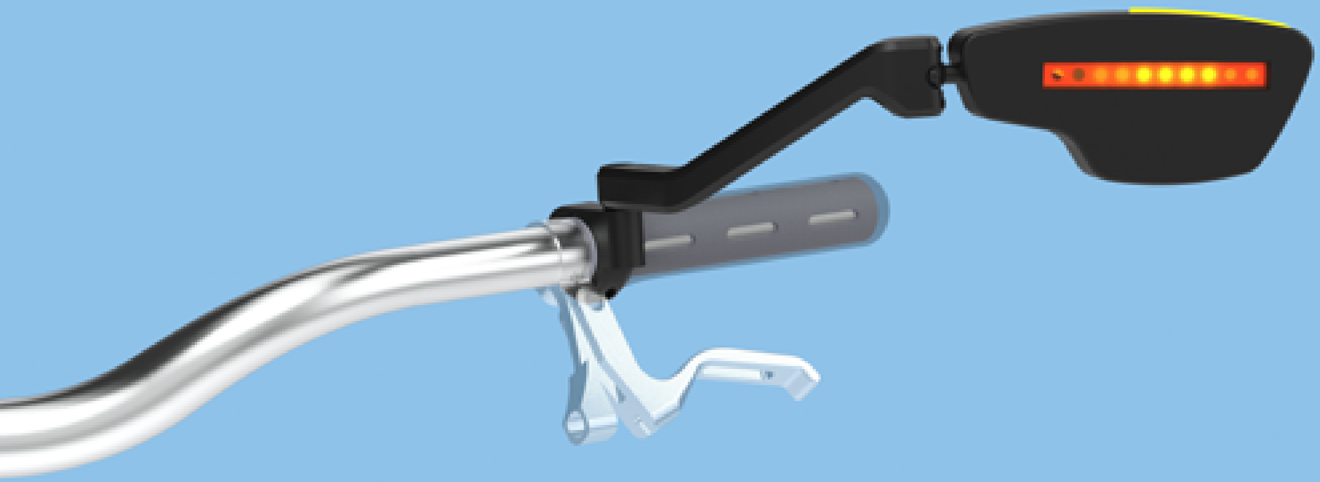
Showing Direction for BBB Cycling

A Collaboration Strategy
and Modular Lockring Accessory
to Enhance Cycling Safety

Teun van Ekeren



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Strategic Product Design
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Master Thesis

Master Strategic Product Design

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Showing Direction for BBB Cycling
A Collaboration Strategy and Modular Lockring Accessory to Enhance Cycling Safety

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BBB Cycling

PREFACE

Here it is, my thesis, marking the end of nearly seven years as a student and the beginning of my professional career. This journey has shaped me both as an industrial designer and as an individual, filled with valuable experiences, inspiring people, and opportunities for growth.

From a young age, I have been fascinated by social themes, sports, and creativity. Discussions at home at the dinner table often revolved around societal issues, science and sports, sparking my curiosity and critical thinking. At the same time, I enjoyed creating and designing, while sports remained a central part of my life, both as a participant and as a fan. This combination of interests naturally led me to pursue Industrial Design Engineering after finishing secondary school. My broad curiosity eventually motivated me to take on the challenge of a double master's degree.

Throughout my studies, I found ways to integrate my passion for sports and exercise. Also, for my graduation project this was the case, and it led me to a collaborative project with BBB Cycling, where I explored cycling safety from the perspective of the cycling industry, bringing together my interests in social impact, creativity, and sports and exercise in a meaningful way.

Over the past eight months, this project has been an amazing learning experience. I discovered a big enthusiasm for the strategic aspects of design, connecting people, gathering insights, and translating them into a strategy. I also realized how cycling safety is deeply interconnected with politics, psychology, mobility infrastructure, industry stakeholders, and many more. Creating real impact in this field is not something an individual can achieve alone; it requires collaboration across multiple domains.

Bridging these disciplines and bringing people together to develop meaningful solutions is what excites me the most. My studies have given me the ability to approach complex challenges from a holistic perspective, while constantly keeping the user in mind, and I look forward to applying this mindset in my future career.

April, 2025

ACKNOWLEDGMENTS

My studies and this project would not have been possible without the help of others. There are a few people I would like to highlight and thank for their support.

Mama en Papa, thank you for all your support throughout my studies. I could always come to you with any questions, and you always made time to help me. I've greatly appreciated your encouragement to pursue what I wanted to do, both academically and beyond, your enthusiastic "Go for it!" or "Just do it!" always meant a lot. Your listening ear during this project was also invaluable, always ready to hear me out and think along about next steps or how to interpret my observations.

My brother **Sep**, we've always been in school at the same time and could bounce ideas off each other about what we did and didn't like. After you set the tone with your thesis last year, I was lucky to be able to turn to you for help, thank you!

Oma en Opa, from my very first project, designing a product to help opa put on his socks more easily, all the way to this final project, you were always involved and knew exactly what I was working on. I have appreciated it so much and I'll truly miss it.

To my **friends and fellow students,** thank you for the wonderful time we shared during our studies! From all the laughs during lectures and group projects to the fun we had outside of university life, I won't forget any of it.

Arjen and Sander, thank you for your guidance and feedback throughout this project. Every time I came by, you took time out of your busy schedules to help me move forward, which I really appreciated.

Tjerk, thank you for the opportunity to carry out my project in collaboration with BBB. Your involvement and willingness to come to the faculty for nearly every meeting, along with our weekly Monday afternoon chats, were incredibly helpful. I really valued your support for the choices I made during the project.

Finally, to **everyone at BBB Cycling,** thank you for the fun and welcoming atmosphere during my time there. From day one, I enjoyed coming into the office and felt like I belonged. During the first round of introductions, I was immediately invited to join a social ride, and thankfully, several more followed. It was genuinely a pleasure getting to know everyone. You all took the time to tell me about BBB, about yourselves, and of course about cycling, always with lots of laughs. Thank you!

EXECUTIVE SUMMARY

This thesis explores how BBB Cycling can contribute to improving cycling safety through strategic collaboration and product innovation. The research first examined the key safety challenges in the current mobility landscape, where the rise of e-bikes, ageing users, and increasingly diverse traffic conditions demand new solutions. Additionally, an internal analysis of BBB Cycling was conducted. Stakeholder insights revealed that product innovation alone is insufficient and collaboration across brands is essential to increase adoption and achieve meaningful safety impact.

As a response, a strategic roadmap was developed to guide BBB Cycling towards deeper and more effective cooperation within the Pon.Bike ecosystem. The roadmap outlines phased steps, from informal alignment to structural integration, enabling shared development efforts without compromising brand autonomy. Internal interviews also highlighted cultural and organisational conditions that must be addressed for such collaboration to succeed.

To translate strategy into practice, a modular product concept was developed: a redesigned lockring that supports integrated safety features such as a mirror with turn signal. Its strength lies in subtle, scalable integration, focussing on increasing the adoption of safety components. Partners could adopt a compatible handlebar design and install it as an OEM component, allowing the lockring from this project to be offered as an aftermarket upgrade, offered by BBB Cycling. Should safety features gain USP value, the platform enables direct OEM adoption as well.

The lockring concept was validated through prototyping, user testing, and expert interviews. Feedback confirmed technical feasibility, user acceptance, and possible market potential. Internal validation also explored how organisational culture and structure influence the feasibility of implementing platform-oriented innovation.

In conclusion, this project demonstrates that improving cycling safety is a collaborative effort, not a challenge BBB Cycling, or any single actor, can address alone. To support a step in this direction, the project illustrates how strategic collaboration and platform-oriented design can provide a pathway toward shared innovation in this field.

TABLE OF CONTENTS

1. Project Outline **9**
1.1 Project Partners 10
1.2 Problem Definition 10
1.3 Assignment 11
1.4 Project approach 12
1.5 Structure 13

2. Cycling Safety Developments **15**
2.1 Current Situation 16
2.2 Measuring Safety 28
2.3 Expectations 31
2.4 Conclusion 35

3. BBB Cycling and Possible Internal Opportunities **37**
3.1 Company Analysis 38
3.2 Potential Other Ways to Design 51
3.3 Implementation 52
3.4 Conclusion 54

4. Finding a Search Area **57**
4.1 Adoption 58
4.2 Deep Dive Into Adoption 59

5. Collaboration and Synergy Advantages **65**
5.1 Possibilities within Pon.Bike Network 66
5.2 Potential Benefits 67
5.3 Implementing Collaboration Effectively 68
5.4 Conclusion 69

6. Roadmap **71**
6.1 Future vision 72
6.2 Phase 1: Exploration and Thrust 73
6.3 Phase 2: Structural Collaboration 74
6.4 Phase 3: Co-Creation as the Norm 75
6.5 Conclusion and Specific Benefits for BBB Cycling 76

7. Ideation and Design Brief **83**
7.1 Possible Directions 85
7.2 Controlling Turn Signal on Grip 88
7.3 Design Brief: Adjustment Initial Idea 89
7.4 Conclusion 91

8. Product Development **93**
8.1 Grips, Lockring Mechanisms, and Shifters 94
8.2 Requirements and Wishes 96
8.3 Designing and Prototyping 97
8.4 Arduino Programming 104
8.5 Materialization and Sustainability 106
8.6 Mounting on a Bike 107
8.7 Modularity of System 108
8.8 Conclusion 108

9. Validation **113**
9.1 User Tests 114
9.2 Expert Validation 119
9.3 Conclusion 121

10. Strategy reflection **123**
10.1 Strategic Positioning of the Product 124
10.2 Internal Culture & Structure for Successful External Collaboration 125
10.3 Conclusion and Recommendations 127

11. Discussion and Recommendations **131**
11.1 Strategy 132
11.2 Product design 133
11.3 Delft Innovation Method 136

12. Conclusion **139**

References **145**

Appendix **153**
Appendix A Project Brief 154
Appendix B HREC 156
Appendix C Search Areas 174
Appendix D Extended COM-B Analysis 176
Appendix E How Grips Are Made 179
Appendix F Arduino Code 180
Appendix G Real Test on Bike Details 184

1. PROJECT OUTLINE

This chapter provides an overview of the project, outlining its context, objectives, and approach. It introduces the partners involved: BBB Cycling and Delft University of Technology. The assignment and problem definition are discussed, explaining the relevance of cycling safety and the challenges BBB Cycling aims to address. Furthermore, the methodology followed throughout the project is described, including the research and design approach. Finally, the structure of the report is outlined, explaining how the different chapters contribute to the overall project.

1.1 PROJECT PARTNERS

This graduation project was carried out in collaboration with BBB Cycling, a Dutch brand well-established in the European bicycle accessories market. BBB Cycling has a portfolio of around 1500 products, including accessories, apparel and tools. The company facilitated the project by providing a workplace at its office, access to necessary knowledge, equipment, and materials, as well as guidance from a company mentor. This ensured that the project was conducted in a professional and industry-relevant environment.

The project is conducted as part of the Strategic Product Design (SPD) and Integrated Product Design (IPD) master's programs at Delft University of Technology.

1.2 PROBLEM DEFINITION

In recent years, the number of cycling incidents, both fatalities and severe injuries, has been rising, a trend that is frequently covered in the news (see Figure 1). While cycling is increasingly promoted as a sustainable and healthy mode of transportation, the rise in accidents highlights the urgent need for improved safety measures. This urgency is further reinforced by developments such as e-bike adoption, urbanization, and increased interaction between cyclists and motorized traffic.

Figure 1. A quick search at news websites around Europe shows the coverage of various cycling incidents

As a key player in the European bicycle accessories market, BBB Cycling recognizes the growing importance of cycling safety. The company sees both an opportunity and a responsibility to develop solutions that contribute to safer cycling experiences. While BBB's historical focus has been on the sports cycling market (road cycling and mountain biking), there is an increased interest in the rapidly expanding comfort cycling segment, driven by urban mobility trends and demographic shifts.

Shifting towards this segment requires a strategic approach to determine how BBB Cycling can effectively position itself in the cycling safety area. The company needs to find out which new products or improvements align with emerging safety needs while remaining true to its current brand and market position. To avoid merely reacting to market changes, BBB seeks to proactively explore future developments in cycling safety and translate these

insights into both strategic direction and product opportunities.

This leads to two main research questions, each focussing on a different master direction:

Main question 1 (SPD):

What is the role of a brand like BBB Cycling within ecosystems addressing cycling-related societal challenges, and how does it position itself in relation to other actors?

Main question 2 (IPD):

How can product design within the cycling industry contribute to improving cycling safety, considering evolving risks and user needs?

These overarching questions are supported by four sub-questions:

Sub-1: What are the main factors influencing cycling safety in the Netherlands and Europe today, and how has the rise of electric bikes impacted overall risk levels?

Sub-2: How is cycling safety expected to change in the coming years based on trends in mobility, infrastructure, and technology?

Sub-3: To what extent will technology be integrated into cycling accessories to enhance safety, and what are the key design considerations for implementation?

Sub-4: How can product testing and validation methods ensure the effectiveness and usability of cycling safety innovations?

1.3 ASSIGNMENT

With the growing urgency of cycling safety and BBB Cycling's recognition of its relevance, this graduation project aims to explore how the company can strategically and product-technically respond to these developments. As this is a double-degree graduation project, it integrates both Strategic Product Design (SPD) and Integrated Product Design (IPD) perspectives.

The project consists of two main components:

1. Strategic Design: understanding the future of cycling safety and identifying strategic opportunities for BBB Cycling in this evolving market.
2. Product Design: translating strategic insights into a tangible product concept, ensuring that BBB Cycling's offerings align with emerging safety needs in the comfort cycling segment.

At the start of the project, both sports cycling safety and comfort cycling safety were considered as potential focus areas. However, early exploration quickly revealed that the comfort cycling segment was the most valuable to investigate, as it is an area where BBB Cycling has limited presence. Focusing on this segment provided the greatest opportunity to gain new insights and explore how BBB could expand its relevance in this growing market.

Comfort cycling includes urban commuters, leisure cyclists, and e-bike users, all of whom have different safety concerns compared to road cyclists and mountain bikers. By examining user needs, technological developments, and market trends, this project aims to define a strategy and an innovative product direction for BBB Cycling.

In Appendix A, the intitial project brief can be found.

1.4 PROJECT APPROACH

This project followed the Delft Innovation Method (DIM), described by Jan Buijs (Buijs, 2012), as a guiding framework, though not strictly at all times. The DIM cycle has a strong focus on product design, whereas its strategic component is more concise. Since this project required a more extensive strategic approach than the method provides, a large part of the research only covers a small portion of the DIM cycle. For product design, however, the method is very comprehensive. As the design in this project serves as a proof of concept rather than a factory-ready product, some steps of the model were only briefly addressed.

The DIM framework was used as an overall method, but in various phases of the project, different specific methods were applied, which are described below.

Research & analysis

To gain a deep understanding of the cycling safety landscape, semi stuctured interviews were conducted: Experts in cycling safety were interviewed to provide insights into industry trends and technological developments. Additionally, discussions with BBB Cycling colleagues and professionals from Pon.Bike provided valuable perspectives on strategy, product positioning, and market dynamics.

To understand the behaviour around adoption and how this can possibly be changed, the COM-B theory was used.

Roadmapping: Based on the book and lectures by Dr. Lianne Simonse, a structured roadmapping approach was used to align strategic decision-making with anticipated developments in cycling safety and product innovation (Simonse, 2018). Although the roadmap in this project is more organization focussed than product development focussed, the tools were still very useful.

Design & development

During the design phase, a combination of iterative design methods and collaborative development helped refine the product concept:

Small co-creation sessions: Weekly creative sessions with designers at the BBB office allowed for discussion and iteration of design ideas. These were complemented by individual feedback sessions with the company mentor.

Prototyping & user testing: The prototype was tested in a real-life scenario to assess its usability and safety-enhancing potential. Additionally, dealers and industry professionals were interviewed to evaluate the prototype's feasibility, market potential, and user acceptance.

ChatGPT : ChatGPT was used as a support tool for writing and refining the Arduino code.

Ethical Considerations

All interviews were conducted in compliance with the Human Research Ethics Committee (HREC) of TU Delft. The necessary documents were submitted, and official permission was granted before conducting any research activities.

All HREC-related documentation can be found in Appendix B.

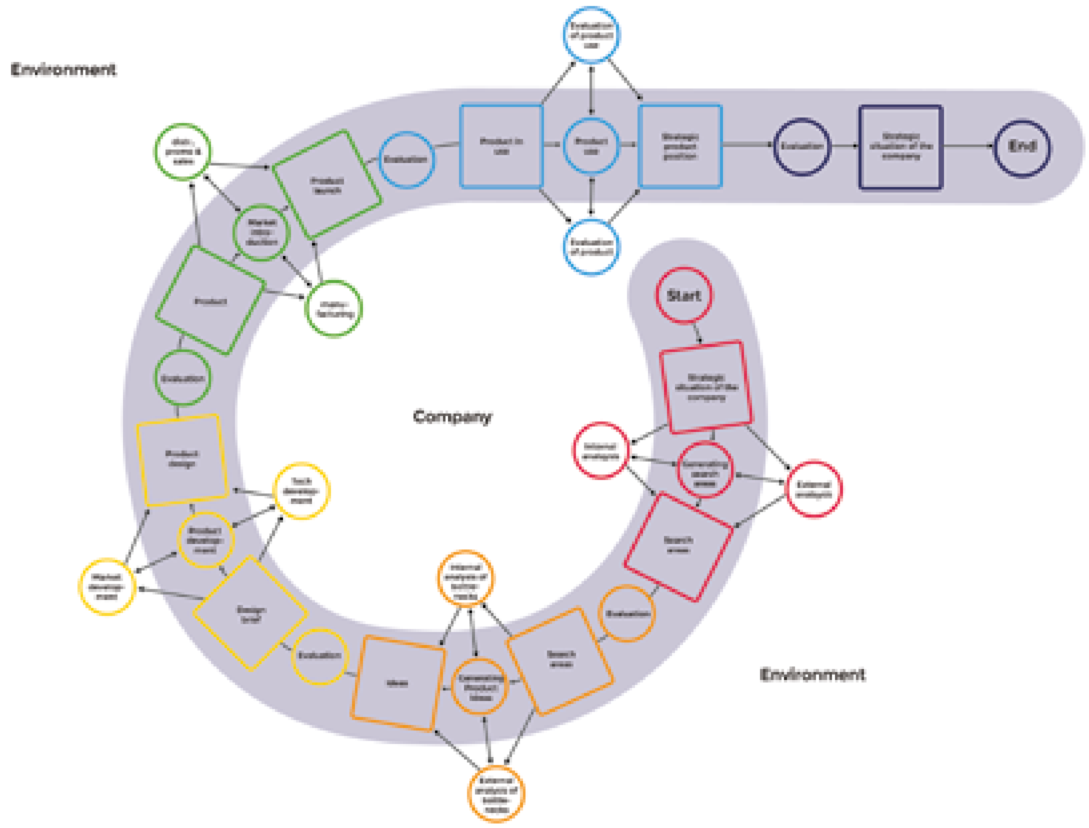


Figure 2. Delft Innovation Method (Buijs, 2012), adepted for this project

1.5 STRUCTURE

This project follows a structured approach that is broadly similar to the Delft Innovation Method (DIM), shown in Figure 2. The report starts with an and internal analysis, examining the current state of cycling safety and BBB Cycling as a company and its position in the market. This phase identifies key opportunities and challenges, laying the foundation for some search areas; areas of potential for the project that fit with the internal capabilities and the external possibilities.

Following this, the thesis explores strategic possibilities, defining how BBB Cycling can effectively position itself in the growing comfort cycling safety market. Important here is assessment of collaboration and synergy advantages within the Pon.Bike network, to explore how partnerships can enhance both the group's and the company's approach to innovation.

After the possibilities for collaboration are discussed, the focus shifts toward a roadmap for implementation, followed by the product design phase. This section describes the steps taken from ideation and concept development to prototyping and testing.

The final part of the thesis reflects on the strategic fit of the developed product, comparing the outcome with the initially proposed strategy. This is followed by a discussion and recommendations, addressing key insights, project limitations, and potential future developments. The thesis concludes with a conclusion on the most significant findings and insights, helping to shape a potential future role for BBB Cycling role in cycling safety.

2. CYCLING SAFETY DEVELOPMENTS

This analysis explores the external trends and developments affecting the future of cycling safety, both positively and negatively. The review focuses on objective safety, examining four key themes: (1) sustainability and mobility, discussing the potential of cycling in the energy transition and the health benefits of cycling; (2) traffic safety, analysing the challenges related to the registration of cycling accidents and the difference in cycling safety between different regions; (3) demographic changes, including the impact of ageing and urbanisation on bicycle use and safety; and (4) technological innovation, such as the rise of smart bicycles, digitalisation, and the development of autonomous driving. These themes are explored in relation to both the current situation and future expectations, providing a structured overview of the key factors influencing cycling safety.

The structure of this analysis reflects that approach: paragraph 2.1 outlines the current situation in cycling safety in the Netherlands and Europe. Paragraph 2.2 discusses the methodological focus on objective safety, based on measurable data such as accident statistics and injury rates. At the same time, it acknowledges the importance of subjective safety: the way cyclists perceive risk and comfort on the road. While subjective safety plays a key role in cycling behaviour, it falls largely outside the scope of this research and is only briefly addressed for context. Paragraph 2.3 explores future expectations based on developments in mobility, infrastructure, and technology, and the analysis concludes with a summary and key takeaways for BBB Cycling in paragraph 2.4.

The aim of this chapter is to provide a comprehensive overview of the key trends and developments shaping the future of cycling safety. This research serves as a foundation for the strategic analysis of BBB Cycling and provides a framework for identifying potential areas in which BBB can respond to the evolving market with new products. Two sub-questions are being answered:

- What are the main factors influencing cycling safety in the Netherlands and Europe today, and how has the rise of electric bikes impacted overall risk levels?

- How is cycling safety expected to change in the coming years based on trends in mobility, infrastructure, and technology?

2.1 CURRENT SITUATION

2.1.1 Sustainability and Mobility

Cycling is increasingly recognized as an essential part of sustainable urban mobility. The mobility sector is undergoing significant transformations driven by climate change (Figure 3), technological innovations and demographic shifts. Cities and towns are prioritizing car-free zones and promoting cycling as a cleaner and greener alternative to motorized transport (Ministerie van Algemene Zaken, 2024; Ministerie van Infrastructuur en Waterstaat, 2023). European governments are investing heavily in cycling infrastructure and providing incentives for the adoption of e-bikes to reduce urban congestion and lower greenhouse gas emissions. However, as cycling gains momentum, safety concerns and the rise in cycling fatalities pose a significant challenge to realizing cycling's full potential as a sustainable mode of transport.

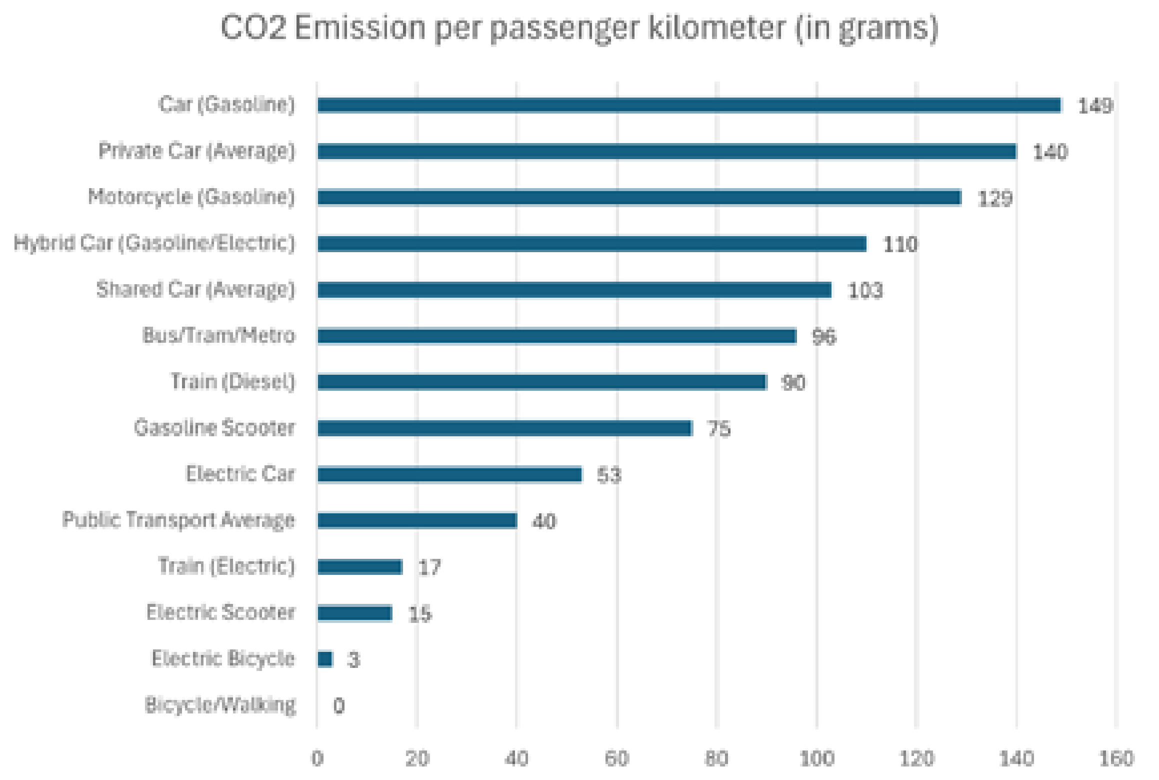


Figure 3. CO2 emission per passenger kilometer (in grams), (Milieu Centraal, n.d.)

The importance of cycling is increasingly acknowledged across Europe, reflected in both international and regional initiatives. In 2021, the United Nations Economic Commission for Europe (UNECE) adopted the 'Pan-European Master Plan for Cycling Promotion', aiming to significantly increase cycling in every country within the region and double cycling by 2030. The plan emphasizes the importance of national policies supported by targeted strategies and programs to achieve these ambitious goals (United Nations Economic Commission for Europe, 2021). Building on this momentum, the European Parliament in 2023 endorsed a resolution calling for the development of an EU-wide cycling strategy. While not legally binding, this resolution aims to double the kilometres cycled in Europe by 2030 (ECF - European Cyclists Federation, 2023).

The rise of electric bicycles (e-bikes) is at the forefront of this transition. E-bikes have revolutionized urban mobility by making cycling more attractive for longer commutes as well as cycling in hilly areas. In the Netherlands, Belgium, and Germany, new e-bike sales have surpassed those of new traditional bikes, illustrating their growing popularity (Van Schaik, 2024). This upward trend is also clearly reflected in recent market data. As illustrated in Figure 4, the number of new e-bikes sold in the Netherlands has steadily increased since 2014, surpassing traditional city bikes around 2018 (BOVAG & RAI Vereniging, 2023). While the total number of new bikes sold has declined slightly in recent years, the share of e-bikes has grown both in terms of volume and value, indicating a significant market shift. This development supports the transition to more sustainable urban mobility by offering a cleaner, more efficient way to travel, thereby reducing CO2 emissions and contributing to the overall reduction of the urban carbon footprint.

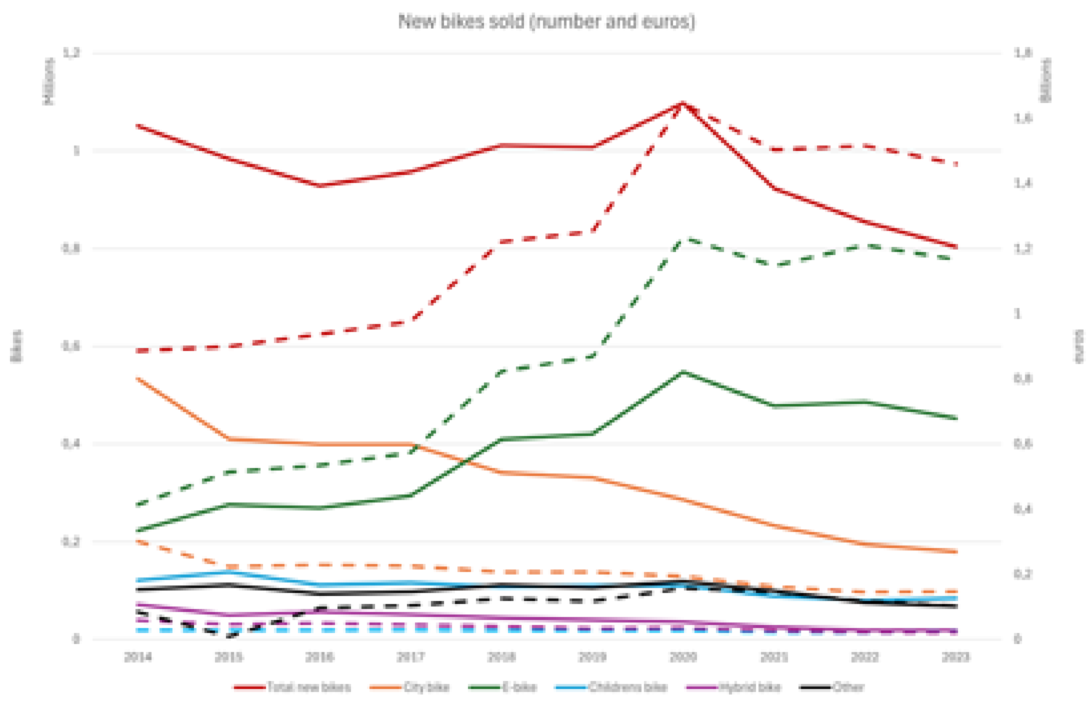


Figure 4. New bike sales in numbers (left) and euros (right), (BOVAG & RAI Vereniging, 2023)

Cycling also provides significant health benefits. Regular physical activity from cycling improves overall health and reduces the risk of chronic conditions such as cardiovascular diseases and diabetes. According to research by De Hartog et al. (2010), the health advantages of cycling outweigh the risks associated with accidents. However, this optimism is tempered by an alarming paradox: while efforts to encourage a shift from cars to bikes are succeeding, the number of cycling fatalities has increased in some regions, even as car-related fatalities have declined. In an interview with a policy officer at the ministry of infrastructure and water management this concern was highlighted, stating that: "things are not going well with bicycle safety, and expectations are also negative." This points to an urgent need for improvements in cycling infrastructure and the implementation of solid safety measures to protect cyclists.

Dutch Government Initiatives on Traffic Safety

The Dutch government recognizes traffic risks and has set a goal to halve road casualties by 2030, aligning with international targets. This would mean a maximum of 300-350 road deaths (SWOV, 2024). To support this, major cities like Amsterdam, Rotterdam, The Hague, and Utrecht advocate for lowering urban speed limits to 30 km/h (Figure 5) (Het Parool, 2023).

Despite these efforts, traffic fatalities increased in 2022 to 745 deaths—163 more than in 2021. Cyclists accounted for nearly 40% of victims, and SWOV Director Martin Damen warns that road safety has regressed to levels

Figure 5. Maximum speed reduction in Amsterdam, (Veilig Verkeer Nederland, 2023)

from 15 years ago (SWOV, 2023b). The SWOV report suggests that halving casualties by 2030 is unlikely but emphasizes that additional bicycle safety measures and speed reductions could still prevent fatalities.

2.1.2 Traffic Safety

As described, cycling is a sustainable and healthy mode of transportation. However, the growing popularity of cycling, particularly in countries such as the Netherlands, Belgium, and Germany, has led to an increase in the number of bicycle-related accidents. While advancements in car safety have reduced road fatalities for motor vehicle users, the same cannot be said for cyclists. This chapter examines the factors of bicycle accidents, explores challenges in reporting, and considers the psychological, infrastructural, and behavioural factors that impact cycling safety.

Trends in Bicycle Accidents

In recent years, the number of fatal bicycle accidents has either stagnated or increased in the Netherlands (Figure 6), Belgium, and Germany (Centraal Bureau voor de Statistiek, 2024; Statistiek Vlaanderen, 2024; Meyer & Zollner, 2024). The risk of sustaining severe injuries while cycling has also risen (SWOV, 2023a). Notably, the percentage of cyclists involved in the total number of road accidents has grown, as can be seen in the graph in Figure 7.

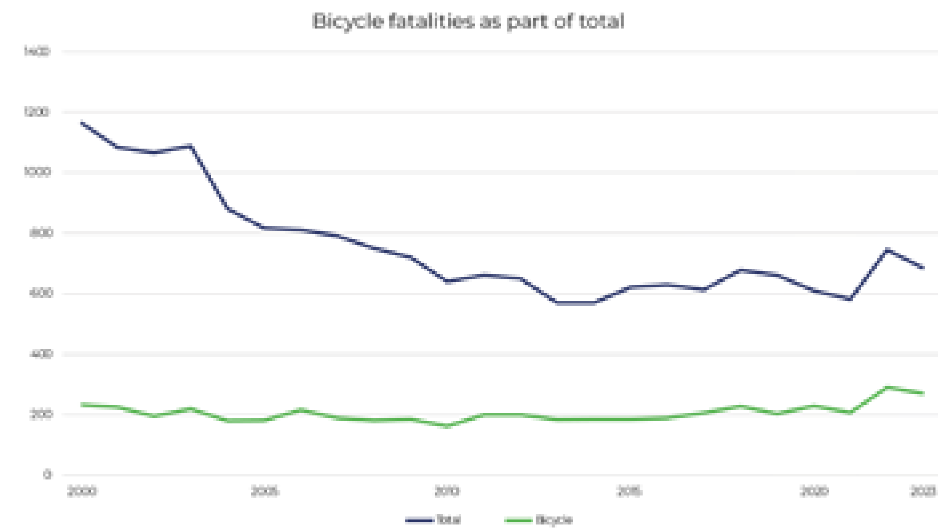


Figure 6. Bicycle fatalities as part of total (CBS, 2024)

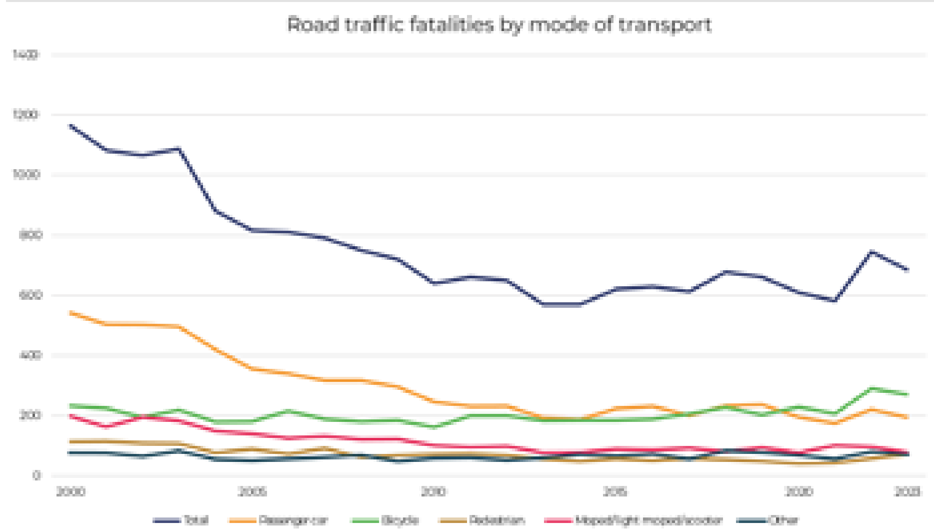


Figure 7. Road traffic fatalities by mode of transport (CBS, 2024)

The different view of the Cycling Professor

In discussions on traffic safety, Professor Marco te Brömmelstroet, nicknamed 'the cycling professor', highlights a critical imbalance: as cars become larger and faster, the responsibility for safety increasingly shifts to cyclists. In his book Movement, he argues that this dynamic places a disproportional burden on cyclists to adopt protective measures, such as wearing helmets and using lights, while the systemic risks posed by motor vehicles remain insufficiently addressed. This perspective challenges the dominant focus on individual responsibility and calls for a revaluation of urban mobility policies to prioritize the safety of vulnerable road users (Verkade & Te Brömmelstroet, 2020).

Supporting this viewpoint, recent incidents underscore the heightened dangers cyclists face due to larger vehicles. For example, the tragic death of cyclist Paul Varry in Paris, who was deliberately struck by an SUV driver, has intensified public debate on road violence and the disproportionate risks posed by larger vehicles to cyclists (Carpentier & Razemon, 2024).

Furthermore, the increasing popularity of high-speed electric bikes, such as fatbikes, has led to a growth in accidents, raising concerns among citizens and policymakers about the safety implications of faster vehicles sharing space with traditional cyclists (NOS, 2024a).

These examples illustrate the pressing need to address the systemic factors contributing to cycling hazards, aligning with te Brömmelstroet's advocacy for a more equal distribution of safety responsibilities between motorists and cyclists.

Crash categories and cycling accident types

Bicycle accidents occur across a wide range of scenarios. In the Netherlands, 75% of all cycling accidents involve conventional bikes or e-bikes, while the remaining 25% involve sports bikes, such as mountain bikes or racing bikes (VeiligheidNL, n.d.). Over the last years, cycling in urban environments is getting more hazardous: in 2020, 31% of cycling accident victims were riding e-bikes, compared to just 21% in 2016. Similarly, Germany has experienced a sharp increase in e-bike accidents, rising from 2,245 in 2014 to nearly 24,000 in 2023 (Destatis, 2024).

Challenges in Reporting Cycling Accidents

Accurate reporting of cycling accidents remains a significant challenge. Many statistics are based on data from cyclists who sought medical treatment, leaving out incidents where cyclists either did not require or did not seek medical attention. Moreover, self-reported questionnaires often introduce biases, such as underreporting distractions or alcohol consumption.

The lack of mandatory insurance for cyclists further exacerbates this issue. Unlike car drivers, whose accidents are typically documented through police reports or insurance claims, many cycling accidents go unregistered. Studies by Gössling et al. (2024) and others have highlighted significant underreporting of cycling injuries, suggesting that official statistics only capture part of the problem. This issue was highlighted by Dr. Marjan Hagenzieker, as some of the issues regarding posts on the road got attention very late, since there was no one registering the fact that a lot of people were cycling into these posts on the road (own communication, 10 October 2024). The ministry of traffic and infrastructure explained this issue, telling there are independent accident databases. The police has its own database (named BRON) and ambulance care also has an own database. Due to the privacy legislation, it is not possible to get insights in the medical reports of from the ambulance database, while it is expected to contain a factor 4-8 more cycling data, compared to the BRON database (own communication, 20 November 2024).

Psychological and Behavioural Factors

Distractions are a major contributor to cycling accidents and can be categorized into four types: visual distractions (e.g., looking at a smartphone), auditory distractions (e.g., listening to music on headphones), biomechanical distractions (e.g., typing on a smartphone), and cognitive distractions (e.g., being lost in thought) (Liberty et al., 2000). Often, multiple forms of distraction occur simultaneously, significantly increasing the risk of accidents. For instance, a Chinese experimental study found that smartphone use while cycling reduced reaction time and caused speed fluctuations. Texting while cycling had the greatest impact on performance, followed by making phone calls and listening to music (Jiang et al., 2021).

While listening to music was commonly observed among cyclists during this project, researchers from the University of Gent found no direct link between music and increased cycling danger, provided the volume allows traffic sounds to be heard (Fietsberaad CROW, 2022). However, with the rise of quiet electric vehicles, this auditory reliance may pose new

Artsen voor Veilig Fietser

Artsen voor Veilig Fietsen

Artsen voor veilig fietsen, translated as 'Doctors for safe cycling', is a Dutch thinktank, started by neurologists to raise awareness around safe cycling, particularly focussing on prevention of brain injuries. Dr. Hamer is involved in this thinktank, and she highlighted that a lot of people are missing important information regarding helmet use. For example, wearing a helmet for children is very important: when children are young, their head is relatively heavy compared to the rest of their body and their skull is soft, this increases the risk on a skull fracture.

Figure 8. Screenshot from documentary (ARTE, 2024)

Figure 8 presents a screenshot from a German documentary (ARTE, 2024) showing what happens to the 'driver' and 'passenger of a cargobike when falling after an evasive maneuver.

risks, particularly when cyclists fail to notice oncoming traffic.

Lack of awareness about cycling risks

A significant factor contributing to accidents is the lack of awareness about the potential risks of cycling. Dr. Elisa Hamer, neurologist at the Radboud UMC in Nijmegen and member of the thinktank 'Artsen voor veilig fietsen' (see block on previous page), notes that many patients she sees are unaware of the consequences of cycling accidents (own communication, 15 October 2024). Despite helmets being a critical safety measure, their use remains very low: in 2023, only 5% of male cyclists and 3% of female cyclists in the Netherlands wore helmets voluntarily (SWOV, 2024).

Even when safety measures are mandatory, compliance not guaranteed. For example, while bike lights are mandatory in many countries, some cyclists still fail to comply with the rule. As the chart shows (Figure 9), the use of bike lights in the Netherlands has increased significantly over the years, with 87% of cyclists using a front light and 82% using a rear light as of 2021/2022. However, this still falls short of universal adoption. Additionally, even among those who do use lights, the quality of some lights is so poor that they fail to provide adequate visibility in traffic. This demonstrates that simply mandating safety measures does not guarantee full compliance or effectiveness.

This lack of awareness is complicated due to cognitive biases such as self-enhancement and unrealistic optimism, where individuals perceive themselves to be better or safer than others. Research highlights that people often underestimate the risks associated with activities they control, such as cycling, leading to riskier behaviour (Koppel et al., 2023; White, 2011). Cultural factors also influence cycling safety. In the Netherlands, where cycling is deeply embedded in daily life, most road users are also cyclists, fostering greater awareness of cyclists' vulnerabilities. However, interest in voluntary safety measures like helmet use remains low, with only 5% of men and 3% of women wearing helmets voluntarily (SWOV, 2024).

Traffic density and infrastructure

Rising traffic density poses additional challenges. Crowded cycling paths, combined with varying speeds of e-bikes and conventional bikes and the behaviour of different cyclists, create hazardous situations (Figure 10). The introduction of micromobility options, such as e-scooters, has further increased congestion and the risk of accidents (Cloud et al., 2023). Research from the municipality of Amsterdam indicates that the number of accidents rises as cycling paths become overcrowded (Oomen & Heijnen, 2024).

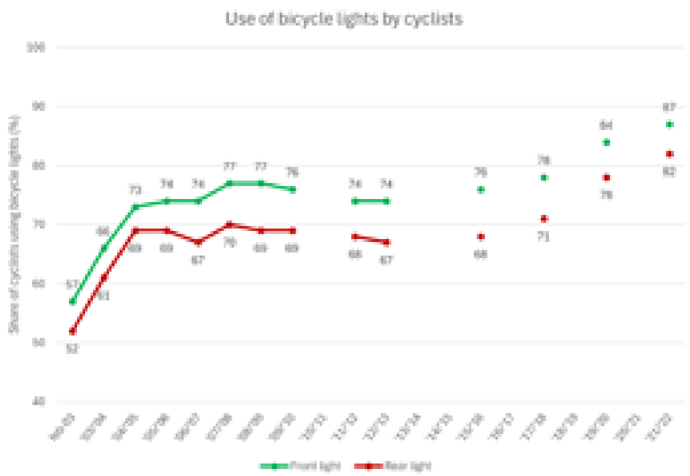


Figure 9. Use of bicycle lights in percentages over the last years (SWOV, 2023b)

Figure 10. Cities are getting busier with traffic, (Goudappel, n.d.) top & (Dutch Cycling Embassy, 2024) bottom

Dutch cycling infrastructure is among the safest in the world, thanks to a clear hierarchy in road design and the separation of cyclists from motorized traffic where necessary (Schepers et al., 2015). However, maintaining and improving infrastructure is critical as cycling continues to grow in popularity.

2.1.3 Social and Societal Developments

Social and societal developments are shaping cycling trends across the globe. Aging populations, urbanization and the rise of emerging cycling markets are influencing who cycles, where someone cycles, and how cycling is integrated into daily life.

The influence of aging on bicycle use

The advent of e-bikes has revolutionized cycling for older adults, enabling them to remain mobile and active despite declining physical strength. With the phenomenon of "double aging" in Europe, where both the number of elderly individuals and the proportion of those over 80 are increasing, cycling habits among the older population are changing significantly (Van Cauwenberg et al., 2018). E-bikes allow older adults to cycle more frequently and over longer distances, promoting physical activity and social inclusion.

However, age-related health issues, such as reduced vision, impaired balance, and slower reflexes, make elderly cyclists more vulnerable to accidents. Falls and collisions with street obstacles or other road users are common, and injuries are often more severe due to their physical vulnerability (Schepers et al., 2020). Tailored safety measures, such as stable bike designs, training programs like those offered by Doortrappen, and increased helmet use, are crucial to addressing these challenges (Figure 11) (Doortrappen, n.d.). Cycling dealers interviewed highlight a growing trend of elderly riders purchasing helmets, indicating an increased awareness of safety in this generation. In addition, the general practitioner of the author said that there is a big need for making bicycles elderly-proof. Since there is a lot of attention on various programmes to keep elderly mobile with confidence, she sees limited involvement from the bicycle industry itself.

Figure 11. Doortrappen, cycling safe till you're 100, (Doortrappen, n.d.)

Urbanization and its impact on cycling

Urbanization is another key factor driving cycling trends. People living in urban areas cycle more frequently than those in rural regions, largely due to shorter travel distances and the practicality of using bicycles for daily commutes. Cities worldwide are promoting cycling as a way to reduce pollution, ease congestion, and create more sustainable urban environments (Khreis et al., 2016).

However, the rise in urban cycling comes with challenges. Nearly three in five registered cycling accidents occur in urban areas, where dense traffic, diverse cyclist populations, and competing demands for space create hazardous conditions, particularly during peak hours (SWOV, 2023a). Urban planners face the challenge of designing infrastructure that accommodates a wide range of cyclists, from commuters and delivery riders to recreational cyclists, while ensuring safety for all road users.

Emerging cycling markets (beyond the Netherlands and Denmark)

While the Netherlands and Denmark are often seen as leaders in cycling, other countries are experiencing a surge in cycling popularity. The Netherlands and Denmark are leaders, largely due to extensive, well-designed cycling infrastructure, such as separated bike lanes, priority traffic systems, and cyclist-friendly urban planning. Additionally, a deeply embedded cycling culture, reinforced by progressive government policies and safety regulations, has made cycling a primary mode of transport rather than just a recreational activity.

Meanwhile, countries like Germany, Belgium, and certain Southern and Eastern European nations are increasingly adopting cycling as a practical and sustainable mode of transport. This trend is driven by government initiatives, environmental awareness, and the expansion of bike-friendly infrastructure.

In emerging cycling markets, growth is heavily influenced by the rise of e-bikes, particularly pedal-assisted models that offer a moped-like experience without requiring helmets or insurance, as explained by Wo Meijer (own communication, 10 October 2024). This contrasts with mature cycling markets, where traditional road bikes and city bikes dominate. However, in many of these newer markets, the lack of extensive cycling infrastructure and cultural perceptions of cycling as leisure rather than daily transport pose significant challenges. Successfully integrating cyclists into existing traffic systems in these regions will require substantial investment and cultural shifts to support the continued growth of cycling as a viable transportation option.

2.1.4 Technological Innovations

Technological innovations are reshaping the way people cycle, offering new tools to enhance safety, convenience, and accessibility. From smart bicycles and e-bikes to digital platforms and autonomous vehicle (AV) systems, these advancements are transforming cycling into a more integrated and efficient mode of urban mobility. This chapter explores key technological trends in cycling, examining their potential impacts and the steps needed to fully realize their benefits.

Smart bicycles and safety technology

The integration of advanced technology into bicycles is making cycling "smarter" and safer. E-bikes now come equipped with GPS systems, walking assistance, and navigation tools, offering real-time guidance and performance tracking. These advancements improve efficiency and provide safety benefits, such as turn-by-turn navigation and alerts for accident-prone areas.

In addition to bicycles, wearable technology like connected helmets with integrated lighting and crash-detection sensors are becoming more common. As Mark van der Kooi, innovation manager at bike manufacturer Gazelle, notes, the demand for "connectedness" in cycling products is growing. Platforms like Kickstarter are fuelling this trend, showcasing innovations like smart locks, automatic lights, and connected accessories (own communication, 26 September 2024). However, challenges remain in integrating these technologies seamlessly into cyclists' routines and ensuring their widespread adoption.

Electrification

Electrification has transformed cycling, making it accessible to a wider demographic, including older adults and those who find traditional cycling physically demanding. Advances in e-bike technology have led to more powerful batteries, extended ranges, and integrated motor systems, making e-bikes a practical alternative for commuting and recreational use.

However, the higher speeds of e-bikes pose new safety risks, especially in urban environments with mixed traffic. To address these concerns, safety-focused innovations such as speed regulators and advanced braking systems are essential. Policymakers and manufacturers must work together to ensure that e-bike safety keeps pace with technological advancements.

Bicycle vs. Car developments

The rise in cycling activity partly explains the increase in accidents, but other factors play a significant role, including the difference in safety advancements between cars and bicycles. Over the years, car safety has improved significantly,

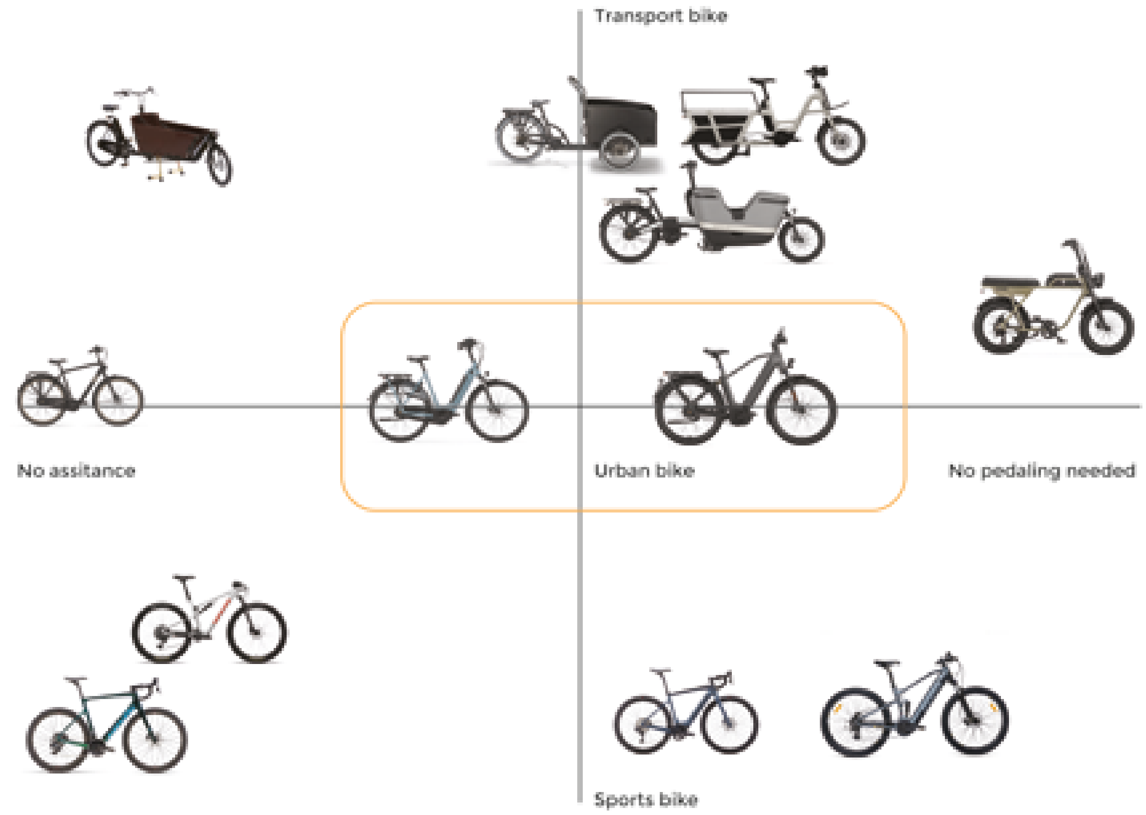


Figure 12. Types of bikes matrix, focus area for this projet in yellow block

Figure 13. Car vs. bike development 1960-now

not only for occupants but also for vulnerable road users, including cyclists. Features such as automatic emergency braking (AEB) with cyclist detection, blind-spot monitoring, and improved front-end vehicle design have made cars more bike-friendly. Additionally, urban policies, such as lower speed limits and improved bike lane infrastructure, contribute to safer interactions between cars and cyclists.

However, despite these advancements, cyclists remain fundamentally vulnerable. While cars have integrated various protective systems, bicycles still lack external protection, meaning that in the event of a collision, the cyclist absorbs the full impact. Although bikes have become more robust, gaining disc brakes, battery-powered assistance, and improved frame materials, these changes primarily enhance performance and comfort rather than direct crash protection (Figure 13).

Another critical factor influencing cycling safety is the increasing diversity of bike types. In recent years, there has been a rapid differentiation in bicycles, including conventional (e-) bikes, cargo e-bikes, speed pedelecs, and fat bikes (Figure 12). While these innovations serve different user needs, they also introduce new safety challenges, such as higher speeds, varying bike sizes, and increased interaction with motorized traffic. Given the projected growth of the European e-bike market, further diversification is expected, leading to both opportunities and additional safety concerns (Mobility Foresights, 2024).

Although technological progress has led to safer car-cyclist interactions, it does not eliminate the inherent risks associated with cycling. As bicycles evolve and traffic conditions change, it remains crucial to explore new product and infrastructure innovations that further enhance both objective and subjective cycling safety.

Autonomous vehicles and their impact on cyclist safety

The rise of autonomous vehicles (AVs) presents both opportunities and challenges for cyclist safety. While AVs have the potential to reduce human error and create safer roads, their ability to detect and respond to cyclists remains a concern. As Dr. Hagenzieker highlights, AV technology is still in development, and a transitional period will see traditional cars, AVs, and cyclists sharing the roads. This creates unpredictability and increased risks for cyclists.

Dr. Eui Young Kim further notes that AV systems struggle to anticipate cyclists' rapid and unpredictable movements (own communication, 10 September 2024). To address these challenges, AV testing protocols must account for common cyclist behaviours, and infrastructure improvements should prioritize safe interactions between AVs and cyclists.

Both academics emphasized that for the near future, autonomy furter than level 3, described in Figure 14, should not be considered realistic. There are too many limitations, mainly financial, technological and political (Sauer, 2023).

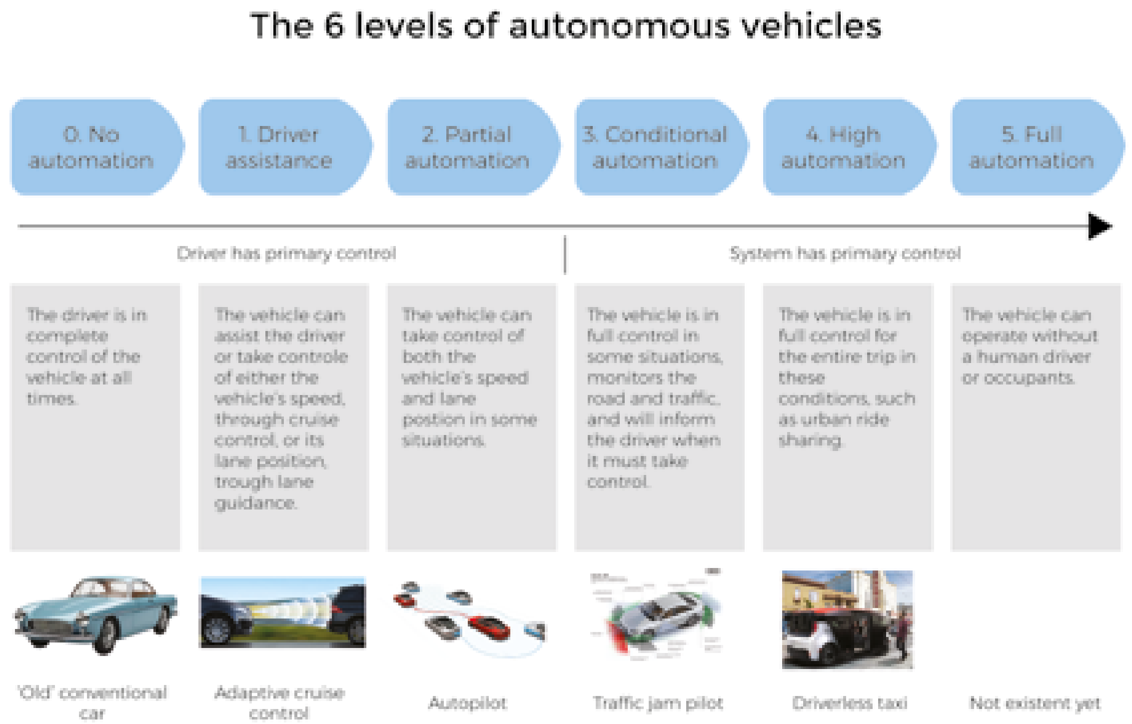


Figure 14. The 6 levels of autonomous vehicles, edited from (PTOLEMUS Consulting Group, 2022)

Mobility as a Service (MaaS) and shared mobility

Mobility as a Service (MaaS) platforms are revolutionizing urban transport by integrating various modes of transportation, including cycling, into a single digital interface. These platforms allow users to plan, book, and pay for transport services, making it easier to incorporate cycling and commuting by public transport into daily routines (Bolt, n.d.; Uber, n.d.; Nederlandse Spoorwegen, n.d.; Greenwheels, n.d.).

For cycling, MaaS offers improved access to bike-sharing systems and supports the integration of bicycles into multi-modal travel plans. This shift could drive innovation in cycling technology, such as smart helmets and personalized route-planning tools, while also emphasizing the importance of safe and accessible cycling infrastructure. To fully realize its potential, MaaS must address challenges related to infrastructure availability, safety, and seamless bike access.

Digitalization

Digitalization is enhancing the cycling experience through tools like ride-tracking apps, safety alert systems, and route-planning platforms. These technologies improve convenience and safety by providing real-time data on traffic conditions, accident hotspots, and optimal routes.

Dr. Hagenzieker emphasizes that digital platforms also contribute to better data collection, offering insights into cyclist behaviour and safety needs. This data can inform urban planning and infrastructure development, ultimately creating safer environments for cyclists. However, concerns about privacy and data security may discourage some users from adopting these technologies. Companies must prioritize robust privacy protections to build trust and encourage widespread adoption.

2.2 MEASURING SAFETY

The previous section outlined the current state of cycling safety in the Netherlands and Europe, based on data such as accident statistics, injury rates, and expert insights. These indicators provide a useful foundation for understanding objective safety, which can be measured and analysed. However, to fully grasp the complexity of cycling safety, it is important to also consider the subjective dimension.

Objective and subjective safety are two distinct yet interconnected aspects of road safety. Objective safety is based on measurable data, such as accident statistics, injury rates, and risk analyses, providing a concrete assessment of safety measures' effectiveness. In contrast, subjective safety is shaped by individual perceptions and psychological responses to the traffic environment, influenced by factors such as past experiences, road design, and interactions with other road users (Sørensen et al., 2009).

While objective safety improvements may reduce accidents, they do not always lead to a greater sense of security if road users, such as cyclists, still feel vulnerable or anxious. For this reason, both perspectives are considered in this section. Paragraph 2.2.1 focuses on objective safety, including the role of expert interviews and stakeholder mapping. Paragraph 2.2.2 discusses subjective safety, its influence on cyclist behaviour, and its relevance for product design and evaluation.

2.2.1 Objective Safety

Objective safety focuses on quantifiable data, such as accident reports, injury rates, and risk analyses. These indicators provide an empirical basis for assessing the effectiveness of infrastructure, traffic policies, and product interventions in improving cycling safety. To better understand how safety is measured, and which actors play a role in shaping it, an analysis was conducted on the different parties involved when a cyclist ends up in an accident, focussing on their relationships and interactions, using the Value Flow Model developed by Den Ouden and Brankaert (2013).

The system map, presented in Figure 15, provides an overview of the interrelationships and dynamics within the cycling ecosystem. It highlights key stakeholders such as emergency services, policymakers, and insurers. When looking at the model, it is remarkable to see that there is no direct value flow between cyclists and bicycle manufacturers. Instead, bicycle manufacturers are only linked with cyclists' unions and policymakers, which means that product designers typically become involved only after accidents have happened, when either policy changes or lobbying pressure from unions is strong enough.

From a cyclist's point of view, the primary victim in an accident, various stakeholders are directly involved. Family and friends, witnesses, and other involved traffic participants are closely connected to the victim, yet they typically have little influence over post-accident processes, treatment, or financial settlement. Additionally, these stakeholders are often only involved in one specific case, which makes it difficult for them to provide a nuanced picture of cycling accidents in general. Therefore, these stakeholders are excluded from this analysis.

On the other hand, certain stakeholders do have a more comprehensive view of cycling accidents. Insurers and emergency services are directly involved in the post-accident processes and treatment of multiple incidents and are therefore well positioned to observe broader patterns over time. To gain deeper insight into accident trends and their implications, interviews were conducted with a neurologist and an insurance representative.

In addition to the direct stakeholders described in the model, experts with a broader perspective on cycling and traffic safety were also interviewed. While these experts are not directly involved in the safety of individual cyclists, they advise policymakers and conduct academic research. Their contributions help frame objective safety within a larger societal and infrastructural context. Moreover, these interviews were conducted not only to gain insight into the current safety situation, but also to understand the experts' expectations for future developments. These expectations are further explored in paragraph 2.3.

2.2.2 Subjective Safety

While objective safety can be measured through hard data, it does not fully capture how cyclists experience their environment. As discussed in the previous section, improvements in infrastructure or product design may lower accident rates, but they do not necessarily make people feel safer. This highlights the importance of subjective safety as a complementary dimension in assessing overall cycling safety.

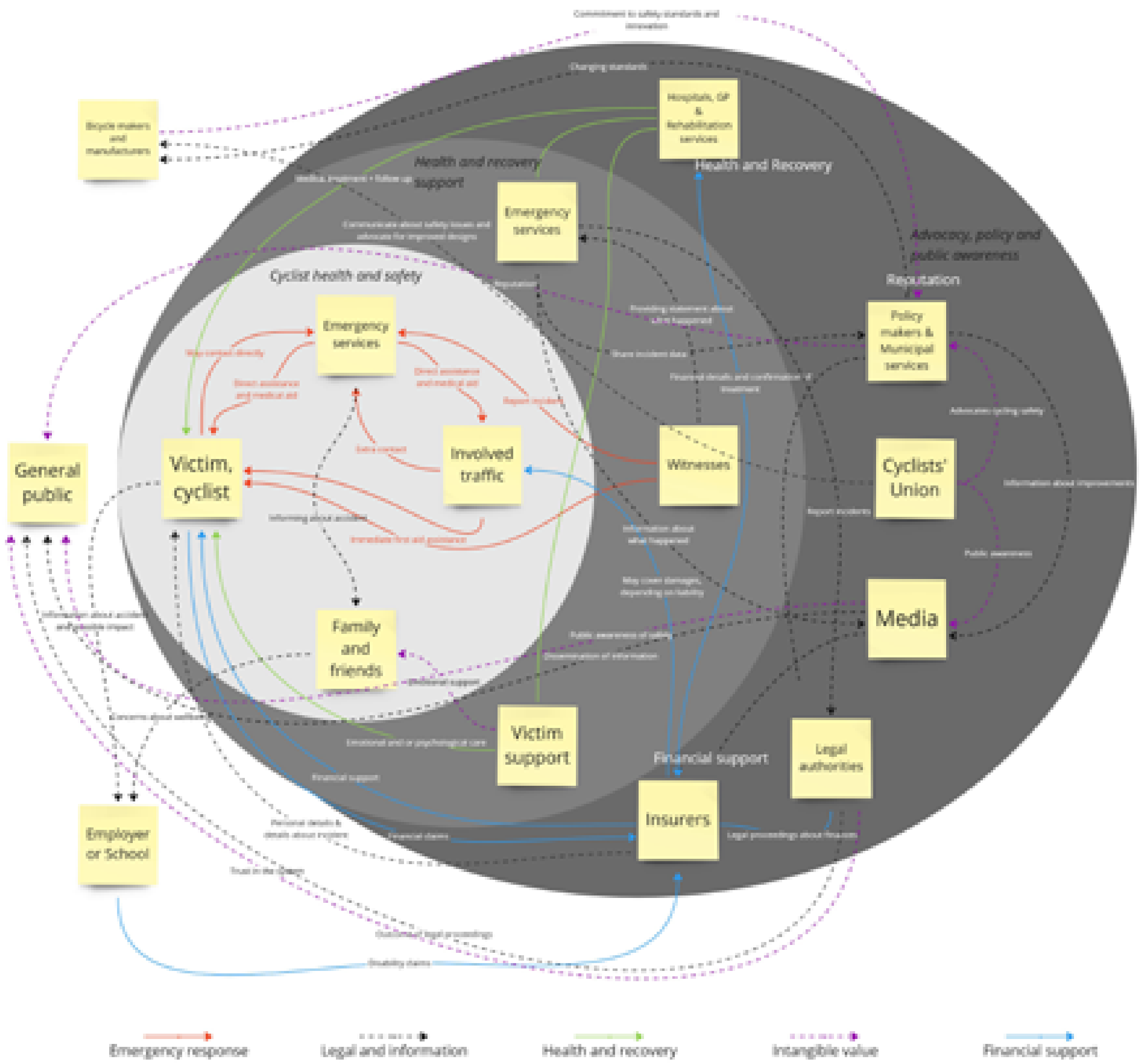


Figure 15. Value Flow Model of cyclist accidents

Subjective safety refers to an individual's perception of safety in a situation, independent of actual risk levels. Unlike objective safety, which is based on measurable accident data and injury statistics, "the concept of subjective safety in traffic refers to feeling safe/unsafe in traffic or to the anticipation of being safe or unsafe in traffic for oneself or others, respectively, and is tangent to people's fear of being involved in a crash" (Furian et al., 2024). While objective safety ensures a measurable reduction in accidents, subjective safety determines whether people feel safe enough to engage in certain behaviours, such as cycling in specific environments.

Importance in Cycling Safety

In the context of cycling, subjective safety is crucial because it directly affects cycling participation and behaviour. Research shows that individuals who perceive cycling as safe are more likely to choose the bicycle as a mode of transportation (Heinen et al., 2010). Perceived dangers such as close interactions with motor vehicles, poor visibility, or unpredictable traffic conditions can discourage cycling (Schepers et al., 2015). This makes subjective safety an essential factor in designing safer cycling environments and promoting sustainable urban mobility.

Measuring Subjective Safety

Since subjective safety cannot be directly observed, it must be assessed through structured evaluation methods. Because it is a complex psychological phenomenon, it cannot be measured by simply asking: "How safe did you feel?" Instead, structured constructs provide a more reliable way to capture how different factors contribute to a cyclist's perception of safety. The following constructs are commonly used in research to measure perceived safety:

Perceived risk evaluates how cyclists estimate the likelihood of an accident in different scenarios. This risk perception is a theory described by Paul Slovic and, in the context of cycling, this perception is based on past experience a person might have with cycling and possible accidents or hazardous situations (Landgreen-Petersen, 2021).

Example question: How likely do you think it is that you will be involved in an accident when using this cycling path? Do you feel this product makes you more visible to other road users?

Stress and comfort levels assess physiological and emotional responses, such as anxiety and tension during cycling. Vansteenkiste et al. (2014) found that on poor-quality bike paths, cyclists focused more on the road, reducing attention to their surroundings. This shift suggests increased cognitive load and reduced comfort, as they must stay actively aware to avoid obstacles.

Example question: How comfortable did you feel while cycling on this route? Were you aware of all road signs along the road?

Behavioural indicators observe whether cyclists change their behaviour due to perceived safety concerns, such as avoiding specific routes or adopting defensive cycling habits. Sanders (2016) found that: "both cyclists and drivers are more comfortable on roadways with separated bicycling facilities than those with shared space."

Example question: Have you changed your cycling behaviour due to safety concerns in this environment? Did you cycle slower because of this 'unsafe' environment?

In product evaluation, these constructs can be applied through surveys, controlled experiments, or biometric measurements (e.g. eye tracking) to assess whether a safety intervention enhances perceived safety. For this research, these constructs will be used to assess whether the designed product positively influences cyclists' perceived safety. The evaluation will be conducted through user testing, where subjective safety perceptions will be measured using surveys and behavioural observations.

It should be noted, however, that this type of research requires time and expertise. Subjective safety does not shift in minutes, it evolves over time. Expertise is crucial for crafting the right questions and interpreting behaviour. Both factors may limit a valuable subjective evaluation in this study.

Conclusion on Subjective Safety

Although this research primarily focuses on objective safety, subjective safety remains an important consideration for understanding cycling behaviour and user needs. Due to its complex and time-intensive nature, fully integrating subjective safety into this study lies beyond its current scope. Nevertheless, it is acknowledged as a relevant direction for future product development and evaluation.

2.3 EXPECTATIONS

While section 2.2 outlined how cycling safety is measured, this section turns to what can objectively be expected in the coming years, drawing on expert insights and recent developments.

2.3.1 Sustainability and Mobility

Sustainability in mobility is becoming an urgent priority as Europe strives to achieve climate neutrality by 2050 under the European Climate Law. While many sectors have made significant strides in reducing emissions, the mobility sector remains a major contributor to greenhouse gas emissions, accounting for 25% of the EU's total in 2022 (European Environment Agency, 2024). Cities are at the forefront of this transformation, adopting car-free initiatives and promoting cycling as a sustainable alternative to motorized transport. This chapter examines these trends and their implications for urban mobility.

Efforts to decarbonize transport focus on expanding cycling infrastructure, enhancing public transportation, and increasing the use of low-emission vehicles. Cycling plays a central role in this shift due to its zero-emission nature, health benefits, and potential to reduce urban congestion. Car-free initiatives are being embraced across Europe, with cities like Amsterdam and Paris leading the way in reclaiming public spaces from cars and prioritizing pedestrian and cycling infrastructure (Schmidt, 2024). Though "car-free" often means reducing rather than eliminating cars, the focus on sustainable alternatives like cycling is improving air quality, optimizing public space, and fostering healthier lifestyles (Johnson, 2024).

The mobility sector's transition toward sustainability is essential for achieving Europe's climate goals. By prioritizing cycling and car-free zones, cities are demonstrating how sustainable urban mobility can benefit both the environment and public health. These changes lay the groundwork for cleaner, greener, and more equitable cities.

2.3.2 Traffic Safety

The growing popularity of cycling, particularly e-bikes, is transforming mobility in Europe. However, this growth is accompanied by rising safety concerns, as accidents and fatalities increase alongside the diversification of bike types and the aging population. This chapter explores key issues in traffic safety, including the integration of e-bikes, the rise in cycling accidents, debates around helmet laws, the interplay between innovation and policy, and the need for improved infrastructure in emerging cycling nations.

E-bikes are revolutionizing cycling, offering flexibility and cost-effective alternatives to cars. Yet, their rapid adoption has contributed to an increase in cycling accidents, especially as aging populations and differing bike speeds exacerbate risks (Verkeerskunde, 2024). To address this, organizations like SWOV and Fietsersbond are advocating for improved safety measures, but government action is crucial (Fietsersbond, 2023).

The diversification of bike types, from pedelecs to cargo bikes, adds complexity to safety regulations and infrastructure design. Meanwhile, debates over mandatory helmet laws highlight the balance between individual responsibility and systemic safety measures. The Dutch House of Representatives has already voted for helmet requirements for fatbikes and children under 14, though enforcement remains challenging (NOS, 2024b). Stan Alewijnse, behavioural psychologist at Team Alert, suggests implementing helmet mandates now for e-bikes, as habits are not yet entrenched (own communication, 16 October 2024). This is supported by Floske Weehuizen, policy advisor at Verbond van Verzekeraars, mentioning the real problem of not using helmets on a bike is the behaviour of people who think that nothing will happen to them (own communication, 15 October 2024). This confidence makes it very hard to bring about behavioural change.

An intriguing insight from an interviewed policy officer at the Ministry of Infrastructure and Waterworks is that laws and regulations can be adapted in response to innovative products that improve cycling safety. For instance, if new technologies or accessories, such as different ways of using bike lights like Ziemi, demonstrate measurable safety benefits, policymakers may adjust regulations to encourage their adoption (Ziemi, n.d.). This highlights the symbiotic relationship between product development and policy evolution, where innovation can drive regulatory shifts. For companies in the cycling industry, this presents an opportunity to influence the regulatory environment by focusing on innovation.

In emerging cycling nations, investments in infrastructure, including dedicated bike lanes and safe intersections, are key to fostering safer cycling environments (Küster & Schusta, 2023; Pucher & Buehler, 2016). These improvements not only accommodate the growing number of cyclists but also reduce the risks associated with shared spaces in urban areas.

Traffic safety remains a critical concern as cycling continues to grow in popularity. Addressing rising accidents requires a multifaceted approach that includes infrastructure improvements, safety regulations,

innovation-driven policy adjustments, and public awareness campaigns. By prioritizing these measures, governments and companies alike can ensure that cycling remains not only a sustainable but also a safe mobility option for all. Furthermore, companies developing innovative safety solutions have a unique opportunity to shape both market trends and regulatory frameworks, advancing the overall safety of cycling ecosystems.

2.3.3 Social and Societal developments

Demographic trends, such as aging populations (with Figure 16, showing that the Dutch population will only get older in the next 15 years), urbanization, and shifting work patterns, are reshaping mobility and cycling across Europe. These changes present both opportunities and challenges, from improving access to cycling for the elderly to addressing rising healthcare costs and adapting to new urban realities.

E-bikes are empowering aging populations to remain active, but their physical vulnerability increases the risk of severe injuries, underscoring the need for prevention programs like Doortrappen. Urbanization is driving demand for sustainable mobility solutions, with concepts like the 15-Minute City promoting compact, mixed-use neighbourhoods where cycling replaces car use (European Commission, 2020).

Remote work trends are shifting cycling patterns from commuting to leisure and exercise, emphasizing the need for recreational infrastructure (Haan, 2023). Meanwhile, rising healthcare costs tied to aging populations highlight the importance of preventive measures, such as fall prevention and safe cycling practices, to reduce strain on healthcare systems

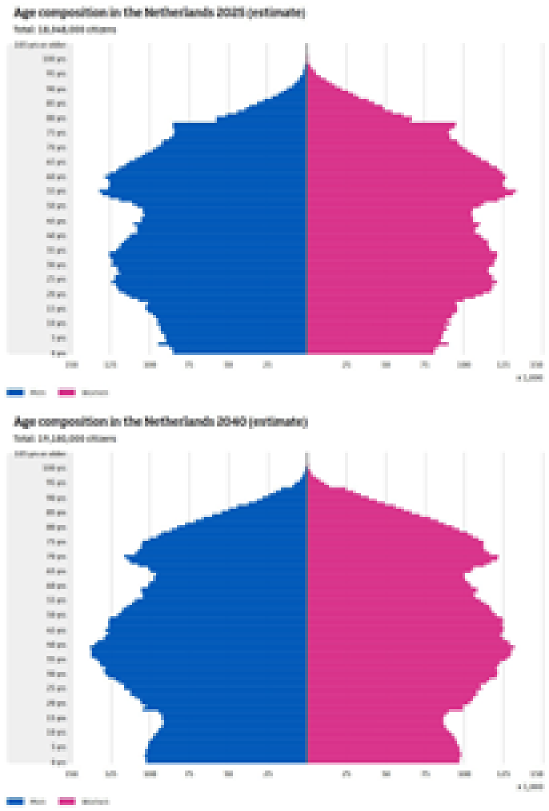


Figure 16. Population pyramid, 2025 vs. 2040 (CBS, n.d.)

(RIVM, 2022; Ministerie van Volksgezondheid, Welzijn en Sport, 2024).

Demographic changes are transforming cycling behaviour and infrastructure needs. By focusing on prevention, inclusive urban planning, and recreational cycling, governments and communities can ensure that cycling supports both individual well-being and societal goals.

2.3.4 Technological Innovations

Technological advancements are driving significant changes in cycling, enhancing safety, performance, and integration with broader mobility systems. From smart and connected bikes to Mobility as a Service (MaaS) and e-cargo bikes, these innovations are reshaping how people move within cities. This chapter explores the role of technology in the future of cycling.

Advancements in cycling technology include smart bikes, connected ecosystems, and self-balancing designs (Figure 17) (TU Delft, 2019). Features like AI-powered hazard detection, predictive maintenance, and anti-lock braking systems (ABS) enhance safety and performance. These innovations are making cycling safer and more accessible, particularly for vulnerable groups like the elderly. According to Mark van der Kooi, there is a growing demand for cyclist-related data, which can improve bike design, safety measures, and urban infrastructure planning. He emphasizes the potential of connected bikes to provide valuable insights into cycling patterns and behaviours.

While autonomous vehicles are not expected to significantly impact cycling safety in the short term, smart city technologies like adaptive traffic lights are creating safer urban environments for cyclists. Dr. Hagenzieker explained that full autonomy (levels 3-5) is still far from reality, particularly in mixed-traffic environments with cyclists and pedestrians. She notes that while AVs may function well on highways with streamlined traffic, the complexities of urban cycling interactions remain a significant challenge.

Additionally, MaaS platforms and shared mobility services are integrating cycling into sustainable transport networks, with e-cargo bikes playing a crucial role in urban logistics (Heineke et al., 2023). The 15-Minute City concept complements these trends by emphasizing local, bike-friendly urban planning, encouraging shorter trips and sustainable commuting options.

Technological innovations are revolutionizing cycling, making it safer, more efficient, and better integrated with sustainable mobility systems. As cities embrace these advancements, the future of cycling promises to be smarter, safer, and more connected, contributing to the broader goals of sustainable urban mobility.

Figure 17. Self-balancing bike (TU Delft, 2019)

2.4 CONCLUSION

This chapter set out to answer two key questions: *What are the main factors influencing cycling safety in the Netherlands and Europe today, and how has the rise of electric bikes impacted overall risk levels?* And: *How is cycling safety expected to change in the coming years based on trends in mobility, infrastructure, demographics and technology?* Through an analysis of current statistics, policy initiatives, stakeholder insights, and broader societal and technological trends, this chapter has provided a comprehensive view of the evolving cycling safety landscape.

The findings indicate that while cycling continues to grow as a sustainable and healthy form of mobility, safety risks have also increased; particularly due to the rapid adoption of e-bikes and the ageing population. These developments highlight the need for improved infrastructure, more consistent accident reporting, and behaviourally informed safety strategies. Looking ahead, cycling safety will be shaped by a combination of demographic change, urban development, innovation in product and system design, and the evolving role of public policy.For BBB Cycling, this shifting landscape presents both a responsibility and an opportunity. The growing emphasis on safety, both objective and perceived, creates space for innovation in products and materials, as well as in user communication and design. Below some key takeaways are presented.

Key takeaways, specifically for BBB Cycling:

Safety concerns and opportunities:

- The rise in cycling fatalities, especially among e-bike users and elderly riders, calls for enhanced safety measures. This can include high-quality helmets, reflective gear, and advanced lighting solutions.
- The attitude of cyclist towards safety promoting products is a concern, since a lot of people are convinced, nothing will happen to them. Finding a way to persuade people to use these products is important.
- Possible helmet laws for e-bikes in countries like the Netherlands present opportunities to anticipate, by offering a variety of helmets for different target groups.

Technological innovations:

- Advances in smart and connected cycling technology, such as GPS tracking, hazard detection, and AI-driven safety systems, open directions for innovative products.
- Accessories like connected helmets, navigation devices, and advanced locks can meet growing consumer demand for data-driven and safety-enhancing solutions.

Demographic trends and urbanization:

- Aging populations and the rise of e-bikes emphasize the need for accessible and ergonomic accessories tailored to older cyclists, such as self-balancing aids and fall-prevention tools.
- Increased healthcare costs require to focus on preventive measures. As more people are cycling and recreational cycling increases, it keeps people fit, but also increases the risk of injuries.

3. BBB CYCLING AND POSSIBLE INTERNAL OPPORTUNITIES

This chapter provides an analysis of BBB Cycling's internal operations and areas for improvement, including its structure, historical evolution, and current position within the industry. Tools like the SWOT analysis and the Corporate Brand Identity Matrix, are used to assess BBB's strengths, weaknesses and opportunities. Alternative design approaches and an implementation strategy are proposed to improve BBB's innovation capacity, brand identity and long-term vision.

3.1 COMPANY ANALYSIS

3.1.1 Company Structure

BBB Cycling designs, develops and sells about 1,500 cycling parts and accessories, excluding bicycles. Founded in 1998 by two former professional cyclists, it began importing products from Taiwan and selling directly to dealers under the name Augusta.

In 2015 it was acquired by Pon Holdings, a Dutch conglomerate in the mobility sector (see section *Exploration of Pon Holdings* on the next page), bringing expectations for a more premium positioning, though operations remained mostly unchanged.

As online sales grew over the last decade, BBB expanded to online dealers and marketplaces, adding a dedicated department. The company now has a structured organization, as shown in Figure 19. All departments are closely related to each other and to its stakeholders. There are several ways BBB offers its products to the consumer. In the middle the focus is on the offering via distributors and dealers, whereas the left side highlights sales via marketplaces and the right side shows B2C sales via its own website.

BBB operates efficiently and systematically, aligning somewhat with Weber's concept of rational-legal bureaucracy (Pugh & Hickson, 2007). This structure ensures well-defined roles, clear procedures, and operational stability. The company has a team of around 50 dedicated

Originally abbreviated humorously from "Bills, Bike, Babes," the name was changed to BBB Cycling for a more professional image. Over time BBB professionalized, moving from rebranding to in-house design and development.

Figure 18. Old product box

employees. However, while Weber's bureaucratic model emphasizes efficiency through structure and consistency, modern organizations also require a strong strategic vision to remain competitive.

3.1.2 Legacy of a Wholesaler

BBB Cycling's current operations reflect a transition from its origins as a wholesaler to a branded company. However, its way of working continues to align more closely with its wholesale past. Following Mintzberg's Machine Bureaucracy model, the company prioritizes efficiency and standardization over innovation. Product development is driven more by dealer demands than by consumer insights (Lunenburg et al., 2012). Mintzberg highlights that such structures, although effective for operational consistency, can hinder responsiveness to market shifts.

Nonetheless, dealers value BBB's strong relationships, product availability, and responsive service. These strengths create a solid base for future improvements. However, the company lacks a clear design vision and consistent internal brand identity. Internally, perceptions of the brand vary, some see BBB as a sporty brand, others as comfort focused.

Over time, BBB developed its own brand but keeps functioning like a wholesaler rather than a design-driven company. Relying mainly on dealer collaboration, with the slogan "we do it together", it lacks a clear long-term vision and brand identity.

Although this dealer focus is valued high by the dealers, it can neither be seen as a clear design vision nor as a long-term plan.

Though profitable and efficient, BBB's brand strength is weak. As managing director Rick de Jong puts it, "BBB is the brand you own but you do not know." Cyclists often use BBB products unknowingly, and it is frequently seen by dealers as a default rather than a premium option. Under Pon's ownership, BBB is expected to elevate its brand status while maintaining reliability and dealer trust.

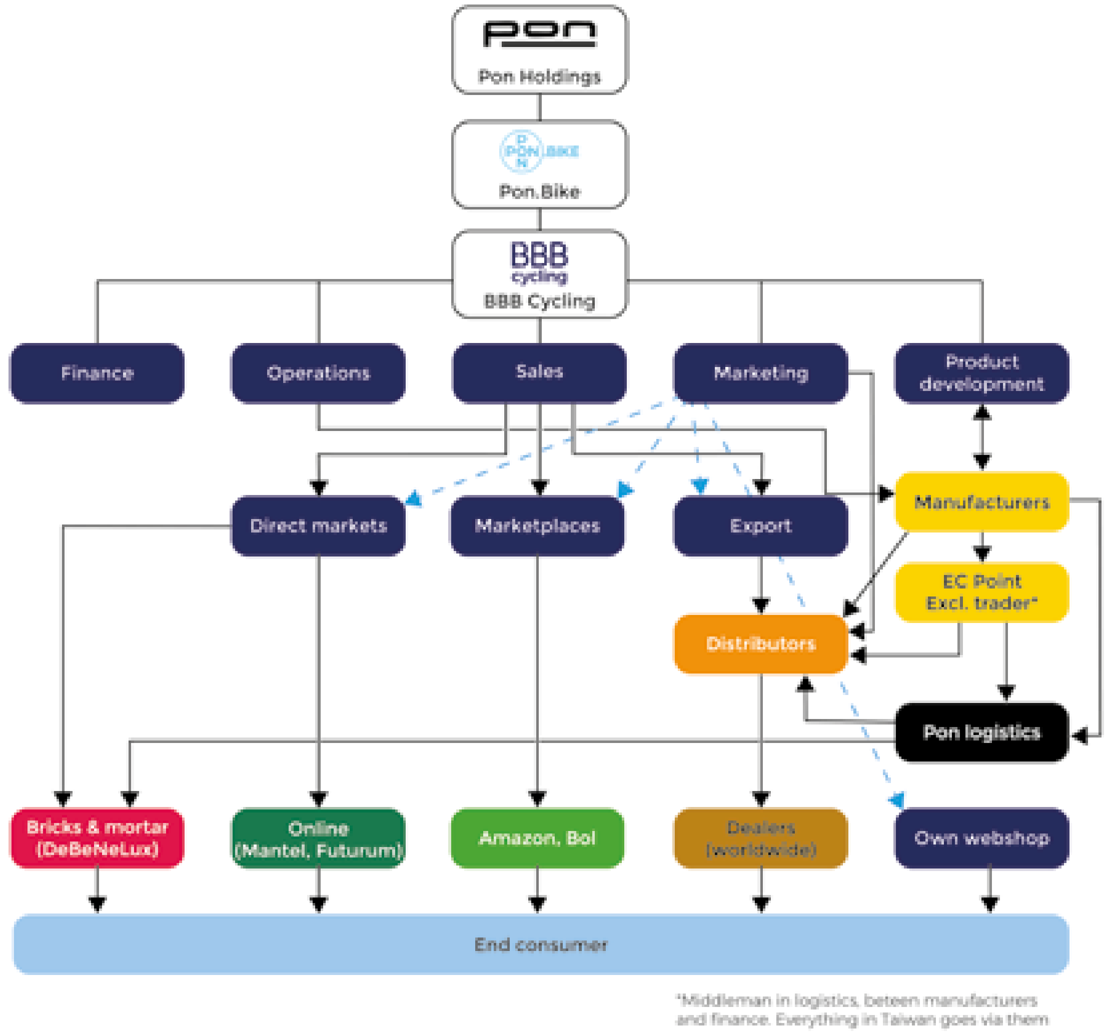


Figure 19. Organizational chart

Explanation of Pon Holdings

Pon Holdings is a Dutch family-owned company and one of the largest businesses in mobility, technology, and industry worldwide. The structure of Pon is divided into various divisions that operate in different sectors:

Pon Automotive: *this is one of Pon's most well-known divisions and includes the import, distribution, and sale of cars and commercial vehicles from brands such as Volkswagen, Audi, Porsche, SEAT, and Škoda in the Netherlands.*

Pon.Bike: *this division focuses on the bicycle industry and includes well-known brands such as Gazelle, Cervélo, Kalkhoff, Urban Arrow, and Santa Cruz. Pon.Bike is one of the largest players in the global bicycle market.*

Pon Equipment & Power Systems: *this division supplies and maintains machinery and engines, including the distribution of Caterpillar construction and mining equipment in the Netherlands and Scandinavia.*

3.1.3 Sales-Driven Culture and Its Impact on Innovation

BBB's product developments are very sales-driven rather than development-driven, focusing on updating existing products based on sales data and dealer requests. While this approach ensures a broad product portfolio, it limits BBB's ability to develop unique, innovative products. New products are designed with the identities 'smart', 'functional' and 'value for money' in mind, and are expected to reflect at least two of these, as illustrated in the Venn diagram in Figure 20.

The portfolio is maintained at a steady size, replacing older products rather than expanding endlessly. This continuous renewal demands considerable effort and leaves limited time for focussing on individual product development. Projects are often fast-tracked, causing dissatisfaction among designers. They note that products typically reach a satisfactory level only after three or four iterations. This limited iteration time and absence of long-term vision complicate true innovation. Internally it is acknowledged that BBB prefers adopting proven innovations over creating new ones. However, managing director Rick de Jong, warns: "If we do not innovate, we become interchangeable."

Despite these limitations, there is genuine interest in innovation within the product development team. Each year, two to three interns are given the opportunity to explore a

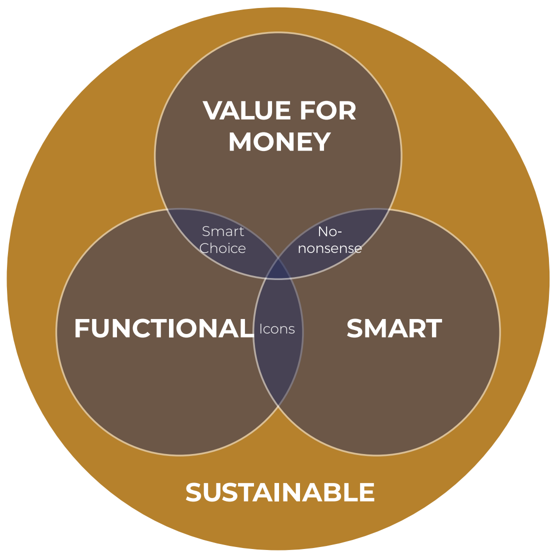


Figure 20. Identities Venn Diagram

specific direction fully and come up with an innovative product. This has led to successes in the past, most notably the DoubleShot mini pump, an innovative product for which BBB even won a Red Dot award (Figure 21). However, realizing such products within the current structure, remains difficult. BBB often hesitates to develop more premium products, fearing misalignment with its price/quality brand identity. As a result, high-end concepts are often downgraded to fit the current brand positioning.

This reflects a deeper confusion within the company. While the identity pillars define product qualities, they don't express what the BBB brand itself stands for. Without a clear long-term vision or direction within product development, aligning efforts across the company remains a significant challenge.

Figure 21. DoubleShot minipump

3.1.4 Internal Misalignments and Process Limitations

Conversations within the company indicate that there is an imbalance between departments, particularly around collaboration, expectations, and brand perceptions (most notable the discussion if BBB is mainly a sporty brand or also suited to step into the comfort segment).

While product designers recognize the company's sales-driven innovation culture, many others view BBB as innovation-driven, seeing as a highly innovative company. This perception gap results from unclear communication and limited cross-department interaction. Although managers meet, discussions are mostly top-down, leaving employees with little insight in each other's work. Unlike in the past, this causes a lack of awareness about product launches. This is clear in the absence of shared drawings, renders and photos within the office that show what is being designed and developed.

As a result, there is confusion over ownership, who owns the BBB brand, and who is responsible for what? This is visible in the absence of a structured feedback culture. Designers typically receive feedback from other departments only after a design is fully developed. Unfortunately, this feedback tends to reflect personal opinions rather than constructive input, leading to discussions or tension rather useful improvements.

This issue stems from imbalance between departments, but also from a missing design process. Product development is primarily sales-driven and not based on clearly defined problems or a strong understanding of the end user. Consumer demand is assumed rather than researched, and the focus lies in updating existing products rather than addressing new or validated needs.

In short, BBB Cycling's wholesale legacy has resulted in a sales-driven culture and an unclear brand identity. The lack of unified vision, clear design process, and strong communication limits innovation and alignment with common goals. Despite enthusiasm within the product development team, cultural and structural changes are essential for BBB to become a design-driven competitive company.

3.1.5 Position in Cycling Industry

The bike manufacturing industry is a highly interconnected supply chain, where manufacturers, suppliers, and dealers work closely to bring products to market. OEM's (original equipment manufacturers) supply parts pre-installed on bicycles (e.g. Shimano or SRAM shifters), while other companies focus on replacement parts or aftermarket accessories. This dependency contributed to supply chain issue during the Covid pandemic, when cycling parts could not meet buyer demand.

BBB, positioned in the middle of this supply chain, primarily offers aftermarket products like helmets, glasses, apparel, and replacement. This position creates challenges in market visibility and product adoption. BBB products are not standard on bicycles but are added later by consumers, relying heavily on dealers and end-users to actively choose them (Figure 23). Bart Bluemink noted: "BBB is finding itself at the end of the distribution chain, which means their products should add direct value to the user, making it very important that BBB distinguishes itself with unique products, meeting the end user's needs" (personal communication, 10 October 2024).

This dynamic makes competing with OEM-integrated brands difficult, especially in the competitive safety and accessories market. Without OEM integration, BBB products are seen as optional rather than essential, limiting consumer reach.

As seen in Figure 22, BBB has no direct connection to bike manufacturers and distributes its products via the same distributors and retailers as the bikes produced in the other part of the chain.

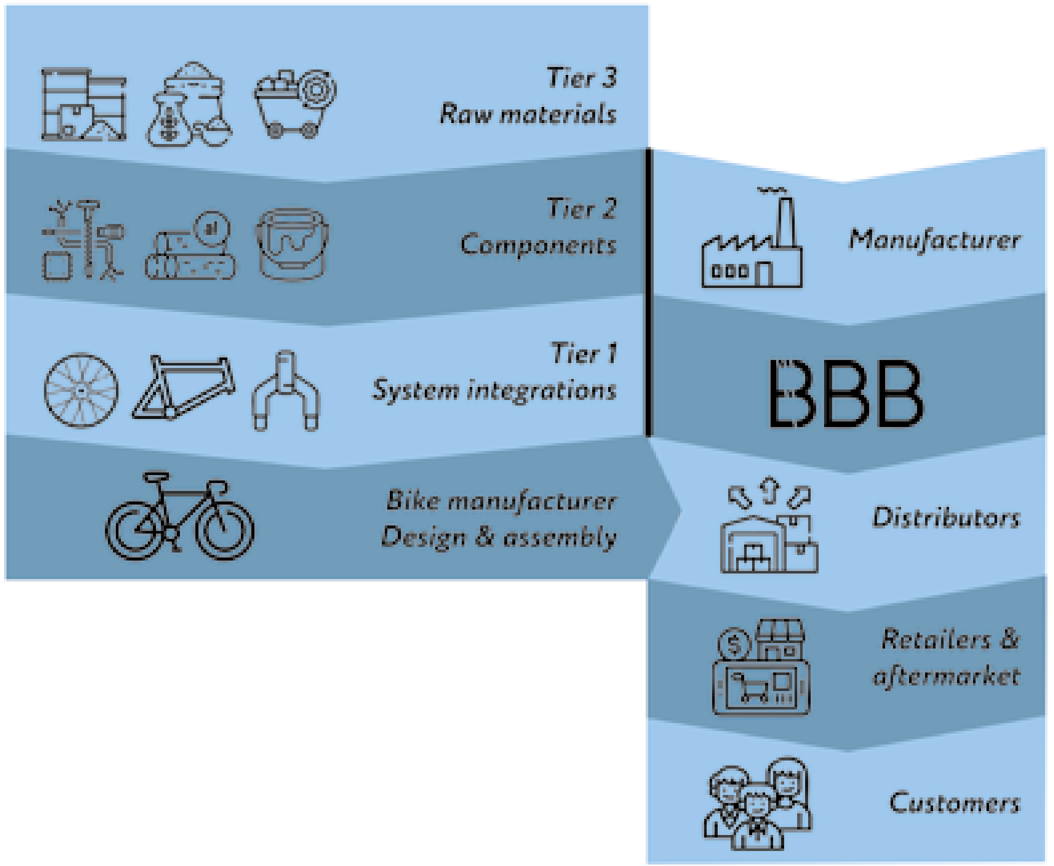


Figure 22. Cycling industry chain

Figure 23. BBB's in-store walls

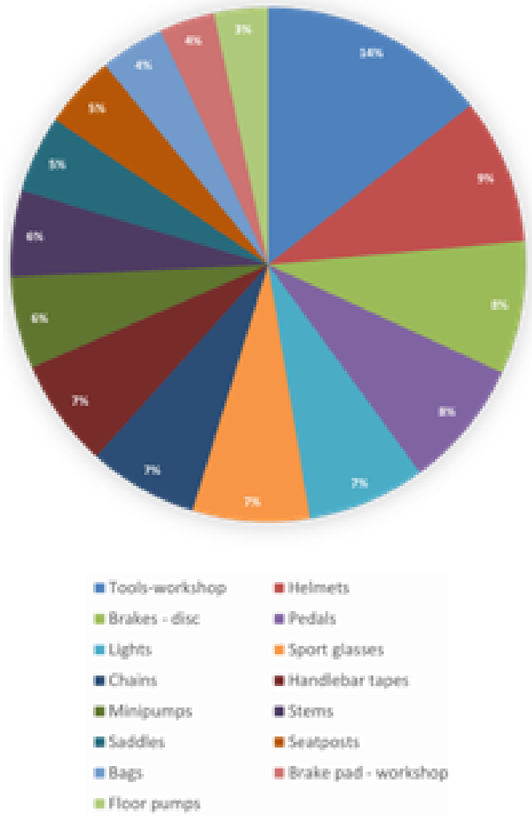


Figure 24. Top Categories in Sales volume

3.1.6 Portfolio Analysis

BBB Cycling's product portfolio is segmented into four main categories: parts, apparel, accessories & tools. Within these segments, the company primarily focuses on the key product groups helmets, saddles, pedals, tools, pumps, lights, glasses, and apparel (Figure 25). These categories represent the core of BBB's offerings and are crucial in meeting the diverse needs of cyclists across different disciplines.

Among these, certain product groups stand out as the best-selling categories. Figure 24 presents a visual overview, showing that tools, helmets, and brakes lead in sales, with lights and glasses also ranking highly. This indicates that BBB Cycling performs particularly well in the safety product segment, as many of its top-selling items contribute to rider protection and visibility. The strong demand for these products reinforces BBB's reputation for delivering high-quality, reliable cycling gear.

Currently, BBB Cycling operates with a team of approximately 50 employees, including a dedicated product development team that continuously updates and refines the product lineup. The brand's reach extends to over 35 countries, making it a well-recognized name in the cycling industry. A big part of BBB's sales remains concentrated in the Benelux region and Germany, where the company has a well-established distribution network with over 1000 dealers.

Figure 25. BBB Cycling main product category overview

Pon.Bike network

As explained previously, BBB was aquired by Pon Holdings and is now part of Pon.Bike specifically. This nework consists mostly of bicycle manufacturers, with BBB Cycling, OneUp, and Nimbl focused on parts and apparel.

It maintains a balance between sports and comfort brands while expanding into mobility services in recent years.

Later in the report, collaboration possibilities within the network will be discussed in detail.

Figure 26. Pon.Bike Portfolio

3.1.7 Sustainability within BBB Cycling

In recent years BBB Cycling has taken significant steps toward Corporate Social Responsibility (CSR) by implementing a sustainability-driven company mission. It focuses on developing long-lasting products to reduce waste and the demand for new raw materials. Additionally, BBB integrates sustainable materials, such as recycled plastic for fenders and bio-based plastic for eyewear, minimizing its environmental impact. Packaging is also optimized by reducing plastic use and incorporating recycled cardboard, aligning with the company's efforts to lower its ecological footprint (Figure 27).

To help consumers make more sustainable choices, BBB has introduced the 'Smart Choice' label, which highlights products designed with sustainability in mind. Recently, BBB received the Thuiswinkel Sustainability Certification, for which the company was independently assessed on six sustainability themes: sustainable strategy, circular economy, sustainable product range, packaging, delivery and returns . Through these initiatives, BBB Cycling not only enhances its environmental responsibility but also strengthens its brand identity as a sustainable company and brand.

To showcase its sustainability focus pilars are placed in the office, shown in Figures 28 and 29.

Figure 27.Smart packaging

Figure 28. Detailed view on sustainability pillars in the office

Figure 29. Sustainability pillars in the middle of BBB's office

3.1.8 Competitor Analysis

This project focuses on cycling safety, with helmets and lighting selected as the two main safety categories for analysis. These are also key categories for BBB, making them a natural focus. Both helmets and lighting are essential for protecting cyclists from injury and enhancing visibility on the road. As a result, these highly competitive markets, with brands positioning themselves across different price points and levels of innovation. The matrix illustrates how BBB is generally positioned relative to its competitors in terms of brand and product image. Given the extensive portfolios of all brands, a separate matrix could be created for each individual product.

Helmet market overview (Figure 30)

The helmet category is dominated by premium brands such as POC, Kask, and Giro, which offer and test new technologies, aerodynamic designs, and lightweight materials. These brands cater to performance-driven cyclists and professionals. In contrast, brands like Decathlon and BBB focus on affordability, ensuring reliable protection at a lower price point. Lazer and MET occupy the middle ground, combining good safety technology with moderate pricing, while ABUS distinguishes itself by offering both high-range and mid-range helmets with innovative features at a more accessible price point.

Lighting market overview (Figure 31)

The lighting category is shaped by technological advancements and visibility standards. Garmin leads the high-end market, integrating radar sensors and smart connectivity into its lighting systems, making it the most premium and innovation-driven brand in this segment. Lezyne, Cateye, and Knog follow BBB as strong mid-range competitors, offering high-lumen, rechargeable, and durable lighting solutions. In contrast, AXA, and Decathlon focus on affordability and functionality, catering to commuters and everyday cyclists who need reliable but straightforward lighting solutions.

The lighting market is shifting towards smart, connected systems, indicating that BBB could differentiate itself by either integrating smart lighting technology or by emphasizing rugged, long-lasting solutions with extended battery life. AXA's stronghold in e-bike lighting, due to OEM assembly, also suggests a potential growth area for BBB.

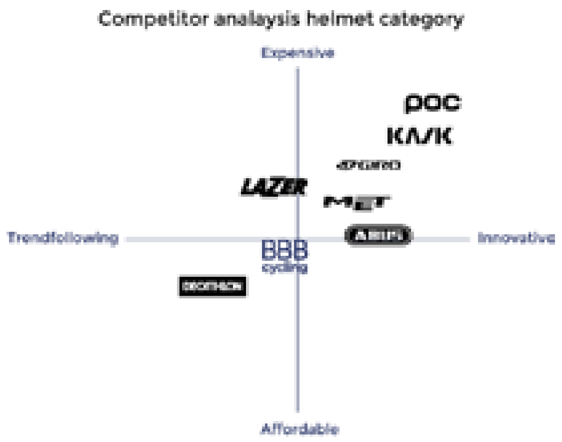


Figure 30. Competitors helmet category

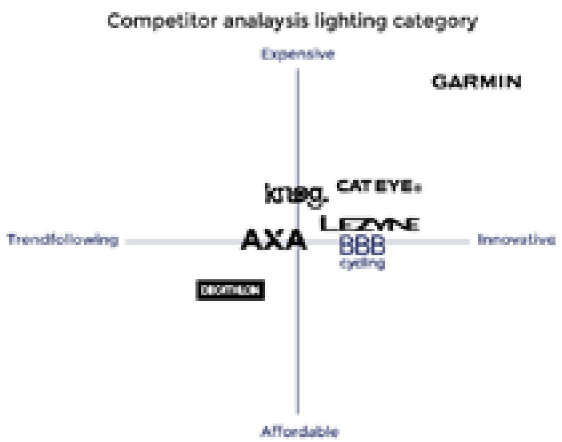


Figure 31. Competitors lighting category

3.1.9 SWOT

The following overview presents the key findings from the SWOT analysis, summarized in Figure 32. The traits identified in this analysis are based on internal evaluations, dealer feedback, brand identity assessment, competitor benchmarking, and industry trend analysis.

Strengths

BBB Cycling has a broad product range, offering 1,500+ cycling accessories, tools, and apparel. This extensive assortment enables the company to serve a wide range of customers, from casual riders to professionals. The strong price-quality of its products ensures they remain competitive, combining affordability with solid performance.

Another notable strength is the company's Dutch design heritage. Dutch cycling culture is globally respected which boosts credibility. Together with its international reach, BBB operates in over 35 countries, this gives the company visibility and recognition in the cycling world.

BBB also benefits from an extensive and trusted dealer network, which ensures steady distribution and market access. Unlike brands that struggle to reach retailers, BBB's strong dealer relationships contribute to reliable sales.

In addition, the company is a frontrunner in corporate social responsibility (CSR). Its sustainability focus aligns with growing consumer demand for eco-conscious products. This positions BBB ahead of competitors who have yet to embrace CSR fully.

Figure 32. SWOT analysis

Weaknesses

While the broad product range is a strength, it can also be a weakness, as it spreads resources thin and making it challenging to keep all products innovative and up to date. BBB's reliance on a sales-driven rather than a design-led innovation process also limits its ability to create groundbreaking products.

The company is highly dependent on the bicycle industry, which makes it vulnerable to shifts in market trends. However, in economically uncertain times, aftermarket sales often increase as consumers prefer repairing bikes over buying new ones.

BBB's reliance on distributors means limited consumer engagement, which affects brand visibility. In some cases, the brand is seen as a white-label provider, reducing consumer loyalty. This perception limits BBB's ability to build a strong emotional connection with users.

Production is heavily reliant on Chinese (10%) and Taiwanese (80%) production. This dependence increases exposure to supply chain disruptions, like those experienced during the COVID-19 pandemic, and makes differentiation from competitors difficult.

Another internal weakness is the absence of a clear external brand vision and long-term strategy. This leads to inconsistent messaging and misalignment of priorities across teams.

Additionally, BBB's innovation capacity is constrained due to its small design team and reactive product development process. Rather than leading with new ideas, BBB responds to dealer requests, limiting the potential for disruptive innovation.

Opportunities

The growing popularity of cycling, especially e-bikes, represents a significant opportunity for BBB. As more consumers turn to e-bikes for commuting and leisure, the demand for compatible accessories, safety gear, and high-quality components is growing. BBB can respond by developing specialized products for this segment, including smart lighting, helmets, and connected cycling tools.

BBB's sustainability initiatives are well aligned with current market trends. By expanding its green product lines and promoting CSR efforts more prominently, the company can further enhance its reputation and appeal to environmentally conscious consumers.

The Pon Holdings' network presents a strategic opportunity. By collaborating with brands like Gazelle, Kalkhoff, and Cervélo, BBB could integrate accessories directly into premium bikes, increasing both exposure and sales.

Shifts in cycling safety legislation also offer potential. As regulations around helmets, lighting, and visibility become stricter, BBB can position itself as a provider of compliant and certified safety products.

Finally, economic uncertainties may make consumers more price conscious. BBB's affordability combined with quality, makes it attractive to budget-conscious riders.

Threats

The conservative nature of the cycling industry makes innovation adoption slow. While BBB aims to innovate, it must at the same time manage resistance to change.

Inflation and rising costs of resources threaten margins. With production largely overseas, any supply chain disruptions, especially in China or Taiwan, could lead to shortages or higher costs.

Competitors like Shimano, SRAM, and Lezyne are innovating rapidly. If BBB doesn't strengthen its design-led innovation process, it risks falling behind. Moreover, with more brands offering direct-to-consumer (DTC) options and digital marketing strengths BBB's limited consumer engagement puts it at a disadvantage

Reliance on Pon Holdings also brings risk. Should BBB fail to meet expectations, it may face restructuring, reduced investment, or to be sold and as a result shifting focus away from long-term development.

Finally, with technology advancing quickly, BBB must adapt to innovations like smart accessories, app integration, and new materials, or risk being left behind in a rapidly evolving market.

Conclusion on SWOT

BBB Cycling has a strong dealer network, international reach, and sustainable positioning, but struggles with brand recognition, innovation limitations, and supply chain dependencies. There are major opportunities in e-bikes, sustainability, and leveraging Pon's network, but rising competition, inflation, and technological shifts pose risks.

3.1.10 Corporate Brand Identity Matrix

The Corporate Brand Identity Matrix (CBIM) method (Figure 33, next page) structures and analyses a brand's identity, ensuring alignment between internal values, external perception, and strategic direction. By mapping brand elements, BBB Cycling can identify strengths, inconsistencies, and areas for improvement in branding and positioning. The CBIM analysis highlights BBB's strong brand core, dealer-focused strategy, and operational reliability, while revealing areas for strategic refinement.

A key insight is that BBB's mission and vision strongly align with its brand core, reinforcing its role as a dealer-first company. However, rather than defining long-term goals and strategic direction, they primarily describe the company's current way of working. A clearer, forward-looking mission and vision could support internal alignment and provide a stronger strategic foundation for future growth.

The relationship between positioning, competences, and consumer recognition also stands out. BBB is positioned as a solid and problem-solving brand with a strong price-quality balance, yet it lacks consumer recognition. Internal branding, such as personality and dealer relationships, is well-defined, but market positioning needs strengthening.

Finally, the disconnect between competences and innovation is notable. While BBB excels operationally and in dealer relations, its sales-driven culture limits groundbreaking innovation. Linking competences more clearly with positioning and long-term brand strategy could boost consumer engagement.

Figure 33. Corporate Brand Identity Matrix

3.1.11 Conclusion

BBB Cycling is a respected and established player in the cycling accessories market, thriving through a strong dealer network, operational excellence, and a comprehensive product portfolio. The company's attractive price-quality ratio, international reach, and commitment to sustainability create a powerful platform for future growth and success. While its wholesale legacy, sales-driven culture, and missing long-term vision offer opportunities for refinement, they also highlight areas where innovation and consumer engagement can be enhanced.

The competitor analysis of helmets and lighting highlights show that BBB holds a strong position in the affordable and mid-tier market segment, competing with premium and innovation-focused brands. BBB's dealer-first philosophy serves as a unique strength, while emerging markets, direct-to-consumer brands and tech-savvy brands are helping to shape the evolving market for smart safety solutions. Insights from the Corporate Brand Identity Matrix (CBIM) and SWOT analysis highlight promising areas for growth, particularly in sharpening brand positioning, strengthening internal cohesion, and embracing design-led innovation.

By building on its sustainable efforts, elevating its brand identity, and aligning internal operations with a clear strategic direction, BBB is well positioned to evolve from a dealer-oriented wholesaler into a highly recognized, consumer-centric brand. As competition intensifies and technology continues to transform the market, BBB has a valuable opportunity to lead with a focus on safety, sustainability, and smart product innovation.

3.2 POTENTIAL OTHER WAYS TO DESIGN

3.2.1 User-Centred Design

User-Centered Design (UCD) provides BBB Cycling with the opportunity to develop products that truly align with the needs and desires of their customers (Norman, n.d.). By placing end-users at the heart of the design process, products become more intuitive, user-friendly, and relevant to the target audience. For a brand like BBB Cycling, operating in the competitive market of bicycle components and accessories, this is crucial for fostering customer loyalty and building a strong brand.

UCD bridges the gap between product development and actual user experience, ensuring that cyclists receive products that truly meet their expectations. This approach includes creating personas that represent key user groups. By integrating personas into the design process, BBB Cycling can better anticipate user challenges and deliver solutions tailored to their preferences and requirements.

For BBB Cycling, applying UCD and incorporating personas means creating products that are better received and enhancing their reputation as an innovative and customer-focused brand. This differentiation can deliver value to both customers and the company itself.

3.2.2 Clear strategy and engagement

A clear design strategy is critical not only for market positioning but also for creating internal clarity and direction. This shared understanding among employees prevents fragmented efforts and promotes effective collaboration across departments. Aligning design and marketing teams under a unified strategic framework ensures that products meet customer needs while being consistently positioned in the market. This alignment enhances efficiency, reduces conflicting priorities, and supports better decision-making.

3.2.3 Clear Product Design Method and Design Environment

A structured product design methodology, encompassing stages such as ideation, validation, prototyping,marketing,development, launch, and improvement, streamlines the entire development cycle. Systematic methods allow for the integration of user needs and market insights, ensuring products remain relevant and competitive. Importantly, a methodical approach ensures that feedback loops optimize product iterations, improving outcomes over time.

In parallel, fostering employee engagement and a feedback-driven culture is essential for successful product development. When employees feel accountable and involved, the quality of their work improves, and collaboration strengthens. A constructive feedback culture encourages open dialogue, mutual respect, and problem-solving, which leads to better-aligned and higher-quality products. Moreover, engagement through a transparent design environment, where ongoing projects are visible, enables collaboration, prevents duplication of effort, and accelerates innovation.

A design environment where all employees are aware of ongoing projects promotes transparency, collaboration, and consistency. This prevents duplicated efforts, accelerates innovation, and enhances employee engagement. Additionally, clarity within the design

3.3 IMPLEMENTATION

3.3.1 Reasons for Change

BBB's acquisition by Pon Holdings in 2015 introduced expectations for premium branding and closer alignment with Pon's portfolio. In recent years, BBB has aimed to move towards a more premium market position, but without significant strategic changes, achieving this goal will remain challenging.

To align more closely with Pon's premium portfolio, BBB could foster collaboration with other Pon brands such as Gazelle and Kalkhoff, leveraging their innovative capabilities and earlier value chain positioning. Furthermore, increased investment from Pon will be necessary to support BBB's transformation into a premium brand. Integration opportunities, such as equipping Pon's Gazelle bikes with BBB-branded saddles, pedals, or bells, could also strengthen brand cohesion across the portfolio.

Without such efforts, BBB risks stagnation and could face adverse outcomes, such as being sold to an investment company focused solely on profitability. A proactive approach is essential to maintaining relevance in the market and aligning with Pon's strategic direction.

3.3.2 What can be changed?

To secure its position in the market and align with Pon's strategic portfolio, BBB Cycling must adopt several fundamental changes to its processes and structure. These changes are essential not only for maintaining relevance with end consumers but also for ensuring a stronger position within Pon's brand ecosystem.

Firstly, BBB needs to develop a cohesive and long-term vision that has broad support within the company. This vision should clarify the company's priorities, aspirations, and overall direction, enabling employees across departments to work toward shared goals. A strong vision also provides a foundation for strategic planning, helping the company decide which product categories to prioritize and which to maintain with minimal effort.

Additionally, strengthening BBB's brand identity is critical. This involves answering key questions such as: What does the BBB brand stand for? What can customers consistently expect from it? Establishing a distinct and consistent brand identity ensures that both internal stakeholders and external audiences clearly understand BBB's value proposition.

A step towards the higher-end segment

BBB has already initiated brand differentiation strategies for international markets. Last year, the company got the rights to sell product on the US and UK markets under the brand name "Fabric", a brand that used to be highly innovative in the past, which was aquired by Cannondale (a Pon.Bike partner). Over the years Cannondale abondonded the name Fabric, chosing to sell the products under its own name. Now that this brand name was availbale, BBB takes the opportunity to breath new life into the brand, with the aim of selling higher end products on the markets Fabric will be active in.

Furthermore, BBB is looking into possibilities to support the Pon.Bike partners in developing high-end apparel.

Another vital change involves implementing a standardized design process that incorporates collaboration across departments. This includes shifting from a purely sales-driven approach to a more design- and user-focused methodology. Engaging other departments during product development fosters creativity and ensures alignment across marketing, sales, and product teams.

Finally, fostering a feedback-driven culture is essential for continuous improvement. Encouraging employees to provide and act on constructive feedback promotes accountability, enhances collaboration, and supports innovation. Equally important is improving internal communication,transparency about ongoing projects and roles ensures alignment, motivates employees, and builds trust.

3.3.3 Unified design process

BBB's current design process more or less follows the following steps, visualized in Figure 34:

- Improvement/Ideation
- Validation
- Prototyping and Development
- Marketing
- Launch

While this structure serves as a foundation, it has notable shortcomings. For example, marketing is often involved before development is finalized, which can lead to misaligned expectations and challenges during product launches. Additionally, combining ideation and improvement into a single step limits the creative exploration of new concepts and hinders targeted refinements.

To address these issues, the following adjustments are recommended, visualized in Figure 35:

- Separate Ideation and Improvement: by treating ideation and improvement as distinct phases, BBB can encourage creativity early in the process while focusing on targeted refinements later. This separation ensures that innovative ideas are fully explored, and products meet high-quality standards before launch.
- Align development and marketing by making sure marketing efforts follow product development to ensure messaging accurately reflects the product's capabilities. This alignment minimizes miscommunication, enhances product positioning, and supports more successful launches. Involving marketing early can also give extra input to the design process, as marketing is often aware of market trends and the marketing strategies of competitors.
- Incorporate user-centred validation: validation and improvement phases should focus on user testing to ensure products meet customer needs.
- By integrating tools such as personas and real-world testing, BBB can gain deeper insights into user expectations and challenges, leading to better-aligned products.

Implementing these changes would allow BBB to operate with greater efficiency and innovation, ensuring products are market-aligned, user-focused, and reflective of the company's strategic goals. A unified design process fosters collaboration across departments, supports clearer communication, and strengthens BBB's position within Pon's portfolio and the broader market.

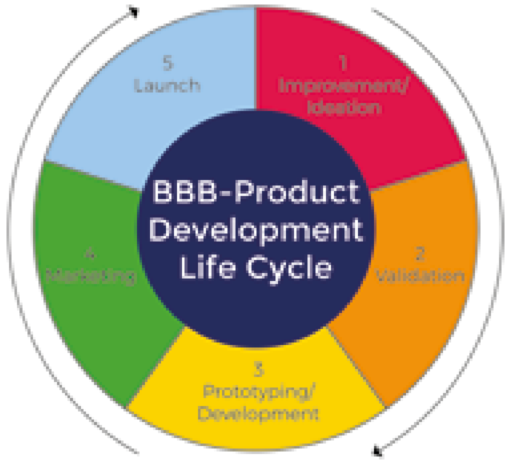


Figure 34. BBB-Product Development Life Cycle as it is now

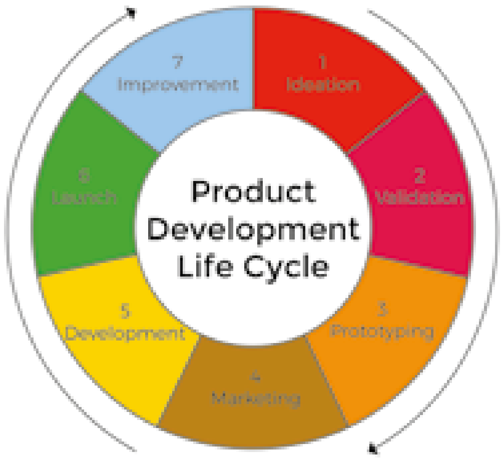


Figure 35. Product Development Life Cycle, edited from Upsilon (2023)

3.4 CONCLUSION

BBB Cycling is a respected and established player in the cycling accessories market, thriving through a strong dealer network, operational excellence, and a comprehensive product portfolio. The company's attractive price-quality ratio, international reach, and commitment to sustainability create a powerful platform for future growth and success. While its wholesale legacy, sales-driven culture, and missing long-term vision offer opportunities for refinement, they also highlight areas where innovation and consumer engagement can be enhanced.

The competitor analysis of helmets and lighting highlights that BBB holds a strong position in the affordable and mid-tier market segment, competing with premium and innovation-focused brands. BBB's dealer-first philosophy serves as a unique strength, while emerging markets, direct-to-consumer brands and tech-savvy brands are helping to shape the evolving market for smart safety solutions. Insights from the Corporate Brand Identity Matrix (CBIM) and SWOT analysis highlight promising areas for growth, particularly in sharpening brand positioning, strengthening internal cohesion, and embracing design-led innovation.

By building on its sustainable efforts, elevating its brand identity, and aligning internal operations with a clear strategic direction, BBB is well positioned to evolve from a dealer-oriented wholesaler into a highly recognized, consumer-centric brand. As competition intensifies and technology continues to transform the market, BBB has a valuable opportunity to lead with a focus on safety, sustainability, and smart product innovation. To support this transition, BBB could benefit from adopting a more structured design process and cultivating a company culture that encourages creativity, transparency, and cross-functional collaboration. As described, implementing a user-centered design approach may help align product development more closely with end-user needs, improving product relevance and overall customer satisfaction. Clearly defined personas, validated testing methods, and transparent design environments might contribute to a stronger market fit and internal cohesion.

In addition, several structural and cultural adjustments might be needed to better align BBB's strategy with Pon's premium brand ecosystem. Establishing a unified, forward-looking vision and a consistent brand identity could help guide internal priorities and external perception. Separating ideation from improvement, involving marketing earlier in the development cycle, and fostering a feedback-driven culture may further support innovation, alignment, and engagement. These shifts could help BBB respond more effectively to future market demands and enhance its position within the broader Pon.Bike portfolio.

4. FINDING A SEARCH AREA

An essential step in the Delft Innovation Method (DIM) is defining various search areas. According to Buijs (2012), "search areas are coherent parts of the future competitive environment, in each of which the innovating company sees potential to find new, unsatisfied needs of clients and customers." A search area can be determined by analysing both internal strengths and external opportunities. However, identifying clear and relevant search areas for this project proved challenging. As this research was conducted independently, without prior experience in applying this method, the process of defining search areas required a more exploratory approach. While Buijs provides a structured framework, the search areas in this study were shaped through an iterative process rather than strictly following predefined guidelines.

This section presents the defined search area of adoption, as it presents the most promising direction for innovation within this study. The other areas considered, prevention, injury mitigation, and technological integration, are described in Appendix C.

4.1 ADOPTION

One of the most significant challenges in cycling safety is the voluntary adoption of safety products. Despite continuous advancements in protective gear, visibility solutions, and accident prevention technologies, the actual use of these products among cyclists remains low. Many cyclists choose not to wear helmets, use proper lighting, or invest in safety-enhancing accessories due to personal preferences, perceived inconvenience, cost, or lack of awareness.

This issue is further influenced by changing traffic dynamics, future regulations, and demographic shifts:

First of all, e-bike growth and changing traffic conditions. The increasing popularity of e-bikes has led to higher speeds among cyclists and more complex traffic interactions, making safety equipment more and more relevant. However, many e-bike users, do not adopt proper safety measures. As the discussion around regulatory and legal developments continues, future legislation, such as helmet laws or mandatory lighting systems, could influence adoption, but as explained, current voluntary adoption rates remain low.

Also the aging population and increased health awareness play a role. As the cycling population grows older, injury risks increase, making safety solutions even more necessary. At the same time, an aging demographic may be less inclined to change habits or adopt new products unless they are seamlessly integrated into their routine.

Lastly, there is the ealier described issue of perceived safety vs. actual safety: many cyclists believe they can ride safely without additional safety products, underestimating risks or prioritizing comfort and aesthetics over protection.

Internal strength and market opportunity

For BBB Cycling, the focus on adoption as a search area is reinforced by both internal capabilities and external market trends. The company is well-positioned to bridge the gap between safety innovation and user adoption, leveraging its strategic strengths while capitalizing on emerging market opportunities.

Internal strengths

- Pon.Bike consortium support: as part of Pon.Bike, BBB Cycling benefits from a strong industry network, offering potential access to expertise, partnerships, and distribution channels that can accelerate the development and implementation of adoption-focused safety solutions.
- Practical product development: BBB has a proven ability to develop user-friendly and accessible products, making it well-suited to design safety innovations that are not only effective but also promote easy adoption.

Market opportunities

- Integration of safety components in bicycles is a growing trend in the cycling industry. The pre-integration of safety features into bicycles is something that is more and more included in the manufacturing stage. This reduces reliance on individual consumer adoption and ensures that safety measures are built into the cycling experience.
- With e-bikes becoming more dominant in urban transportation, there is an increasing need for safety solutions that cater a broader audience. This includes commuters and younger cyclists, who currently may not invest in standalone safety products.
- A regulatory push for safety standards and advice by governments and municipalities that are increasingly taking a stand for the safety of cyclists. Campaigns on safe cycling are becoming more common and discussions on legislation regarding e-bikes are also increasing. When such regulations become the norm, the demand for integrated and user-friendly safety solutions will increase. BBB Cycling can anticipate these changes by developing adoption-friendly products that are aligned with future regulatory requirements, ensuring compliance without compromising user comfort.

Conclusion on adoption

For BBB Cycling, overcoming adoption barriers represents a strategic opportunity. With its strong expertise in designing practical and user-friendly solutions, the company is well-positioned to develop products that are not only effective but also desirable and convenient for cyclists. By focusing on adoption, BBB can bridge the gap between safety innovation and real-world application, ensuring that safety products are not just available, but actively utilized by cyclists.

Given BBB's internal expertise in product development and the external market opportunities, adoption is selected as the primary search area. In the following section, the challenges and opportunities within adoption will be further explored, along with strategies to increase the use of safety products among cyclists.

4.2 DEEP DIVE INTO ADOPTION

4.2.1 Definition of Adoption

Adoption, in the context of cycling safety, refers to the extent to which cyclists accept, use, and integrate safety products into their daily routines. It is a behavioural process influenced by perceived risk, motivation, awareness, and practical usability. While numerous safety solutions exist, their effectiveness depends on whether cyclists choose to use them.

At its core, adoption is a matter of behavioural change, requiring cyclists to recognize the importance of safety measures, perceive them as beneficial, and integrate them into their routines. Several factors influence this process:

- Risk perception and attitude: cyclists who underestimate risks are less likely to adopt safety measures, whereas those with higher risk awareness may be more inclined to use protective gear.
- Safety awareness and motivation: some cyclists may be aware of safety risks but lack the motivation to act on them. Effective adoption strategies must not only inform but also encourage action.
- Facilitating adoption: even motivated individuals may avoid using safety products if they are inconvenient, uncomfortable, or socially unappealing. A well-designed product must fit seamlessly into a cyclist's lifestyle.

To illustrate the barriers to adoption, several common problem statements in cycling safety can be identified:

- The bicycle helmet is cumbersome and impractical to carry around all day.
- High-visibility clothing is only available in fluorescent colors, which many cyclists find unattractive.
- Current bicycle helmets are difficult to adapt to varying weather conditions.
- Safety products like knee or elbow pads are almost non-existent for adult cyclists or are too conspicuous and designed for other activities.
- Safety products insufficiently address cyclists who combine cycling with other forms of transportation.

By focusing on adoption, BBB can address these practical barriers, respond to changing external conditions, and leverage its own strengths effectively. The following section will explore how the COM-B theory, a widely used behavioural model, can help explain and guide adoption in cycling safety.

4.2.2 COM-B Theory

To understand adoption and how to influence the adoption of cycling safety products, the COM-B model (Capability, Opportunity, Motivation – Behaviour model) provides a useful framework, see Figure 36 (Michie et al., 2011). This model explains behavioural change by identifying three essential components:

1. Capability (C): the physical and psychological ability to perform a behaviour, such as knowledge of safe cycling and the ability to wear and use safety products comfortably.
2. Opportunity (O): external factors that facilitate or hinder behaviour, such as infrastructure, accessibility, affordability, and social influences.
3. Motivation (M): internal drivers, including habits, emotions, and conscious decision-making, which determine whether cyclists feel the need to adopt safety measures.

In the context of cycling safety, these three components interact to shape adoption behaviour. Common barriers include:

- Lack of awareness or knowledge (Capability): cyclists may not recognize the risks of not using safety equipment or may find products difficult to use.
- Environmental and social constraints (Opportunity): poor infrastructure, peer pressure, or inconvenience may discourage use.
- Risk perception and habitual behaviour (Motivation): many cyclists underestimate danger, prioritize convenience, or resist behavioural change.

A structured breakdown of these barriers is provided in Appendix D, which further details the psychological, physical, social, and environmental factors affecting adoption.

From theory to implementation

While the COM-B model is useful in understanding behaviour, it does not directly guide how to design solutions that encourage adoption. The model is often used in social science, by policy makes and behavioural scientists. For this project it was used in a design context, where it also proved to be useful tool. To bridge the gap from behaviour to design, the next section explores how these behavioural insights can be translated into design strategies, focusing on environmental restructuring and enablement as the most viable approaches for BBB Cycling.

4.2.3 Application in Design

While the COM-B model provides valuable insights into why cyclists do or do not adopt safety products, it does not directly translate into design strategies. To bridge this gap, behavioural insights from COM-B can be applied through intervention functions that influence adoption (these are on the outside ring of the COM-B wheel in Figure 36). For BBB Cycling, the most relevant design-focused interventions are environmental restructuring and enablement, as they align with the company's role in product development and market positioning. The reasoning behind this analysis can be fond in Appendix D.

Figure 36. COM-B wheel

Environmental restructuring

Environmental restructuring refers to modifying the physical or social environment to encourage safe behaviour. This is interpreted as designing products and systems that naturally integrate safety solutions, making adoption effortless rather than requiring conscious decision-making.

Below, three potential ways of environmental restructuring are described:

- Pre-integrating safety features into bicycles is seen as one of the most effective ways to increase adoption. This ensures that safety elements are already built into the bike itself, reducing reliance on aftermarket purchases. For example, lights and reflectors are already integrated, so in the future, even smart safety features could come pre-installed on bicycles.
- Creating visually and socially acceptable safety products, because social norms strongly influence adoption. If helmets and visibility gear are perceived as "uncool," many cyclists, especially young people, will resist using them. Design can address this by

developing stylish, minimalistic, or multipurpose safety products that blend with different cycling styles.
- Encouraging habitual use through design cues by making subtle design interventions, such as reminders integrated into cycling accessories, could nudge users toward safer behaviour, similar to how seatbelt warnings encourage car safety.

Enablement

Enablement here is interpreted as removing obstacles that prevent cyclists from using safety products, whether practical, financial, or psychological. This approach ensures that even cyclists with low motivation or limited awareness can easily engage with safety-enhancing solutions.

Below, three potential ways of enablement are described:

- Making safety products more convenient and multifunctional, for example by designing helmets that adapt to different weather conditions, foldable designs for portability can address common usability complaints.
- Reducing financial and logistical barriers indicating that if productas are affordable, easy to obtain and require minimal efort to use, adoption will increase. Collaborations with bike retailers to bundle safety gear with purchases, supplying each sold bike with a helmet or offering trade-in discounts for outdated helmets, could encourage broader use.
- Leveraging technology for seamless adoption with smart integrations, such as helmets with built-in lighting and crash detection, could appeal to tech-savvy cyclists while providing additional incentives for adoption.

Since BBB Cycling currently focuses on aftermarket sales, integrating safety directly into bicycles would require a shift in strategy toward working more closely with bicycle manufacturers (OEM collaboration). This shift is discussed further in Chapter 5, where potential industry partnerships are explored.

4.2.4 Conclusion: from Behaviour to Design Strategy

The analysis of the search areas highlights that focussing on adoption offers the most promising direction for innovation within this project. While prevention, injury reduction, and technological integration present valuable opportunities, the technical and market challenges make them less suitable for BBB and this project. Adoption on the other hand, aligns strategically with the company's capabilities and the external possibilities.

As described the key challenge in bicycle safety is the acceptance of safety products. Despite advancements in protective gear, visibility, and accident prevention, adoption rates remain low due to personal preferences, costs, and limited awareness or motivation. This issue is further complicated by the rise of e-bikes, shifting traffic conditions, evolving regulations, and an aging cycling population, reinforcing the need for user-friendly and aesthetically appealing safety solutions. Using the COM-B model showed that environmental restructuring and enablement are two intervention possibilities that can help contributing to increase adoption rates.

As part of Pon.Bike, BBB has a huge pool of expertise, partnerships, and distribution channels to accelerate the implementation of adoption-focussed safety innovations. The trend towards integrating various components in bicycles presents an opportunity to embed solutions directly at the source, reducing the reliance on voluntary consumer adoption. By leveraging the intervention functions from the COM-B model, BBB and its partners can drive behavioural change through pre-installed safety features, multifunctional product designs, ultimately fostering a safer cycling environment. The next chapter explores potential collaborations and business strategies to implement these design solutions effectively, ensuring that adoption is not just encouraged but actively facilitated.

5. COLLABORATION AND SYNERGY ADVANTAGES

To explore the possibilities for collaboration and synergy advantages, it is essential to understand the Pon.Bike network and the viewpoints of some of its partners. As discussed in paragraph 3.1.1, BBB Cycling was acquired by Pon Holdings in 2015 and is now part of the Pon.Bike branch within the Pon conglomerate. BBB stands out within Pon.Bike as it does not focus on bicycle production but on aftermarket products (see block on page 45). This unique position means that for BBB to thrive when it comes to integrating components on bikes, collaboration with Pon.Bike partners is crucial. Understanding why partners should work with BBB, what possibilities exist for mutual benefit, and how collaboration can stimulate the adoption of safety-related products is vital. Interviews with designers from Gazelle, Kalkhoff, and Pacific Cycle, along with insights from Rick de Jong, provided valuable perspectives on these matters.

5.1 POSSIBILITIES WITHIN PON.BIKE NETWORK

The Pon.Bike network offers significant potential for collaboration, particularly for BBB Cycling. Since BBB develops components that many partners need for their bicycles, there are natural opportunities for cooperation. However, when discussing OEM parts with Gazelle and Kalkhoff, price emerged as the primary deciding factor. Large-scale purchasing and cost efficiency were the main reasons for selecting specific suppliers over BBB. Additionally, brand perception played a crucial role; for example, premium e-bikes often feature Selle Royal saddles because consumers expect them. Regarding OEM parts selection, all three managers from Gazelle, Kalkhoff, and Pacific Cycle unanimously stated that price is the most important factor in choosing components. When producing 80,000 bikes of the same type, even a few cents per bike can have a significant financial impact. This economic reality makes price competition a primary driver in procurement decisions. Additionally, collaborative procurement plays a role in achieving economies of scale. By purchasing components collectively, Pon.Bike brands benefit from lower costs while maintaining brand-specific product configurations. It is important to mention here that all companies within Pon.Bike have their own financial balance and all are expected to report black figures every year.

Despite this strong focus on price, Pon.Bike's collaboration philosophy deliberately does not force brands to collaborate. Pon.Bike believes that each brand should retain its own identity and autonomy while benefiting from the broader network. Brands are encouraged to remain independent within the group, in order to ensure that their unique characteristics and market positions remain intact.

Collaboration on the other hand, is already taking place in various for. Parts are frequently shared among brands like Gazelle and Kalkhoff, a process that has been significantly accelerated because they operate within the same SAP system, allowing for streamlined integration and supply chain efficiencies. A notable characteristic of most collaboration among employees of various Pon. Bike partners is its informality. All interviewees emphasized that the bicycle industry is inherently informal, making it easy for counterparts at different brands to reach out to each other. This ease of communication can facilitate quick decision-making and encourages cross-brand knowledge sharing without the need for rigid structures.

When it comes to more holistic issues, such as sustainability, there is already some structured collaboration. Sustainability initiatives require a broader approach, and Pon.Bike brands recognize the advantages of working together to implement environmentally responsible practices in materials, production, and end-of-life product strategies. Pon.Bike's influence in portfolio management has also been increasing. In particular, for niche bikes, Pon.Bike is critical in preventing multiple brands from developing similar products. This ensures a more diverse and well-structured product lineup across all brands, minimizing internal competition and optimizing market coverage.

Pon.Bike does, play an influential role in budget allocation. If two brands are developing the same innovation independently, Pon.Bike actively intervenes to encourage collaboration or decide which party should continue the project. However, this does not always result in seamless cooperation. An example was shared where two brands were both working on bike frame innovation. Despite discussions, no consensus was reached on collaboration, and as a result, Pon.Bike decided to abort the project entirely. This highlights Pon. Bike's role as a strategic coordinator in ensuring efficient allocation of development resources.

Lastly, outsourcing within Pon.Bike has been recognized as a promising direction. This would allow brands to develop customized components for specific models while enabling suppliers like BBB to also sell those same products under its own brand in the aftermarket. Such a system would balance internal specialization with broader market opportunities, reinforcing Pon.Bike's ecosystem.

Thus, while product integration faces economic and branding challenges, both knowledge sharing and joint development offer viable paths for collaboration.

5.2 POTENTIAL BENEFITS

Collaboration within Pon.Bike offers numerous benefits that can drive efficiency, innovation, and market positioning for all participating brands. By leveraging shared knowledge, standardizing key components, and outsourcing within the group, brands can unlock new opportunities for growth.

One major benefit is knowledge sharing and accelerated innovation. Sharing expertise across different brands leads to faster technological advancements. BBB, for example, specializes in accessories, while other brands focus on full bike systems. By merging these competencies, high-end and more integrated products can be developed. Additionally, standardizing safety features across multiple brands can shift consumer expectations, transforming safety into a competitive advantage rather than a cost burden. Knowledge sharing is particularly relevant given that bike brands develop models a few years in advance. If this information is openly shared within the Pon. Bike network, safety innovations and complementary accessories can be designed proactively, ensuring smoother integration and market readiness.

Another crucial benefit is cost efficiency. When brands collaborate on development and procurement, they achieve economies of scale. Bulk purchasing, shared R&D investments, and aligned production efforts reduce costs. Instead of each brand independently designing safety features or accessories, joint projects allow for cost-effective innovation. This approach also prevents redundant development efforts, ensuring that investments are directed toward improvements that can have a high impact.

Additionally, collaboration enhances market positioning. When Pon.Bike brands align on safety and innovation, the whole group strengthens its industry reputation. Consumers recognize unified safety standards as a mark of quality, increasing trust in Pon.Bike products. A well-coordinated product portfolio also ensures that brands do not cannibalize each other's sales, instead allowing each to dominate its specific category or niche. Furthermore, a unified approach enhances negotiation power with suppliers, allowing for better pricing and technological support.

By balancing collaboration with brand independence, Pon.Bike can create a synergized ecosystem where all brands benefit from shared expertise while maintaining their unique market identities. Formalizing collaboration in key areas such as procurement, R&D, and sustainability will ensure that Pon.Bike remains at the forefront of the bicycle industry while unlocking cost efficiencies and market differentiation.

5.3 IMPLEMENTING COLLABORATION EFFECTIVELY

While the benefits of collaboration are clear, the key question remains: how can this be implemented effectively? In discussions with Rick de Jong, it was evident that BBB should not simply expect Pon.Bike partners to adopt its products. Instead, a culture of knowledge sharing, learning, and daring to fail is crucial.

Since safety features are not currently seen as a unique selling point among bike manufacturers, Pon.Bike brands should engage in structured discussions on how to incorporate or facilitate these features in the future. This could be done by lowering barriers for aftermarket sales, ensuring that safety components are more accessible to consumers even if they are not initially integrated into OEM models. Another approach could involve early alignment with product development cycles, so safety innovations align with upcoming bicycle models, improving their likelihood of adoption.

Importantly, all interviewees expressed enthusiasm about potential collaborations and had a positive view of BBB as a brand and its employees. This reputation within Pon.Bike creates a solid foundation for future partnerships.

To ensure these collaborative efforts are effectively implemented, a strategic roadmap will be outlined in the next chapter. This roadmap provides a phased approach, detailing how Pon.Bike brands and BBB can work together over time to integrate safety and innovation into their products. By fostering open communication, strategic alignment, and gradual implementation, Pon.Bike can ensure that safety innovations and other collaborative efforts are successfully integrated across its brands while maintaining their unique identities.

5.4 CONCLUSION

Collaboration within the Pon.Bike network presents a significant opportunity for driving innovation, efficiency, and market growth for BBB Cycling. While each brand operates independently, informal connections, shared procurement strategies, and the increasing role of Pon.Bike in portfolio management provide a framework for cooperation. Knowledge sharing has proven to be particularly valuable, as brands develop new models years in advance, allowing complementary innovations, such as safety features, to be anticipated and strategically integrated.

However, collaboration cannot be forced. The culture within Pon.Bike prioritizes autonomy, and partners must find common ground through shared interests and practical benefits. The main challenge remains the commercial reality, where price competition continues to be the dominant factor in procurement decisions. Nonetheless, by fostering voluntary cooperation, aligning development cycles, and creating an ecosystem where brands both share knowledge and innovate together, Pon.Bike can strengthen its collective market position.

To translate these insights into action, the next chapter introduces a structured roadmap, outlining a future vision to work towards. Three phases of collaboration are presented, each detailing how brands within Pon.Bike can gradually align their efforts while maintaining their unique identities. This roadmap provides a practical guide for implementing shared innovations, particularly in areas such as safety, technology integration, and sustainability.

6. ROADMAP

To ensure that collaboration in the field of design within Pon.Bike is implemented effectively and yields tangible results, a structured roadmap is developed. While this thesis primarily focuses on cycling safety, the roadmap takes a broader perspective, addressing various industry-wide challenges, such as innovation, efficiency, and sustainability, that can be tackled more effectively through collaboration and synergy advantages.

This roadmap is designed to gradually build trust, deepen collaboration, and align efforts across different brands while maintaining their autonomy. It provides a phased approach that allows for incremental innovation, structured collaboration, and ultimately, full co-creation among Pon.Bike brands.

The roadmap is directly linked to the findings of Chapter 5, which highlight that voluntary cooperation, knowledge sharing, and structured discussions are crucial for effective collaboration. While Pon.Bike does not mandate integration among brands, it plays a strategic role in fostering cooperation, optimizing resource allocation, and minimizing redundancy.

By following this roadmap, Pon.Bike brands can systematically enhance their collaboration, capitalize on synergy advantages, and ultimately position themselves as global leaders in cycling innovation. While cycling safety remains a key focus of this thesis, this roadmap demonstrates how collaboration can address broader challenges, ensuring long-term industry leadership. The next sections outline each phase in detail, including their specific goals, focus points, success criteria, and example projects.

6.1 FUTURE VISION

As one of the largest players in the global cycling industry, Pon.bike holds a key position in shaping the future of mobility, safety, and sustainability. With its extensive portfolio of brands, Pon.bike has both the opportunity and responsibility to set industry standards that influence competitors and the market. Rather than following trends, Pon.bike can leverage internal synergies and structured collaboration to establish new benchmarks in innovation, efficiency, and sustainability.

This roadmap envisions a future where collaboration is embedded in Pon. bike's innovation strategy, allowing brands to maintain their unique identities while benefiting from shared knowledge, technology, and economies of scale. By strategically leveraging synergies, Pon.bike can position itself as the leader in integrated cycling solutions, setting industry standards in smart mobility, safety, and sustainability.

For Pon.bike brands, this vision includes the seamless integration of cutting-edge innovations, such as modular e-bike platforms, standardized battery solutions, and advanced connectivity features, ensuring that innovation flows across brands while preserving their individual DNA. This approach drives internal efficiencies while also influencing the broader cycling industry through shared advancements.

For BBB Cycling, the future lies in a balanced strategy of integration and independence. As a potential OEM and knowledge partner within Pon. bike, BBB could lead the development of safety solutions and accessories that integrate seamlessly with new Pon.bike models. At the same time, BBB maintains its aftermarket focus, innovating independently and serving a broader market. This dual approach allows BBB to expand within Pon.bike while preserving its strong afetermarket focus..

6.2 PHASE 1: EXPLORATION AND THRUST (1-2 YEARS)

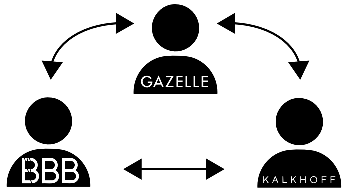


Figure 37. Example of Phase 1 collaboration

The first phase of the roadmap is built around voluntary cooperation, where brands familiarize themselves with collaboration opportunities through knowledge-sharing and small-scale pilot projects with few partners involved (Figure 37). The focus is on building trust between partners and allowing them to explore synergies in a low-risk environment.

However, voluntary cooperation presents both opportunities and challenges. While it allows brands to collaborate freely and without pressure, there is also the risk of inactivity. Experience from other industries suggests that collaboration is often only successful when there is a clear incentive, such as financial gain or a structured project with concrete goals. Feedback from one of the supervisors of the project highlighted that voluntary cooperation alone may not be enough to bring brands together in a meaningful way. If collaboration remains purely voluntary, it does not fundamentally change the current situation, where cooperation is limited and inconsistent.

To address this, the Exploration & Trust phase should introduce structured incentives to encourage participation while still maintaining an open and voluntary approach. One effective method is to provide Pon.Bike-backed pilot projects, where Pon.Bike offers funding or strategic support to ensure initial success and demonstrate the value of collaboration. This funding can reduce hesitation from brands that are reluctant to invest in cooperation without clear benefits.

To make this phase successful, brands should focus on small-scale, non-binding pilot projects that allow them to test collaborative efforts without significant financial obligations. The informal nature of the bicycle industry works to Pon. Bike's advantage, as brands already have open lines of communication. A centralized knowledge-sharing platform, such as Google Workspace, can facilitate discussions and provide a space where partners can share experiences, challenges, and best practices.

One effective way to build collaboration is by leveraging existing products for small improvements rather than launching large-scale co-developments. Minor innovations, such as adapting handlebar grips or integrating safety mirrors, can serve as an easy starting point for cooperation. Furthermore, brands in close geographical proximity may find it easier to initiate such projects, enabling quick feedback loops and enhancing trust within the network.

To maintain momentum, Pon.Bike should encourage participation through recognition programs, ensuring that teams involved in successful collaborations receive visibility. Additionally, low-risk funding opportunities can be introduced to support pilot projects and reduce hesitation from brands that are unsure of the benefits. Pon.Bike can also play a moderating role, ensuring that pilot projects align with broader strategic goals rather than remaining isolated experiments.

Success in this phase will be measured by at least three joint initiatives or pilot projects among Pon.Bike brands, as well as clear examples of knowledge sharing that lead to product optimizations. Positive evaluations from participating brands will demonstrate an interest in expanding collaboration, and at least one technology or product should be adapted across multiple brands as a direct result of shared insights.

By the end of Phase 1, brands should feel comfortable engaging in more structured collaborations, paving the way for Phase 2: Structural Collaboration. An overview of the details on this phase, including specific product ideas and collaborative strategies, can be found in the roadmap visualization provided at the end of this chapter.

6.3 PHASE 2: STRUCTURAL COLLABORATION (2-5 YEARS)

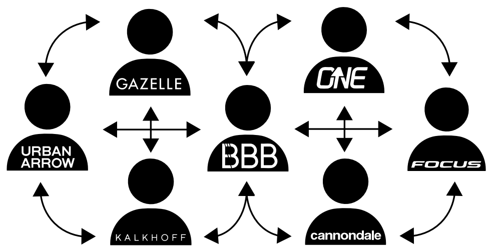


Figure 38. Example of Phase 2 collaboration

In the second phase, collaboration within Pon.Bike progresses beyond small-scale pilots to structured joint development initiatives. Once brands have established sufficient trust and confidence in cooperation, they may engage in shared R&D, larger scale innovation projects, and deeper integration of successful technologies across multiple product lines.

A key shift in this phase is the transition from more voluntary based, informal knowledge-sharing to some more formalized collaboration agreements, where multiple brands commit to structured projects with clear goals and responsibilities, involving multiple partners at the same time (Figure 38). This ensures that collaborative efforts do not remain isolated experiments but instead contribute to scalable, long-term innovations.

If alignment proves beneficial, brands may begin to coordinate their product roadmaps, ensuring that shared developments, such as safety innovations, battery technologies, and connectivity solutions, are integrated across multiple product lines. This phase also includes leveraging existing production capacities in e.g. Taiwan and China, where small adjustments to components can be made efficiently to benefit multiple brands.

Furthermore, structural collaboration enables brands to respond more effectively to societal trends, such as aging populations, urban mobility challenges, and sustainability. By sharing data and customer insights, brands can refine their products to better meet evolving market demands.

Example projects in this phase are the possible shared integration of a radar system into a bike or developing a unified e-bike battery system with all e-bike partners, to provide unity and facilitate exchanging some of these components among each other.

Pon.Bike needs to play a stronger role in budget allocation, ensuring that resources are directed towards projects with the highest potential impact. If multiple brands are working on similar innovations, Pon.Bike may intervene to facilitate joint efforts or consolidate projects to prevent duplication of work. This is somewhat

similar as they are doing right now, like mentioned in the interviews with the partners.

By the end of Phase 2, at least five structural collaboration projects should be in place, with shared R&D and production resources utilized across brands. Successful technologies from Phase 1 will be scaled to a broader product range, and brands will have established a more formalized, yet flexible approach to collaboration, setting the stage for Phase 3: Co-Creation as the Norm.

6.4 PHASE 3: CO-CREATION AS THE NORM (5-10 YEARS)

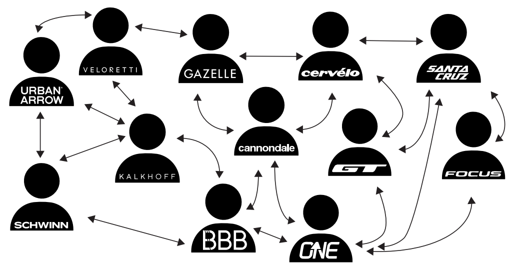


Figure 39. Example of Phase 3 collaboration

The third and final phase of the roadmap establishes co-creation as the standard, with Pon.Bike brands collaborating from the earliest stages of product development. If the structural collaboration in Phase 2 has been successful, brands will have gained confidence in sharing knowledge, aligning innovation strategies, and jointly investing in large-scale projects. This phase represents the shift from coordination to deep integration of technological advancements and production capabilities across multiple brands.

The core idea of this phase is that collaboration is no longer seen as an add-on but rather as an intrinsic part of how Pon.Bike brands operate. At this stage, joint product development will be embedded in strategic decision-making, ensuring that innovation is streamlined across brands while maintaining individual brand identities.

A major change in this phase is the establishment of a joint innovation lab, where brands co-develop key technologies that benefit multiple market segments. This can include modular e-bike platforms, fully recyclable materials, and advanced safety features. A key project here can be developing a bike with fully integrated technology e.g. V2X compatibility, where all partners can contribue and make use off. Even more revolutionary could be the development of an 'industry standard' bike, existing of fully interchangeable parts and component.

While individual brands retain their unique positioning and market focus, they leverage shared expertise, economies of scale, and production capacities to develop pioneering products.

Additionally, outsourcing within Pon.Bike becomes a widely adopted practice, where one brand leads the development of a specific technology or component, while others integrate it into their own product offerings. This ensures that resources are utilized efficiently, and technological advancements benefit the entire network.

At this stage, joint market launches and shared investments with the whole group (Figure 39) become common practice. This means that not only are technologies developed together, but brands also work towards launching products simultaneously, reinforcing Pon.Bike's market leadership. Additionally, the ability to pool resources for innovation funding allows for more ambitious projects that push the boundaries of the cycling industry.

By the end of this phase, at least three fully co-developed products should be launched, clearly demonstrating economies of scale, increased market recognition, and enhanced product differentiation. Innovations should not only improve cycling performance but also contribute to sustainability and circular economy goals, further strenghten Pon.Bike's role as an industry leader.

6.5 CONCLUSION AND SPECIFIC BENEFITS FOR BBB CYCLING

The roadmap provides a structured path for fostering collaboration within Pon.Bike, ensuring brands can work together efficiently while retaining their distinct identities. By progressing through the three phases, Exploration & Trust, Structural Collaboration, and Co-Creation as the Norm, Pon.Bike brands can move from an informal knowledge-sharing culture to fully integrated product development culture.

While voluntary cooperation is a strong starting point, real progress requires structured incentives, shared investments, and formalized projects. The Volkswagen group strategy serves as an example of how innovation can be shared while maintaining brand differentiation, offering key insights for Pon.Bike's future direction. Pon.Bike brands can retain their unique market positions while leveraging shared technologies, R&D resources, and production capacities to drive efficiency and innovation.

For BBB Cycling, the roadmap presents a major opportunity to transition from an aftermarket brand to an integral innovation partner within Pon.Bike, while still maintaining its independent market position. By gaining early access to product development insights, BBB can align its safety products with upcoming bike models, ensuring smoother integration rather than being limited to aftermarket sales. This approach strengthens BBB's relevance in the industry and allows it to contribute more effectively to Pon.Bike's overall innovation strategy.

Additionally, participation in shared R&D investments will allow BBB to develop safety innovations alongside other Pon.Bike brands, becoming a frontrunner in colaboratively working on cycling safety. By engaging in joint development projects and leveraging Pon.Bike's production capabilities, BBB can supply key safety components for integration into bike models while continuing to operate in the aftermarket. This creates a dual advantage: expanding BBB's reach within Pon.Bike while preserving its standalone brand identity.

While the roadmap allows BBB to grow within the Pon.Bike ecosystem, it is equally important for the brand to maintain its current market presence. Continuing to innovate independently in the aftermarket sector ensures that BBB remains competitive outside of Pon.Bike. The ability to balance internal collaboration with external independence will be key to its long-term success.

By following this roadmap, Pon.Bike can maximize economies of scale, accelerate technological advancements, and ensure a leading position in the cycling industry. The ability to share expertise, resources, and innovation platforms will benefit individual brands while strengthening Pon.Bike's overall competitive advantage. The next steps involve gradual execution, continuous measurement of success, and ongoing refinement to ensure long-term sustainability and growth in the evolving cycling market.

Case study: Volkswagen Group

A relevant example of successful structured collaboration within a multi-brand ecosystem is the Volkswagen Group's strategy (Volkswagen Group, 2021). This group, part of another branch within Pon, includes car brands like Volkswagen, Audi, SEAT, and Škoda. While each brand maintains its own identity, they share key technologies and components, such as chassis platforms, infotainment systems, and technological features, shown in Figure 40. This approach has led to major cost savings, production efficiency, and faster innovation, establishing Volkswagen as a global industry leader.

The relevance to Pon.Bike lies in the potential to share modular technologies, such as battery systems, safety features, and connectivity solutions, across brands. This avoids redundant innovation and enables more efficient, collaborative development while preserving brand uniqueness.

However, it is important to note a key difference. Volkswagen's model involves a high degree of integration and interdependence among brands, which can sometimes blur brand autonomy. In contrast, Pon.Bike aims for voluntary collaboration that respects each brand's independence. Rather than mandating integration, Pon.Bike encourages structured cooperation to leverage synergy advantages, while still allowing brands like BBB to maintain their own focus and character.

This comparison highlights valuable lessons from Volkswagen's success but also underscores the need for a tailored approach within Pon.Bike, one that balances shared innovation with flexibility and brand autonomy.

Figure 40. Three 'different' car designs from the Volkswagen Group brands

Annotations with roadmap

The next pages present the roadmap described in this chapter. First an extensive roadmap, with descriptions, steps and goals. Secondly, a clearer version, with less text which gives a better overview of all the steps and how to reach the future vision..

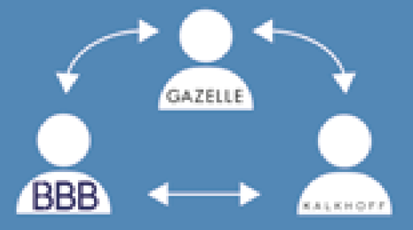
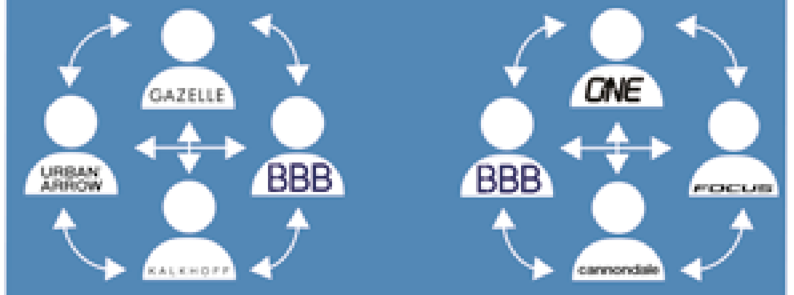
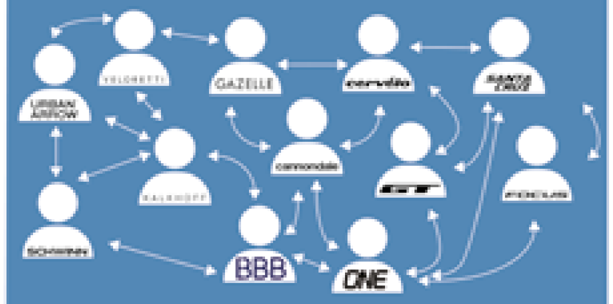
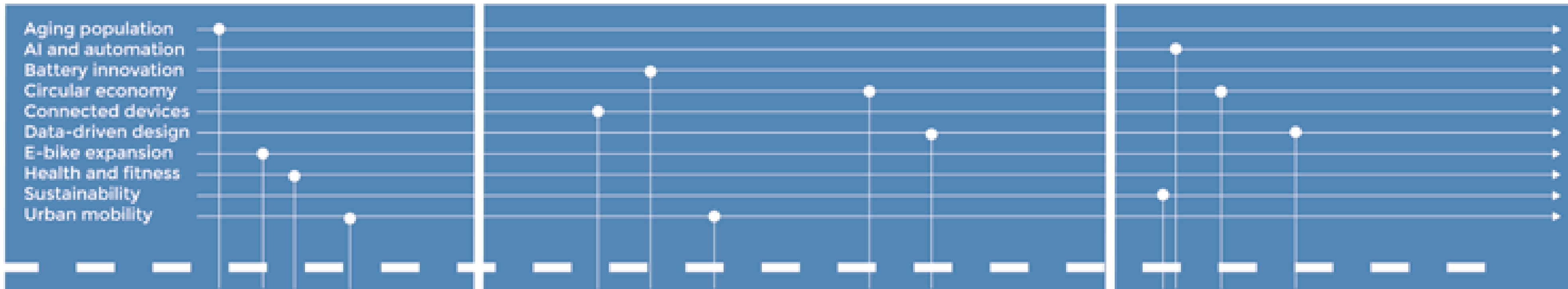
The phases described are placed in colums, so it is easy to see what all belongs to which phase.

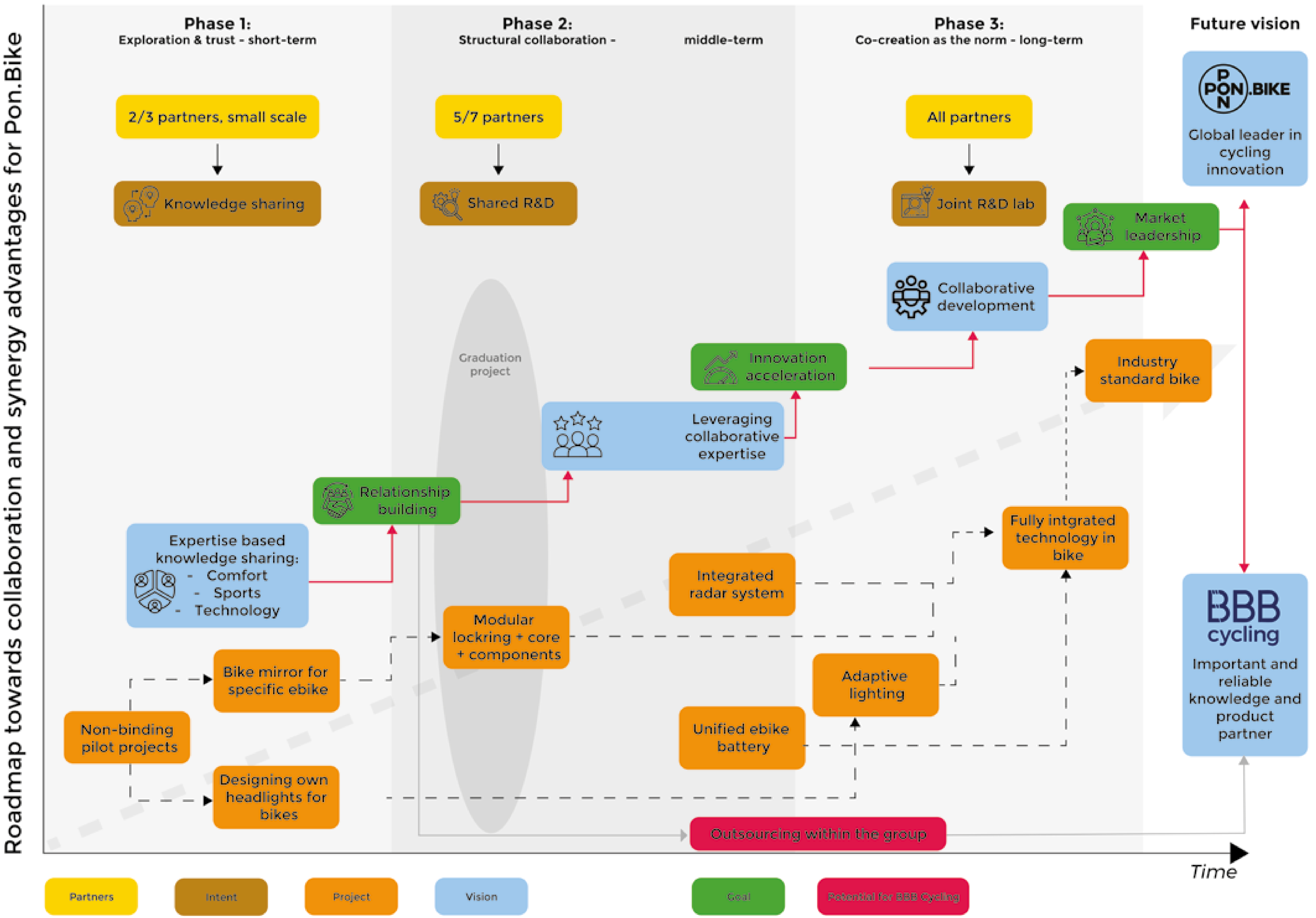
On the next page, the rows in the roadmap present various components explaining what to do in each phase. First of all the goal per phase is described, with a visualization of the potential partners involved and the values that relate to it.

The light blue row presents the focus points, as described in this chapter and the succes criteria, when it is expected the group can move on to the next phase.

Lastly, some of the trends from chapter 2 and some product ideas, related to those trends, per phase are described. These product ideas will be further discussed in the next chapter.

On the second roadmap, the legend explains what the colours mean.

	Phase 1: Exploration & trust - 1-2 years	Phase 2: Structural collaboration - 2-5 years	Phase 3: Co-creation as the norm - 5-10 years	Future vision
Goal	Familiarize, share knowledge, and initiate small joint projects without financial obligations.	Larger projects in Pon.Bike brands on product which multiple structurally collaborate development.	Co-creation becomes the standard, with brands jointly developing new products from the concept phase.	PON.BIKE Pon.Bike brands become the global leader in cycling innovation, setting new industry standards through seamless voluntary collaboration, and by leveraging synergy advantages.
Partners				
Values	• Efficiency: by sharing insights and working together, resources are used more effectively. • Risk reduction: testing innovations on a small scale minimizes the risk before larger rollouts. • Relationship building: strengthens inter-brand trust and collaboration within Pon.bike.	• Economies of scale: and R&D reduce costs • Market expansion: brands to enter new collective expertise. • Innovation acceleration: knowledge accelerates shared production facilities across brands. collaborative projects allow segments by leveraging pooling resources and development cycles.	• Market leadership: Pon.bike sets the industry standard for innovation and sustainability. • Brand synergy: collaborative development enhances brand identity and strength across all partners. • Revenue growth: joint investments and co-created products open new revenue streams across markets.	
Focus points	• Non-binding pilot projects focussed on knowledge sharing. • Utilizing existing products and improving them with small innovations. • Collaboration between brands located geographically close to each other. • Sharing experiences and insights through Google Workspace (or another platform for communication and knowledge sharing). • Evaluation of existing projects and technologies within Pon.bike to avoid duplication of effort and share best practices.	• Collaboration on development with shared • Utilizing existing Taiwan/China for small components. • Scaling successful broader product lines. • Increased focus on populations, sustainability. • Adapting existing feedback and joint technology and product R&D. production capacity in adjustments to existing technologies from phase 1 to societal trends such as aging and urban mobility. products based on customer evaluations.	• Shared innovation projects and a joint R&D lab. • Full integration of technologies across different brands and product lines. • Joint market launches and shared investments. • Focus on major innovations such as modular e-bike platforms and fully recyclable materials. • Outsourcing within Pon.bike, where one brand leads and other brands join to utilize existing capacities.	BBB cycling BBB Cycling becomes an important and reliable knowledge and product partner within the group, while mainting its aftermarket focus
Success criteria	• At least 3 joint initiatives or pilots. • Projects focused on knowledge sharing and product optimization. • Positive evaluation and willingness to explore further collaboration. • At least one tangible product or technology adapted or reused by multiple brands.	• At least 5 structural • Utilization of shared • Involvement of multiple • Partners identify and share others can leverage. projects. resources and knowledge. brands within Pon.bike. key local market trends that	• At least 3 products fully developed in co-creation. • Clear economies of scale through joint production and development. • Innovations leading to broader market recognition (awards, media attention). • Launch of one groundbreaking product that symbolized the collective strength of Pon.bike	
Trends				
Example product ideas/ projects	• Bike mirror for specific e-bike model (Gazelle x BBB) • Ergonomic handlebar grips (Kalkhoff x BBB) • Bike mirror with signal lights and specific grip (BBB x Gazelle x Kalkhoff)	• Radar system integrated in Kalkhoff) • Unified e-bike battery Arrow x BBB) • Adaptive lighting Kalkhoff x Gazelle) bike (BBB x Cannondale x (Kalkhoff x Gazelle x Urban (adaptive brightness) (BBB x	• Bike with fully integrated technology (radar, turn signal, object recognition, and active transponder for other traffic(V2X)) (Pon.bike partners) • First fully industry standard bike, with interchangeble parts (Pon.bike partners)	



Roadmap towards collaboration and synergy advantages for Pon.Bike
Phase 1:
Exploration & trust - short-term
Phase 2:
Structural collaboration - middle-term
Phase 3:
Co-creation as the norm - long-term
Future vision
2/3 partners, small scale
Knowledge sharing
5/7 partners
Shared R&D
All partners
Joint R&D lab
PON.BIKE
Global leader in cycling innovation
Market leadership
Collaborative development
Innovation acceleration
Industry standard bike
Graduation project
Leveraging collaborative expertise
Relationship building
Expertise based knowledge sharing:
- Comfort
- Sports
- Technology
Fully intgrated technology in bike
Integrated radar system
Modular lockring + core + components
Bike mirror for specific ebike
Adaptive lighting
Non-binding pilot projects
Unified ebike battery
Designing own headlights for bikes
Outsourcing within the group
BBB cycling
Important and reliable knowledge and product partner
Time
Partners
Intent
Project
Vision
Goal
Potential for BBB Cycling

7. IDEATION AND DESIGN BRIEF

As described in previous chapters and the roadmap, collaboration between Pon. Bike partners and the integration of safety components on bicycles represent a key possibility for BBB Cycling to shift towards the comfort cycling segment and become more involved in facilitating safe cycling.

With implementation as a central focus, the ideation phase aims to explore possible design directions that align with both BBB's competencies and the market trends. When integrating components onto a bicycle, there are two approaches: embedding them in the frame or attaching them externally. For this project, the latter is more suitable, as bike manufacturers differentiate themselves through their frame designs, it is challenging to convince them to incorporate components into their models.

Therefore, the ideation process focusses on add-on components that can be mounted when assembling a bike. Several potential areas were identified for integration: the handlebar and its components, the seat post, pedals, bike rack, and fenders (see Figure 41).

Additionally, discussions with Gazelle explored the potential for a collaborative project. Although the timing and project scope did not align for cooperation in this project, the insights from these conversations remain valuable for possible future collaborations between BBB and Gazelle.

Lastly, this chapter presents the design brief, which was developed in consultation with the company, particularly with Tjerk Bakker, product manager, and company mentor in this project. The brief outlines the concept of integrating components within a lockring and describing the target group for such a product.

Figure 41. Potential areas for integration

7.1 POSSIBLE DIRECTIONS

Several product ideas across three horizons were explored, considering both safety innovations and insights from discussions with Pon.Bike partners.

Phase 1:

- Dead angle alarm
- Speaker + horn via button on steer
- Turn signal in pedals
- Turn signal in mirror
- Lowering saddle at low speeds
- Fold-out stand at low speeds
- Automatic lock when leaving bike (like VanMoof had)

Phase 2:

- Radar system integrated into the bike
- Standardized e-bike battery
- Adaptive lighting with adjustable brightness
- USB-C port for accessory integration
- Automatically adjustable suspension

Phase 3:

- Bike with fully integrated technology (exploring the question: how can the future bike cockpit be functional without causing distractions?)
- Bike built with industry-standard parts (exploring the question: what can BBB supply when everything is standardized?)
- Bike-to-vehicle / V2X transponder system
- Dynamic lane projection

From these options, some focused directly on safety, while others addressed broader industry challenges and opportunities.

For each horizon, one idea was selected to develop further and examine its feasibility for this project in greater detail.

7.1.1 Mirror with Turn Signal (phase 1)

More and more cyclists are installing mirrors on their e-bikes to view traffic behind them without turning their heads. Currently, mirrors are primarily aftermarket products, and BBB has seen strong sales in this category. According to Tjerk Bakker: "bike dealers now keep a box full of mirrors in their stores because demand is increasing, and cyclists recognize their benefits."

With the growing integration of various technologies in bikes, combining a mirror with a turn signal presents an interesting opportunity. This idea is already explored by manufacturers of BBB, shown in Figure 42, and other companies in the cycling industry, but so far it either was an inconvenient product with a battery or must be wired all around the bike. Since the mirror extends beyond the bike's frame, it provides an ideal position for a turn signal, enhancing visibility and safety.

Figure 42. Existing mirror concept made by manufacturer of BBB

The idea for this phase is to combine a handlebar grip and a mirror into one component with a button on the grip to put the turn signal on and off. By making it one product, a cable can be put though the handlebar making it invisible and prevents the cables from damaging.

7.1.2 Adaptive Lighting (phase 2)

E-bikes increasingly feature powerful lighting systems, thanks to their high-capacity batteries. Unlike conventional bikes, e-bikes can support stronger lights, significantly improving visibility. However, in many cases, these lights are too bright for the environment. For instance, a 2000-lumen light is unnecessary in well-lit urban areas but highly beneficial in rural or unlit regions, where it enhances safety and comfort (Figures 43 shows the differences in light intensity).

Another issue is improper adjustment, which can blind oncoming traffic. An article by Wielerflits (2025), highlights how overly bright e-bike lights pose a danger to other cyclists.

An adaptive lighting system that adjusts brightness based on location and ambient light levels could solve this problem. This solution would ensure optimal visibility in all conditions without blinding other cyclists and road users.

Figure 43. Impression of a 2000 Lumen bicycle light

7.1.3 Bike with Integrated Technology; how will the cockpit look like? (phase 3)

As described before, modern bicycles are incorporating more and more components, particularly e-bikes, which often feature dedicated screens and control buttons. As technology advances, handlebars are likely to become increasingly cluttered. To illustrate what could be integrated into a bike cockpit, a list of possible components and features was compiled:

- Brake handles
- Bell
- Shifters
- Lighting switch
- Phone mount or integration
- E-bike system screen and controls, including:
  - Radar
  - Brake light
  - Rear camera
  - Service notifications
  - Navigation

If all these elements are implemented, the handlebar risks becoming overly complex and crowded, as is already the case with some current bikes, shown in Figures 44 and 45. This raises an important question: How can the cockpit of the bike be developed in such a way that these technologies are integrated, without becoming distracting or overwhelming, while making cycling safer?

To address this, innovative ways to redesign handlebar design need to be explored while maintaining functionality and safety. The challenge lies in balancing technological advancements with user-friendly design, ensuring cyclists can access essential features without compromising comfort or focus.

Figure 44. Example of currently available components on a bike

Figure 45. Example how a bike is equipped when sold

Additional Direction: V2X Exploration with Gazelle

During interviews with Pon.Bike partners about collaboration opportunities, Mark van der Kooij from Gazelle highlighted the role of his colleague, Maarten Pelgrims, in driving vehicle-to-everything (V2X) technology innovation for bikes via the Coalition for Cyclist Safety (own communication, 16 January 2025). He suggested that a discussion between Gazelle and BBB about integrating V2X components could be valuable, particularly in exploring how BBB could bring this technology to the aftermarket. While Gazelle can incorporate V2X directly into their new bike models, they see significant potential in BBB offering it as an add-on for existing bikes.

Together with Mark and Maarten, potential collaboration for this thesis was discussed, focusing on a key challenge: How can we design a compact (6x3x3 cm) V2X module that fits all existing bikes and ensures reliable power supply? While V2X is still in its early stages, particularly in the cycling industry, Maarten was enthusiastic about using this project as an opportunity to explore its future potential. Similar technologies are already in use in industries like mining (Spectrum 59, see Figure 46).

Figure 46. V2X in mining industry, (Spectrumfiftynine, 2025)

Collaborating with Gazelle on this project was an exciting prospect, but two main constraints emerged:

1. *Limited relevance to this research: the focus would have been on designing an easily mountable box rather than a product that supports adoption.*

2. *Timing: this discussion took place late in the project when conceptualization, described in paragraph 7.3, had already started.*

Given these constraints, the decision was made to relay Gazelle's interest in V2X to BBB as a potential opportunity for future collaboration. While the project didn't fit within this thesis, the conversation gives an interesting direction for BBB to explore V2X integration in possible future collaborative projects with Gazelle.

7.2 CONTROLLING TURN SIGNAL ON GRIP

Among the ideas explored, the mirror with an integrated turn signal stood out as the most promising concept for further development in this project. This innovation aligns with market trends and represents a new direction for BBB, expanding its product range beyond traditional aftermarket components: developing a product with the aim of integration into bikes, either in collaboration with partners, or as OEM partner, is a limited explored direction for BBB.

A first experimental setup, shown in Figure 47, was created using using an existing mirror with Arduino components taped to both the mirror and the handlebar. This simple setup allowed for initial testing and provided a foundation for further development and discussion.

Figure 47. First experimental setup

Feedback from Gazelle & Kalkhoff

When a project around the mirror with turn signal was proposed to Gazelle, their response was clear: safety components are not a unique selling point. Their market research indicated that customers are generally unwilling to pay extra for safety features, making such additions unlikely to boost sales. In fact, Gazelle saw the potential inclusion of safety components as counterproductive, possibly even leading to a negative perception of their bikes.

However, they acknowledged that if consumer attitudes toward safety components change in the future, they would be the first to integrate them into their product roadmap. For now, though, Gazelle does not see value in pursuing this type of innovation.

Kalkhoff, on the other hand, raised concerns about regulatory challenges in Germany. The country's strict road laws regarding bicycle lighting would make it difficult to bring bikes equipped with turn signals to market. This legal barrier added another layer of complexity, further limiting the feasibility of integrating turn signals directly into bikes.

7.3 DESIGN BRIEF: ADJUSTMENT INITIAL IDEA

The initial idea for this project was to explore the integration of turn signals on bicycles, responding to increasing safety concerns and emerging technological trends. However, discussions with Pon.Bike partners revealed significant obstacles. Gazelle indicated that safety components are not a unique selling point, as consumers are generally unwilling to pay extra for them. Kalkhoff raised additional concerns, noting that German road regulations impose strict requirements on bicycle lighting, making it difficult to introduce turn signals into the market.

Faced with these challenges, a shift in approach was necessary. Instead of focusing on a single product, the project evolved toward a more flexible and widely applicable solution: the development of a standardized lockring capable of housing various safety components. The lockring, a common feature on most bicycle grips, presented an opportunity to simplify integration while making safety innovations more accessible.

A universal integration platform

The lockring-based approach provides a modular solution, allowing manufacturers to equip bicycles with BBB grips or grips co-developed with BBB that feature a standardized lockring. This enables the easy addition or replacement of safety components, such as turn signals, lighting, or even future technological advancements. By leveraging an existing bicycle component, this system avoids the challenges associated with integrating new technology directly into the frame, one of the major concerns raised by manufacturers.

An important consideration in this design process is that grips are engineered to fit only a specific lockring. This means that a newly designed lockring cannot be used on existing grips, as it would not fit properly. As a result, the introduction of this system also requires the development of new grips that are compatible with the standardized lockring, to ensure a secure and funtional fit.

Although the bicycle industry lacks standardization in many areas, the handlebar diameter in the e-bike category is standardized, providing a reliable foundation for grip compatibility. This creates an opportunity for BBB to establish a new standard for lockring-equipped grips, both for OEM integration on new bikes and as an aftermarket solution for riders looking to upgrade their safety features.

Idealy, such a system is available to all Pon.Bike partners, to either make their bikes ready for safety components, or use the system to sell bikes with safety components. BBB can then offer the components which are not directly installed via the aftermarket.

Project scope

The development of this project brief evolved naturally through discussions with Tjerk Bakker. Due to the time limitations and the shared interest in exploring the potential of this system, the focus remained on designing a solution that is both practical and adaptable, ensuring feasibility, while allowing flexibility for future developments. As a result, the decision was made to prioritize the lockring concept rather than investigating different directions. This approach kept the project within scope while effectively addressing the challenge of integrating safety components into bicycles.

It is important to mention that although the initial idea of the turn signal was a phase 1 idea, this concept should rather be seen as a phase 2 project. Developing and launching a system like this will require several years, both to refine the product, get partners on board and to prepare the market for integrated cycling safety solutions. The primary goal of this project is to demonstrate feasibility and explore integration possibilities, rather than deliver a factory-ready product for immediate market introduction.

Key Considerations Moving Forward

In the next phase, several aspects require further exploration:

- Technical feasibility: how should the new grip and lockring be designed to ensure functionality, easy installation, and compatibility with a variety of safety components?
- Modularity: how can this system remain flexible enough to accommodate future safety and technology integrations?
- Industry response: which partners are most likely to support this system, and how can they be convinced of its benefits?

Target Group

Because safety components like mirrors are already widely adopted by older cyclists, the focus of this project is on a slightly younger demographic. With e-bikes becoming increasingly popular younger cyclists and commuters, the target group is defined as all e-bike cyclists younger than 65 years old.

This group represents a growing segment of e-bike users who value safety but are not yet fully accustomed to using safety accessories. Since older cyclists already adopt mirrors widely, this project aims to make safety components more appealing and accessible to those who might not yet consider them a necessity. By integrating safety features into an existing component like the lockring, the goal is to provide a subtle and user-friendly solution that fits naturally into their cycling habits, promoting adoption.

7.4 CONCLUSION

This chapter explored the ideation and design process for integrating safety components into bicycles, leading to the development of a standardized lockring system. Initially focused on integrating turn signals in grips and direct OEM application, feedback from Gazelle and Kalkhoff revealed obstacles, including low market demand and strict German regulations on bicycle lighting.

To address these challenges, the focus shifted to a modular lockring system, allowing manufacturers to equip bikes with compatible grips while enabling easy integration of safety components. Since existing grips only fit specific lockrings, a new grip design must most likely be designed. However, the standardized e-bike handlebar diameter provides a foundation for compatibility.

The target group for this project is e-bike cyclists aged under 65, a growing segment of e-bike users who may benefit from integrated safety features. By embedding safety into a functional and existing component, the goal is to increase adoption without altering the bike's aesthetics.

8. PRODUCT DEVELOPMENT

The goal of this chapter is to develop and prototype a universal lockring system capable of integrating various safety components on a bicycle. Given the lack of standardization in the cycling industry, the challenge is to design a modular and adaptable solution that allows for easy installation and adjustment on a grip to provide the possibility of mounting different components without requiring modifications to the bicycle frame.

Throughout the design and prototyping process, several aspects are explored. The lockring mechanism is developed to provide secure mounting and rotational adjustability, ensuring that components can be positioned in every desired angle. To show how components can be mounted on the lockring, a turn signal system is made, by modifying the arm and mirror of an existing BBB design. Additionaly, Arduino components are implemented in the lockring and mirror to test the functionality.

Once the components were finalized, the system was mounted onto a bicycle to assess its physical integration. A key focus is on ensuring that the lockring not only works with the mirror but also has the potential to support other safety-related add-ons. This modularity opens the door for future safety components, such as electronic horns, brake lights, or smart connectivity features.

All development steps were taken in close collaboration with BBB, ensuring alignment with the scope of this project and technical feasibility. While final design choices were made in consultation with Tjerk Bakker, support from other designers and the weekly creative sessions, in which all design projects are discussed, also played a role in refining the concept.

8.1 GRIPS, LOCKRING MECHANISMS, AND SHIFTERS

8.1.1 Grips

Before diving into the design process, it is important to understand the different types of cycling grips and their manufacturing methods. Grips play a crucial role in providing comfort, control, and stability while riding, and their design varies depending on the type of bike and rider preference.

Grips can be classified into two main categories (Figure 48):

- Ergonomic grips: designed to enhance rider comfort. These grips support the natural position of the hands and arms, reducing fatigue and improving the overall riding experience.
- Round grips: these grips have a uniform cylindrical shape, allowing riders to hold them in any position without predefined ergonomic support.

Since this project focuses on e-bikes, ergonomic grips are the standard choice. E-bikes are often used for longer rides or commuting, where comfort and proper hand positioning are desired. Therefore, ergonomic grips are a key requirement in this design process.

Figure 48. Ergonomic and round grips

8.1.2 Lockring mechanisms

When it comes to lockring systems, there is no standard at all. All systems look very similar, but the lockring is slightly different, like puzzle pieces looking similar, but they only fit one place. Lockrings have the specific function of tightening the grip to keep it in the right position. There are differences between various brands, but also within brands, there are variations. Grips can have a lockring on the inside or outside, but there are also grips with an internal tightening mechanism.

Grips can feature lockrings in different positions:

- Inside mounted lockrings: placed on the inner side of the grip (closer to the rider) (shown in Figure 49).
- Outside mounted lockrings: positioned at the outer end of the grip, though less frequently seen.
- Internal tightening mechanisms: hidden within the grip for a seamless appearance, but not suitable for this project.

Lockring systems are essential for securing grips in place, preventing rotation or sliding while holding the grip. With inside and outside mounted lockrings, the lockring is mounted on a designated part of the core where no rubber is moulded. This section of the core extends slightly beyond the rubber layer, creating a mounting surface for the lockring to slide into place and clamp the grip securely onto the handlebar. However, as there is no universal standard for lockring designs, different brands implement different solutions, and even within the same brand, variations exist.

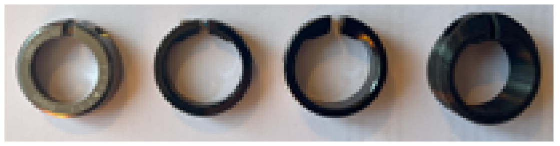


Figure 49. Various lockrings

Since lockrings on the outside are rare and internal lockrings are impossible to work with regarding the scope of this project, the initial focus for the project is to look for possibilities to work with lockrings mounted on the inside of the grip.

8.1.3 Shifters

In the e-bike category, two main types of shifters are commonly used. shown in Figure 50:

- Grip shift: this system functions as an extension of the grip, allowing the rider to shift gears by rotating a section of the grip.
- Trigger shift: this system consists of two small levers positioned beneath the grip, which can be pushed or pulled to change gears.

As grip shift is the only system that is compatible with an inside-mounted lockring, the trigger shift system is taken as a primary reference. And since e-bikes come with either one of the shifter systems, keeping the initial focus on the trigger shift ensures relevancy for a big part of the e-bike market.

Figure 50. Grip shift and trigger shift

8.2 REQUIREMENTS AND WISHES

To ensure the design meets the right needs, a program of requirements and wishes has been established, Table 1. The requirements define the essential aspects that the lockring design must incorporate, such as compatibility with ergonomic grips and trigger shift. Additionally, the possibility to mount key safety features, including the option to mount a mirror and integrate turn signals, and the ability to connect to the e-bike battery are considered essential for this project.

A major focus of this project is the lockring itself, as it represents a new approach to integrating safety components on bicycles. Rather than solely designing the lockring component, the goal is to demonstrate the lockring's potential as a modular platform for multiple safety features. This means only designing a lockring is not sufficient, it must be validated to ensure it functions properly, especially when integrating buttons, cables, and electronic components.

Since this project is focused on proving feasibility rather than delivering a factory-ready design, the emphasis is on demonstrating that the system can be developed and integrated, rather than finalizing production details. Implementing the lockring system in collaboration with partners will take several years, making this phase primarily about laying the groundwork for future development.

Beyond these core requirements, the wishes outline desirable features that enhance security, usability, and adaptability. These include theft-proofing, integration of components on both the inside and outside of the grip, and optional add-ons such as an electric horn, radar connectivity, and a dimmer for lighting. Furthermore, sustainability and durability are key considerations, prioritizing a 5-year lifespan under normal use, repairable electronic components, and replaceable parts.

Table 1. List of requirements and wishes

Requirements	Wishes
Compatible with ergonomic grip	
Compatible with trigger shift	Theft proof
Integration in lockring on inside	Integration on both inside and outside
Possibility to mount a mirror	Mounting an electric horn
Turn signal feature	Mounting a dimmer for lighting
Connecting to e-bike battery	Radar connection possibility
Possibility to mount different components	
Same material as the BBB City View (BBM-05)	
Complies with European legislation	
5 year lifespan under normal use	
Parts of components should be replaceable	Electronic components should be repairable

8.3 DESIGNING AND PROTOTYPING

With the boundaries set, the design and prototyping phase could begin. To facilitate quick testing, the comfort-style handlebar purchased earlier could be used together with a 3D-printed mounting standard. This setup gave good reference, while on the desk, and allowed for rapid iterations of prototypes and printed components, ensuring that designs could be evaluated efficiently.

The design process followed a structured approach, focusing on three main components:

- Lockring
- Arm and mirror to validate the lockring and showing how a safety component can be attached to the lockring mechanism. For the design of the arm and mirror, the BBB CityView (BBM-05) was used as a reference (Figure 51).

By integrating physical prototyping with proof-of-concept testing, this phase provided crucial insights into the practicality and integration potential of the lockring system. The findings from each prototyping version informed further design refinements and helped define the next steps in the development process. All versions are separately described, a visual overview can be found in the design evolution at the end of paragraph 8.3.1.

Figure 51. BBB CityView mirror (BBM-05)

8.3.1 Lockring Design and Mounting Mechanism

As explained, lockring designs vary between brands and even within brands, so it is important to find a universal lockring and mounting system on the and of a grip. This could either be a lockring and mounting mechanism based on an existing product or a newly designed lockring and associated mounting mechanism on the core of the grip.

While there are many differences between various types of grips, they all share a common inside diameter of 22.2 millimetres, matching the outside diameter of handlebars in the e-bike category.

The main challenge is to find a uniform lockring mechanism that can facilitate all different kinds of safety components, while maintaining ease of installation and adjustment. This section explains the exploration of this search.

Version 1

The first lockring was an adaption of the latest lockring and grip design by BBB. A cylinder was added to the lockring, which made it possible to mount components with a round base, like the existing CityView arm (page 100, top).

However, initial testing quickly revealed issues:

- As the end of the grip has a dedicated slot to slide the lockring over, and immediately secure it in the right position, it was useful for secure mounting but prevented rotational adjustments. This because the ergonomic grip can only be used in a specific position and tilting it would change the position of the grip and mounting position.

- Adjusting would only be possible by rotating the mounted component with a separate hinge mechanism.

Version 2

As it turned out, rotating the lockring around the steer, independent from the grip, was very important, designing the next version of the lockring was focussed on ways to make it possible to change the angle of the lockring, while maintaining secure mounting. Two approaches, using fixed angles were tested:

- The first idea was to take a circle and cut three sides out, as shown at page 100 in the middle, so it would be possible to adjust the arm in three different angles. It was thought that only three different angles would be sufficient, since the component is always mounted in the same way on a bike. However, as there are a lot of different types of steers and some cyclists prefer to mount, e.g. a mirror downwards, is was clear soon that this was not a suitable solution to continue with.
- The second idea was to design the lockring with a hexadecagon on the insight, with the aim of providing a variety of angles to put the arm in. The end of the bar was made by leaving out every second end of the hexadecagon, which would give the possibility to tighten the end by squeezing the eight ends that stick out of the grip. Working with a haxadecagon made angle changes of 22,5° possible, but as it turned out, adjusting a mirror is sometimes only done by changing the angle slightly, with only a few degrees. This solution would not give the possibility for small adjustments.

Version 3

Out of version one and two, it became clear that there should be a nearly continuous range of rotating angles. So, the focus of version three was to look at ways to make the number of angles almost endless, while still making sure it would be possible to tighten the lockring in a fixed position.

- The first idea was to make a lot of lugs protruding from the bar end, which would fall into small gaps in the lockring (page 100, bottom). This idea was a first step into the right direction, but the way it was made at this point was rather inconvenient to manufacture and use.
- A simple alternative was to make the lugs as wide as the lockring and put them way closer to each other. This way, it would be possible to adjust the angle and feel some small 'clicks' when rotating. This version was working very well, and will work convenient when mounting, as this type of mechanism is used in various other applications in the cycling industry.

Version 4

Now that a way to rotate the lockring is found, the next step is to address the design of the lockring itself and how e.g. an arm or other component can possibly be mounted. Looking at the ring of the CityView mirror, it can be seen that this design provides 360° rotation possibilities. However, as there is a possibility of pulling cables through the lockring and the connected component. It was thought essential find a way to limit the rotation of various components.

Two variations were made here:

- The first idea was to clamp the arm in the lock ring (page 101, left top). This would give the possibility to limit the rotation of the component on the two walls of the lock ring.
- The second idea was to put the component on a plateau and screw it together with the lockring in a tight position.

Both ideas were explored with the arm of a mirror in mind, but did not work as required. First, in both ideas, the arm is be screwed tight with the same bolt as the lockring itself. This gives the benefit of only using one bolt, but the downside was that it is only really works if the lockring does not have any gaps and the arm needs to be tightened strongly which would prevent the arm from rotating at all. Furthermore, this way of mounting limits the possibility of adding other components to the system, since is focussed on the mirror arm too much.

Version 5

The learnings from version four were considered and it was concluded that using one bolt for both securing the lockring in the right position and tightening the arm was not convenient. Also, a review of the current mount ring of the CityView showed that the possibility of rotating the component 360° was not necessarily a problem. Indeed, there would be cables running, but as mirrors make a bike wider, a possibility to fold the mirror towards the inside of the bike, and subsequently making the bike 'narrower' had to be incorporated anyway.

With this information in mind, the same cylinder from versions one and two was reintroduced but better integrated in the lockring as one single piece.

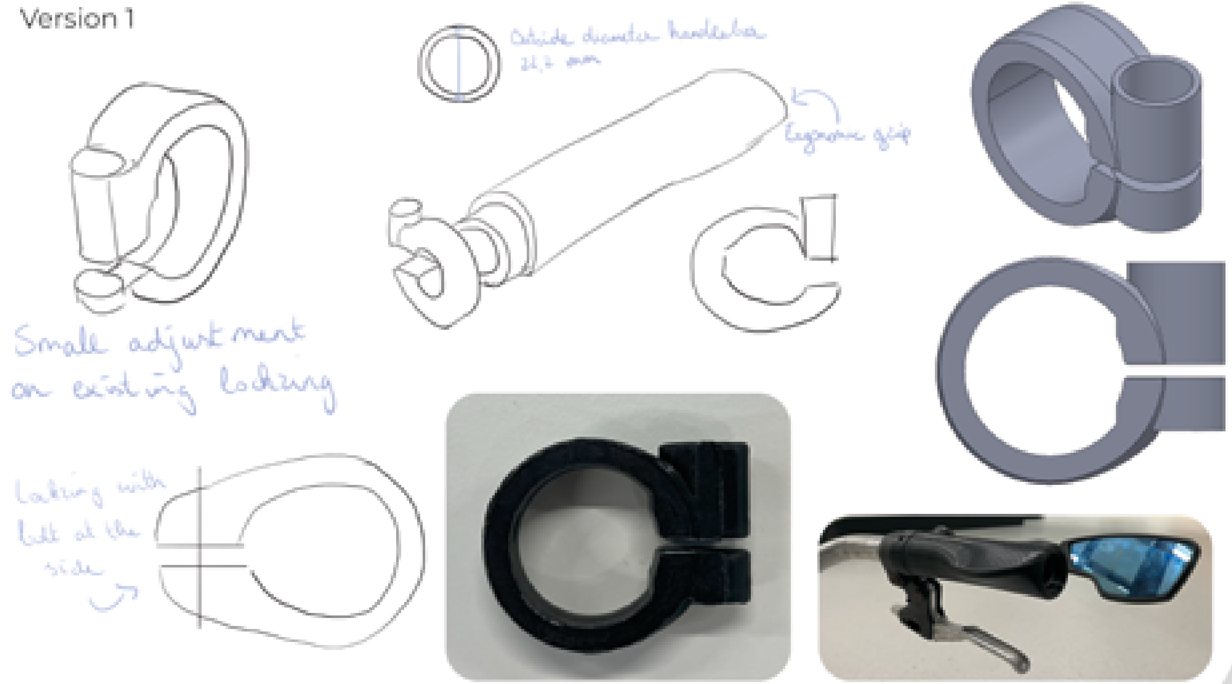
Final version 5.1

Now that the lockring design is defined, the next step is to investigate possibilities to integrate a button in the lockring. The size of the button was based on a 'standard' 6-millimetre push button, ordered via internet. A 6x6 millimetre cutout was made on the most convenient place on the lockring (page 101, middle). This place was chosen because it is easiest to reach with the thumb when hands are on the grip. Additionally, two gutters were made to guide the cables from and to the button. A few 3d-prints were made to test how the button fits and to see if the gutters were wide enough to guide the cables. Small adjustments were made to the size of the cutouts, but the overall design did not change, as can be seen on page 101 at the bottom..

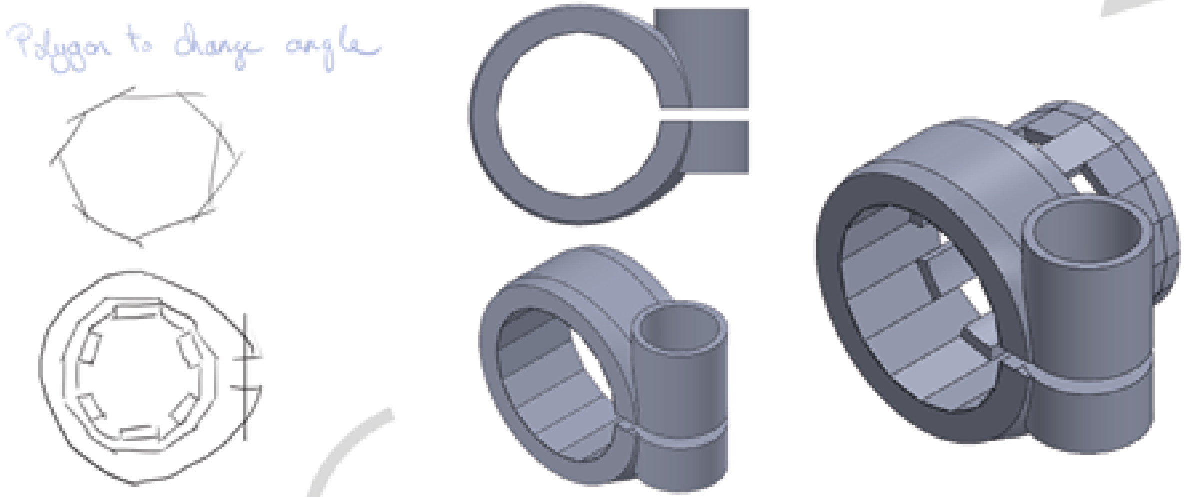
Possibilities for modularity

Now that this lockring is made in such a way that that it can be rotated to every preferred angle, it can also be used to mount other components on the bike, different than the mirror, discussed in the remainer of this chapter.

Version 1

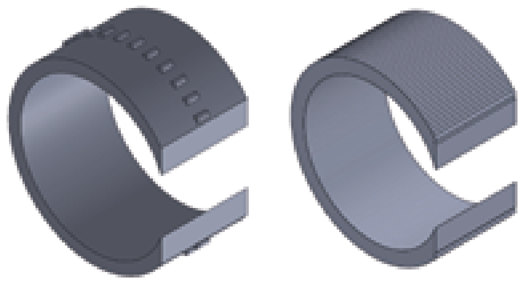


Version 2

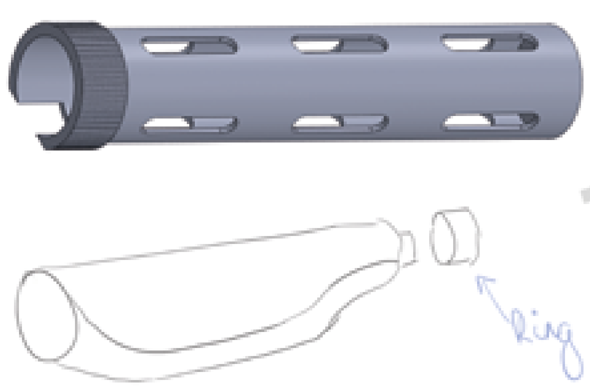


Version 3

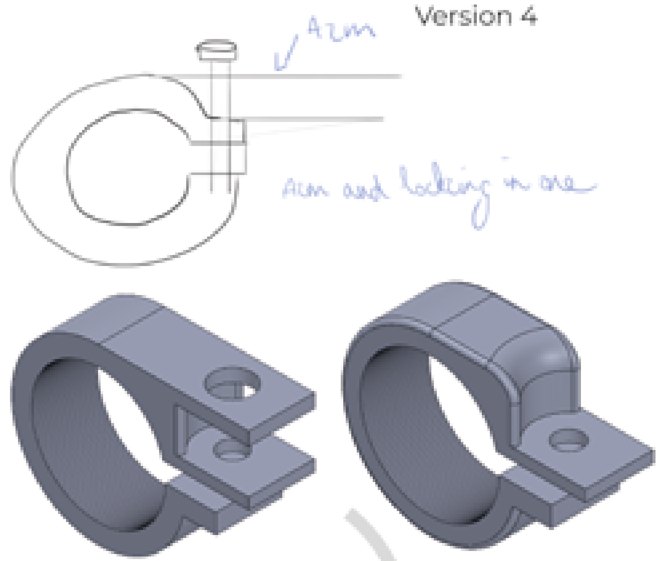
Two ways of placing the lugs



Core of the grip with lugs

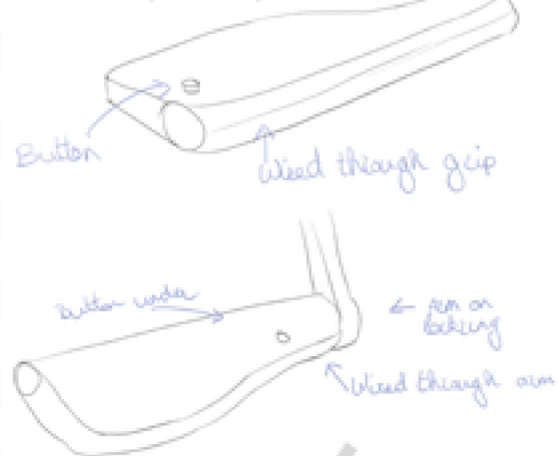


Version 4

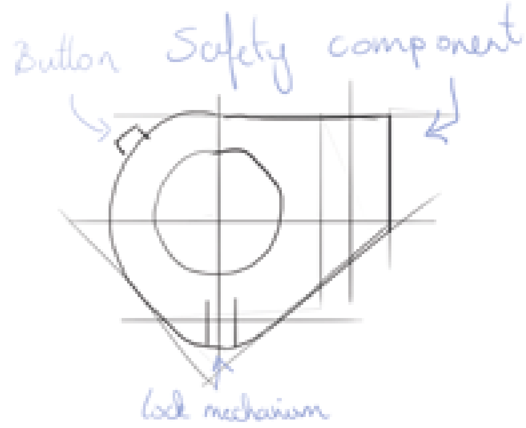


Button 1

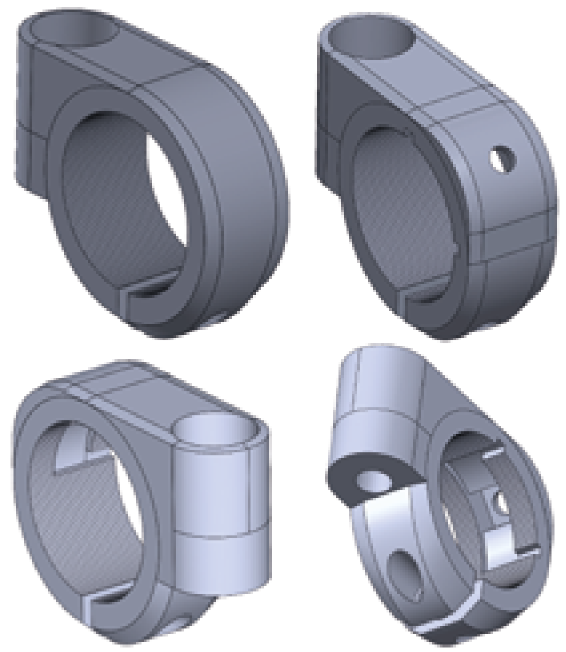
Button integrated in grip

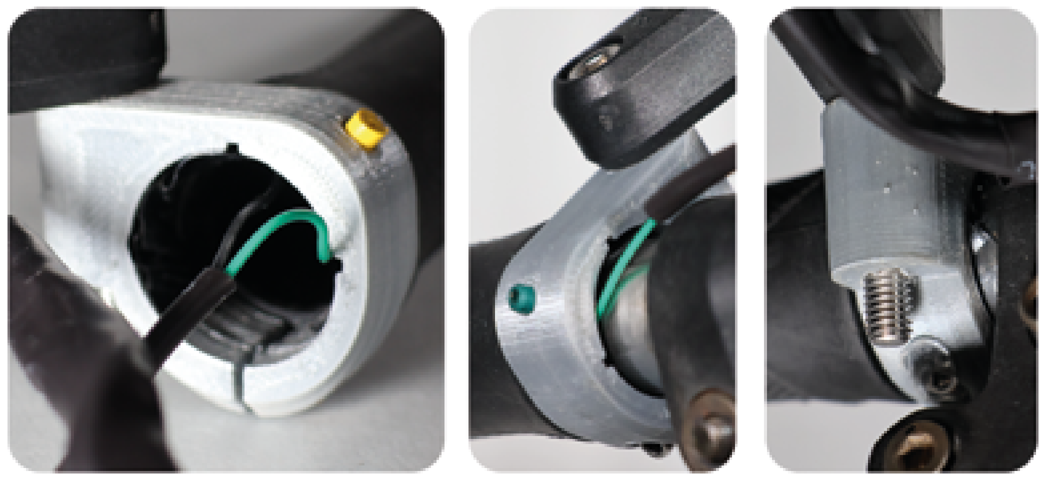


Version 5, Button 2



Two separate mechanisms, one for rotation and one for the safety component, and a separate button, placed on the top





3D-print of lockring mounted on handlebar with button installed

8.3.2 Arm

With the lockring mechanism finalized, the next step was to design the arm of the mirror. The arm of the CityView mirror was used as a starting point, permission was given to use the SolidWorks files from the original arm. Modifications were necessary, since the mirror is placed more to the outside compared to the original CityView, the arm had to be a bit shorter. Also, to include the LED indicator for the radar, the design should be slightly changed to make this possible.

Indicator

One of the wishes for this system was the potential integration of a radar indicator. Most e-bikes are equipped with some sort of display or onboard computer to provide information about the speed and the different support modes when cycling. Connecting a radar to this system can be hard, especially since the systems belong to the original manufacturer, most likely Bosch or Shimano.

So, if BBB, or a Pon.Bike partner, want to release a radar for e-bikes in the future, there needs to be some way to warn the cyclist and visualize how close a vehicle is approaching. For that reason, putting a radar indicator in the arm of the mirror can be a way to implement it. The implementation here only to show a proof of concept, rather than making it work with a radar system, since this system is still in development.

Seeedstudio has a LED bar that can function as an indicator, so it was chosen to try to implement this element in the arm.

Version 1

The first, and only, version of the arm designed had a slightly adjusted length and angle compared to the original arm and had the possibility to implement a LED indicator, shown in Figure 52. Although this new arm met the requirements described, it was chosen not to continue designing a new arm. Mainly for two reasons: 1. Implementing and making the indicator work was a proof of concept. Rather than a radar, a light sensor was used to mimic the function of a radar, since the radar prototype did not fully work or connect with the indicator, it currently serves no purpose; and 2. The 3d printed arm was not as strong as the original arm, which is a big problem in testing the system later in the project.

As a result, the decision was made to continue using the existing CityView arm for further testing, preventing potential structural weaknesses.

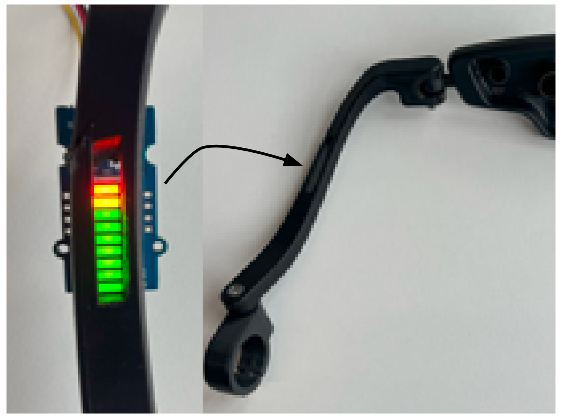


Figure 52. Arm with LED indicator

8.3.3 Mirror

For the integration of lights in the mirror it was chosen to use a LED on the back side of the mirror, so opposing traffic can see the light, and a LED placed on the side of the mirror, so it is also possible to see the LED from the side, e.g. on a roundabout or intersection. If possible, placing one LED over the top and the side would be ideal. As the current CityView mirror has some fillets and chamfers, the mirror had to be adjusted to make implementation of the LED components possible (see figure 53).

To make implementation possible, the original SolidWorks file of the mirror was taken and with some adjustments a block was placed on the backside of the original model. This gave to possibility to make new cutouts and fillets where it was needed to implement the LED's.

The components that needed to be integrated were a Seeeduino grove LED stick, with ten separately controllable LED's and an Adafruit nOOds LED 'noodle'. The stick is placed on the back on the mirror and the Noods on the side of the mirror.

Version 1

One version of the mirror was made, where the components mentioned were integrated into, shown in Figures 54 and 55. Because it was not the goal of the project to redesign the mirror, but to show that it is possible to implement the LED's in a mirror, the original design was only slightly adjusted. To prevent the mirror from being able to spin endlessly through the ball joint, two studs were placed on the ball.

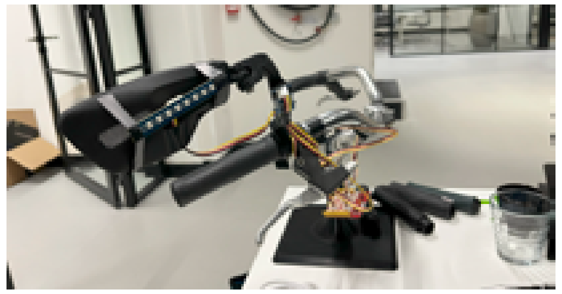


Figure 53. Components taped on CityView mirror

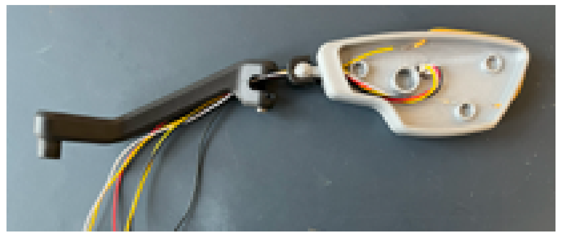


Figure 54. Printed model of mirror with LED installed

The benefit of keeping the original design, is that the mirror shape and mounting mechanism of the CityView, which is clicked in the four holes, could be used.

8.3.4 Component Integration

As described in the previous sections, several electronic components are integrated in the various parts of the prototype. This section provides an overview of the components used and their purpose within the system, shown in Table 2 on the next page.

The primary objective of the prototype was to demonstrate the feasibility of integrating electronic components into a lockring-based system. To keep development simple and flexible, Arduino/Seeeduino components were used. These components are easy to connect via Grove connectors or by directly soldering pins. All components were wired to a Seeeduino Lotus board, which can be controlled using the Arduino app. The specific code and setup are explained in the next section:

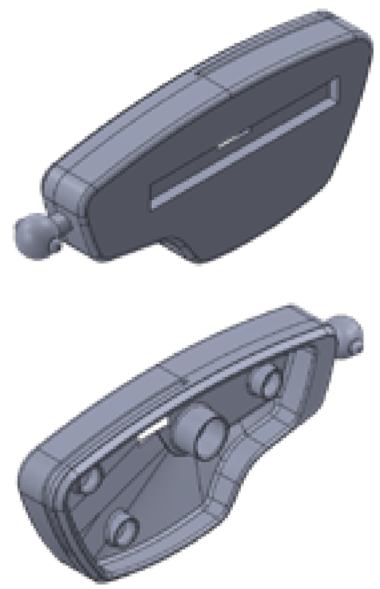


Figure 55. SolidWorks model of mirror

- First, the LED's, to indicate the direction: for this, a grove LED stick and a nOOds flexible LED filament is used.
- The buttons used are 'standard' 6x6 mm push buttons .

These three components are all connected to a Seeeduino Lotus board .

Additional components

In addition to the core components, two additional modules were used during prototyping, to explore the modularity and expandability of the system.

- A LED bar was used as an indicator, as explained in the arm section.
- A grove speaker was used, to mimic the fuction of an electric horn. This component was just connected to the board and taped on the setup.

Since these two components were mainly used in prototyping, to show the possibility of adding different components, they are not discussed in the remainder of this paragraph but will be discussed in the possibilities of the system later.

8.4 ARDUINO PROGRAMMING

Now that all components and system parts have been explained, this paragraph describes a bit on how the system was programmed to function as intended.

For this project, a Seeeduino Lotus board was used, the wiring scheme is shown in Figure 56. This board operates on the Arduino software, meaning it can be programmed using the Arduino app and programming language. Previous projects, particularly in the Bachelor of Industrial Design Engineering, had already utilized Arduino, providing some foundational knowledge. However, this was not sufficient to develop the fully functional scripts required for this project.

Utilizing AI for programming

Recent advancements in artificial intelligence (AI) and large language models (LLMs), such as ChatGPT, provided a valuable tool for writing Arduino scripts. By using AI, scripts could be generated quickly based on specific prompts, significantly speeding up the development process.

Table 2. List of components and functions

Component	**Function**
Seeeduino grove LED stick	10 seperately controllable LED's to be placed on the front
Adafruit nOOds flexible LED filament	Flexible led to place on the side and top of the mirror
Button	Small button to be placed in the lockring
Seeeduino Lotus board	Board to control all components
Seeeduino grove LED Bar	LED to mimic radar indicator
Seeeduino grove Speaker	Speaker to mimic the electric horn

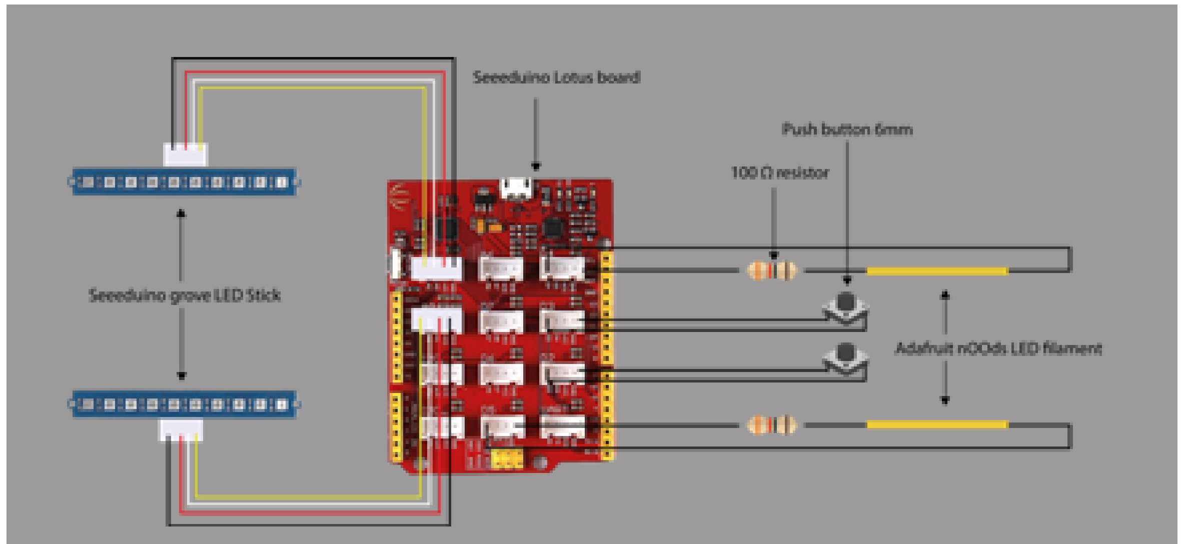


Figure 56. Arduino wiring scheme

However, while AI can generate large amounts of code in seconds, it is rarely flawless. This meant that extensive debugging and re-prompting were necessary to ensure the scripts ran as intended. During the project, skills in debugging, writing code, and optimizing AI-generated scripts improved, leading to a fully functional prototype.

As multiple configurations and test setups were explored throughout development, various scripts were written for different functions. The final working prototype code, along with scripts for specific tests, described in the next chapter, can be found in Appendix F.

Turn signal LED fading and single-press functionality

A key feature of the turn signal system was the fading LED effect, similar to the turn signalused in modern cars. Instead of all LEDs switching on and off simultaneously, the effect was programmed so that the LEDs light up progressively from the inside to the outside, creating a smooth directional transition. This enhances visibility and clarity for other road users, making the cyclist's intention more noticeable.

Additionally, a key programming challenge was ensuring that a single button press did not register as a double-click, which could cause unintended behaviour. To prevent this, software-based debouncing was implemented, ensuring that each button press was only recognized once, even if the user accidentally pressed it slightly longer than intended.

Lastly, it could be chosen what happens with the signal when pressing the button. Initially it was chosen to let the signal blink five times and then turning of automatically. Later, for the validation and testing, the signal was turned on with one click and had to be turned off with another click.

8.5 MATERIALIZATION AND SUSTAINABILITY

The program of requirements and wishes already outlined key material and sustainability considerations. The primary material requirements include a 5-year lifespan under normal use, assuming careful handling and avoiding damage from crowded bicycle sheds. Additionally, the design aimed to use the same materials as the BBB CityView wherever possible, particularly for the arm and mirror.

Material selection and design considerations

Discussions with BBB confirmed that the redesigned components could likely be produced using the same material as the current CityView, which is polyamide nylon, 30% recycled. However, because the focus of this project was on integrating electronic components rather than minimizing material use, the prototype contains more material than the original CityView mirror. In future iterations, it is interesting to look at reshaping the backside of the mirror to reduce material useage, while maintaining functionality.

Since the arm design remained unchanged, it follows the same material selection and durability expectations as the original CityView arm.

Electronic component requirements

A key requirement for electronic components is that they must be replaceable, allowing users to swap out individual parts without replacing the entire system. For example, the mirror should be replaceable separately from the lockring and arm. Complementary to this, a wish was that electronic components should be repairable whenever possible, increasing product lifespan and reducing waste.

As previously explained, this prototype was developed primarily to demonstrate integration possibilities, meaning that all components were separately wired and connected to a Seeeduino Lotus board. This setup allows full modularity and replacement of individual components, but there is a lot of wiring through the components which is difficult to replace.

This way of integrating the components is both undesirable and unlike to be feasible for mass production. In Chapter 11 Disucssion and Recommendations, the limitations of the prototype will be reviewed, and some alternatives will be proposed to make separate replacement of components possible.

Take-back requirements and EU regulations

Electronic products sold in the European Union (EU) must comply with take-back and recycling regulations, ensuring that discarded devices do not contribute to electronic waste. Under the Waste Electrical and Electronic Equipment (WEEE) Directive, manufacturers are responsible for (European Union, n.d.) :

- "Registering with the responsible national authorities ("registers") in each country where you distribute or sell equipment."
- "Filing a regular report on the amount of sold electrical and electronic equipment,
- organising or financing the collection, treatment, recycling and recovery of your products."
- "As a distributor, providing a take-back service, whereby your customers can return electric and electronic waste free of charge."
- "As a manufacturer, complying with the directive on the restriction of hazardous substances."

For a future product, compliance with WEEE regulations would mean that BBB, must offer a recycling or disposal solution for electronic components, particularly for integrated LEDs, circuit boards, and batteries. As BBB is already selling electronic powered devices, this is not something new, and it was indicated that they are in close contact with an external party, which is taking care of this process.

Future battery integration considerations

Initially, the system was designed to be fully wired, requiring all components to be connected with cables to the e-bike battery. However, an alternative approach could involve using a button-cell battery-powered button, while keeping the turn signal lights connected to the e-bike battery. This would reduce wiring complexity, improve ease of installation, and potentially allow for wireless communication between the button and LEDs, maybe even on other places of the bike.

8.6 MOUNTING ON A BIKE

With all components designed, printed, and programmed, the final step was to mount the complete system onto a bike. Throughout the design and prototyping phase, individual elements were already tested on the handlebar on the standard, to ensure they fit and functioned correctly (Figure 57). However, since development focused on one side of the handlebar, the prototype could only be fully completed once the opposite side was printed and assembled, shown in figure 60 in the next chapter.

The first step was to mount everything onto the test handlebar and standard placed on the desk during the project. This allowed for final adjustments and ensured that all components aligned properly before transferring the system to a fully assembled bicycle for real-world evaluation (see Figure 59 on the next page for renders of individual parts and everything mounted on a handlebar).

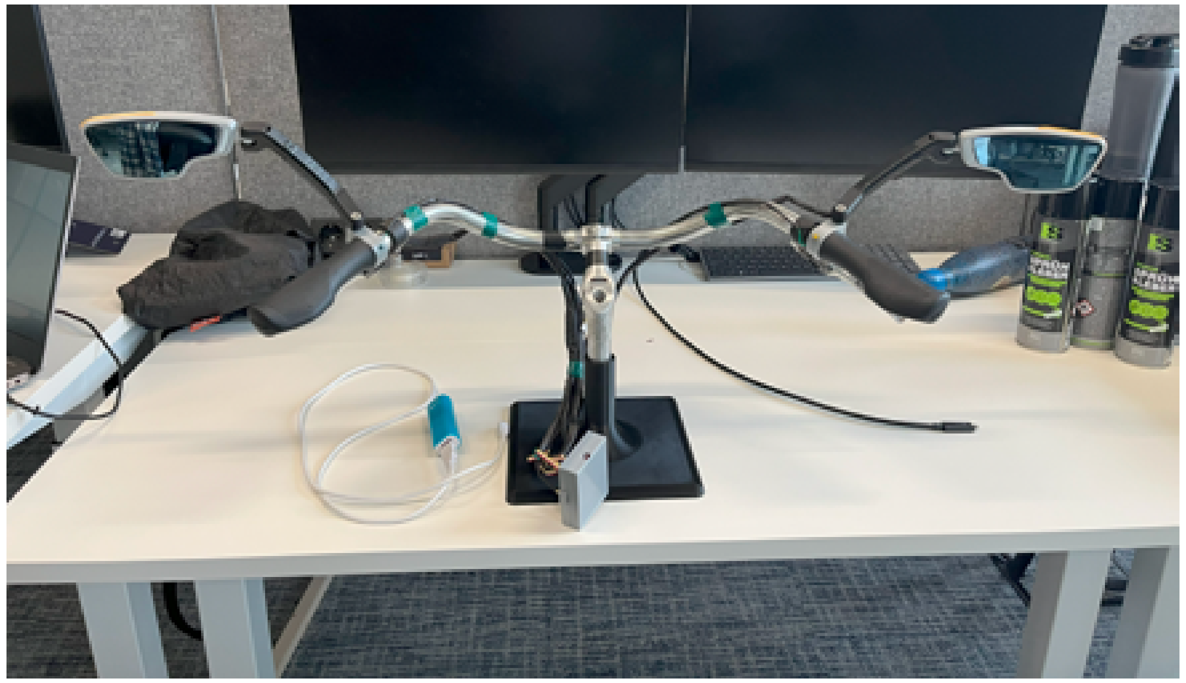


Figure 57. Everything mounted on the desk set-up handlebar

8.7 MODULARITY OF SYSTEM

The lockring mechanism was designed as a modular integration platform, allowing for the attachment of different safety and convenience components beyond just the mirror. This flexibility ensures that users can customize their setup based on personal preferences and specific use cases.

Existing components

Currently, existing components can be installed on the lockring:

- As explained in this chapter, a mirror with turn signal.
- Electronic horn, which can be activated via the button on the lockring, serving as an additional safety feature (Figure 58, left).

Future component possibilities

The modular design of the lockring allows for future expansion, meaning that new components can be developed and integrated into the system without requiring major structural changes:

- Radar indicator, as explored in this chapter, a future radar indicator can be mounted to the lockring, either with or without a mirror component (Figure 58, right).
- To be designed safety components can all be mounted to the lockring, considering the right diameter of the mounting mechanism.

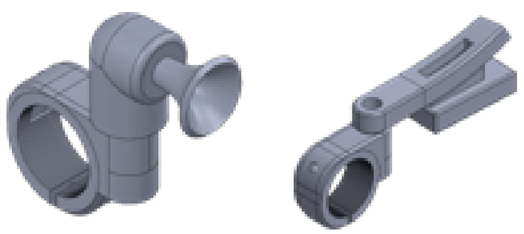


Figure 58. SolidWorks impression of electric horn on lockring and of detached indicator on arm

8.8 CONCLUSION

The development of a universal lockring system for bicycle safety components has proven to be a feasible concept. By creating a secure and adaptable mounting mechanism, this design allows for the integration of various safety features, such as mirrors with turn signals and potentially components like a horn, radar indicators and also future safety components. Given the cycling industry's lack of standardization, introducing a system like this presents challenges, but the prototype successfully demonstrates its potential as a modular safety solution.

The lockring mechanism was designed to adjustability into every desired angle, small lugs on the handlebar end were incorporated to give subtle feedback when rotating the lockring, allowing for precise positioning. In addition, the electronic integration of LED indicators and button controls confirmed that smart features can be incorporated without compromising the overall design.

Although this phase successfully proved the concept's feasibility, further validation is necessary. The next phase will focus on testing the system with cyclists to provide insights into usability, ergonomics, and functionality in real-world conditions. Discussions with bike store owners and industry representatives will help determine commercial viability and consumer interest, while collaboration with Pon.Bike partners will be crucial in exploring potential for collaboration on a product like this.

An impression of the model is shown on the spread on the next page.

Figure 59. Render of impression when everything is mounted on a handlebar

9. VALIDATION

To validate the usability, feasibility of the prototype and market potential of the concept, multiple tests and interviews were conducted with users, BBB's industry representatives, and bike dealers. The goal was to gather insights on real-world functionality, ease of use, and commercial viability, as well as to identify potential improvements.

Although the lockring is the central element of the concept, the validation in this project focused primarily on the mirror and turn signal modules. This choice was made because these components provided the most concrete and testable use case within the available time. Testing the lockring in isolation would not have yielded meaningful user feedback, as its value lies in enabling modular, functional add-ons. By validating one clear application, integrated turn signals and mirrors, it became possible to assess real-world usability, gather input from potential users and dealers, and initiate discussion about future applications. In this way, the prototype served not only to test interaction and visibility, but also to demonstrate the potential of the system concept as a whole.

The user tests focused on how cyclists interact with the system, both in real traffic and in a controlled setting. These tests revealed key findings regarding signal activation, trigger preferences, and overall usability. Discussions with company representatives and bike dealers provided valuable perspectives on market positioning, installation challenges, and integration possibilities. The combined findings from this validation phase can be used for future development steps and will later be highlighted in Chapter 11 Discussion and Recommendations.

9.1 USER TESTS

To evaluate the usability of the prototype, two user tests were conducted. The first test, a real bike test, focused on observing how users interacted with the turn signals in actual traffic conditions. This test highlighted key insights regarding signal activation, visibility, and user behaviour, but also revealed a lack of feedback in the trigger mechanism, leading to a second test. A small follow-up test on the trigger mechanism was conducted using the desk setup, where users compared different trigger types for activating the turn signals. However, no clear preference emerged, as opinions varied based on personal habits and expectations. These tests provided valuable insights into both real-world application and user interaction, which are very useful for a next iteration and future developments.

9.1.1 Real Test on Bike

Objective

The objective of this test was to observe how participants would use the prototype in a real-world scenario. Instead of testing a specific hypothesis, the experiment aimed to explore:

- How frequently do participants use the turn signals in normal cycling behaviour?
- Whether the system is easy and intuitive to use
- Do users encounter difficulties when using the system in traffic?
- Potential improvements based on real-world experiences

Test setup

The test was conducted in a real-world setting where participants cycled a predefined route in a familiar residential area. The prototype was securely mounted on a bicycle without shifters, with handbrakes, and an Insta360 action camera was used to capture the entire ride (see Figure 60). Using this type of camera gives a 360° video, which allowed for a full review of how participants interacted with the turn signals while also being able to see the other traffic. Also the logger function of the Arduino was used to be able to review the number of button presses per side afterwards.

Figure 60. All components and Insta360 mounted on bike

The route participants had to cycle was based on cycling two 'blocks' including crossroads, a roundabout and a quick left-right-left turn. The total time to cycle the route was around eight minutes, with in total nine turns to the right and three turns to the left.

Before the test, a pilot run was run to ensure that all aspects of the setup functioned as expected. Based on this preliminary test, two small adjustments were made on the Arduino script to optimize the prototype for testing:

- Increased animation speed: the initial animation speed of the turn signal appeared to be too slow, which made it impractical for real traffic situations.Brighter lighting: while the lights appeared bright indoors, they were not sufficiently visible in outdoor conditions. The intensity was increased to the maximum.

Participants

Participants for this project were family members of the student, who only knew a little or even less about the project and the prototype. All of them were aged between 55 and 65, fitting the target group for this project. A total number of six participants were recruited.

Before participating, all participants filled in a consent form, got basic instructions on how to use the buttons to switch the turn signal and were instructed on the route they had to cycle.

Findings

A comprehensive overview of the findings is described here. A turn-by-turn analaysis of the test can be found in Appendix G

First, the findings of the logger, as explained the route contained nine right turns and three left turns. If the prototype was used at every turn, by putting it on and off, this would lead to 18 presses on the right button and 6 presses on the left button. The table below shows the number of presses on each side per participant:

Button use per user

Table 3. Button use per user, left and right

	Left	Right
User 1	18	6
User 2	12	4
User 3	17	9
User 4	20	10
User 5	12	4
User 6	18	6

Table 3 indicates that only two of the users used the turn signals at all the possible turns. The other four users either used the buttons less or more. Less indicating that there must be turns in which they did not use the signal, more indicating that in-between turns, they probably used the buttons to put the turn signal on and off again, maybe because they were not able to see clearly of the signal was on or off.

Secondly, the observations from the video: most of the users had difficulties with seeing if the buttons were turned on or off. The test took place on a sunny afternoon and the brightness of the sun probably hindered the view (Figure 61). Also, it was interesting to see that some of the users still sticked their arms out when crossing an intersection; especially intersections where they had to cross the whole intersection, so on a left turn (see Figure 62 for the intersection explantion and Figures 63 and 64 for the difference between a user sticking out the hand while looking over the shoulder, and one using the mirror). Some participants were taller than others, leading to adjusting the mirrors pointing the back of the mirror downwards. As they looked from high, the angle of the mirror was put in such a way that they could see the traffic behind them, but this led to the LED's pointing a bit downwards.

Lastly, feedback after the test: the first feedback almost all users gave when finishing the test was that they had difficulties in seeing if the lights were on or off, indicating the sun hindered this. Getting some additional feedback on the button or arm of the mirror would be an upgrade they told. Additionally, the buttons were very small, some of the users indicated they would prefer to have a bigger button or an on/off switch for example. Also, it was mentioned that when using turn signals in a car, they automatically go off after a turn, something that would also be very convenient on a bike. A more practical issue was the width of the bike when the mirrors were mounted. The bike was a bit too wide to get it through the gate of the backyard where the test was started, so this is also an area for improvement.

Limitations

- It was a very short test, only an 8-minute route. It is interesting to see how people will use it if they get a week to test is. Will they use it at every turn? Will they use it at all?
- The test was conducted on a Sunday in a residential area. This was the perfect environment for a first test where it was safe to conduct the research, but the amount of traffic was limited most of the time.
- Since everybody got an instruction on how to use the turn signals, they were curious to use it. At almost every turn users used it because it was only a short test. Also, a camera recording the trip can be a motivation to do exactly that what is expected.

- It could not be seen in this test if other traffic was well aware of the turn signal (see Figure 65, where a car is waiting at the roundabout). People were watching the bike every now and then, but the question remains whether that was out of curiosity or if that was because they saw the indicators.

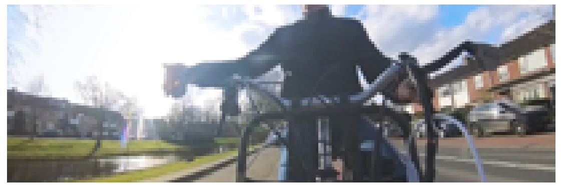


Figure 61. User checking if the turn signal is on

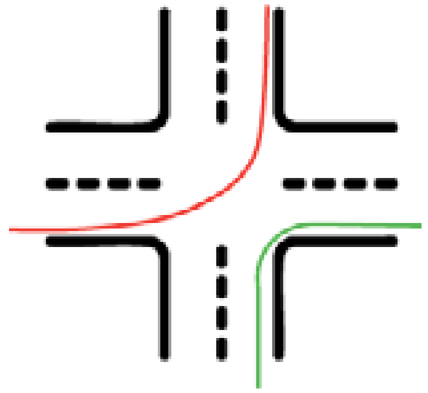


Figure 62. Two types of turns at intersection, short (green) and long (red)

Figure 63.User using the turn signal and looking in the mirror

Figure 64. User using the turn signal, sticking out hand, and looking over shoulder

Figure 65. User using the turn signal but car is waiting on the roundabout

9.1.2 Trigger Test

Since the real bike test revealed a lack of feedback in the trigger, a small follow-up test was conducted with six users using the desk setup. The goal was to determine a preferred trigger type for activating the turn signals, but no clear consensus emerged. Each participant had their own reasoning for preferring or rejecting a specific trigger.

Three different triggers were tested: a push button (as in the prototype), an on/off switch, and a five-way switch capable of registering multiple directions and a push function (see Figure 66). Despite these variations, results in Table 4 show that no single option was universally preferred, as user preferences differed significantly. The table further reinforces this, with each participant ranking the three trigger options differently.

Quick discussions also showed some specific user preference. User 2 preferred the five-way switch due to prior experience with motorcycles or scooters, while user 4 emphasized the importance of not having to switch off the signal manually. User 6 mentioned a preference for a trigger on both sides of the handlebar, adding another layer of complexity to the design considerations.

A designer at BBB summarized this challenge well, stating: "Everything can work, it really depends on your design and how you implement it." Rather than searching for a universally preferred trigger, the focus should be on seamless integration within the overall design to ensure intuitive and effortless operation.

Table 4. Button preference, top 3 per user

	Preference		
	1	2	3
User 1	Switch	Push Button	Fiveway
User 2	Fiveway	Push button	Switch
User 3	Push button	Switch	Fiveway
User 4	Fiveway	Switch	Push button
User 5	Fiveway	Push button	Switch
User 6	Push button/ Switch		Fiveway

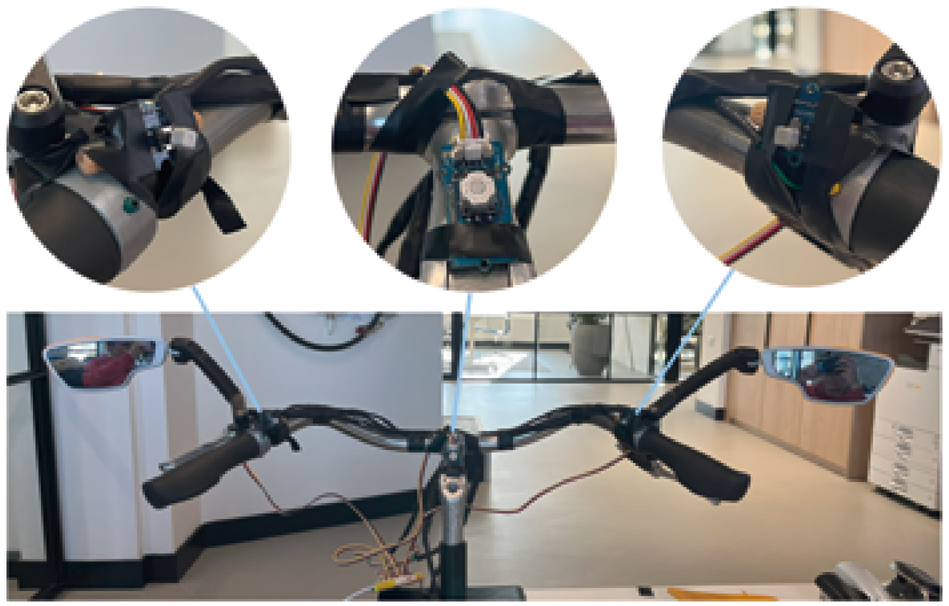


Figure 66. Three different triggers on handlebar

9.2 EXPERT VALIDATION

To assess the market potential and feasibility of the prototype, discussions were held with BBB's industry representatives and bike dealers. The representatives saw potential, particularly for pedelecs and high-end e-bikes, emphasizing the need for integration and usability.

Bike dealers provided insights from a retail and installation perspective, highlighting the importance of ease of installation and seamless integration. Notably, older dealers saw turn signals as part of a broader safety trend, while younger dealers associated them more with elderly cyclists. Both agreed that warranty, reliability, and after-sales support would be crucial for success.

9.2.1 Check with Representatives

During a representative meeting at BBB's office, an opportunity was provided to gather direct feedback on the prototype. The representatives, who travel across the Netherlands and Belgium every day, to visit bicycle dealers and cycling fairs, possess in-depth knowledge of current market trends and available products. Their insights were valuable in assessing the prototype's market potential and usability.

The prototype was mounted on the desk setup, and a few predefined questions were composed to facilitate a structured discussion and gather useful feedback. The questions were based on first impressions, distinctiveness, longevity of turn signals, risk of competitors doing the same, and added value for cyclists and BBB.

The prototype sparked a useful discussion, it was received, with representatives recognizing it as a unique product. It was considered especially relevant for the pedelec and high-end e-bike segment. While it is currently a niche product, they acknowledged its potential as a future innovation rather than a product for 'now'.

In terms of usability, representatives emphasized that each button should have a single, dedicated function, particularly for elderly users. Some also preferred placing the mirror/turn signal at the end of the handlebar rather than its current position. Additionally, the requirement to mount two mirrors was noted as a potential drawback.

Regarding competition, there are currently no direct competitors offering an identical product. The closest alternative is Busch & Müller's Turntec system, which operates through a wired setup and is an entirely separate system.

As for market trends, turn signals on bicycles were seen as a possible trend rather than a necessity at this moment. Some expressed concerns about cyclists not wanting to appear as though they were "driving around like a circus." However, they acknowledged that once users experience the system in traffic, they tend to recognize its value. Also, safety and lighting are increasingly important in the industry, with a growing focus on improved visibility beyond just the winter season, which strengthens the relevance of turn signal systems in the evolving market landscape.

9.2.2 Check with Dealers

To understand the market potential and practicality of the prototype from a dealer's perspective, two bicycle dealers were interviewed. The discussion focused on installation, usability, and commercial viability, with particular attention to what is important for dealers when working with electronic add-ons for bikes.

Both dealers acknowledged that the prototype had potential, though they were sceptical about its current form (they had a bit of difficulty seeing the product as a prototype, rather than as a market-ready product). They emphasized that consumers nowadays prefer integrated solutions over externally mounted accessories. One dealer pointed out that the best way to implement a system like this would be by routing the wiring through the handlebars, as handlebars are hollow, allowing for a cleaner and more seamless integration. However, the second dealer raised concerns about integration, noting that it could be too time-consuming for mechanics to implement. If installing the system takes too long, it would quickly become unappealing for dealers to offer as an add-on when selling a bike, since preparing the bike for use is always done for free after selling a bike. Instead, he preferred a plug-and-play system that would allow for quick and effortless installation, ensuring that mechanics could prepare bikes efficiently for customers.

From a market perspective, both dealers saw the prototype as a nice addition rather than a game-changer in cycling safety. It was not viewed as a strong unique selling point (USP) for a new bike but could work well as an optional extra for e-bike customers. Interestingly, the age difference between the two interviewees provided an intriguing contrast in perspectives. The first dealer, consisting of an older man and woman (likely in their fifties), saw turn signals as a natural development in the cycling industry, even if not in the exact form presented. They believed that the industry was moving towards more integrated safety features, making this type of innovation a logical step for the future.

The second dealer, a younger man likely in his twenties, viewed the system more as a gadget specifically for elderly cyclists, suggesting that older riders might appreciate the feature, but most others would not see the need. He also mentioned that many elderly cyclists already use mirrors and are comfortable with traditional hand signals. This generational difference in perception is interesting, as it suggests that while younger individuals might associate turn signals more with aging riders, older aged dealers see the broader trend of safety innovations becoming standard in the cycling industry.

When discussing maintenance and after-sales service, the dealers agreed that warranty and product reliability would play a crucial role. If BBB could provide a strong guarantee and support, there would be no major concerns regarding repairs or servicing. While maintenance itself was not seen as a major challenge, the durability of the product over time would be key to earning trust from both dealers and customers.

Lockring discussion

Since the turn signal is the most prominent feature of the prototype, the discussions primarily focused on its added value. However, there was also a brief discussion about the lockring mechanism, to which both dealers responded enthusiastically. They indicated that integrating features into the lockring has potential, and can help them to mount components quickly, suggesting it is be a valuable direction for future development.

9.3 CONCLUSION

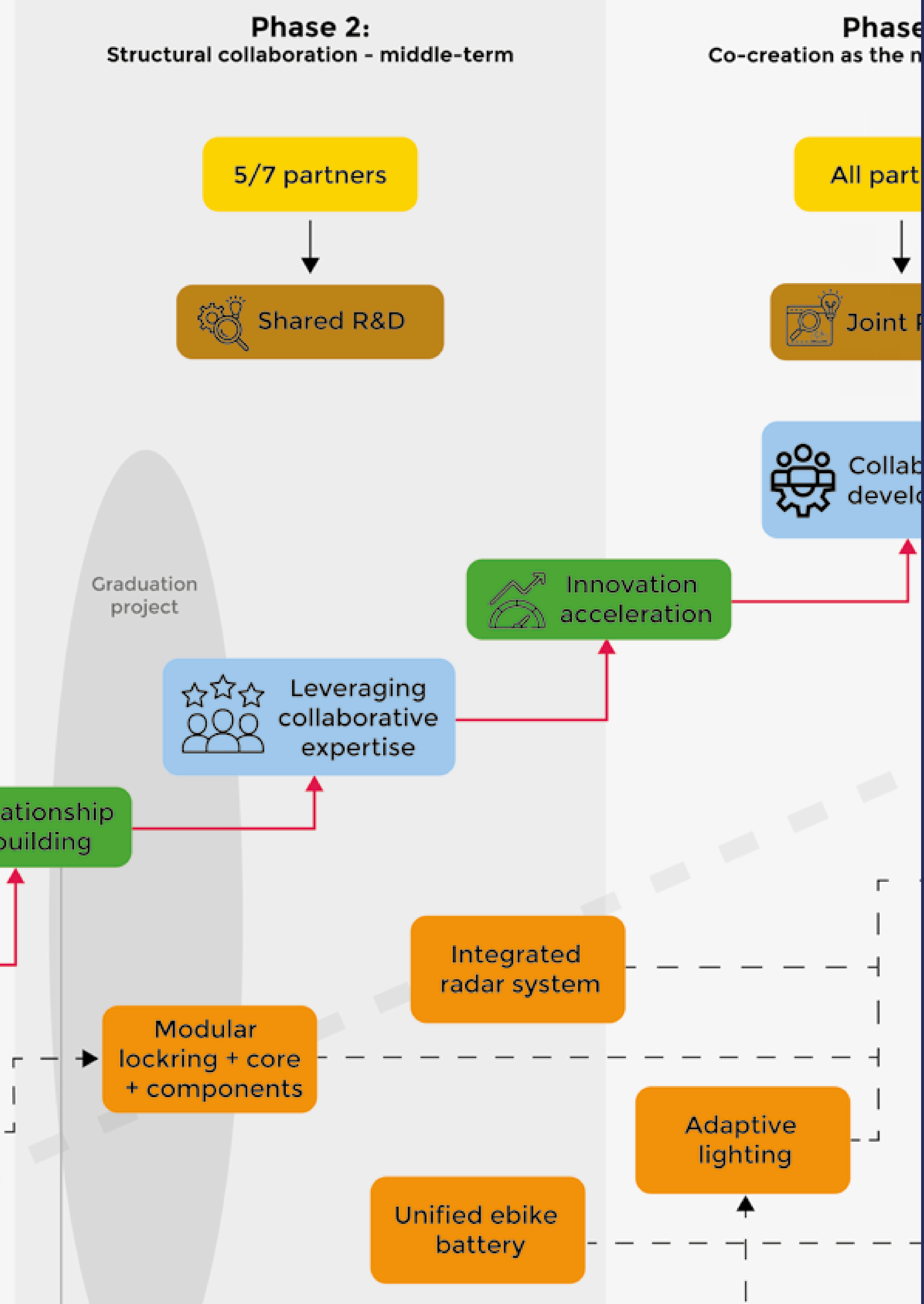
The validation phase offered valuable insights into both the usability and perceived market potential of the prototype. While the lockring itself was not directly tested, the assessment of the mirror and turn signal modules enabled a meaningful real-world evaluation of the broader concept. Across user tests and expert interviews, several consistent themes emerged that inform future design and development considerations.

First, visibility remains a key challenge, particularly in bright outdoor conditions. Participants frequently struggled to confirm whether the turn signals were active, indicating a strong need for integrated feedback, either visual, auditory, or tactile, within the trigger mechanism. The issue was strengthened by the small size of the current buttons and the fixed brightness of the LEDs, both of which limit usability and confidence during use.

Second, the trigger mechanism proved to be a subjective matter. No single design was universally preferred, with users favouring different options based on prior experience and ergonomic comfort. This underlines the importance of prioritising intuitive operation over a one-size-fits-all solution, and suggests future development should focus on seamless integration within the lockring's architecture, allowing for adaptability.

Third, expert feedback from company representatives and dealers highlighted the importance of installation and integration. Plug-and-play functionality and minimal setup time were seen as essential for commercial viability, particularly for bicycle retailers. Moreover, while some dealers viewed the concept as particularly appealing to elderly users, others saw it as part of a broader trend towards integrated safety features in the cycling industry, especially within the high-end e-bike segment.

Together, these findings suggest that while the concept has clear potential, its success will depend on a careful balance of ergonomic design, intuitive interaction, and market-ready integration. These considerations form the foundation for the recommendations and future directions discussed in Chapter 11.



10. STRATEGY REFLECTION

This chapter reflects on the implications of the proposed strategy and accompanying product within the broader context of BBB Cycling and the Pon. Bike network. It explores the practical implementation of the strategy, the extent to which the developed product aligns with this direction, and organizational conditions required to support sustained long-term success.

By linking the proposal to BBB's internal culture and structure, as well as to the dynamics of cross-brand collaboration, this chapter provides insights into the feasibility of the strategy and outlines practical recommendations to sustain its momentum beyond this project.

10.1 STRATEGIC POSITIONING OF THE PRODUCT

The product developed during this graduation project serves primarily as an example of what collaborative projects within Pon.Bike could accomplish. Rather than being intended solely for use by BBB Cycling, the product was designed from the outset as a shared platform, with the potential to be adopted by multiple brands across the Pon.Bike network. As mentioned in Chapter 5, knowledge sharing and shared development are crucial factors for collaboration and this demonstrates how collective innovation can generate added value for the group as a whole.

From a strategic perspective, it is particularly interesting for BBB Cycling to develop unique components that are compatible with bicycles from other Pon.Bike brands. While safety features may not yet be regarded as a distinct USP by all partners, the system allows for forward-compatible integration. Pon.Bike brands can deliver bikes equipped with standardised grips and lockrings, enabling BBB to serve the aftermarket by offering modular safety components directly to consumers or through dealers. In the future, should safety become a stronger commercial focus, Pon.Bike brands could begin integrating such components into their bicycles or design their own versions using the shared system.

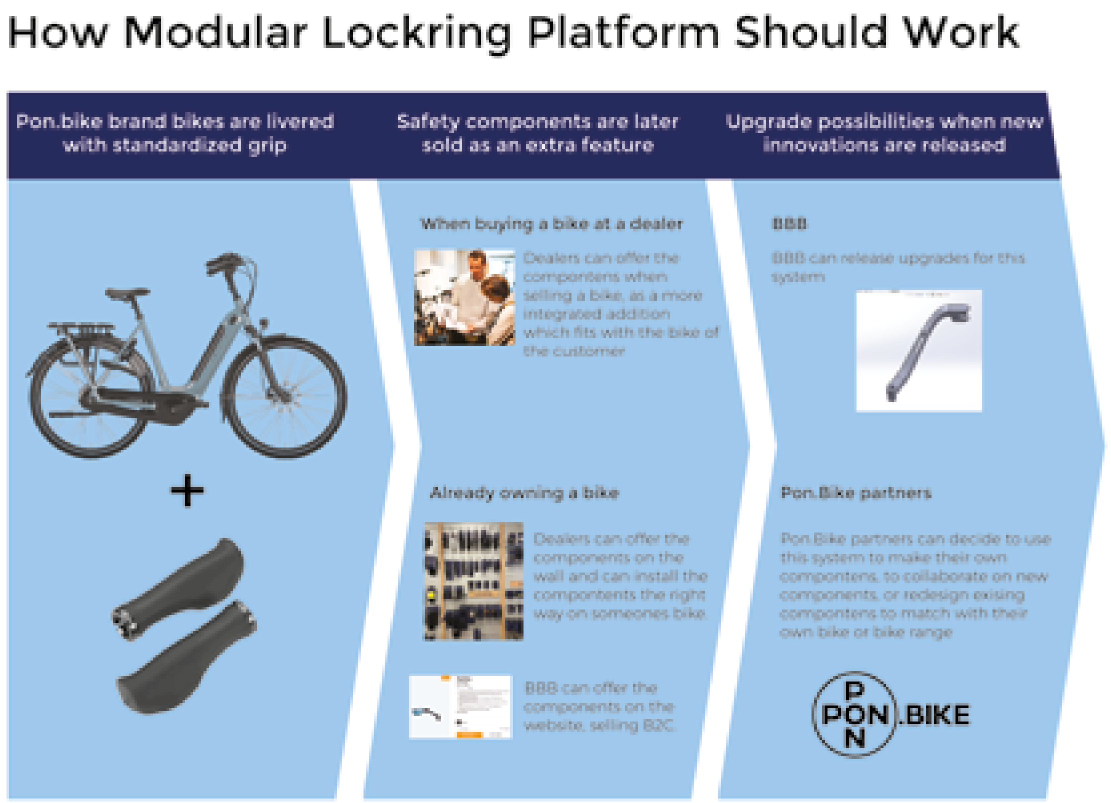


Figure 67. Platform explanation

Throughout the development process, it was repeatedly emphasised that the product should not be viewed as proprietary to BBB, but rather as a platform that enhances collaboration. Brands can opt to include the mounting system on their bicycles, while BBB serves the aftermarket channel. This dual approach not only enhances scalability but also fosters synergy within the group. To support this narrative, the platform model has been visualised (see Figure 67). This illustration outlines how the system can operate across the bicycle lifecycle: from OEM integration, to aftermarket distribution, to future component upgrades.

Moreover, the design process itself served as a valuable catalyst for dialogue, stimulating strategic conversations around cycling safety and future collaboration models. The product thus not only resulted in a tangible prototype but also helped shape broader thinking about BBB's potential position within the Pon.Bike ecosystem.

10.2 INTERNAL CULTURE & STRUCTURE FOR SUCCESSFUL EXTERNAL COLLABORATION

While the product developed in this project serves as an example of collaborative potential within Pon. Bike, the successful implementation of such strategic initiatives depends heavily on the internal context of BBB Cycling, specifically its organisational culture and structure. Interviews and informal conversations within the company reveal that there is general openness to collaboration, yet a number of cultural and structural barriers continue to inhibit the organic development of cooperative projects.

From a cultural perspective, BBB Cycling shows several characteristics associated with a clan culture, described by Cameron & Quinn (2005) in the Competing Values Framework (CVF) (Figure 68). These include informality, a relatively small organisational size, and a strong sense of cohesion within teams. This fits within the earlier described informal way of communication in the cycling industry, but to fulfil the potential of structural collaboration, a systematic approach might help.

However, key aspects of a clan culture; structured feedback, open communication, and a clear understanding of ongoing work across teams, might be underdeveloped. Interviews revealed a degree of internal reluctance to embrace change or external input. As one employee remarked: "You describe building trust among brands as a first step in the roadmap, but trust might need to be fixed internally before we start building it externally." This underscores a critical insight: external collaboration is unlikely to succeed unless internal communication and alignment are first reinforced.

This cultural profile is important, because Büschgens et al. (2013) conclude that innovation is most strongly supported by a developmental culture, which is similar to the adhocracy culture in the CVF. Such a culture emphasises creativity, external orientation, and flexibility, traits that are currently underrepresented within BBB's working environment. While elements of a clan culture may offer a good foundation, the absence of openness and feedback mechanisms suggests that BBB's current culture is not yet sufficiently aligned with what the literature identifies as an innovation-supportive environment.

From a structural perspective, BBB operates with relatively clear role definitions and individual accountability, but without the rigid formality of a traditional bureaucracy. Nevertheless, this role-oriented structure can unintentionally reinforce siloed thinking, especially in combination with limited capacity. Interviewees repeatedly mentioned that the product development team is heavily occupied with maintaining the existing product portfolio, leaving little room to explore or manage external partnerships. As such, collaboration is often perceived as something extra, rather than as a structurally supported part of the workflow.

These observations align with the findings of Burns and Stalker (1961), who distinguish between mechanistic and organic forms of organisation. While mechanistic structures promote stability through clear roles and hierarchical control, they tend to limit innovation and adaptability. In contrast, organic structures allow for more flexible roles, decentralised communication, and adaptive behaviour, factors that are essential for effective cross-brand cooperation. Although BBB's structure is not rigidly mechanistic,

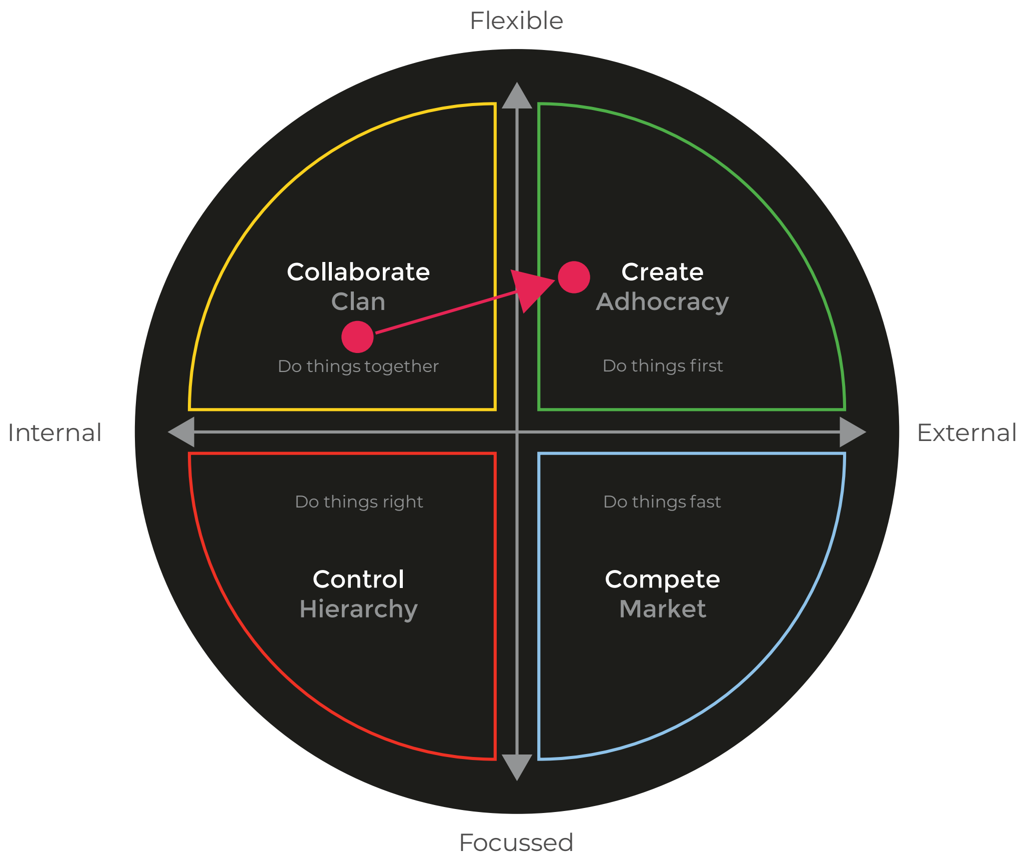


Figure 68. Competing Values Framework, with BBB's current position and proposed position shift, edited from Mulder (2025)

certain tendencies, such as specific task definition and project overload, hinder the kind of agile collaboration that would be needed to implement the strategy outlined in this project.

This capacity issue is strengthened by Pon.Bike's overarching organisational model, in which each brand operates with a high degree of independence and financial responsibility. As one interviewee put it, "every brand needs to stand on its own feet." While this autonomy supports operational efficiency, it also introduces a competitive logic between sister brands, in which collaborative opportunities are assessed primarily on short-term, individual, commercial gain. Furthermore, several respondents highlighted that top-down initiatives are more likely to succeed than bottom-up proposals, as gaining access to senior decision-makers across brands remains difficult at the operational level.

The roadmap developed in this project addresses these challenges directly. In Phase 1 (Exploration & Trust), the goal is to establish informal channels of cooperation through low-stakes, knowledge-sharing initiatives. Yet, as the internal analysis shows, even this seemingly modest objective requires organisational support: in the form of leadership endorsement, time allocation, and open communication. Without these enablers, collaboration remains an abstract ideal rather than an operational reality.

10.3 CONCLUSION AND RECOMMENDATIONS

This project has explored how strategic collaboration within Pon. Bike can generate added value for both BBB Cycling and the wider group, using the design of a modular safety system as a tangible demonstration. The product serves not only as a potential innovation but also as a catalyst for dialogue. The platform model shown in this chapter highlights opportunities for flexible integration in both OEM and aftermarket channels, offering a platform-based approach that leverages shared infrastructure while preserving brand autonomy.

However, the successful implementation of such a strategy requires more than a promising concept. As demonstrated in the cultural and structural analysis, BBB currently faces several internal barriers that limit its ability to initiate and sustain cross-brand collaboration. Structurally, the high degree of autonomy granted to Pon. Bike brands creates a fragmented environment where collaboration must be explicitly facilitated, rather than assumed.

One insight that emerged during interviews is that the benefits of collaboration for BBB are generally clear: as a relatively small brand, BBB stands to gain access to larger product platforms, knowledge, and extended commercial reach. What is less obvious however, is what other Pon.Bike partners stand to gain from engaging in collaboration with BBB. Unless this mutual value is clearly articulated, cooperation may be perceived as asymmetrical, and therefore less attractive.

Based on these findings, the following recommendations are proposed to ensure that the strategic momentum generated by this project can be sustained after its conclusion:

- Strengthen internal collaboration first: before external partnerships can be expanded, BBB should invest in improving internal communication and transparency. This may include regular cross-functional meetings, structured feedback practices, and explicit visibility into ongoing design activities .
- Formalise collaboration as part of the workflow: rather than treating external cooperation as an additional task, it should be integrated into project planning and team responsibilities. Time and capacity must be allocated structurally .
- Clearly define mutual value in collaboration: BBB should actively identify and communicate how other Pon.Bike partners can benefit from working together. While BBB's own motivations, such as increased visibility, platform access, and aftermarket growth are evident, the advantages for other partners may not be equally clear.

Most Pon.Bike brands focus on complete bicycle assembly and rely on external suppliers for their components. This opens a unique opportunity: by collaborating with BBB, these brands can gain access to customisable, brand-specific components developed to match their product positioning and user experience. In doing so, they can differentiate more strongly from competitors without needing to internalise component design capabilities.

Additionally, BBB's established aftermarket presence allows Pon. Bike partners to extend their value proposition to end users through optional upgrades. By equipping bicycles with compatible infrastructure, such as grips or lockrings, these brands can offer consumers the option to add advanced features later on, distributed via BBB's channels. This model enhances product value without adding complexity to the partner brand's core business.

Although BBB may not currently position itself as a premium consumer brand, this does not hinder its effectiveness as a development partner and system supplier. By acting as a modular platform provider and outsourcing partner behind the scenes, BBB can support technical innovation while allowing Pon.Bike partners to retain full ownership of the brand experience.

- Seek top-down sponsorship for pilot projects: given the current challenges in initiating bottom-up efforts, leadership involvement is essential. Strategic pilot projects should be endorsed and supported at the Pon.Bike level to lower the threshold for participation and signal long-term commitment.
- Continue developing platform-oriented products: the modular lockring system exemplifies how BBB can act as a facilitator of cross-brand innovation. Future projects should follow a similar logic, focusing on scalable, shared technologies that benefit multiple stakeholders.

In conclusion, this project has shown the possibilities and steps towards a more collaborative future within Pon.Bike. Realising this potential will require deliberate cultural and structural adjustments, as well as a shared understanding of the value created on both sides of any collaboration. The enthusiasm observed at BBB, particularly in early engagements with brands such as Cannondale, demonstrates that the willingness exists.

11. DISCUSSION AND RECOMMENDATIONS

11.1 STRATEGY

11.1.1 Discussion

This project originated from a central question: *how can BBB Cycling contribute to improving bicycle safety?* Although the topic has gained momentum in recent years, adoption of safety products remains limited. A key insight from the analysis was that these products are often perceived as optional or disconnected add-ons, which limits their perceived value.

To achieve greater impact, integration of safety features into the bicycle itself is essential. Since BBB does not produce bicycles but specialises in parts and accessories, this requires collaboration with bicycle developers, of which some are already present within the Pon.Bike group. This strategic dependency led to the development of a roadmap for cross-brand collaboration, as presented in Chapter 6.

However, the project revealed that collaboration within Pon.Bike is not straightforward. Focus on short term financial gains, hierarchical structures, limited access to strategic layers, time constraints and cultural barriers complicate the establishment of meaningful partnerships. While informal communication between counterparts is relatively smooth, engaging higher-level stakeholders proved far more difficult. For a graduation project, initiating strategic dialogue across brands was particularly challenging.

BBB's internal culture reflects characteristics of a clan culture, but lacks the structured feedback, transparency and interdepartmental alignment needed to support external collaboration. Combined with limited capacity and a strong task focus, these factors contribute to a context where cross-brand cooperation is not yet structurally embedded.

The strategic position of BBB adds another layer of complexity. As a smaller, parts & accessory-focused brand, BBB is not always perceived as a key partner by the group's bicycle manufacturers. The benefits of collaboration may not be immediately apparent to others, especially when short-term commercial gains are unclear. For BBB however, the need to innovate is more urgent. Without continued development, the brand risks becoming interchangeable in a highly competitive and price-driven market.

This makes collaboration not just desirable but strategically necessary for BBB. Sharing knowledge and working with other brands may accelerate its ability to integrate into product development cycles and create longer-term relevance. This perspective also aligns with a potential future role for BBB as an internal development or outsourcing partner within Pon.Bike, an idea that was explicitly supported by the company's Managing Director during interviews. By supporting other brands with specialised development capacity, BBB could reinforce its own strategic relevance while contributing value across the group.

An important reflection during the project concerned the gap between the idealistic perspective of a graduation project and the realities of commercial decision-making. While this project allowed for the exploration of what should be done to create long-term value, companies often operate under short-term financial constraints. As a result, even well-founded proposals may be set aside if they do not yield immediate returns.

Interestingly, several insights from this project were not perceived as new by senior management, but rather as confirmations of existing intuitions. This indicates that the value of the work lies not only in its novelty, but in making implicit ambitions explicit by giving shape and language to strategic directions that had not yet been formalised.

Ultimately, this reinforces the earlier statement made in the report: *"structural and cultural changes are essential for BBB to fully transition into a design-oriented company capable of competing effectively."* With a more open feedback culture, increased internal transparency and shared ownership of product development (as discussed in Chapter 3.3), strategic collaboration can evolve from an aspiration into a strong operational reality.

11.1.2 Recommendations

Below some recommendations are briefly discussed.

Use the roadmap as a tool for dialogue. Rather than treating it as a fixed plan, the roadmap should serve as a starting point for conversation. It can help initiate strategic discussions with other Pon.Bike brands around shared objectives, encouraging mutual understanding and co-creation.

Start small and informal. Large-scale collaboration requires trust, which takes time to build. Low-risk pilots around shared themes, such as cycling safety, can serve as accessible first steps and demonstrate potential value.

Engage middle management early. While top-down support is important, middle managers are essential for translating strategic intent into practice. Their early involvement increases the chance that collaboration becomes part of daily routines rather than an isolated effort.

Reposition BBB as a facilitator rather than a requester. Collaboration is more likely to succeed when it is framed around shared value. BBB can take initiative by using its non-competing role to bring stakeholders together and offer relevant expertise in product development, user needs and the aftermarket. This makes BBB a connector and contributor, not just a beneficiary.

As the original topic was cycling safety, a last recommendation is to also dive into the possibilities of external collaboration on this topic. Cycling safety offers opportunities for broader collaboration beyond Pon.Bike. External partnerships, for example with insurers, advocacy groups, government bodies or knowledge institutions, could further position BBB as a committed innovator. Exploring these thematic alliances may also reinforce internal momentum and strategic clarity.

11.2 PRODUCT DESIGN

11.2.1 Discussion

The product developed during this project serves as a concrete illustration of the kind of innovation that could emerge from collaborative development within Pon.Bike. Designed as a modular safety component, the lockring system demonstrates how shared infrastructure could support both integration into new bicycles and aftermarket upgrades. It reflects the potential of cross-brand alignment around safety-oriented design.

Due to time constraints, it was not possible to co-develop the product with a partner brand. While this limited the opportunity to showcase true collaborative development, the prototype still offers strategic value. It gives form to an idea that might otherwise remain abstract and provides a tangible starting point for future discussions.

Although the product remains a proof-of-concept and is not yet production-ready, it enabled valuable rounds of validation. Test rides with users, conversations with dealers, and internal reviews by BBB staff helped assess both technical feasibility and perceived value. These validation moments yielded several recommendations for further refinement. One important aspect that was not addressed during validation is the role of subjective safety, as discussed in Chapter 2.2. Subjective safety concerns the perception of safety from the user's perspective, which may differ from actual, objectively assessed risk. Although this project focused primarily on objective safety for methodological reasons, subjective safety may hold significant commercial value. Many cyclists make purchase decisions based on perceived comfort and confidence, rather than measurable protection. With more time and broader user testing, this psychological dimension could become a relevant factor in both product design and market positioning.

It is important to note however, that most validation focused on the light modules mounted to the lockring rather than the lockring system itself as a multi-component platform. As such, the broader concept of modularity and the ease of mounting the lockring has not yet been fully tested. Future development should revisit the system-level perspective and explore which other safety-related components, such as electric bells, or technological components like the radar indicator, could be integrated, and how the lockring design may need to evolve to accommodate them.

Moreover, the presence of a physical prototype likely makes future collaboration more approachable. When a model already exists, it becomes easier for other parties to see where and how they might contribute. Yet this also highlights a potential barrier: initiating collaboration around a loosely defined idea may be challenging when partners are unsure of their role or the concrete benefits. In this context, the prototype not only demonstrates a design direction, but also acts as a tool to lower the threshold for engagement.

Recent observations by BBB employees at an international trade fair in Taiwan, further underline the relevance of this development direction. At the event, they encountered a concept bike equipped with integrated indicators and a rear-facing camera, closely aligned with the principles explored in this project (Figure 69). While the exact configuration may differ, such sightings confirm that the industry is already moving in this direction. The prototype developed here may therefore not represent the final answer, but it does show that BBB would benefit from exploring similar system-level innovations going forward.

11.2.2 Recommendations

The lockring itself should be the primary focus in a next design iteration. Unifying the left and right lockring components would streamline manufacturing, reduce tooling complexity and simplify installation for mechanics and end users alike. In addition, the current design should be revisited with a system-wide perspective. While the prototype was tested mainly with light modules, the original concept envisions a broader range of attachable safety components. Future development should explore which other elements, such as bells or other tech components like a radar indicator, could be supported, and how the lockring could be adapted to enable such versatility without compromising simplicity.

Beyond the core system, improvements to the user interface are also needed. A refined button mechanism, potentially with a two-stage trigger, similar to that of a camera shutter, could enhance the user experience by allowing both temporary and continuous activation modes.

Lighting performance should be improved to guarantee visibility under all conditions, including bright sunlight. Finally, ease of installation remains a key factor for adoption: the entire setup should be plug-and-play to ensure that dealers can integrate it quickly and confidently into their workflow.

Figure 69. Concept with rear view and turn signal on a fair in Taiwan

11.3 DELFT INNOVATION METHOD

While the Delft Innovation Method (DIM) provides a valuable cyclical framework for innovation processes, several limitations became apparent during its application in this graduation project. Despite its iterative nature, the model visually presents a closed and linear cycle, offering limited support for the kind of backtracking and reflection that is typical in design practice. Incorporating visual elements such as reverse arrows or more open-ended transitions could better reflect the non-linear nature of innovation. Additionally, the method assumes a level of design experience that may not be present in all teams. The cognitive mode required at each stage, whether analytical, creative, or strategic, is not made explicit, which could lead to inconsistent application by less experienced users. Another limitation is the model's strong emphasis on the development and market introduction of entirely new products. In this project, the design outcome served more as a strategic prototype or vision artifact, a proof of concept and a tool for discussion rather than a finalised product, something not fully accommodated by the DIM. Furthermore, the model remains grounded in traditional product development language, with terms such as "manufacturing" and "distribution" that are less relevant in today's landscape of digital products, services, and product-service systems. As design continues to evolve toward more systemic, experiential, and service-oriented domains, the applicability of the DIM in these contexts becomes increasingly limited.

To address some of these limitations, particularly the underdeveloped strategic dimension of the Delft Innovation Method, elements from Design Roadmapping, as developed by Simonse (2018), could offer valuable enhancements . Integrating roadmapping practices shortly after the identification of the company's strategic situation would allow for the creation of an early vision that guides the exploration of innovation opportunities. This vision can serve as a compass for generating coherent search areas, aligning future design directions with long-term ambitions. Once search areas are identified, the incorporation of design roadmapping techniques such as technology scouting and time-pacing strategies can further structure the innovation trajectory. These tools help bridge the gap between abstract strategic intent and concrete product development by offering a timeline-based perspective on opportunity development. As such, blending the structured creativity of the DIM with the future-oriented planning tools of Design Roadmapping could lead to a more holistic innovation framework, one that is not only grounded in design execution but also deeply aligned with long-term strategic objectives.

Figure 70 shows the model with the steps described above. The blue part is where this project ended, but as the method follows a cycle, 'start' wil be ' evaluation' again and the cycle can start again. The arrows show the interaction with the steps and show how it was thought some of the roadmapping steps could be added.

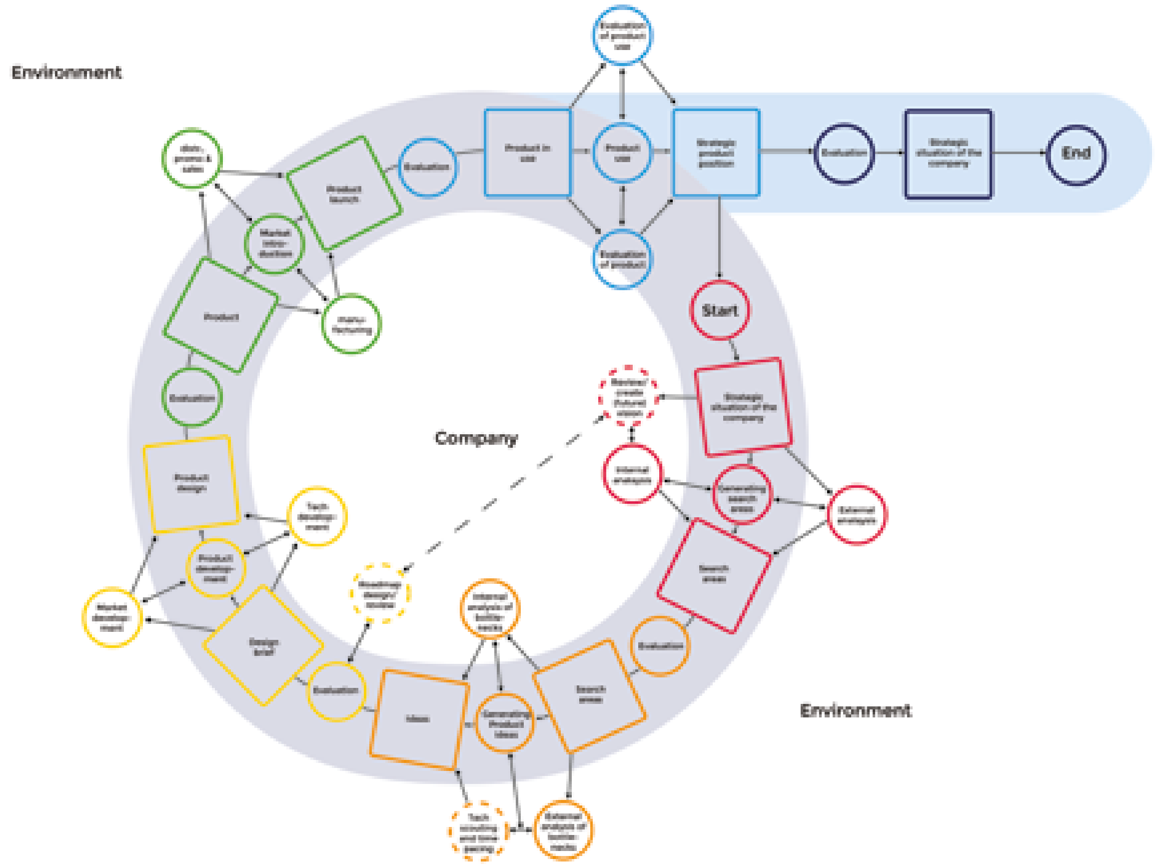
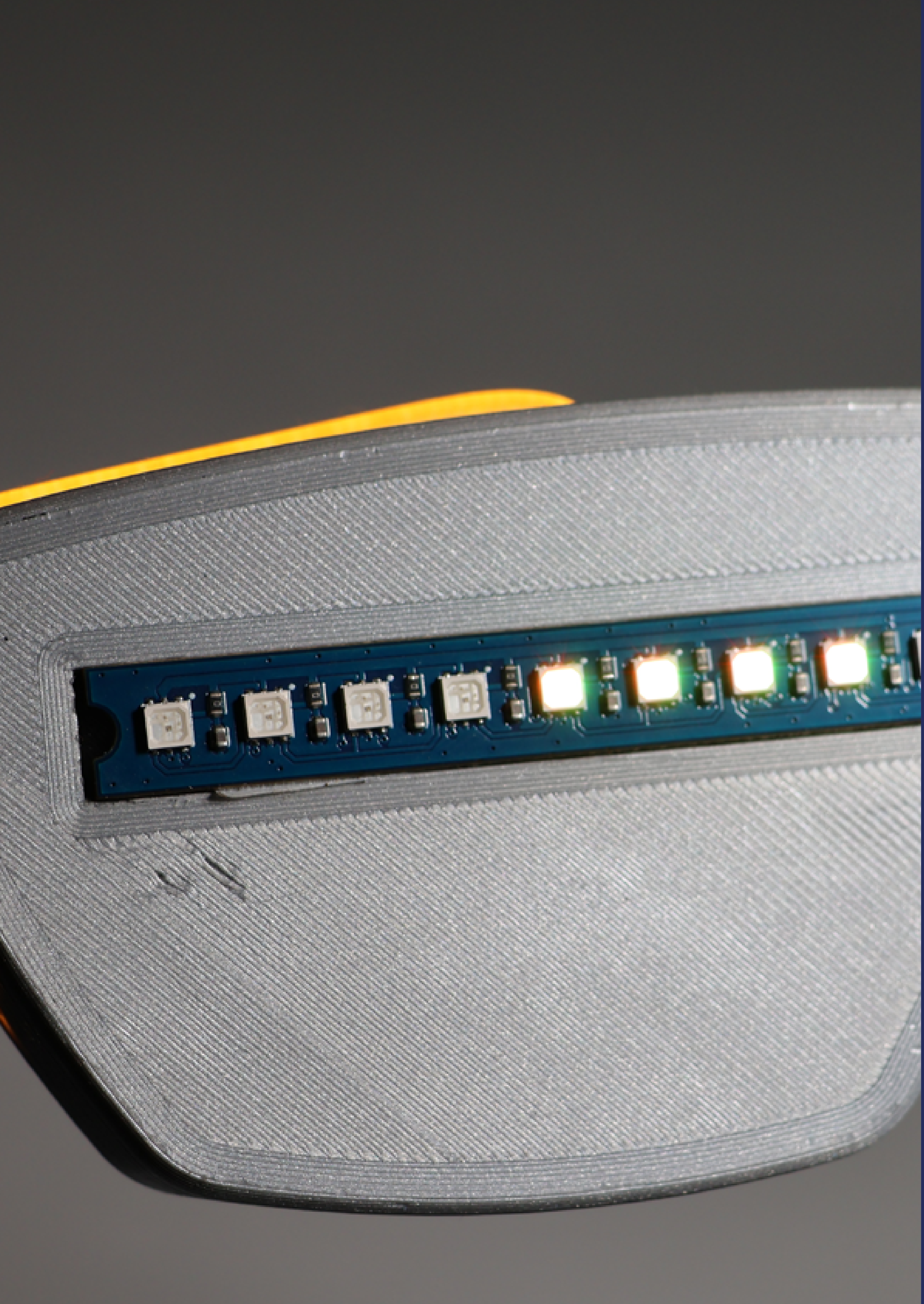


Figure 70. DIM with extra steps from the roadmapping method



12. CONCLUSION

This project set out to analyse how BBB Cycling and the cycling industry as a whole can contribute to improving cycling safety. This was done by conducting an external and internal analysis, followed by designing a collaboration strategy. The focus was put on collaboration, because this is seen as the way to go for the industry to tackle holistic problems like cycling safety. To support the strategy, a modular lockring with a safety component was designed, to show the possibilities of the strategy, both technical as well as showing the platform possibilities.

In the project outline, two main research questions, and four sub-questions were presented. In this conclusion, the questions will be answered, based on the findings and experiences in this project. Each sub-question is addressed first, the two overarching questions are then answered, distinguishing between strategic and product design implications.

Sub-question 1: What are the main factors influencing cycling safety in the Netherlands and Europe today, and how has the rise of electric bikes impacted overall risk levels?

The research reveals that cycling safety in both the Netherlands and Europe is being shaped by a complex interplay of infrastructure, behavioural factors, and demographic shifts. Despite growing policy efforts and infrastructure investment, safety risks remain significant and are, in some areas, increasing.

One of the most prominent drivers of this trend is the rapid rise of electric bicycles. E-bikes have changed the dynamics of cycling behaviour by increasing speeds and expanding the range users can cycle, particularly among older adults. While this development supports active ageing and sustainable transport, it also introduces new risks. The combination of higher speeds and reduced risk perception among inexperienced users has led to a measurable increase in the severity and frequency of crashes.

Furthermore, current infrastructure often fails to accommodate the diversity in cycling behaviour introduced by new vehicle types. Shared paths are increasingly crowded and heterogeneous, while accident reporting remains inconsistent, making targeted policy responses difficult. The findings indicate that the current system lacks the nuance to distinguish between traditional bicycle risks and those emerging from newer forms of mobility.

All in all, the rise of e-bikes has both enabled and complicated the cycling landscape. A critical barrier to promoting safety is the lack of synchronisation between user behaviour, infrastructural design, the cycling industry and policy oversight.

Sub-question 2: How is cycling safety expected to change in the coming years based on trends in mobility, infrastructure, and technology?

Looking forward, cycling safety is expected to evolve in response to a range of demographic and societal developments. The ongoing ageing of the population, combined with urban densification and increasing bicycle modal share, suggests that more vulnerable and diverse user groups will be present on the roads. This strengthens the need for inclusive safety strategies and adaptive infrastructure design.

At the same time, trends in technology and mobility, such as increasing electrification, the expansion of smart city infrastructure, and the availability of real-time data, create opportunities to better monitor, anticipate, and respond to safety challenges.

Public policy has a crucial role in promoting cycling safety in the coming years. On the one hand organizations want to promote cycling and on the other hand they are scared to propose safety increasing policies as they might discourage people to cycle. Choices need to be made, since healthcare costs are rising, and it is expected that the number of cycling accident will rise on the long term.

For companies like BBB Cycling this presents a major strategic opportunity: as safety rises on both the political and consumer agenda, there is space to innovate, through improved products, shared developments, and product platforms that prioritise safety.

Sub-question 3: To what extent will technology be integrated into cycling accessories to enhance safety, and what are the key design considerations for implementation?

This project explored technological integration through the development of a modular platform anchored in a redesigned lockring mechanism. The primary value of this system lies not only in its individual features, such as the mirror with turn signal, but in its ability to serve as a foundation for future safety add-ons such as radar sensors, or light and sound signals.

This modularity reflects a deliberate design philosophy that prioritises the integration of safety components and long-term adaptability. The lockring platform supports the integration of electronic components in a robust, user-friendly, and scalable way. It allows both end-users (aftermarket) and partners (OEM) to adopt new safety functionalities over time, by integrating the lockring and/or its components in their bikes.

Design challenges included balancing robustness with usability, embedding electronics without compromising aesthetics, and ensuring intuitiveness. Validation tests were conducted to test interaction triggers, light visibility, and ergonomic comfort, with varying user responses confirming that no single solution fits all needs. When technologies like this are developed in the (near) future, finding this balance will be a key factor for success, indicating that involving the end users is essential.

Sub-question 4: How can product testing and validation methods ensure the effectiveness and usability of cycling safety innovations?

The analysis in Chapter 2 explicitly described both objective and subjective safety. Although objective indicators, such as signal activation frequency and light visibility, were measured directly in the validation section in Chapter 9, the subjective dimension proved to be much more difficult to measure. Full-scale subjective safety research was beyond the scope of this project, but early findings indicate that perceived safety enhancements (e.g., clear visibility or ergonomic control) increase the likelihood of product adoption. It is advised to, next to the practical tests, also explicitly focus on user comfort, perceived confidence, and intuitive interaction when designing and testing a product to enhance safety. These emotional and behavioural responses could be leveraged in future product evaluation and marketing.

Moreover, commercial validation via interviews with bike dealers and industry experts revealed that safety remains a low-priority USP in retail contexts. However, they confirmed interest in modularity and aftermarket upgrade possibilities, particularly when it can be easily mounted on existing bikes and enhance perceived user value.

Main question 1: How can the cycling industry contribute to improving cycling safety in response to emerging trends in mobility, infrastructure, and technology?

From a strategic standpoint, industry collaboration is the key enabler for systemic safety improvements. This project demonstrated that cross-brand cooperation, especially within networks like Pon.Bike, should be viable and beneficial, despite its challenges. Current collaborations tend to be either informal, based on personal networks, or based on top-down initiatives. While this fosters agility, it lacks the structure needed to scale safety innovation.

A more strategic form of cooperation, build around holistic themes like cycling safety, could accelerate product innovation, reduce redundancy, and strengthen market positioning. However, this requires cultural and organisational shifts.

The proposed collaboration roadmap, described in Chapter 6 offers a phased model, from informal knowledge sharing to full co-creation, which at the same time aims to align with Pon.Bike's decentralised culture. Beyond Pon.Bike, collaboration with policymakers, insurance providers, and mobility platforms could further reinforce the industry's systemic role in promoting cycling safety.

Overarching question 2: How can product design within the cycling industry contribute to improving cycling safety, considering evolving risks and user needs?

This project argues that product design contributes to safety most effectively when it facilitates shared innovation. The developed lockring platform exemplifies this: a component that supports multiple functions, can be embedded as OEM part on new bikes or sold aftermarket, and invites contributions from other brands and developers. All with the aim to lower the barrier to adopt cycling safety components.

This type of modular platform enables flexibility for users and scalability for producers. It also lowers the barriers for safety innovation by offering a consistent, shared, technical interface. Brands can experiment with new features without developing entirely new systems, and consumers can upgrade their safety setup over time.

However, realising this vision is not without challenges. Identified barriers within BBB Cycling and Pon. Bike include limited development capacity, unclear commercial incentives, and the complexity of OEM integration. Overcoming these barriers requires both cultural change and structural support within and across organisations.

Final reflection

This project has shown that the cycling industry is in a strong position to enhance safety, not only through product design, but also through the way it chooses to collaborate and innovate. Strategically, embracing cross-brand cooperation and aligning innovation efforts can create a more cohesive and impactful industry response to the safety challenges posed by trends in mobility, infrastructure and technology. On a product level, design should focus on increasing adoption rates, by lowering barriers and increase usability, makes safety more accessible, accepted, and ultimately more effective.

Throughout this process, it also became clear how deeply cycling safety is embedded within a broader ecosystem of industrial, infrastructural, psychological and political dynamics. Creating real impact in this field is not something an individual, or a single company, can achieve alone. It requires sustained, interdisciplinary collaboration and a shared commitment to safer urban mobility.

By connecting system-level vision with human-centred design, the cycling industry can embed safety in the everyday experience of riding, not as an obligation, but as a natural and valuable part of the journey forward.

REFERENCES

TEXTUAL REFERENCES

ARTE. (2024, July 13). ARTE Re: Tödliche Fahrradunfälle - Die ganze Doku. https://www.arte.tv/de/videos/118265-007-A/re-toedliche-fahrradunfaelle/

Bolt. (n.d.). Ontdek alle Bolt diensten | De alles-in-één mobiliteitsapp. https://bolt.eu/nl-nl/

BOVAG & RAI Vereniging. (2023). Mobiliteit in Cijfers Tweewielers 2023 - 2024. In Mobiliteit in Cijfers Tweewielers. https://mijn.bovag.nl/getattachment/Actueel/Nieuws/2023/oktober/Nu-beschikbaar-Mobiliteit-in-cijfers-Tweewielers-2/MIC_TWEEWIELERS_clickable.pdf?lang=nl-NL

Buijs, J. (2012). The Delft Innovation Method: A Design Thinker's Guide to Innovation. Eleven International Pub.

Burns, T., & Stalker, G. M. (1961). The management of innovation.

Büschgens, T., Bausch, A., & Balkin, D. B. (2013). Organizational Culture and Innovation: A Meta-Analytic Review. Journal of Product Innovation Management, 30(4), 763–781. https://doi.org/10.1111/jpim.12021

Cameron, K. S., & Quinn, R. E. (2005). Diagnosing and changing organizational culture: Based on the Competing Values Framework. Jossey-Bass.

Carpentier, A., & Razemon, O. (2024, October 26). Cyclist's death in Paris sparks public debate on road violence. Le Monde.fr. https://www.lemonde.fr/en/france/article/2024/10/26/cyclist-s-death-in-paris-sparks-public-debate-on-road-violence_6730559_7.html

Centraal Bureau voor de Statistiek. (2024, April 9). 684 verkeersdoden in 2023. Centraal Bureau Voor De Statistiek. https://www.cbs.nl/nl-nl/nieuws/2024/15/684-verkeersdoden-in-2023

Cloud, C., Heß, S., & Kasinger, J. (2023). Shared e-scooter services and road safety: Evidence from six European countries. European Economic Review, 160, 104593. https://doi.org/10.1016/j.euroecorev.2023.104593

De Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the Health Benefits of Cycling Outweigh the Risks? Environmental Health Perspectives, 118(8), 1109–1116. https://doi.org/10.1289/ehp.0901747

Den Ouden, P. H., & Brankaert, R. G. A. (2013). Designing new ecosystems : the value flow model. Onderzoeksportaal Eindhoven University of Technology. https://research.tue.nl/nl/publications/designing-new-ecosystems-the-value-flow-model

Destatis. (2024, March 27). Pedelec-Unfälle: Verunglückte sind immer jünger. Statistisches Bundesamt. https://www.destatis.de/DE/Presse/Pressemitteilungen/2024/03/PD24_N014_46241.html

Doortrappen. (n.d.). Doortrappen - Platform Doortrappen. Platform Doortrappen. https://doortrappen.nl/default.aspx

ECF - European Cyclists Federation. (2023, February). European Parliament calls to double cycling in Europe by 2030. ECF. https://www.ecf.com/en/news/european-parliament-calls-to-double-cycling-in-europe-by-2030/

European Commission. (2020, July 3). Urbanisation in Europe | Knowledge for Policy. https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/urbanisation-europe_en

European Environment Agency. (2024, October 10). Sustainability of Europe's mobility systems. European Environment Agency's Home Page. https://www.eea.europa.eu/en/analysis/publications/sustainability-of-europes-mobility-systems

European Union. (n.d.). WEEE responsibilities for manufacturers and producers. Your Europe. https://europa.eu/youreurope/business/product-requirements/recycling-waste-management/weee-responsibilities/index_en.htm

Fietsberaad CROW. (2022, March 1). Fietsen met oortjes, het risico lijkt mee te vallen - Fietsberaad. https://www.fietsberaad.nl/Kennisbank/Fietsen-met-oortjes,-het-risico-lijkt-mee-te-valle

Fietsersbond. (2023, December 13). Snel ingrijpen noodzakelijk om stijging verkeersslachtoffers te stoppen. https://www.fietsersbond.nl/nieuws/snel-ingrijpen-noodzakelijk-om-stijging-verkeersslachtoffers-te-stoppen/

Furian, G., Kaiser, S., & Soteropoulos, A. (2024). Subjective Safety and Risk Perception. In Austrian Road Safety Board - KFV, ESRA3 Thematic Report Nr. 2 (No. 2024-R-19-EN). Austrian Road Safety Board KFV. https://www.esranet.eu/storage/minisites/esra2023thematicreportno2subjectivesafetyandriskperception.pdf

Gössling, S., Kees, J., Hologa, R., Riach, N., & Von Stülpnagel, R. (2024). Children's safe routes to school: Real and perceived risks, and evidence of an incapacity-incapability space. Journal of Cycling and Micromobility Research, 2, 100019. https://doi.org/10.1016/j.jcmr.2024.100019

Greenwheels. (n.d.). Greenwheels: een deelauto als het jou uitkomt. Deelauto's Van Greenwheels. https://www.greenwheels.nl/

Haan, K. (2023, June 12). Top Remote Work Statistics And Trends. Forbes Advisor. https://www.forbes.com/advisor/business/remote-work-statistics/

Heineke, K., Kloss, B., Ruden, A. M., Möller, T., & Wiemuth, C. (2023, January 5). Shared mobility: Sustainable cities, shared destinies. McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/shared-mobility-sustainable-cities-shared-destinies

Heinen, E., Maat, K., & Van Wee, B. (2010). 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, 16(2), 102–109. https://doi.org/10.1016/j.trd.2010.08.010

Het Parool. (2023, December 8). Vanaf 8 december mag je hier nog maar 30 kilometer per uur rijden in Amsterdam. Het Parool. https://www.parool.nl/amsterdam/wegen-30-kilometer-per-uur-amsterdam~b0ac0553/?referrer=https%3A%2F%2Fwww.google.com%2F

Jiang, K., Yang, Z., Feng, Z., Sze, N., Yu, Z., Huang, Z., & Chen, J. (2021). Effects of using mobile phones while cycling: A study from the perspectives of manipulation and visual strategies. Transportation Research Part F Traffic Psychology and Behaviour, 83, 291–303. https://doi.org/10.1016/j.trf.2021.10.010

Johnson, R. (2024, May 9). Why Car-Free Cities are the Next Big Thing in Urban Planning. Momentum Mag. https://momentummag.com/why-car-free-cities-are-the-next-big-thing-in-urban-planning/

Khreis, H., Warsow, K. M., Verlinghieri, E., Guzman, A., Pellecuer, L., Ferreira, A., Jones, I., Heinen, E., Rojas-Rueda, D., Mueller, N., Schepers, P., Lucas, K., & Nieuwenhuijsen, M. (2016). The health impacts of traffic-related exposures in urban areas: Understanding real effects, underlying driving forces and co-producing future directions. Journal of Transport & Health, 3(3), 249–267. https://doi.org/10.1016/j.jth.2016.07.002

Koppel, L., Andersson, D., Tinghög, G., Västfjäll, D., & Feldman, G. (2023). We are all less risky and more skillful than our fellow drivers: Successful replication and extension of Svenson (1981)‎ . Meta-Psychology, 7. https://doi.org/10.15626/mp.2021.2932

Küster, F., & Schusta, B. (2023). The state of national cycling strategies in Europe. In M. Brennan (Ed.), European Cyclists' Federation (3rd ed.). https://ecf.com/system/files/The-State-of-National-Cycling-Strategies-2023_ECF.pdf

Landgreeen-Petersen, G. (2021, October 13). The Perception of Risk. RoC Consult ApS. https://rocconsult.eu/the-perception-of-risk/

Liberty, E., Mazzae, E., Garrott, W. R., & Goodman, M. J. (2000). NHTSA Driver Distraction Research: Past Present and Future. ResearchGate. https://www.researchgate.net/publication/255669554_NHTSA_Driver_Distraction_Research_Past_Present_and_Future

Lunenburg, F. C., Jr., Sam Houston State University, Nelson & Quick, Galbraith, Greenberg, Oliveira & Takahashi, Kuprenas, Brickley, Smith, Zimmerman, & Willett, Hall & Tolbert, & Miles, Snow, Meyer, & Coleman. (2012). Organizational Structure: Mintzberg's Framework. In INTERNATIONAL JOURNAL OF SCHOLARLY, ACADEMIC, INTELLECTUAL DIVERSITY (No. 1; Vol. 14). https://platform.europeanmoocs.eu/users/8/Lunenburg-Fred-C.-Organizational-Structure-Mintzberg-Framework-IJSAID-V14-N1-2012.pdf

Meyer, H., & Zollner, P. (2024, July 2). Helmpflicht für Radfahrer: Pro und contra. https://www.adac.de/rund-ums-fahrzeug/zweirad/fahrrad-ebike-pedelec/vorschriften-verhalten/helmpflicht-fahrrad/

Michie, S., Van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6(1). https://doi.

org/10.1186/1748-5908-6-42

Ministerie van Algemene Zaken. (2024, August 22). Kabinet: meer mensen op de fiets. Fiets | Rijksoverheid.nl. https://www.rijksoverheid.nl/onderwerpen/fiets/fiets-beleid

Ministerie van Infrastructuur en Waterstaat. (2023, September 26). Veel gemeenten zetten in op autoluwe stad. Nieuwsbericht | Kennisinstituut Voor Mobiliteitsbeleid. https://www.kimnet.nl/actueel/nieuws/2023/09/26/veel-gemeenten-zetten-in-op-autoluwe-stad

Ministerie van Volksgezondheid, Welzijn en Sport. (2024, May 31). Personeelstekorten in de zorg. Inzet Personeel in De Zorg | Inspectie Gezondheidszorg En Jeugd. https://www.igj.nl/onderwerpen/inzet-personeel-in-de-zorg/personeelstekort

Mobility Foresights. (2024, July 26). Europe E-Bike Market 2024-2030. https://mobilityforesights.com/product/europe-e-bike-market/

Nederlandse Spoorwegen. (n.d.). OV-fiets huren l Reis verder met OV-fiets | NS. https://www.ns.nl/deur-tot-deur/ov-fiets

Norman, D. (n.d.). What is User Centered Design (UCD)? The Interaction Design Foundation. https://www.interaction-design.org/literature/topics/user-centered-design

NOS. (2024a, September 23). VeiligheidNL: meer ongelukken met fatbikes, maar exacte cijfers moeilijk te krijgen. https://nos.nl/artikel/2538196-veiligheidnl-meer-ongelukken-met-fatbikes-maar-exacte-cijfers-moeilijk-te-krijgen

NOS. (2024b, September 24). Meerderheid Tweede Kamer stemt voor helmplicht en verbod op fatbike onder de 14. https://nos.nl/artikel/2538348-meerderheid-tweede-kamer-stemt-voor-helmplicht-en-verbod-op-fatbike-onder-de-14

Oomen, M., & Heijnen, M. (2024, April 17). Verkeer in cijfers | Website Onderzoek en Statistiek. https://onderzoek.amsterdam.nl/artikel/verkeer-in-cijfers-2024

Pucher, J., & Buehler, R. (2016). Safer Cycling Through Improved Infrastructure. American Journal of Public Health, 106(12), 2089–2091. https://doi.org/10.2105/ajph.2016.303507

Pugh, D., & Hickson, D. (2007). Writers on organizations. https://doi.org/10.4135/9781483329628

RIVM. (2022, July 6). Effecten van vergrijzing steeds beter zichtbaar in uitgaven gezondheidszorg | RIVM. https://www.rivm.nl/nieuws/effecten-van-vergrijzing-steeds-beter-zichtbaar-in-uitgaven-gezondheidszorg

Sanders, R. L. (2016). We can all get along: The alignment of driver and bicyclist roadway design preferences in the San Francisco Bay Area. Transportation Research Part a Policy and Practice, 91, 120–133. https://doi.org/10.1016/j.tra.2016.06.002

Sauer, K., PhD. (2023, August 22). How Far Are We From Level 5 Autonomy? https://blog.guardknox.com/how-far-are-we-from-level-5-autonomy

Schepers, J. P., Weijermars, W. A. M., Boele, M. J., Dijkstra, A., & Bos, N. M. (2020). Oudere fietsers. In SWOV (R-2020-22A; p. 107). SWOV, Den Haag. https://swov.nl/system/files/publication-downloads/r-2020-22a.pdf

Schepers, P., Twisk, D., Fishman, E., Fyhri, A., & Jensen, A. (2015). The Dutch road to a high level of cycling safety. Safety Science, 92, 264–273. https://doi.org/10.1016/j.ssci.2015.06.005

Schmidt, S. (2024, December 3). Urban Transformation: The Journey to Car-Free Cities. PTV Blog. https://blog.ptvgroup.com/en/trend-topics/car-free-cities/

Sørensen, M., Mosslemi, M., & Institute of Transport Economics. (2009). TØI report 1009/2009 (p. 140). Institute of Transport Economics. https://www.toi.no/getfile.php/1311745-1243515338/Publikasjoner/T%C3%98I%20rapporter/2009/1009-2009/1009-2009-Sum.pdf

Statistiek Vlaanderen. (2024, July). Verkeersslachtoffers. Vlaanderen. https://www.vlaanderen.be/statistiek-vlaanderen/mobiliteit/verkeersslachtoffers

SWOV. (2023a). De Staat van de Verkeersveiligheid 2023. In SWOV (Report R-2023-12; pp. 3–4). https://swov.nl/sites/default/files/bestanden/downloads/R-2023-12.pdf

SWOV. (2023b). SWOV fact sheet Cyclists. In SWOV Fact Sheet (pp. 1–23). https://swov.nl/en/news/updated-fact-sheet-road-deaths-netherlands

SWOV. (2024). Fietshelmen - 2. Hoe vaak wordt in Nederland een fietshelm gedragen? https://swov.nl/nl/fact/fietshelmen-2-hoe-vaak-wordt-nederland-een-fietshelm-gedragen

TU Delft. (2019, April 13). TU Delft - Smart motor in handlebars prevents bicycles from falling over [Video]. YouTube. https://www.youtube.com/watch?v=rBOQp2uY_lk

Uber. (n.d.). Taxi near me: Request Uber Taxi On Your Phone. https://www.uber.com/nl/en/ride/ubertaxi/

United Nations Economic Commission for Europe. (2021). Draft Pan-European Master Plan for Cycling Promotion. In Unece (ECE/AC.21/2021/4–EUCHP2018924/4.3.4). Economic and Social Council. https://unece.org/sites/default/files/2023-03/2103412E.pdf

Van Cauwenberg, J., De Bourdeaudhuij, I., Clarys, P., De Geus, B., & Deforche, B. (2018). E-bikes among older adults: benefits, disadvantages, usage and crash characteristics. Transportation, 46(6), 2151–2172. https://doi.org/10.1007/s11116-018-9919-y

Van Schaik, J. (2024). european-e-bike-sales-take-step-back-in-2023. https://www.bike-eu.com/47619/european-e-bike-sales-take-step-back-in-2023

Vansteenkiste, P., Zeuwts, L., Cardon, G., Philippaerts, R., & Lenoir, M. (2014). The implications of low quality bicycle paths on gaze behavior of cyclists: A field test. Transportation Research Part F Traffic Psychology and Behaviour, 23, 81–87. https://doi.org/10.1016/j.trf.2013.12.019

VeiligheidNL. (n.d.). Risico's en oorzaken van fietsongevallen en snor- en bromfietsongevallen in Nederland [Report]. https://www.veiligheid.nl/sites/default/files/2022-06/VeiligheidNL%20infographic%20fietsongevallen.pdf

Verkade, T., & Te Brömmelstroet, M. (2020). Het recht van de snelste. Wat er verkeerd is aan ons verkeer.

Verkeerskunde. (2024, February 1). E-bike zelf geen oorzaak toename verkeersslachtoffers. https://www.verkeerskunde.nl/artikel/e-bike-zelf-geen-oorzaak-toename-verkeersslachtoffers

Volkswagen Group. (2021, March 16). Volkswagen Group set to use platform model for issues of the future. https://www.volkswagen-group.com/en/press-releases/volkswagen-group-set-to-use-platform-model-for-issues-of-the-future-16746

White, M. (2011). Young drivers' optimism bias for accident risk and driving skill: Accountability and insight experience manipulations. www.academia.edu. https://www.academia.edu/13796541/Young_drivers_optimism_bias_for_accident_risk_and_driving_skill_Accountability_and_insight_experience_manipulations

Wielerflits. (2025, January 9). 'Verblindende fietsverlichting zorgt voor gevaar, e-bikes zijn een probleem' | Fietstoerisme | Alles over de mooiste fietsbestemmingen. WielerFlits. https://www.wielerflits.nl/fietstoerisme/verblindende-fietsverlichting-zorgt-voor-gevaar-e-bikes-zijn-een-probleem/

Ziemi. (n.d.). Ziemi - Zorg dat je gezien wordt. https://www.ziemi.com/

VISUAL REFERENCES

Figures

Figure 1, Kristensen, K. E. (2024, December 8). Kvindelig cyklist er i kritisk tilstand efter uheld i Aarhus. TV2 Østjylland. https://www.tv2ostjylland.dk/aarhus/alvorlig-ulykke-cyklist-i-kritisk-tilstand

Omroep Flevoland. (2025, February 12). Weer een fietsongeluk in Lelystad: gemeenteraad wil meer actie. https://www.omroepflevoland.nl/nieuws/415557/weer-een-fietsongeluk-in-lelystad-gemeenteraad-wil-meer-actie

Renfer, M. (2025, March 2). Genève: accident entre un tram et un vélo à Lancy. Tribune De Genève. https://www.tdg.ch/geneve-accident-entre-un-tram-et-un-velo-a-lancy-397834462661

RTV Drenthe. (2024, September 1). Traumahelikopter ingezet na ernstig fietsongeluk in Meppel. RTV Drenthe. https://www.rtvdrenthe.nl/nieuws/16792661/trauma-helikopter-ingezet-na-ernstig-fietsongeluk-in-meppel

Sassone, E., & Ó Broin, C. (2025, February 28). Cyclist seriously injured in second major crash on N17 today. Irish Independent. https://www.independent.ie/regionals/galway/news/cyclist-seriously-injured-in-second-major-crash-on-n17-today/a1880824907.html

T-Online. (2025, February 28). Berlin: 37-jähriger Radfahrer stirbt nach Sturz – Polizei sucht Zeugen. T-online. https://www.t-online.de/region/berlin/id_100615868/berlin-37-jaehriger-radfahrer-stirbt-nach-sturz-polizei-sucht-zeugen.html

Figure 2, Buijs, J. (2012). The Delft Innovation Method: A Design Thinker's Guide to Innovation. Eleven International Pub.

Figure 3, Milieu Centraal. (n.d.). Fiets, ov of auto. https://www.milieucentraal.nl/duurzaam-vervoer/co2-uitstoot-fiets-ov-en-auto/

Figure 4, BOVAG & RAI Vereniging. (2023). Mobiliteit in Cijfers Tweewielers 2023 - 2024. In Mobiliteit in Cijfers Tweewielers. https://mijn.bovag.nl/getattachment/Actueel/Nieuws/2023/oktober/Nu-beschikbaar-Mobiliteit-in-cijfers-Tweewielers-2/MIC_TWEEWIELERS_clickable.pdf?lang=nl-NL

Figure 5 Veilig Verkeer Nederland. (2023, October). Amsterdam maakt zich op voor 30 km/uur. https://vvn.nl/nieuws/amsterdam-maakt-zich-op-voor-30-kmuur

Figure 6 Centraal Bureau voor de Statistiek. (2024, April 9). 684 verkeersdoden in 2023. Centraal Bureau Voor De Statistiek. https://www.cbs.nl/nl-nl/nieuws/2024/15/684-verkeersdoden-in-2023

Figure 7 Centraal Bureau voor de Statistiek. (2024, April 9). 684 verkeersdoden in 2023. Centraal Bureau Voor De Statistiek. https://www.cbs.nl/nl-nl/nieuws/2024/15/684-verkeersdoden-in-2023

Figure 8, ARTE. (2024, July 13). ARTE Re: Tödliche Fahrradunfälle - Die ganze Doku. https://www.arte.tv/de/videos/118265-007-A/re-toedliche-fahrradunfaelle/

Figure 9, SWOV. (2023b). Hoe vaak rijden fietsers zonder licht en hoe onveilig is dat? https://swov.nl/nl/fact/fietsers-15-hoe-vaak-rijden-fietsers-zonder-licht-en-hoe-onveilig-dat

Figure 10, Goudappel. (n.d.). Toegankelijke en veilige fietspaden? Brede fietspaden! https://www.goudappel.nl/nl/themas/fiets/toegankelijke-en-veilige-fietspaden-brede-fietspaden (on top)

Dutch Cycling Embassy. (2024). Dutch Cycling Embassy on LinkedIn. https://www.linkedin.com/posts/dutch-cycling-embassy_today-the-speed-limit-on-80-of-the-roads-activity-7138814627672387584-8y3g/ (on bottom)

Figure 11, Doortrappen. (n.d.). Doortrappen - Platform Doortrappen. Platform Doortrappen. https://doortrappen.nl/default.aspx

Figure 14 PTOLEMUS Consulting Group. (2022, August 25). What are the six levels of vehicle automation? - PTOLEMUS Consulting Group. https://www.ptolemus.com/what-are-the-six-levels-of-vehicle-automation/

Figure 15, Den Ouden, P. H., & Brankaert, R. G. A. (2013). Designing new ecosystems : the value flow model. Onderzoeksportaal Eindhoven University of Technology. https://research.tue.nl/nl/publications/designing-new-ecosystems-the-value-flow-model

Figure 16 Centraal Bureau voor de Statistiek. (n.d.). Bevolkingspiramide. Centraal Bureau Voor De Statistiek. https://www.cbs.nl/nl-nl/visualisaties/dashboard-bevolking/bevolkingspiramide

Figure 17 TU Delft. (2019, April 13). TU Delft - Smart motor in handlebars prevents bicycles from falling over [Video]. YouTube. https://www.youtube.com/watch?v=rBO-Qp2uY_lk

Figures 21, products on 25, 27, 48, 51 BBB website

Figure 24 BBB financial archive

Figures 28, 29 Photos made by Pon Holding

Figure 35 Upsilon. (2023, July 25). Understanding the stages of product development life cycle. https://www.upsilonit.com/blog/product-development-life-cycle-key-stages-explained

Figure 36 Michie, S., Van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6(1). https://doi.org/10.1186/1748-5908-6-42

Figure 40 ArenaEV.com. (2022, June 19). VW ID.4, Audi Q4 and Skoda Enyaq - three identical yet so different EVs. ArenaEV.com. https://www.arenaev.com/vw_id4_audi_q4_and_skoda_enyaq__three_identical_yet_so_different_evs-news-390.php

Figures 43 Mantel. (n.d.). BBB Cycling StrikeDuo 2000 BLS-173 Koplamp. https://www.mantel.com/bbb-cycling-strikeduo-2000-bls-173?autocomplete=1

Figure 46 Spectrum FiftyNine. (n.d.). Spectrum FiftyNine. https://spectrumfiftynine.com/

Figure 50 ROSE Bikes. (n.d.). GX EagleTM Grip Shift draaischakelaar schakelversteller. SRAM GX EagleTM Grip Shift Draaischakelaar Schakelversteller Nu Bestellen | ROSE Bikes. https://www.rosebikes.nl/sram-gx-eagletm-grip-shift-draaischakelaar-schakelversteller-2680555 (Grip shift)

Just Pedal Bikeshop. (n.d.). Trigger Shifter. https://www.justpedal.nl/en/Trigger-Shifter (Trigger shift)

Figure 72 indiamart.com. (n.d.). Handle grip plastic injection mold. Indiamart. https://www.indiamart.com/proddetail/handle-grip-plastic-injection-mold-2853604558697.html

Chapter photo's

Chapter 1 Baumeister, M. (2019, December 16). parked bike lot. Unsplash. https://unsplash.com/photos/parked-bike-lot-pYtsEYKD_gs

Chapter 2 Vishal. (2021, February 7). red and white stop sign. Unsplash. https://unsplash.com/photos/red-and-white-stop-sign-lBOuDA7Kw0A

Chapter 3 BBB archive

Chapter 4 BBB website

Chapter 5 Félix, A. (2018, February 3). red tandem bicycle hanging on wall. Unsplash. https://unsplash.com/photos/red-tandem-bicycle-hanging-on-wall-Iqwlfc1cn-nw

Chapter 6 König, M. (2020, June 14). yellow and black arrow sign. Unsplash. https://unsplash.com/photos/yellow-and-black-arrow-sign-ECGv8s2IPG0

Chapters 7, 8, 9, 12 Own archive

Chapter 11 BBB archive

References Bohovyk, O. (2020, February 1). Brown Wooden Book shelves with books · Free Stock photo. Pexels. https://www.pexels.com/photo/brown-wooden-book-shelves-with-books-3646105/

Appendix Weiss, E. (2022, December 12). You Have Too Much Old Bike Stuff. Here's What to Do with It. Outside Online. https://www.outsideonline.com/outdoor-gear/bikes-and-biking/you-have-too-much-old-bike-stuff-heres-what-to-do-with-it/

APPENDIX

APPENDIX A PROJECT BRIEF

Personal Project Brief – IDE Master Graduation Project

Name student Teun van Ekeren **Student number** 4,844,750

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Strategic roadmap and safety-focussed bicycle accessory prototype for BBB Cycling

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

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The mobility sector requires significant transformations due to climate change, demographic shifts and technological innovations. Cities are increasingly becoming car-free, climate zones are being established and thus cycling is being encouraged. This leads to an increase in bicycle use and a greater variety of different types of bicycles on the streets (regular city bikes, e-bikes, cargo bikes, hybrid bikes, etc.). The Netherlands is a leader in electric biking in Europe, and the sales of new e-bikes here exceed those of new 'traditional' bikes. This trend is expected to spread to other European countries, particularly those with similar and developing cycling infrastructure like Germany, France, Denmark, and the UK. Also, the amount of people that use a bike for sports (road cycling, mountain biking, gravelling) is increasing.

With the increasing number of cyclists, the variation in speed and the experience level between different types of bicycles, more dangerous situations arise. Distractions for other road users further contribute to an increase in the number of accidents with injuries. Consequently, there is increasing interest in safety. BBB Cycling designs and sells a wide range of bicycle accessories and parts, from clothing to tools, and from lighting to helmets.

It is crucial for BBB to gain insights into future mobility trends and safety issues to align their product offerings accordingly. Because I am following a double degree masters, in both SPD and IPD, this project aims to strategically and design-wise prepare BBB for these changes.

→ *space available for images / figures on next page*

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The problem to be addressed is understanding the future needs and safety requirements of cyclists in the evolving mobility landscape. This understanding will determine if, and to what extent, BBB needs to adapt its product portfolio. This includes developing a product that addresses emerging safety concerns and aligns with trends of increased bicycle use and variety. By focusing both on strategic analysis and product design, the project aims to provide a comprehensive approach that combines in-depth research with practical application, ensuring that BBB can make well-informed decisions and develop innovative products that meet the diverse needs of future cyclists and also fits the BBB portfolio.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design/Investigate/Validate/Create) a (what will be the deliverable -> prototype/ roadmap/process/ intervention/approach/ guideline/strategy/...) to (what should it do -> create/ understand/evaluate/validate/improve/execute/analyse/...) (the objective -> experience/ value/process/product/...) for (whom -> target group/ client/...) in (what context).

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

In this project I conduct strategic research into mobility and cycling trends, safety issues, and legislation in Western Europe, analyse BBB's current product portfolio, and identify strengths and weaknesses. This leads to the development of a strategic roadmap outlining potential successful directions for BBB over the next 5-10 years. Following the analysis, in the product design phase an innovative, safety-enhancing accessory (prototype/boundary object) tailored to diverse cyclist needs is developed. This phase includes iterative prototyping and testing, involving potential future users to gain feedback. The final phase includes a strategic evaluation of the developed products against the roadmap and recommendations for portfolio adjustments and implementation.

BBB sees this integrated approach as a significant benefit, providing a clear direction for future product development and market positioning.

APPENDIX B HREC

Appendix B1,B2 and B3 contain the materials used for the approved application.

The last part of Appendix B (B4,B5 and B6) contains the HREC application documents for the user test. All documents were submitted through Lab Servant to be evaluated, on the 26th of February. As of the 7th of April, still no reaction was given on this application. Because it took longer than expected, and the project had to move on, it was decided, in consultation with the supervisors, to conduct the research anyway. The AMA advisor had given permission to test the prototype, so this risk was already moved out of the way, and since the consent form was already approved for the interviews, the same format was used again.

Appendix B.1 Application Form

I. Applicant Information

PROJECT TITLE:	**Strategic roadmap and safety-focussed bicycle accessory prototype for BBB Cycling**
Research period: *Over what period of time will this specific part of the research take place*	**September 2024 – April 2025**
Faculty:	**Industrial Design Engineering**
Department:	
Type of the research project: *(Bachelor's, Master's, DreamTeam, PhD, PostDoc, Senior Researcher, Organisational etc.)*	**Master's thesis**
Funder of research: *(EU, NWO, TUD, other – in which case please elaborate)*	**TUD/BBB?**
Name of Corresponding Researcher: *(If different from the Responsible Researcher)*	**Teun van Ekeren**
Position of Corresponding Researcher: *(Masters, DreamTeam, PhD, PostDoc, Assistant/ Associate/ Full Professor)*	**Masters**
Name of Responsible Researcher: ***Note:** all student work must have a named Responsible Researcher to approve, sign and submit this application*	**Arjen Jansen**
Position of Responsible Researcher : *(PhD, PostDoc, Associate/ Assistant/ Full Professor)*	**Associate professor**

II. Research Overview

***NOTE:** You can find more guidance on completing this checklist here*

a) Please summarise your research very briefly (100-200 words)
What are you looking into, who is involved, how many participants there will be, how they will be recruited and what are they expected to do?

Add your text here – (please avoid jargon and abbrevations)
This research is part of my masters thesis at IDE. The project aims to explore the safety of cyclists by investigating expert perspectives and testing innovative safety prototypes. Interviews will be conducted with 10 participants, including experts such as medical professionals specializing in trauma, mobility experts, and design specialists. These interviews will focus on understanding the current challenges and potential future advancements in cycling safety. Also an additional questionnaire will be send to gather context specific information from shop owners and cyclists. In the prototyping phase, 10 users will be involved in testing self-made prototypes designed to improve cyclist safety. The tests will evaluate the effectiveness and user experience of the prototypes, providing feedback for iterations and further development. For the interviews participants will be recruited by looking for experts both online and within the company, they are expected to answer my questions and help me with their specific knowledge. For the user-tests, participants will be recruited from my own network and they are expected to analyze the prototypes in the first phase and later on test the prototypes.

b) **If your application is an additional project** related to an existing approved HREC submission, please provide a brief explanation including the existing relevant HREC submission number/s.

Add your text here – (please avoid jargon and abbrevations)
n/a

c) **If your application is a simple extension of, or amendment to,** an existing approved HREC submission, you can simply submit an HREC Amendment Form as a submission through LabServant.

III. Risk Assessment and Mitigation Plan

***NOTE:** You can find more guidance on completing this checklist here*

Please complete the following table in full for all points to which your answer is "yes". Bear in mind that the vast majority of projects involving human participants as Research Subjects also involve the collection of **Personally Identifiable Information (PII)** and/or **Personally Identifiable Research Data (PIRD)** which may pose potential risks to participants as detailed in Section G: Data Processing and Privacy below.

To ensure alighment between your risk assessment, data management and what you agree with your Research Subjects you can use the last two columns in the table below to refer to specific points in your Data Management Plan (DMP) and Informed Consent Form (ICF) – **but this is not compulsory**.

It's worth noting that **you're much more likely to need to resubmit your application if you neglect to identify potential risks**, than if you identify a potential risk and demonstrate how you will mitigate it. If necessary, the HREC will always work with you and colleagues in the Privacy Team and Data Management Services to see how, if at all possible, your research can be conducted.

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
A: Partners and collaboration						
1. Will the research be carried out in collaboration with additional organisational partners such as: • One or more collaborating research and/or commercial organisations • Either a research, or a work experience internship provider[1] *[1] If yes, please include the graduation agreement in this application*	**Yes**		**Confidentiality risks:** collaboration with external party may involve sharing of sensitive or proprietary information, which could lead to breaches of confidentiality or misuse of data.	**Confidentiality agreements:** I'll establish clear confidentiality agreements with all partners to ensure that sensitive information is protected.		
2. Is this research dependent on a Data Transfer or Processing Agreement with a collaborating partner or third party supplier? *If yes please provide a copy of the signed DTA/DPA*		**NO**				
3. Has this research been approved by another (external) research ethics committee (e.g.: HREC and/or MREC/METC)? *If yes, please provide a copy of the approval (if possible) and summarise any key points in your Risk Management section below*		**NO**				
B: Location						
4. Will the research take place in a country or countries, other than the Netherlands, within the EU?		**No**				
5. Will the research take place in a country or countries outside the EU?		**No**				
6. Will the research take place in a place/region or of higher risk – including known dangerous locations (in any country) or locations with non-democratic regimes?		**No**				
C: Participants						
7. Will the study involve participants who **may** be vulnerable and possibly (legally) unable to give informed consent? (e.g., children below the legal age for giving consent, people with learning difficulties, people living in care or nursing homes,).		**No**				
8. Will the study involve participants who **may** be vulnerable under specific circumstances and in specific contexts, such as victims and witnesses of violence, including domestic violence; sex workers; members of minority groups, refugees, irregular migrants or dissidents?		**No**				
9. Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator (such as own children, own students or employees of either TU Delft and/or a collaborating partner organisation)? *It is essential that you safeguard against possible adverse consequences of this situation (such as allowing a student's failure to participate to your satisfaction to affect your evaluation of their coursework).*		**No**				
10. Is there a high possibility of re-identification for your participants? (e.g., do they have a very specialist job of which there are only a small number in a given country, are they members of a small community, or employees from a partner company collaborating in the research? Or are they one of only a handful of (expert) participants in the study?	**Yes**		**Re-identification risk:** Given that participants include professionals or specialists with unique expertise or roles within a company, there is a high possibility that they can be re-identified, especially if there are few individuals with similar profiles in the given field or organization.	**Anonymization of data:** I'll apply rigorous anonymization techniques to all collected data, such as removing or altering identifiable details like job titiles, specific project names, or other contextual clues that could lead to re-identification.		
D: Recruiting Participants						
11. Will your participants be recruited through your own, professional, channels such as conference attendance lists, or through specific network/s such as self-help groups		**No**				
12. Will the participants be recruited or accessed in the longer term by a (legal or customary) gatekeeper? (e.g., an adult professional working with children; a community leader or family member who has this customary role – within or outside the EU; the data producer of a long-term cohort study)		**No**				
13. Will you be recruiting your participants through a crowd-sourcing service and/or involve a third party data-gathering service, such as a survey platform?		**No**				
14. Will you be offering any financial, or other, remuneration to participants, and might this induce or bias participation?		**No**				
E: Subject Matter *Research related to medical questions/health may require special attention. See also the website of the CCMO before contacting the HREC.*						
15. Will your research involve any of the following: • Medical research and/or clinical trials • Invasive sampling and/or medical imaging • Medical and *In Vitro Diagnostic Medical* Devices Research		**No**				
16. Will drugs, placebos, or other substances (e.g., drinks, foods, food or drink constituents, dietary supplements) be administered to the study participants? *If yes see here to determine whether medical ethical approval is required*		**No**				
17. Will blood or tissue samples be obtained from participants? *If yes see here to determine whether medical ethical approval is required*		**No**				
18. Does the study risk causing psychological stress or anxiety beyond that normally encountered by the participants in their life outside research?		**No**				
19. Will the study involve discussion of personal sensitive data which could put participants at increased legal, financial, reputational, security or other risk? (e.g., financial data, location data, data relating to children or other vulnerable groups) *Definitions of sensitive personal data, and special cases are provided on the TUD Privacy Team website.*		**No**				
20. Will the study involve disclosing commercially or professionally sensitive, or confidential information? (e.g., relating to decision-making processes or business strategies which might, for example, be of interest to competitors)		**No**				
21. Has your study been identified by the TU Delft Privacy Team as requiring a Data Processing Impact Assessment (DPIA)? *If yes please attach the advice/ approval from the Privacy Team to this application*		**No**				
22. Does your research investigate causes or areas of conflict? *If yes please confirm that your fieldwork has been discussed with the appropriate safety/security advisors and approved by your Department/Faculty.*		**No**				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
23. Does your research involve observing illegal activities or data processed or provided by authorities responsible for preventing, investigating, detecting or prosecuting criminal offences *If so please confirm that your work has been discussed with the appropriate legal advisors and approved by your Department/Faculty.*		**No**				
F: Research Methods						
24. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people in non-public places).		**No**				
25. Will the study involve actively deceiving the participants? (For example, will participants be deliberately falsely informed, will information be withheld from them or will they be misled in such a way that they are likely to object or show unease when debriefed about the study).		**No**				
26. Is pain or more than mild discomfort likely to result from the study? And/or could your research activity cause an accident involving (non-) participants?		**No**				
27. Will the experiment involve the use of devices that are not 'CE' certified? *Only, if 'yes': continue with the following questions:*	**Yes**		**Not CE-certified:** may pose safety risks during testing with participants. It has the potential to malfunction or cause harm if not properly inspected.	**In-house construction**: the prototype will be build in-house, allowing for close monitoring of its design and construction process. **Safety inspection:** the prototype will undergo a thorough inspection by a qualified safety expert at TU Delft prior to any testing (most likely an expert at the PMB workplace at the IDE faculty) .		
• Was the device built in-house?	**Yes**		**Limited expertise in building specific prototype:** may lead to making a prototype that does not work as it should do.	See above		
• Was it inspected by a safety expert at TU Delft? *If yes, please provide a signed device report*						
• If it was not built in-house and not CE-certified, was it inspected by some other, qualified authority in safety and approved? *If yes, please provide records of the inspection*						
28. Will your research involve face-to-face encounters with your participants and if so how will you assess and address Covid considerations?	**Yes**		**Infect other people:** there is a risk of infecting other people.	**Safety measures when having face-to-face encounters:** If I do not feel well, or the participant does not feel well, I'll make sure safety measure will be taken. Either the session will be postponed or face masks will be used.		
29. Will your research involve **either:** a) "big data", combined datasets, new data-gathering or new data-merging techniques which might lead to re-identification of your participants **and/or** b) artificial intelligence or algorithm training where, for example biased datasets could lead to biased outcomes?		**No**				
G: Data Processing and Privacy						
30. Will the research involve collecting, processing and/or storing any directly identifiable PII (Personally Identifiable Information) including name or email address that will be used for administrative purposes only? (eg: obtaining Informed Consent or disbursing remuneration)	**Yes**		**Potential for unauthorized access or misuse:** possible risk of unauthorized access or misuse of Personally Identifiable Information such as names or email addresses, which could compromise participant privacy. Also risks related to data breaches or inadvertent sharing of PII during the research process.	**Safe storage of data:** Data will be stored in the secure locations designated by TU Delft. **Secure data handling:** PII will only be used for necessary administrative purposes (e.g. obtaining informed consent) and will not be shared beyond this specific research. **Anonymization:** where possible, PII will be anonymized to further protect participant identiy. **Data retention:** PII will be deleted or securely archived after the research concluded, in line with data protection regulations.		
31. Will the research involve collecting, processing and/or storing any directly or indirectly identifiable PIRD (Personally Identifiable Research Data) including videos, pictures, IP address, gender, age etc and **what other Personal Research Data** (including personal or professional views) will you be collecting?	**Yes**		**Re-identification**: risk of re-identification of participants through indirectly identifiable data such as video recordings, professional views, or demographic information.	**Anonymization:** PIRD such as videos or demographic details will be anonymized where possible. Secific identifiers will be removed or masked in datasets, photo's or videos. **Access controls:** I'm the only one with access to PIRD, and this data will be securely stored. **Consent:** Participants will be fully informed about the types of PIRD collected and the purposes of its use, with options to withdraw their data at any time. **Secure sharing:** Any sharing of PIRD will be done through secure, controlled channels, and only de-identified data will be used for publication.		
32. Will this research involve collecting data from the internet, social media and/or publicly available datasets which have been originally contributed by human participants		**No**				
33. Will your research findings be published in one or more forms in the public domain, as e.g., Masters thesis, journal publication, conference presentation or wider public dissemination?	**Yes**		The possibility that published findings could inadvertently reveal participant identities or sensitive information, particularly if findings are	**Anonymization:** where possible, to prevent identities. As described above, where possible I'll anonomyze data and if needed things will be paraphrased, blurred, etc. to hide personal details.		
			based on a small sample size or highly specialized individuals.			
34. Will your research data be archived for re-use and/or teaching in an open, private or semi-open archive?		**No**				

H: More on Informed Consent and Data Management

NOTE: You can find guidance and templates for preparing your Informed Consent materials) here

Your research involves human participants as Research Subjects if you are recruiting them or actively involving or influencing, manipulating or directing them in any way in your research activities. This means you must seek informed consent and agree/ implement appropriate safeguards regardless of whether you are collecting any PIRD.

Where you are also collecting PIRD, and using Informed Consent as the legal basis for your research, you need to also make sure that your IC materials are clear on any related risks and the mitigating measures you will take – including through responsible data management.

Got a comment on this checklist or the HREC process? You can leave your comments here

IV. Signature/s

Please note that by signing this checklist list as the sole, or Responsible, researcher you are providing approval of the completeness and quality of the submission, as well as confirming alignment between GDPR, Data Management and Informed Consent requirements.

Name of Corresponding Researcher (if different from the Responsible Researcher) (print)

T.P.B. van Ekeren

Signature of Corresponding Researcher:
Date: September 25, 2024

Name of Responsible Researcher (print)

dr.ir. A.J.Jansen

Signature (or upload consent by mail) Responsible Researcher:

Date: August 30, 2024

V. Completing your HREC application

Please use the following list to check that you have provided all relevant documentation

Required:

- **Always:** This completed HREC checklist
- **Always:** A data management plan (reviewed, where necessary, by a data-steward)
- **Usually:** A complete Informed Consent form (including Participant Information) and/or Opening Statement (for online consent)

Appendix B.2 Data managment plan

Plan Overview

A Data Management Plan created using DMPonline

Title: Strategic roadmap and safety-focussed bicycle accessory prototype for BBB Cycling

Creator: Teun van Ekeren

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

Project abstract:

This research is part of my masters thesis at IDE. The project aims to explore the safety of cyclists by investigating expert perspectives and testing innovative safety prototypes. Interviews will be conducted with 20 participants, including 10 experts such as medical professionals specializing in trauma, mobility experts, and design specialists. These interviews will focus on understanding the current challenges and potential future advancements in cycling safety. In the prototyping phase, 10 users will be involved in testing self-made prototypes designed to improve cyclist safety. The tests will evaluate the effectiveness and user experience of the prototypes, providing feedback for iterations and further development. For the interviews participants will be recruited by looking for experts both online and within the company, they are expected to answer my questions and help me with their specific knowledge. For the user-tests, participants will be recruited from my own network and they are expected to analyse the prototypes in the first phase and later on test the prototypes.

ID: 157951

Start date: 27-08-2024

End date: 15-04-2025

Last modified: 30-08-2024

Strategic roadmap and safety-focussed bicycle accessory prototype for BBB Cycling

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

2. Date of consultation with support staff.

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Interviews (raw)	.mp3	Using an audio recorder	To get insights about safetey	OneDrive	Me
Interviews (transcriptions)	.txt/.docx	Typing/transcribing the interviews and using notes made during the interview. If possible with the use of an online transcribing program.	To quote people in my report & other findings	as above	Me, and maybe my TUD supervisors and the supervisor at the company I'm graduating
Focus group outcomes (photos of white boards)	.jpg	Miro, whiteboards, etc.	To capture results of the sessions	as above	as above
Usability test photos	.jpg	(Video)camera or phone	(if of added value) to capture how people are using the prototype	laptop or offline hard drive	as above

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Methodology of data collection

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- OneDrive

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, first ask your Faculty Data Steward for advice. You can also check with the privacy website . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

The data I collect and the results from it will be owned by myself.

10. Which personal data will you process? Tick all that apply

- Signed consent forms
- Gender, date of birth and/or age
- Email addresses and/or other addresses for digital communication
- Telephone numbers
- Names and addresses

11. Please list the categories of data subjects

For interviews: medical professionals, mobility experts, design specialists, shop owners and suppliers of products
For user-testing: potential future users

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

People I interview, join a co-creation session or a user test will sign an adapted form of the consent form provided by TU Delft (HREC).

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).
If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.
If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.
If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Personal research data will be destroyed after the end of the research project

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) produced in the project

29. How will you share research data (and code), including the one mentioned in question 22?

- My data will be shared in a different way - please explain below

My data will be shared as part of my graduation report in the TUD education repository.

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- At the end of the research project

32. Under what licence will be the data/code released?

- CC BY

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below

In this project I'm working for an external company: BBB Cycling.

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

My project - along with all of its data - will likely be deleted if I leave the university. If I am working with anyone who wishes to continue the work, I will leave a copy of the data with my supervisor, Arjen Jansen.

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

None - I will handle all data management on my own using resources provided by the university.

Appendix B.3 Consent Form Interviews

Consent form user test

Future Mobility

This research is being conducted as part of the MSc program in Integrated Product Design at TU Delft, in collaboration with BBB Cycling.

Student: Teun van Ekeren

Contact person:

[CONTACT PERSON'S NAME + EMAIL ADDRESS + PHONE NUMBER]

Participant Consent Declaration

I voluntarily agree to participate in this research.

I acknowledge that I have received sufficient information and explanation about this research beforehand and that all my questions have been satisfactorily answered. I have had the time I needed to agree to participate. At any time, I may ask questions regarding the research.

I understand that this research consists of:
1. User test
2. Short interview after the user test

Participation in this research means taking part in a user test, during which several steps will be followed. These steps will be clearly explained prior to the test. After the user test, there will be a short interview where questions will be asked about the experiences of the test.

I understand that my participation involves the following risks [to be specified]. I understand that these risks will be minimized by [to be specified].

I am aware that during the research, data will be collected in the form of notes and audio recordings. I give my consent for the collection of this data and the making of audio recordings during the research. Data will be anonymized and analyzed (without name or other identifiable information). These data will only be available to the research team and their TU Delft supervisors.

The audio recordings will be used to support the analysis of the collected data. The interviews will be transcribed, after which the audio recordings will be deleted.

I give consent for the use of audio recordings and publication of statements from my participation:

(please select what applies)

☐ in which I am identifiable for publications and presentations about the project.
    ☐ I want to review the transcript before using it for further research.

☐ in which I am not identifiable for publications and presentations about the project.

☐ for data analysis purposes only, not for publications and presentations about the project.

I give permission for the data to be stored and used for educational and research purposes for up to 2 years after the conclusion of this research.

I acknowledge that no financial compensation is given for participation in the research.

I have read and understood the information about the research dated DD/MM/2024, or it has been read to me. I have had the opportunity to ask questions about the research, and my questions have been answered to my satisfaction.

By signing, I confirm that I have read the information about the research and that I understand the nature of my participation. I understand that I can withdraw or stop my participation in the research at any time. I understand that I am not obliged to answer questions that I do not wish to answer, and that I can communicate this to the research team.

A copy of this consent form will be given to me.

Last Name   First Name

___ / ___ / 2024   ______________________

Date (dd/mm/yyyy)   Signature

Appendix B.4 Device Report Signed

Delft University of Technology
INSPECTION REPORT FOR DEVICES TO BE USED IN CONNECTION WITH HUMAN SUBJECT RESEARCH

This report should be completed for every experimental device that is to be used in interaction with humans and that is not CE certified or used in a setting where the CE certification no longer applies[1].

The first part of the report has to be completed by the researcher and/or a responsible technician.

Then, the safety officer (Heath, Security and Environment advisor) of the faculty responsible for the device has to inspect the device and fill in the second part of this form. An actual list of safety-officers is provided on this webpage.

Note that in addition to this, all experiments that involve human subjects have to be approved by the Human Research Ethics Committee of TU Delft. Information on ethics topics, including the application process, is provided on the HREC website.

Device identification (name, location):

- Name: Bicycle mirror with integrated turn signals
- Location: Faculty of Industrial Design Engineering, TU Delft

Configurations inspected[2]:

- Bicycle with attached left and right mirrors, each containing integrated LED turn signals

Type of experiment to be carried out on the device:[3]

- User interaction test: Observing how participants use the turn signal function during real-world cycling.
- Ergonomic evaluation: Assessing ease of activation and user comfort.
- Safety perception analysis: Investigating whether users feel more visible and in control when using the mirrors with integrated signals.

Name(s) of applicants(s):

- **Dr. A.J. Jansen**

1 Modified, altered, used for a purpose not reasonably foreseen in the CE certification

2 If the devices can be used in multiple configurations, otherwise insert NA

3 e.g. driving, flying, VR navigation, physical exercise, ...

1

Job title(s) of applicants(s):

- **Associate professor**

(Please note that the inspection report should be filled in by a TU Delft employee. In case of a BSc/MSc thesis project, the responsible supervisor has to fill in and sign the inspection report.)

Date:

- **18-02-2025**

Signature(s):

Setup summary

Please provide a brief description of the experimental device (functions and components) and the setup in which context it supposed to be used. Please document with pictures where necessary.

More elaborate descriptions should be added as an appendix (see below).

Device Description:

The device consists of two bicycle mirrors equipped with integrated LED turn signals. The system is designed to help cyclists indicate their intentions without removing their hands from the handlebars. The mirrors enhance rear visibility, while the LED indicators provide active visibility cues to other road users.

Components:

- Left and right mirrors: Provide rear visibility while cycling.
- Integrated LED turn signals: Enhance visibility and safety.
- Handlebar-mounted push button: Allows activation of the turn signals.
- Battery power supply: Rechargeable battery system.
- Adjustable mounting brackets: Ensures secure attachment to the bicycle.

Setup Context:

The device will be tested in real-world conditions (urban cycling routes).

Participants will be instructed to cycle for approximately 10 minutes while interacting with the device.

Risk checklist

Please fill in the following checklist and consider these hazards that are typically present in many research setups. If a hazard is present, please describe how it is dealt with.

Also, mention any other hazards that are present.

Hazard type	Present	Hazard source	Mitigation measures
Mechanical (sharp edges, moving equipment, etc.)	No		
Electrical	Yes	Battery powered LEDs	Securely enclosed battery pack, no exposed wiring.
Structural failure	Yes	Mirror detachment risk	Secure mounting brackets tested for stability
Touch Temperature	No		
Electromagnetic radiation	No		
Ionizing radiation	No		
(Near-)optical radiation (lasers, IR-, UV-, bright visible light sources)	Yes	LED indicators	LEDs operate within safe brightness levels
Noise exposure	No		
Materials (flammability, offgassing, etc.)	No		
Chemical processes	No		
Fall risk	Yes	Bike	People are offered the possibility to wear a helmet
Other:			
Other:			
Other:			

Appendices

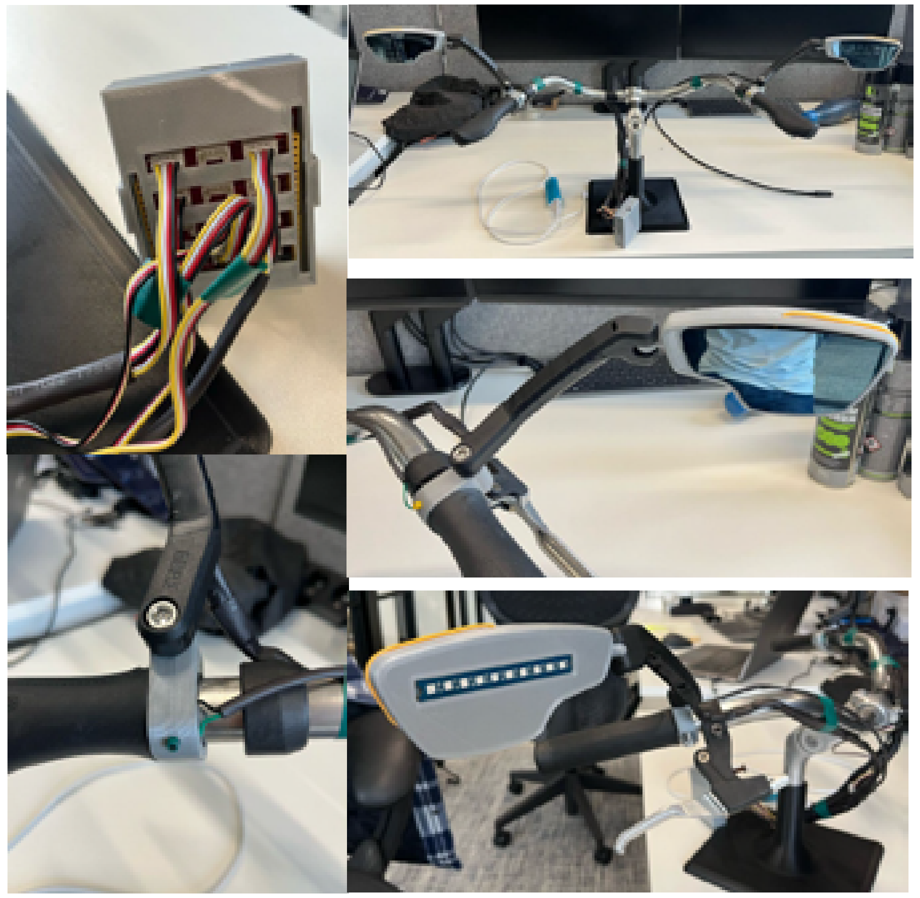
Here, you may add one or more appendices describing more detailed aspects of your setup or the research procedures.

Images op test setup

The test setup here is made on a platform, but for the test, the prototype will be put on a regular bike, so the grips and mirrors will be switched with the original ones which are on the bike currently.

The bike use will be a 'leenfiets' which has no gears and a coaster break, so there will be no other cables running over the steer, like on the photos.

To make things safer, head shrinking tube was used to put all the cables together.



Device inspection

(to be filled in by the AMA advisor of the corresponding faculty)

Name: Peter Kohne

Faculty: IO

The device and its surroundings described above have been inspected. During this inspection I could not detect any extraordinary risks.

(Briefly describe what components have been inspected and to what extent (i.e. visually, mechanical testing, measurements for electrical safety etc.)

Omdat de kandidaten nu meer op de spiegels letten etc. zou ik een fietsroute kiezen die rustig is, dus met weinig verkeer! De instructie moet ook zijn dat men zich moet houden aan aan de verkeersregels etc. en zich niet te veel laten afleiden door de spiegels/leds!

Date: 19-02-2025

Signature:

Inspection valid until[4]:

Note: changes to the device or set-up, or use of the device for an experiment type that it was not inspected for require a renewed inspection

4 Indicate validity of the inspection, with a maximum of 3 years

Appendix B.5 Research Plan for Testing Prototype

Research plan for testing mirror with turn signal prototype

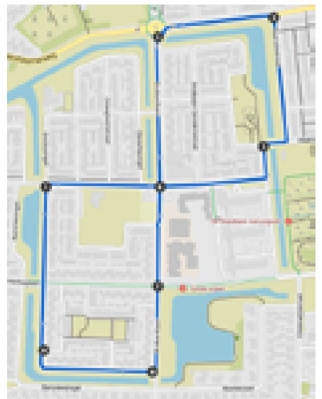
Teun van Ekeren – 26/02/2025

In this user test, the prototype of my graduation project will be tested. The prototype are two mirrors with integrated turning lights, which allow people to indicate their direction while keeping their hands on their bike.

The plan is to let participants cycle a predefined route through a residential area without much traffic. People are informed about the possibilities of the turn signals but are not required to use them.

The bike used, will be equipped with the mirrors and a Insta360, 360 degrees camera to capture the ride, to make it possible to review their ride afterwards. All faces will be made unrecognizable if the participants want.

After they have cycled the route, a few questions will be asked regarding their experiences.



Number of participants:

- ±5

Route:

- 2.24 km through residential area in Vught

Analysis of data:

- A 360 degrees camera is used to record the ride. Also, the Arduino is programmed in such a way that the number of presses on the buttons is logged internally. Both are manually reviewed afterwards.

Ethical considerations:

- Informed consent: Clearly communicate the study's purpose, procedures, and any potential risks to participants, ensuring they understand their involvement is voluntary.
- Privacy protection: Anonymize all collected data. Video recordings will have faces, and any identifying features blurred to maintain confidentiality.
- Safety measures: Conduct the study in low-traffic areas to minimize risk. Ensure the test bicycle is in optimal condition, and if requested by they participants, they will be provided with appropriate safety gear, such as helmets.

Goal of the study:

- To see if people are actually using the turn signal, how they use it and how other traffic responds to it.

Additionally to this plan, there is a device report and a consent form.

Appendix B.6 Consent Form User Test

Consent Form for User Test: Bicycle Mirror with Integrated Turn Signals

Future Mobility

This research is being conducted as part of the MSc program in Strategic Product Design at TU Delft, in collaboration with BBB Cycling.

Student: Teun van Ekeren

Contact mail adress:

Participant Consent Declaration

I voluntarily agree to participate in this research.

I acknowledge that I have received sufficient information and explanation about this research beforehand and that all my questions have been satisfactorily answered. I have had the time I needed to agree to participate. At any time, I may ask questions regarding the research.

I understand that this research consists of:

- Completing a pre-test questionnaire regarding your cycling habits and perception of safety.
- Taking part in a user test where you will cycle with a bicycle equipped with the test device.
- Answering a post-test questionnaire about your experience using the device.
- A short interview to gather additional feedback.

The total duration of participation is approximately 20 minutes.

Voluntary Participation & Right to Withdraw

Your participation in this study is entirely voluntary. You are free to decline to participate or withdraw from the study at any time without giving a reason and without any consequences. You are also free to skip any questions you do not wish to answer.

Potential Risks & Mitigation Measures

Participation in this study involves the same level of risk as normal cycling. However, the following risks and mitigation strategies have been identified:

Device failure: The device has been inspected for mechanical and electrical safety. A researcher will be present during the test to address any issues.

Cycling in traffic: The test will take place in a safe environment, away from high-traffic areas where possible.

Physical discomfort: The device setup has been designed for ergonomic use, but adjustments can be made before the test to ensure participant comfort.

Confidentiality & Data Storage

Your responses and test data will be anonymized and stored securely. The collected data will be used solely for research purposes and will not contain any personally identifiable information. The anonymized data may be used for scientific publications or presentations. Data will be retained for a maximum of 2 years before being securely deleted.

Data Collection & Use

During the study, the following data will be collected:

- Responses to questionnaires
- Observational notes on device usage
- Video and audio recordings (to review the ride afterwards)
- Logger data (if applicable, for recording button presses)

Please indicate your consent for the use of data:

☐ I consent to my responses being used for research analysis.

☐ I consent to my ride being video and audio recorded for analysis purposes.

  ☐ I consent snapshot of these videos are used in the report, to show how the analysis was conducted

  ☐ I consent these snapshots are used anonymously

  ☐ I do not consent snapshots to be used in any publication

☐ I consent to anonymized quotes from my responses being used in reports or publications.

☐ I consent to my participation data being stored for up to 2 years.

Contact Information

For any questions regarding this study, you can contact:

Teun van Ekeren -

Participant Consent Confirmation

I confirm that:

- I have read and understood the information about the study.
- I have had the opportunity to ask questions, and these have been answered satisfactorily.
- I voluntarily agree to participate in this research.

Participant Name: ________________________________Date (DD/MM/YYYY): __ / __ / 2025

Signature: ________________________________

A copy of this consent form will be provided to you.

APPENDIX C SEARCH AREAS

The other possible search areas, touched upon in Chapter 4, are desribed here in more detail.

Prevetion

Both literature and expert interviews emphasize that accident and incident prevention is a crucial factor in cycling safety. Effective prevention strategies not only reduce injuries and healthcare costs but also enhance cyclists' confidence, encouraging greater adoption of cycling as a mode of transport. Within this theme, two key areas have been identified:

Visibility (lighting & clothing)

The increasing variation in cycling speeds, particularly due to e-bikes, makes visibility essential in mixed traffic environments to prevent collisions. Existing visibility solutions are often not optimized for higher cycling speeds and longer travel distances, reducing their effectiveness in modern traffic conditions.

Fall prevention

The higher speeds of e-bikes increase the risk of single-bike accidents, particularly due to unexpected obstacles or sharp turns. Older cyclists face additional risks due to reduced reaction times and balance, requiring stability-enhancing systems to mitigate falls.

Conclusion on prevention

While prevention is a critical factor in cycling safety, this search area will not be pursued further in this project. Visibility solutions, particularly bicycle lighting, are expected to be increasingly integrated into e-bikes due to technological evolution. Also, as described previously, lighting is already a major product category of BBB Cycling. Furthermore, smart bicycle technologies and stability systems fall outside BBB Cycling's current expertise and product portfolio, making them less viable directions for innovation.

Injury mitigation

Another key area identified in the analysis is reducing the severity of injuries through advanced protective products. While prevention aims to avoid accidents altogether, injury mitigation focuses on minimizing harm when accidents do occur. Two key directions have been explored within this field:

Airbags

Hip injuries are a common consequence of single-bike accidents among older cyclists. While airbags could potentially mitigate such injuries, their practical implementation remains a significant challenge.

Improved helmet designs

Cyclists often perceive helmets as impractical or heavy, leading to low adoption rates despite the known safety benefits. If obligatory helmet laws are introduced in the future, acceptance will probably remain low unless helmets are designed to be lightweight, ergonomic, and visually appealing.

There is a lack of innovative solutions tailored to different types of cyclists, such as modular helmets or wearable airbags that enhance both comfort and protection.

Conclusion on injury mitigation

Despite its importance, this search area will not be pursued further in this project. Airbag solutions face considerable technical challenges and limited demand, making them difficult to develop and commercialize. Additionally, helmet innovation is already a highly active research area, with numerous ongoing projects and pilots. Given these factors, further development in this domain is not particularly interesting for this project.

Technological integration

The integration of smart technology into cycling products aligns with industry trends and the increasing digitalization of mobility. As cycling safety becomes a growing concern, technology-driven solutions can play a significant role in improving awareness, accident prevention, and injury mitigation. However, rather than treating technological integration as a standalone search area, its potential lies in enhancing other safety-related innovations. Four different potential roles for technology in cycling safety have been defined and will be described below.

Potential roles of technology in cycling safety

- Smart visibility solutions: advanced lighting systems could be integrated with smart sensors and vehicle-to-everything (V2X) communication, allowing cyclists to become more visible to both autonomous vehicles and connected road systems.
- Fall detection and emergency response: wearable technology and connected helmets could detect falls and collisions, automatically alerting emergency contacts or medical services.
- Predictive safety systems : AI-powered predictive analytics could help cyclists anticipate hazards, such as sharp turns, road obstacles, or approaching vehicles, by providing real-time feedback.
- Enhanced user experience: smart cycling accessories, such as adaptive lighting, navigation assistance, or crash analytics, could improve both safety and usability for different rider segments.

Conclusion on technological integration

While technological advancements present valuable opportunities, this search area will not be treated as an independent field but, but as an area that will be included in the final serach area. Smart technology can be leveraged to strengthen and complement other safety innovations, particularly in the adoption of cycling safety products. The challenge is not in developing the technology itself but ensuring cyclists recognize its value and integrate it into their daily rides, an issue directly related to the most critical search area for this project: adoption.

APPENDIX D EXTENDED COM-B ANALYSIS

This appendix provides a detailed breakdown of the COM-B model's application to cycling safety, including behavioural influences, barriers, and potential interventions. While the main text summarizes key points, this section serves as an in-depth reference for further analysis.

Understanding Behaviour Through the COM-B Model

The COM-B model (Capability, Opportunity, Motivation – Behaviour) explains why cyclists do or do not adopt safety-enhancing products. Table 5 below provides a structured overview of the psychological, physical, social, and environmental factors that influence behaviour.

Steps to Identify and Address Behaviour

The COM-B model is often applied using three structured steps to analyse behaviour and design effective interventions. The way this is done in this project is based on this video: https://www.youtube.com/watch?v=uhMipNkHF9M

Table 5. Overview of psychological, physical, social and environmental factors

Capability	Opportunity	Motivation
Psychological (capacity to engage in necessary thought processes)	**Physical** (physical opportunity provided by the environment)	**Reflective** (evaluations and plans)
Lack of knowledge about traffic rules and safe cycling behaviour Unaware of risks related to distraction or high speed Inability to properly assess risky situations Fear or lack of confidence	Poorly maintained or unsafe infrastructure Lack of clear separation between cyclists and other road users Lack of access to protective equipment and lighting Busy traffic conditions that create an unsafe feeling	Underestimation of risks of cycling without protective equipment Misconception about the need for safe behaviour Resistance to behavioural change Focus on convenience and speed over safety (such as quickly cycling through a red light)
Physical (capacity to engage in necessary physical processes)	**Social** (cultural milieu that dictate the way we think about things)	**Automatic** (emotions and impulses arising from associative learning and/or innate dispositions)
Insufficient balance or coordination Physical limitations that affect reaction speed Lack of experience	Social norms that discourage safe behavior Lack of role models Influence of peer pressure Limited support from schools, employers, or communities for campaigns	Habitual behavior (such as texting and cycling without lights) Fear or frustration Lack of motivation Distraction by external stimuli

Stage 1: Understanding behaviour

1. Define the problem in behavioural terms:

The primary issue in this research is the low adoption of cycling safety products despite increasing accident rates.

2. Select the target behaviour:

The focus is on encouraging the use of safety-enhancing products by identifying barriers and motivators.

3. Specify the target behaviour:

Who? Cyclists, with a focus on e-bike users, the elderly, and young riders.

What? Increase awareness of risks, encourage visibility, improve balance and control, and promote helmet use.

When? During all cycling activities, especially in high-risk situations (e.g., intersections, urban environments).

Where? Across all cycling environments.

With whom? Individually, in groups, and in interaction with other road users.

Stage 2: Selecting Intervention Functions

4. To increase adoption, intervention strategies must align with the specific barriers identified in COM-B. Subsequently each intervention function can be related to a behaviour change technique (BCT). The most relevant intervention functions and related BCTs for BBB Cycling are:

Education

Increasing knowledge and awareness of safe cycling behaviour. However, eduction has a big limitations for this project and BBB, it is really difficult to implement education commercially; educational efforts often require policy-driven approaches rather than product-based, commercialy viable, strategies.

In the end, eduction was not considered useful for this project. As it was hard to make education to increase adoption commercialy viable.

Environmental Restructuring

Changing the environment to make safety adoption more intuitive.

Enablement

Removing barriers to make adoption effortless.

The other intervention functions described in the model were not considered a feasible option for this project.

Stage 3: Behaviour Change Techniques (BCTs)

5. To implement intervention functions effectively, specific behaviour change techniques (BCTs) can be applied. Table 6 below summarizes the most relevant techniques for BBB Cycling, categorized by intervention type.

More detailed descriptions of each BCT and its expected effectiveness can be found in via this link: https://digitalwellbeing.org/wp-content/uploads/2016/11/BCTTv1_PDF_version.pdf

Applying COM-B to BBB Cycling's Business Model

While many policy-driven interventions focus on educational campaigns or legal enforcement, these are not commercially viable for BBB Cycling, like explained before. Instead, environmental restructuring and eneblement are considered most relevant, and the most feasible applications involve:

- Collaborating with bicycle manufacturers to integrate safety products at the OEM level.

- Designing cycling gear that aligns with existing user habits and preferences, making adoption effortless rather than forced.

- Encouraging aftermarket adoption through smart product design, ensuring safety gear is seen as a desirable and convenient accessory.

Table 6. Most relevant BCT per intervention type

Intervention	Behaviour Change Techniques (BCTs)
Education	Providing risk-awareness information, demonstrating proper product use, offering practical cycling safety instructions.
Environmental Restructuring	Embedding safety features into bicycles, designing intuitive and aesthetically pleasing safety products, integrating technology (e.g., smart helmets with built-in lights).
Enablement	Making safety gear multifunctional (e.g., hybrid-use helmets), reducing costs through partnerships, and leveraging e-bike manufacturers for OEM integration.

APPENDIX E HOW GRIPS ARE MADE

Cycling grips are composed of two main parts, shown in Figure 71:

- The core: made of hard plastic, providing a stable base.
- The outer layer: usually rubber, offering grip, cushioning, and durability. In some cases, there is leather, or imitation of leather, stitched around the grip.

Both components are produced through injection moulding (Figure 72). The rubber exterior can be made from a single type of rubber or a combination of up to three different rubber types, depending on the grip's performance requirements.

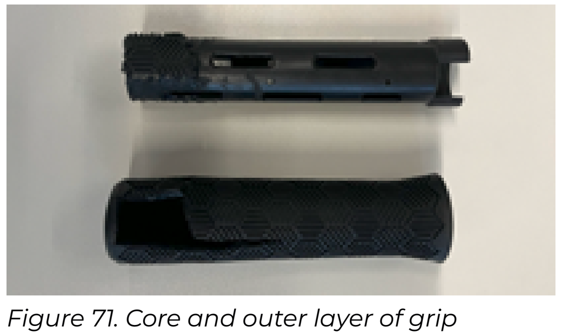


Figure 71. Core and outer layer of grip

Figure 72. Grip mould

APPENDIX F ARDUINO CODE

Appendix F.1 Code to control turn signal and log button presses

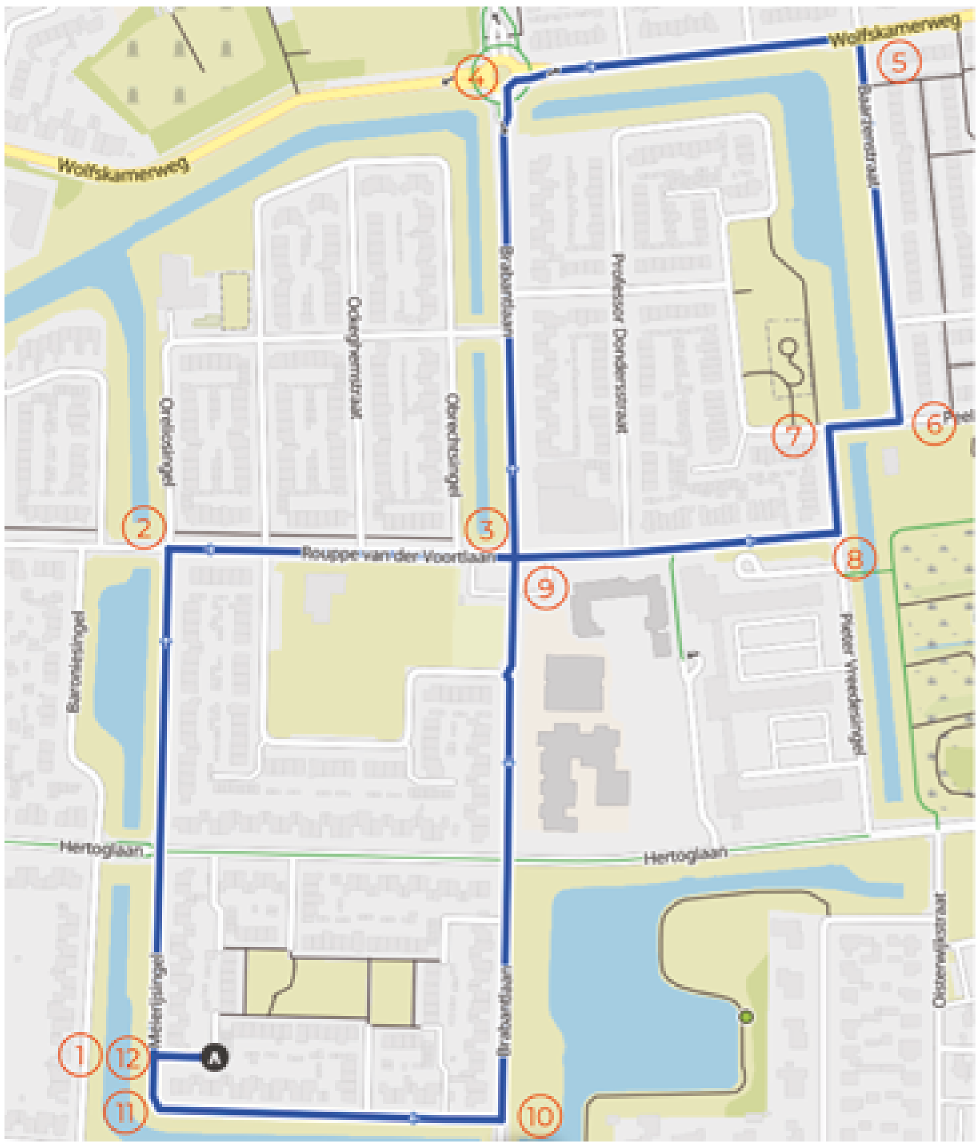
```
#include <FastLED.h>
#include <Adafruit_NeoPixel.h>
#include <EEPROM.h>

#define BUTTON_RIGHT 2  // Button right on D2
#define BUTTON_LEFT 6   // Button left on D6
#define RESET_BUTTON 7  // Reset button on D7, to reset
logger after each test

#define LEDSTICK_RIGHT A0 // LED Stick right on A0
#define LEDSTICK_LEFT A2 // LED Stick left on A2
#define NOODS_RIGHT 4   // nOOds right on D4
#define NOODS_LEFT 5    // nOOds left on D5

#define RGB_LED_COUNT 10 // Number of LEDs per stick

Adafruit_NeoPixel stripRight(RGB_LED_COUNT, LED-
STICK_RIGHT, NEO_GRB + NEO_KHZ800);
Adafruit_NeoPixel stripLeft(RGB_LED_COUNT, LEDSTICK_
LEFT, NEO_GRB + NEO_KHZ800);

CRGB ledsRight[RGB_LED_COUNT];
CRGB ledsLeft[RGB_LED_COUNT];

const unsigned long debounceDelay = 200;
const unsigned long updateInterval = 50;

bool buttonPrevStateRight = LOW;
bool buttonPrevStateLeft = LOW;
bool buttonPrevStateReset = LOW;
unsigned long debounceTimeRight = 0;
unsigned long debounceTimeLeft = 0;
unsigned long debounceTimeReset = 0;

bool isAnimationRunning = false;
unsigned long lastUpdateTime = 0;
int animationStep = 0;
int animationCycle = 0;
bool reverseAnimation = false;
int activeNoodsPin = -1;
Adafruit_NeoPixel* activeStrip = nullptr;
CRGB* activeLeds = nullptr;

// EEPROM-addresses, to safe counting
#define EEPROM_RIGHT_ADDR 0
#define EEPROM_LEFT_ADDR 4

void setup() {
  Serial.begin(9600);
  pinMode(BUTTON_RIGHT, INPUT_PULLUP);
  pinMode(BUTTON_LEFT, INPUT_PULLUP);
  pinMode(RESET_BUTTON, INPUT_PULLUP);
  pinMode(NOODS_RIGHT, OUTPUT);
  pinMode(NOODS_LEFT, OUTPUT);

  stripRight.begin();
  stripRight.setBrightness(250);
  stripRight.show();

  stripLeft.begin();
  stripLeft.setBrightness(250);
  stripLeft.show();

  FastLED.addLeds<WS2812, LEDSTICK_RIGHT, GRB>(leds-
Right, RGB_LED_COUNT);
  FastLED.addLeds<WS2812, LEDSTICK_LEFT, GRB>(led-
sLeft, RGB_LED_COUNT);

  FastLED.clear();
  FastLED.show();
  FastLED.setBrightness(100);

  // Reading the logger when the Seeeduino is plugged
back in the PC
  Serial.print("Starting: Number of presses right: ");
  Serial.print(readCountFromEEPROM(EEPROM_RIGHT_
ADDR));
  Serial.print(" | number of presses left: ");
  Serial.println(readCountFromEEPROM(EEPROM_LEFT_
ADDR));
}

void loop() {
  Serial.print("Button Right: ");
  Serial.print(digitalRead(BUTTON_RIGHT));
  Serial.print(" | Button Left: ");
  Serial.println(digitalRead(BUTTON_LEFT));

  handleButtonPress(BUTTON_RIGHT, &button-
PrevStateRight, &debounceTimeRight, NOODS_RIGHT,
&stripRight, ledsRight, false, EEPROM_RIGHT_ADDR);
  handleButtonPress(BUTTON_LEFT, &buttonPrevStateLeft,
&debounceTimeLeft, NOODS_LEFT, &stripLeft, ledsLeft,
true, EEPROM_LEFT_ADDR);

  handleResetButton();

  if (isAnimationRunning) {
    updateAnimation();
  }
}

void handleButtonPress(int buttonPin, bool *button-
PrevState, unsigned long *debounceTime, int noodsPin,
Adafruit_NeoPixel *strip, CRGB *leds, bool reverse, int ee-
promAddress) {
  bool buttonCurrentState = digitalRead(buttonPin);
  unsigned long currentTime = millis();

  if (buttonCurrentState == LOW && *buttonPrevState ==
HIGH && (currentTime - *debounceTime > debounceDelay))
{
    *debounceTime = currentTime;

    // Counting in logger
    int count = readCountFromEEPROM(eepromAddress)
+ 1;
    writeCountToEEPROM(eepromAddress, count);
    Serial.print("Button on pin ");
    Serial.print(buttonPin);
    Serial.print(" pressed, new number: ");
    Serial.println(count);

    if (isAnimationRunning) {
      Serial.println("Kill switch activated: stop animation");
      isAnimationRunning = false;
      FastLED.clear();
      strip->clear();
      FastLED.show();
      strip->show();
      digitalWrite(noodsPin, LOW);
    } else {
      Serial.println("Start turn signal");
      isAnimationRunning = true;
      animationStep = 0;
      animationCycle = 0;
      reverseAnimation = reverse;
      activeNoodsPin = noodsPin;
      activeStrip = strip;
      activeLeds = leds;
    }
  }
  *buttonPrevState = buttonCurrentState;
}

void handleResetButton() {
  bool buttonCurrentState = digitalRead(RESET_BUTTON);

  if (buttonCurrentState == LOW && buttonPrevStateReset
== HIGH) {
    Serial.println("Reset button pressed! Counter back to
0.");

    // Reset EEPROM waarden naar 0
    writeCountToEEPROM(EEPROM_RIGHT_ADDR, 0);
    writeCountToEEPROM(EEPROM_LEFT_ADDR, 0);

    // Check if reset succeeded
    int rightCount = readCountFromEEPROM(EEPROM_
RIGHT_ADDR);
    int leftCount = readCountFromEEPROM(EEPROM_
LEFT_ADDR);

    Serial.print("After reset: right: ");
    Serial.print(rightCount);
    Serial.print(" | left: ");
    Serial.println(leftCount);
  }
  buttonPrevStateReset = buttonCurrentState;
}

void updateAnimation() {
  unsigned long currentTime = millis();
  if (currentTime - lastUpdateTime < updateInterval) return;
  lastUpdateTime = currentTime;

  FastLED.clear();
  activeStrip->clear();

  // nOOds on at start of fade
  digitalWrite(activeNoodsPin, HIGH);

  for (int j = 0; j < 4; j++) {
    int ledIndex = reverseAnimation ? (9 - (animationStep +
j)) : (animationStep + j);
    if (ledIndex >= 0 && ledIndex < RGB_LED_COUNT) {
      activeLeds[ledIndex] = CRGB(255, 165, 0);
      activeStrip->setPixelColor(ledIndex, activeStrip->Col-
or(255, 165, 0));
    }
  }

  FastLED.show();
  activeStrip->show();

  delay(100);  // Speed of the animation

  animationStep++;
  if (animationStep > 6) {
    animationStep = 0;

    // nOOds off after fade
    digitalWrite(activeNoodsPin, LOW);

    FastLED.clear();
    activeStrip->clear();
    FastLED.show();
    activeStrip->show();

    delay(300);  // Delay inbetween series
  }
}

// Data logging
int readCountFromEEPROM(int address) {
  int count;
  EEPROM.get(address, count);
  if (count < 0 || count > 10000) {  // Preventing corrupt data
    count = 0;
  }
  return count;
}

void writeCountToEEPROM(int address, int count) {
  EEPROM.put(address, count);
}
```

Appendix F.2 Code for Button Test - Push Button, Switch, Fivevay Switch

```
#include <FastLED.h>
#include <Adafruit_NeoPixel.h>
#include <Wire.h>
#include "Grove_Multi_Switch.h"

#define BUTTON_LEFT 3    // Knop voor links op D3
#define SWITCH_RIGHT 2   // Schakelaar voor rechts op D2

#define LEDSTICK_RIGHT A0 // LED Stick rechts op A0
#define LEDSTICK_LEFT A2  // LED Stick links op A2
#define NOODS_RIGHT 4    // nOOds rechts op D4
#define NOODS_LEFT 5     // nOOds links op D5

#define RGB_LED_COUNT 10 // Aantal LEDs per stick

Adafruit_NeoPixel stripRight(RGB_LED_COUNT, LEDSTICK_RIGHT, NEO_GRB + NEO_KHZ800);
Adafruit_NeoPixel stripLeft(RGB_LED_COUNT, LEDSTICK_LEFT, NEO_GRB + NEO_KHZ800);

CRGB ledsRight[RGB_LED_COUNT];
CRGB ledsLeft[RGB_LED_COUNT];

const unsigned long blinkInterval = 500; // Knipperinterval in ms
bool leftAnimationRunning = false;
bool rightAnimationRunning = false;
bool leftBlinkOn = false;
bool rightBlinkOn = false;
unsigned long previousMillisLeft = 0;
unsigned long previousMillisRight = 0;
GroveMultiSwitch mswitch;
const char* key_names[] = {"RIGHT", "UP", "LEFT", "DOWN", "CENTER"};

void setup() {
  Serial.begin(9600);
  Wire.begin(); // Initialiseer I2C
  pinMode(BUTTON_LEFT, INPUT_PULLUP);
  pinMode(SWITCH_RIGHT, INPUT);
  pinMode(NOODS_RIGHT, OUTPUT);
  pinMode(NOODS_LEFT, OUTPUT);

  stripRight.begin();
  stripRight.setBrightness(50);
  stripRight.show();
  stripLeft.begin();
  stripLeft.setBrightness(50);
  stripLeft.show();

  FastLED.addLeds<WS2812, LEDSTICK_RIGHT, GRB>(ledsRight, RGB_LED_COUNT);
  FastLED.addLeds<WS2812, LEDSTICK_LEFT, GRB>(ledsLeft, RGB_LED_COUNT);
  FastLED.clear();
  FastLED.show();
  FastLED.setBrightness(100);

  if (!mswitch.begin()) {
    Serial.println("***** Five-way switch niet gedetecteerd op I2C *****");
  }
}

void loop() {
  processFiveWaySwitch();
  handleButtonPress();
  handleSwitch();
  updateBlinkingLeds();
}

void processFiveWaySwitch() {
  GroveMultiSwitch::ButtonEvent_t* evt = mswitch.getEvent();
  if (!evt) return;

  for (int i = 0; i < mswitch.getSwitchCount(); i++) {
    if (evt->button[i] & GroveMultiSwitch::BTN_EV_SINGLE_CLICK) {
      Serial.print("Button Pressed: ");
      Serial.println(key_names[i]);

      if (i == 2) {
        leftAnimationRunning = !leftAnimationRunning;
        Serial.println(leftAnimationRunning ? "Left Animation Started" : "Left Animation Stopped");
      }
      if (i == 0) {
        rightAnimationRunning = !rightAnimationRunning;
        Serial.println(rightAnimationRunning ? "Right Animation Started" : "Right Animation Stopped");
      }
      if (i == 4) {
        leftAnimationRunning = !leftAnimationRunning;
        rightAnimationRunning = !rightAnimationRunning;
        Serial.println("Center Button Pressed: Toggling Both Animations");
      }
      if (!leftAnimationRunning) stopAnimation(NOODS_LEFT, &stripLeft);
      if (!rightAnimationRunning) stopAnimation(NOODS_RIGHT, &stripRight);
    }
  }
}

void handleButtonPress() {
  static bool buttonPrevState = HIGH;
  bool buttonState = digitalRead(BUTTON_LEFT);

  if (buttonState == LOW && buttonPrevState == HIGH) {
    leftAnimationRunning = !leftAnimationRunning;
    Serial.println(leftAnimationRunning ? "Button pressed, left LEDs start" : "Button pressed, left LEDs STOP");
    if (!leftAnimationRunning) stopAnimation(NOODS_LEFT, &stripLeft);
  }
  buttonPrevState = buttonState;
}

void handleSwitch() {
  bool switchState = digitalRead(SWITCH_RIGHT);
  if (switchState == HIGH && !rightAnimationRunning) {
    rightAnimationRunning = true;
    Serial.println("Switch HIGH! Right LEDs START");
  } else if (switchState == LOW && rightAnimationRunning) {
    rightAnimationRunning = false;
    Serial.println("Switch LOW! Right LEDs STOP");
    stopAnimation(NOODS_RIGHT, &stripRight);
  }
}

void updateBlinkingLeds() {
  unsigned long currentMillis = millis();

  if (leftAnimationRunning && (currentMillis - previousMillisLeft >= blinkInterval)) {
    previousMillisLeft = currentMillis;
    leftBlinkOn = !leftBlinkOn;
    Serial.println(leftBlinkOn ? "Left LEDs ON" : "Left LEDs OFF");
    if (leftBlinkOn) {
      startAnimation(NOODS_LEFT, &stripLeft);
    } else {
      stopAnimation(NOODS_LEFT, &stripLeft);
    }
  }

  if (rightAnimationRunning && (currentMillis - previousMillisRight >= blinkInterval)) {
    previousMillisRight = currentMillis;
    rightBlinkOn = !rightBlinkOn;
    Serial.println(rightBlinkOn ? "Right LEDs ON" : "Right LEDs OFF");
    if (rightBlinkOn) {
      startAnimation(NOODS_RIGHT, &stripRight);
    } else {
      stopAnimation(NOODS_RIGHT, &stripRight);
    }
  }
}

void startAnimation(int noodsPin, Adafruit_NeoPixel *strip)
{
  digitalWrite(noodsPin, HIGH);
  strip->clear();
  for (int i = 0; i < RGB_LED_COUNT; i++) {
    strip->setPixelColor(i, strip->Color(255, 165, 0));
  }
  strip->show();
}

void stopAnimation(int noodsPin, Adafruit_NeoPixel *strip)
{
  digitalWrite(noodsPin, LOW);
  strip->clear();
  strip->show();
}
```

APPENDIX G REAL TEST ON BIKE DETAILS

Appendix G.1 Test Route Details



Route user test
Trough Vught (de Baarzen) 2,31 kilomters

Right: 9 times (18 clicks)
Left: 3 times (6 clicks)

1. (Right) Exit Kampenhout to Meierijsingel
2. (Right) Intersection Meierijsingel - Rouppe v/d Voortlaan
3. (Left) Intersection Rouppe v/d Voortlaan - Brabantlaan
4. (Right) Roundabout Brabantlaan - Wolfskamerweg
5. (Right) Exit Wolsfkamerweg to Baarzenstraat
6. (Right) Bifurcation Baarzenstraat - Peellandstraat
7. (Left) Bifurcation Peellandstraat - Pieter Vreedesingel
8. (Right) Exit Pieter Vreedesingel - Rouppe v/d Voortlaan
9. (Left) Exit Rouppe v/d Voortlaan - Brabantlaan
10. (Right) Exit Brabantlaan - Meierijsingel
11. (Right) Bend Meierijsingel
12. (Right) Entrance Meierijsingel to Kampehout

Appendix G.2 Details per Turn

1 (Right) Exit Kampenhout to Meierijsingel

Observation videos:

User 1: Turn signal on and sticking out arm
Turn signal on long and checking if its off
Adjusting mirrors while cycling

User 2: Lights not used, arm not sticked out.

User 3: Turn signal used as intended. Checking when turned off, if it was turned off.

User 4: Lights were used as intended.

User 5: Light turned on when going right, but forgot to turn it off.

User 6: Mirrors adjusted when leaving, lights were used as intended.

2 (Right) Intersection Meierijsingel - Rouppe v/d Voortlaan

Observation videos:

User 1: Turn signal on and checking if its on. Turning lights off quickly after turn.

User 2: Lights not used, arm not sticked out

User 3: Turn signal was used as intended.

User 4: Lights used as intended.

User 5: Because light was still on, it was turned off when reaching the intersection. After the intersection, the button was not pressed again.

User 6: Lights used as intended.

(3) (Left) Intersection Rouppe v/d Voortlaan - Brabantlaan

Observation videos:

User 1: Looking over shoulder, turning lights on and sticking out arm. Turning lights off quickly aftr turn.

User 2: Lights used, but not turned off.

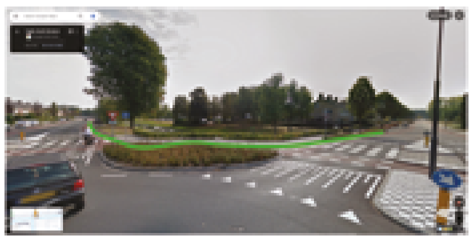
User 3: Turn signal used as intended. After the intersection it took a while to check if it was turned off.

User 4: Lights used as intended.

User 5: Turn signal put on, looked over shoulder and sticking out arm. Light put off after the turn.

User 6: Lights used as intended.

(4) (Right) Roundabout Brabantlaan - Wolfskamerweg



Observation videos:

User 1: Turning lights on before entering the roundabout, sticking out arm when leaving the roundabout. Turning lights off quickly after leaving the roundabout.

User 2: Due to the fact that the left light was still on, pushinig the right button turned the left one off. When leaving the roundabout, the button was pushed again, turning the right lights on again. So right light was turned on all the way.

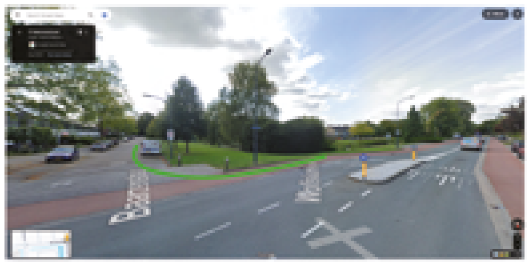
User 3: Light turned on as intended. However, cars on the roundabout could not see it so they waited. Tried to turn it of by pressing button, but it did not turn off. Figured out it was still on along the way, turned it off later.

User 4: Lights used as intended, but grip was turned, so mirror turned downwards. Immediately adjusted by user. When adjusting the mirrors even more, suddenly the right turn signal turned on. It was turned off along the way.

User 5: Turn signal used as intended, arm sticked out as extra signal to cars on the roundabout.

User 6: Lights used as intended. However, cars on the roundabout could not see it so they waited.

(5) (Right) Exit Wolfskamerweg to Baarzenstraat



Observation videos:

User 1: Turn lights on before turning to the right. Misclick after the turn, lights keep blinking.

User 2: Light turned off and on again. The way of using was as intended, only the lights were working the other way around.

User 3: Lights used as intended, but a double check due to misclick at previous turn.

User 4: Lights used as intended.

User 5: Light turned on as intended, but forgot to turn it off.

User 6: Lights used as intended.

(6) (Right) Bifurcation Baarzenstraat - Peellandstraat

Observation videos:

User 1: Lights were not put of when entering the street, so before turning the lights were put off instead of on. After turn, the lights were put on again. Quickly realizes they were on and then turned off.

User 2: Use of the lights was good again, only on/off was still turned around. Arm was sticked out for the first time.

User 3: Lights used as intended.

User 4: Lights used as intended.

User 5: Light turned off, because it was still on from the previous turn. After turn, button was not pressed again.

User 6: Lights used as intended.

7 (Left) Bifurcation Peellandstraat - Pieter Vreedesingel

Observation videos:

User 1: Very quickly turned on and off when turning to the left. Quick turn after the perivious turn 6.

User 2: Lights were not used, arm was sticked out Quick turn after the previous turn 6.

User 3: Lights used as intened, but a lot of distraction by checking the lights in these two/three short turns.

User 4: Lights used as intended, there was some traffic and difficulties with turning off.

User 5: Light turned on as intended, but not turned off.

User 6: Lights used as intended.

8 (Right) Exit Pieter Vreedesingel - Rouppe v/d Voortlaan

Observation videos:

User 1: Lights used as intended, nothing noteworthy. After the turn randomly turning on and off, because it was not clear if the turn signal was turned off corretly after the turn.

User 2: Missed this turn. Took the next available turn, where lights were swiched off and on again. Arm was streched again.

User 3: Lights used as intended.

User 4: Due to some traffic and struggles with turning of from the previous turn, the lights were not turned on in this turn. After the turn they were tured on.

User 5: Button was pressed as intended, putting the left light off, but not the right light on. After the turn, the button was not pressed again.

User 6: Lights used as intended.

9 (Left) Exit Rouppe v/d Voortlaan - Brabantlaan

Observation videos:

User 1: Turn signal used as inteded, but checking if it was on. When turning looking over shoulder and streching out arm. Lights turned off after turning.

User 2: User took a different route, but went left into the same street at the next block. Left button was pushed, resulting in turning both lights off. After the turn, the left light was turned on again. Arm was streched at this turn.

User 3: Lights used as intented, after turn checking if the light was off. Along the Brabantlaan, both mirrors were adjusted.

User 4; Because the right turn was still on, it was turned off by pressing the left turn. However, pressing the left turn once in this case was not enough to put the right ligth on. So the turn was taken without a light on. After the turn, the button was pressed again, putting the light on.

User 5: At a previous intersection, the left turn signal was put on, because there was doubt about the right turn. The used did not turn eventually, continued the right route, but did not put the left light off. At the right turn, number 9, the light was put off because the button was pressed again. After the turn, the button was not pressed again.

User 6: Lights used as intended.

10 (Right) Exit Brabantlaan - Meierijsingel

Observation videos:

User 1: Lights used as intended, nothing noteworthy.

User 2: Lights not used.

User 3: Lights used as intended.

User 4; Since left light was still on, right button press led to both lights turning off. After the turn, the button was pressed again, the light went on. This was noticed quickly, light was put off. Along the way, both mirrors were checked if they were still on.

User 5: Light turned on as intended, but was not turned off.

User 6: Lights used as intended.

11 (Right) Bend Meierijsingel

Observation videos:

User 1: Light not used

User 2: Light not used

User 3: Lights used as intended

User 4: Used as intended.

User 5: Light was still on, buttons not pressed.

User 6: Light not used.

12 (Right) Entrance Meierijsingel to Kampehout

Observation videos:

User 1: Lights used, not turned off. Might be due to the fact that it was the end of the route and the researcher was waiting when entering the street.

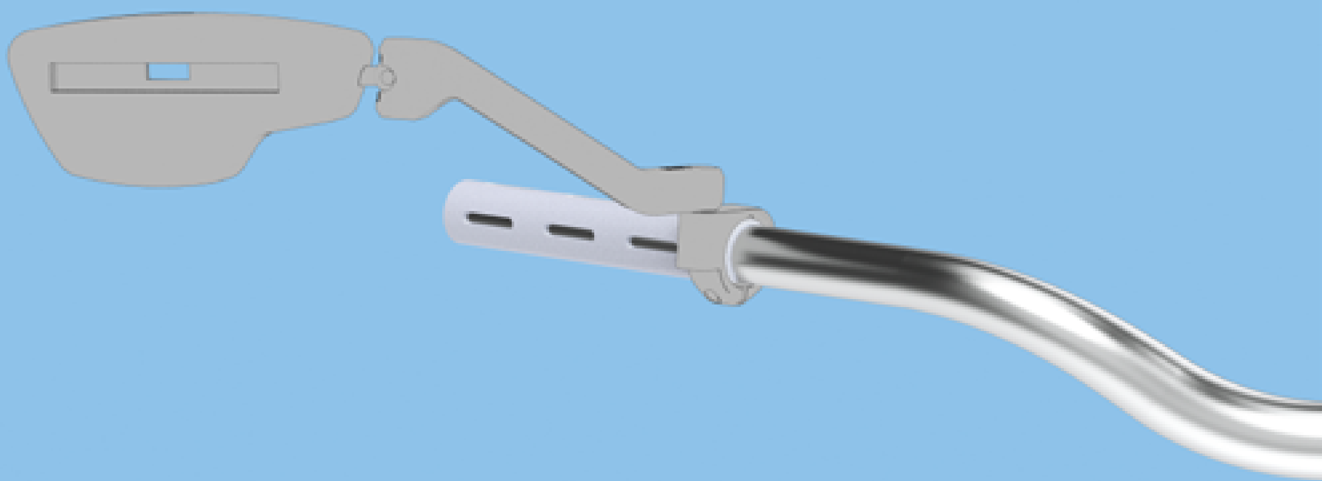
User 2: Light not used, left light was still on when ending the route.

Used 3: Lights used as intended.

User 4: Lights were put on, since right-right turn was quickly after each other. Turned off after arriving.

User 5: Light turned off, to turn right. When arriving, the light was off.

User 6: Lights used as intended.



BBB cycling

TU Delft