	**1 IV with 2 levels (independent groups).**	Gender (Female/Male).	Mann- Whitney test.
				Nationality (Dutch/non-Dutch).	Mann- Whitney test.
			1 IV with 2 or more levels (independent groups).	Age group (adolescence/early adulthood/mature adulthood).	Kruskal-Wallis H test.
				Cycling experience (beginner/novice, intermediate/advanced/expert).	Kruskal-Wallis H test / Jonckheere-Terpstra test.
				Occupation (Student/PhD/ working / unemployed).	Kruskal-Wallis H test.

	Categorical variable	• Crossing behaviour with the WEpods.	**1 IV with 2 levels (independent groups).**	Gender (Female/Male).	Chi-square test of independence (R x N).
				Nationality (Dutch/non-Dutch).	Chi-square test of independence (R x N).
			1 IV with 2 or more levels (independent groups).	Age group (adolescence/early adulthood/mature adulthood).	Chi-square test of independence (R x N).
				Cycling experience (beginner/novice/ intermediate/advanced/expert).	Chi-square test of independence (R x N).
				Occupation (Student/PhD/working/ unemployed).	Chi-square test of independence (R x N).

Association between the variables of knowledge of the WEpods

An unsaturated model was chosen using SPSS Statistics' hierarchical log-linear model selection procedure with a backwards elimination stepwise procedure. This produced a model that included all the three main effects and two two-way associations, "familiar with the WEpods" * "Awareness of the automated technology" and "familiar with the WEpods" * "Sighting the WEpods". The model had a likelihood ratio of $\chi^2(2) = 1.45, p = 0.485$ ($p > 0.05$ indicates that the model was a good fit to the observed data). Partial likelihood ratio χ^2 are presented in Table 15 and log linear parameter estimates in Table 16.

Table 15 Partial association of the variables

Effect	Partial Chi-Square	Sig.
Awareness the WEpods*Have seen the WEpods?	37.351	0.00
Awareness the WEpods*Awareness automated technology	36.372	0.00
Have seen the WEpods? *Awareness automated technology	0.318	0.573
Awareness the WEpods	6.650	0.010
Have seen the WEpods?	27.078	0.00
Awareness automated technology	18.666	0.00

Table 16 Parameter estimates for the hypercritical Model (Awareness the WEpods Awareness automated technology) and (Have seen the WEpods? *Awareness the WEpods)*

Parameter	Estimate	Z	Sig.
Constant	4,199		
Have seen the WEpods? = No	-2,512	-5,919	0,000
Awareness the WEpods = No	-0,833	-4,122	0,000
Awareness automated technology = Never/few times have heard of it	-2,197	-5,896	0,000
Awareness the WEpods= No * Awareness automated technology= Never/few times have heard of it	2,266	5,442	0,000
Have seen the WEpods? = No *Awareness the WEpods = No	2,443	5,273	0,000