GRADUATION THESIS

A Modular Accessory System Design for Promoting Bicycle Helmet Usage in the Netherland

Yifan Miao
MSc. Integrated Product Design

Chair: Daan van Eijk
Mentor: Ernest van Breemen

MSc. Graduation Thesis

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Yifan Miao
Integrated Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Chair
Daan van Eijk
Applied Ergonomics and Design
Human Centered Design

Mentor
Ernest van Breemen
Emerging Materials
Sustainable Design Engineering

Client
Antoinette Rozeboom
Rob Verdonschot
Erasmus MC

ABSTRACT

This thesis presents a modular accessory system designed to promote bicycle helmet usage in the Netherlands. The project aims to address the barriers to helmet usage by integrating functional, customizable, and attractive helmet accessories that align with the needs and preferences of young urban cyclists.

Through extensive research involving context research, helmet product analysis, and user research, the study identifies key factors influencing helmet use, including social norms, potential functions, and problems of helmet products. Social norm is the most influencial factor among them, which indicates that the low helmet acceptance is not merely due to dissatisfaction with functionality but is influenced by multiple social norms. This explains why conventional helmet designs often fail to attract users. A further case studies is conducted to identify effective design strategies targeting young urban populations.

The modular system incorporates clip-on connection system with four accessory modules. The connection system uses a unique magnetic clip structure that is easy to operate and ensures a secure fit. The four accessories, including a rain hood, visor, head lights, and earphones, tailored to target user needs and preferences to enhance convenience, safety, and personalization. By addressing functional shortcomings and leveraging the appeal of customization, the modular accessory system aims to shift social perceptions of helmet use, making it a more integral part of the cycling culture in the Netherlands.

Additionally, the scalability of the project contributes to the further service system development and commercialization plan to support future market development.

CONTENTS

1 INTRODUCTION

1.1 Background & Project Brief

The Netherlands is renowned as one of the most cycling-friendly countries in the world; however, it is rare to see people wearing helmets while riding. Despite the well-developed cycling infrastructure, the number of cycling-related injuries, particularly head injuries, is increasing in recent years. The proportion of cyclists wearing helmets in the Netherlands remains significantly low compared to many countries in Europe. Raising awareness and motivating people to wear helmets can prevent injuries and reduce the strain on public healthcare.

The ultimate goal of this graduation project, received from the client, is to design a product that promotes helmet wearing in the Netherlands with potential for commercial application in near future. This project is supervised by Prof. ir. Daan van Eijk and Ir. Ernest van Breemen and commissioned by Dr. Antoinette Rozeboom and Dr. Rob Verdonschot from Erasmus MC. The client team has been actively researching head injury prevention and promoting helmet use among Dutch cyclists. Prior to this project, Bosch Remco, an SPD (Strategic Product Design) graduate from TU Delft, conducted a study on the factors influencing helmet use and argued that a fashionable luxury design style could significantly increase the willingness to wear a helmet. Although this graduation project is an independent research effort and does not directly follow Bosch’s approach, his research provided valuable data and insights that have supplemented this work. Additionally, I received theoretical and practical guidance from Linda Plaude in fashion design and fabric processes, and behaviour change model insights from course materials provided by Dr. Jos Kraal.

1.2 Process

The project is organized into four main sections across nine chapters of this report:

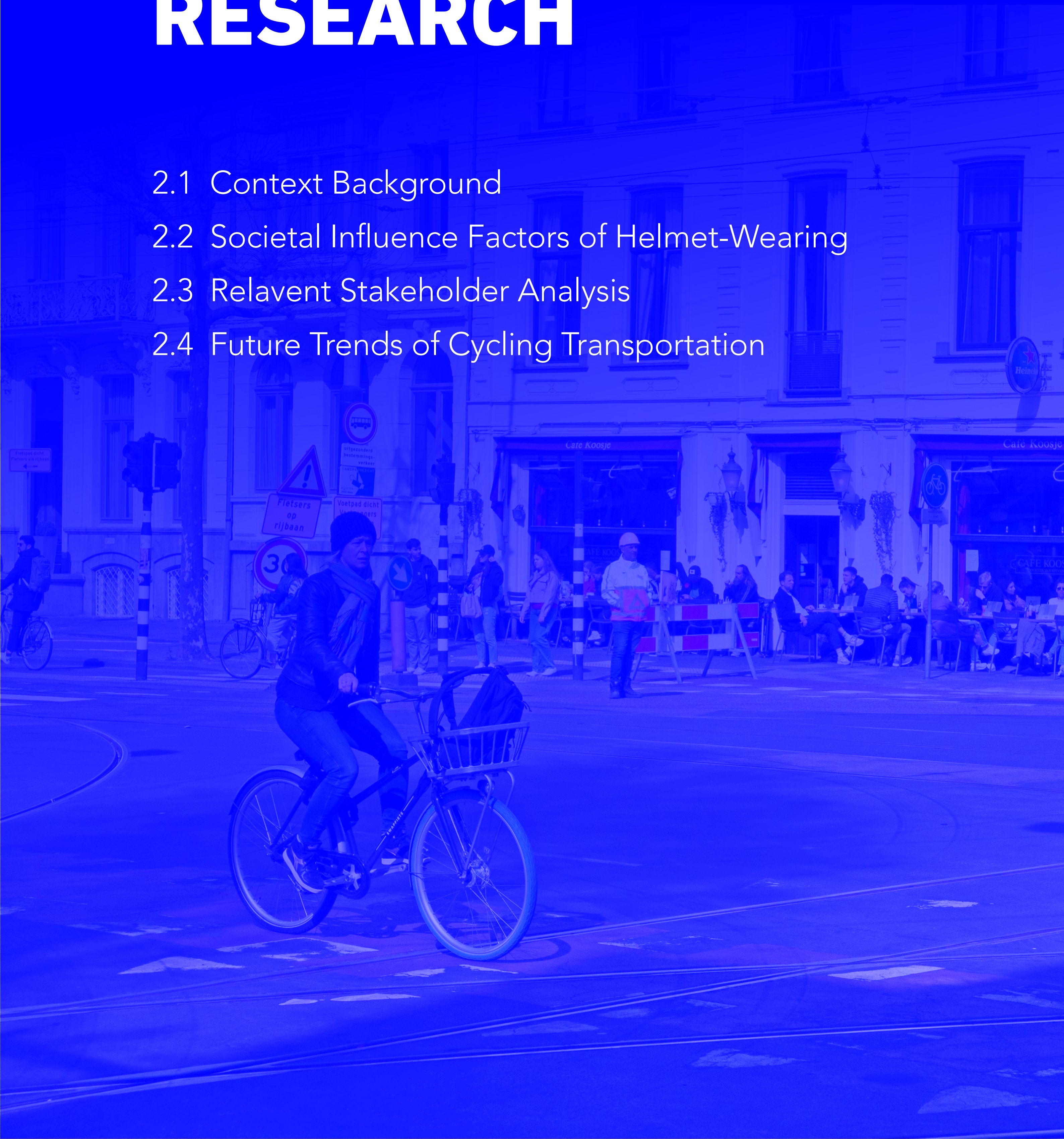
Researching & Framing: This section explores the factors influencing people's intention to wear bike helmets through literature review, quantitative, and qualitative research approaches. Chapters 2, 3, and 4 separately analyse the current status and potential influence factors from different aspect of the context background, helmet products, and user characteristics.

Envisioning & Defining: This section defines the design strategy and concept for further development. Chapter 5 details the envisioning process, including target user identification, problem definition, and possible design strategies and opportunities. Chapter 6 further defines the concept, including product functions, styling, requirements and project management.

Developing & Validation: This section iterates physical design outcomes based on design concept and validates their efficiency. the connection system and hood are developed into functional prototypes with detailed features, while the other three accessories reach the stage of appearance volume prototypes and renderings. A validation study conducted during development verifies the design's effectiveness in increasing the willingness of target users to wear bike helmets.

Disscussion & reflection: This section provides future development recommendations after completing the main development phase. I also reflect on the overall product development process, addressing the limitations and insights gained throughout this graduation project.

2 CONTEXT RESEARCH



2.1 Context Background

The Netherlands is the highest bicycle usage country in the world, with notable cycling-friendly infrastructure and culture. However, cycling still poses certain risks and these risks are increasing in the Netherlands. The number of SEH (Spoedeisende Hulp) visits related to serious injuries from cycling road traffic accidents increased by 18% over the 10-year period from 2012 to 2021 (Valkenberg et al., 2022b). In 2023, cyclists comprised 63% of the total number of traffic accident victims treated in emergency rooms.

Brain injury is a common injury of cycling as well as one of the most dangerous types of injuries. About 20% of bike accidents results in head injuries (Valkenberg, H. et al., 2022). Multiple studies have shown that wearing a bike helmet can effectively protect against brain injury (Olivier & Creighton, 2016; Olivier & Radun, 2017; Van Den Brand et al., 2020). According to Dutch accident statistics from VeiligheidNL (2023), the risk of brain injury is one-third lower for cyclists who wear helmets compared to those without helmet. However, helmet usage in the Netherlands remains in a low level. Cyclists' helmet-wearing behaviour are closely related to the types of bikes they ride. Only 3% of regular bicycle riders and 2% of e-bike riders wear helmets (Ministerie van Infrastructuur en Waterstaat et al., 2018), yet these two groups of riders account for most bike accidents. In 2023, 79% of bike accidents involved regular bikes and 14% involved e-bikes (VeiligheidNL, 2023).

2.2 Societal Influence Factors of Helmet-wearing

Various factors contribute to the low helmet-wearing rate from societal level, including legislation, education, and cultural influence, etc.

While legislation mandating helmet use is often considered as the most effective way to increase daily helmet use, the comprehensive benefits is a complex issue influenced by local conditions. In the Netherlands, helmet use is not mandatory for bicycles and pedelecs (e-bikes with pedal assistance up to 25 km/hour) (SWOV, 2019). Considering the large population in the Netherlands that uses bicycles as most common transportation method, mandatory helmet legislation could decrease the willingness to cycle for commuting purposes and reduce the positively impacts public health and transportation sustainability. According to De Jong's research, in regions where cycling is already safe, mandatory helmet laws could result in more significant unintended negative health impacts than the protective benefits gained (2012), which contradicts the original intent of legislator to improve public health and promote sustainable mobility.

Education and publicity have also proven effective in increasing helmet use. Long-term tracking (2004-2022) research in Denmark shows that, education and awareness campaigns have achieved relatively high helmet-wearing rates without mandatory regulations by continuously promoting helmet wearing in school children (Olsson, 2023). In the Netherlands, the education and publicity of bike helmet is still underappreciated. Recent publicity efforts, such as the "Day of the Bike Helmet" (DAG VAN DE FIETSHELM) launched by "Doctors For Safety Cycling Organization" (Artsen voor Veilig Fietsen) since 2022, have gained support from local governments, medical organizations, insurance companies, and traffic safety organizations. Relative education initiatives, such as distributing helmets in primary schools, are also underway. But those efforts all require decades of time to assess their effectiveness.

At the same time, the opposition voices remain strong in a wide range. The Dutch cyclist organization Fietsersbond have argued that improving infrastructure is more important than promoting helmet use (Marloesmol, 2024) and consider helmet promotion as "victim blaming" (NPO, 2022) in their article. The negative image of helmet wearers is also evident in social media and among some celebrities and opinion leaders who see helmet-wearing as a not smart appearance or a cultural trait of tourist. Consequently, education and publicity efforts are far from establish social or cultural norms that encourage helmet wearing.

With the context of most social influence factor not beneficial to helmet promotion, the attractiveness of helmet design is identified as an effective in promoting helmet use in the short term. This also underscores the necessity of using design approaches to achieve the goals of this project. However, in the long term, product design appeal cannot achieve sustained success by itself, it must be complemented by education and social consensus-building, which are mutually reinforcing.

2.3 Relevant Stakeholder Analysis

Helmet wearing is a complex problem that is influenced by multiple people or organizations across different societal sectors. I categorize those influential stakeholders into five groups: users, helmet industry, mobility providers, institutions and society organizations, and cross-industry influencers. Their characteristics and interest are described separately below.

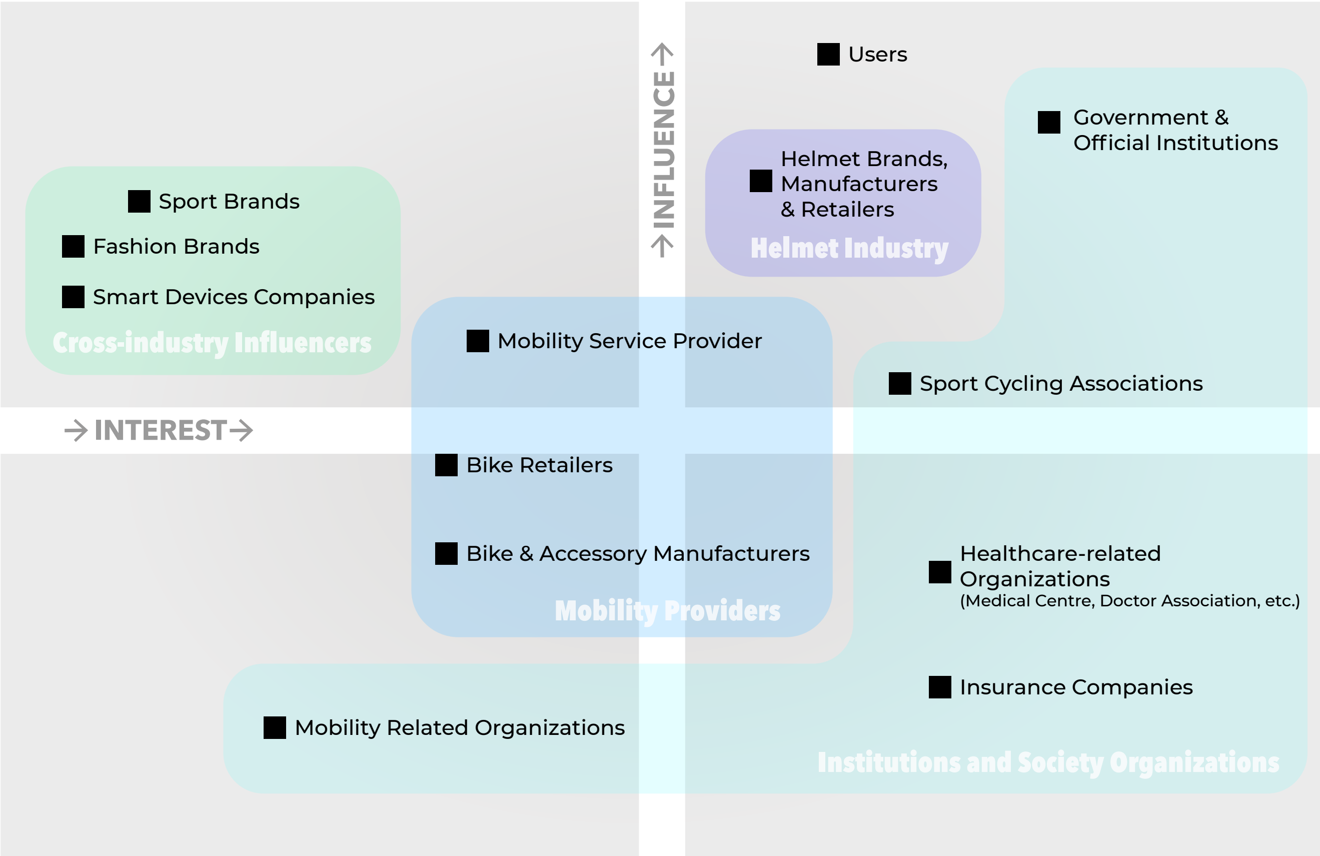


Figure 1. Stakeholder map

User

Generally, most bike riders in the Netherlands are against to wear helmet during daily bike riding, distinguish with sport riding, with complicated reasons and remains a very low rate of helmet wearing. Users are highly influenced by the social context and influential industries. Among different user groups, we can also find significant difference in their riding scenarios, user habits and common riding scenarios. The detailed analysis of user will be presented below in Chapter 4 "User Research".

Helmet Industry

Helmet industry, including the manufacturer and retailers, provides helmet product to users. Their product design, functionality features and promotion will directly influence the purchasing decisions and user experience of helmets. The details of the Helmets market will be analysed in chapter 3.1.

The helmet industry seeks to benefit from the popularity of helmet wearing. However, they prioritize safety features and regulatory compliance over user experience or product attractiveness. Consequently, they are relatively conservative in product innovation and reluctant to introduce features that might be more appealing but carry risks (Bosch, 2023), such as integrated audio functions.

Mobility Providers

With the advancement of transportation, diverse personal mobility tools and services have become integral to daily life. Besides traditional bicycles, e-bikes and scooters are gaining significant market share. Transport-based services are increasingly prevalent and integrated. Rental or shared bikes, pedelecs, and scooters are ubiquitous in the Netherlands. They have the capacity and social responsibility to provide safer travel services, but do not have the will to do so because it would reduce the number of customers.

Institutions and Society Organizations

Institutions and societal organizations have varying attitudes toward helmet wearing based on their interests. They can influence legislation and social norms by acting as influencers and practitioners of public affairs.

Government and official institutions, healthcare organizations, insurance companies, and sport cycling organizations generally support promoting helmet wearing as it potentially reduces their capital and labour costs. The initiators and supporters of the “Day of the Bike Helmet” (DAG VAN DE FIETSHELM) mentioned in section 2.2 are predominantly these types of organizations.

In contrast, mobility-related organizations and organizations representing ordinary commute riders often oppose helmet wearing, fearing it would result in a loss of support and decrease the use of their transportation products or services.

Cross-industry Influencers

Though their impact is often less significant, cross-industry influencers, such as sports brands, fashion brands, or other service providers, can occasionally influence helmet wearing. Social trends driven by their marketing strategies or technological innovations can subtly influence people’s attitudes towards wearing helmets. Additionally, promoting helmet use aligns with corporate social responsibility, as seen with companies providing delivery services like Uber Eats and Thuisbezorgd, which mandate helmet use among their delivery workers to enhance safety. These measures, though primarily aimed at protecting employees, can unintentionally influence broader social norms. The ripple effect of these actions may gradually alter public perceptions and daily habits related to helmet wearing, contributing to a cultural shift towards increased helmet use.

2.4 Future Trends of Cycling Transportation

Infrastructures: According to the Road Safety Strategic Plan 2030, there are plans to build and upgrade wider cycle lanes and enhance cycle lane separation from motor vehicle lanes on more roads. These plans aim to reduce the number of cars overall and encourage sustainable mobility. Additionally, the Netherlands is planning to implement intelligent traffic management systems assist in co-ordination traffic and ensure traffic safety. (Ministerie van Infrastructuur en Waterstaat et al., 2018)

Figure 2. future expectation of Dutch cycling path from ANWB (Verkeer in De Stad | ANWB, n.d.)

Beyond traditional bikes, the diverse use of light electric vehicles (LEVs) is a trend supported by the future development strategy outlined in the Road Safety Strategic Plan 2030. The sale of e-bikes and scooters is increasing in the Netherlands. E-bikes are particularly popular among elderly users. Scooters, cargo bike, skateboards, etc, are also more commonly used for commuting.

Diverse Transportation Services: The trend toward diverse transportation services is also evident. The sharing business model is widely implemented across various transportation sectors, making it easier for people to access different modes of transport.

3 HELMET PRODUCT RESEARCH

3.1 Market Research

Cycling helmet (head protection gear) market is a niche market, which is already oversaturated with very little differentiation amongst helmet products and few essential differences brought by product renewal. Currently, there are still no effective alternative head protection gears other than helmets on the market. A very famous neck hanging device Hövding airbag have permanently closed their web shop (Hövding 3 - Matches Your Style, n.d.). Other active guard or road-implemented safety equipment is also difficult to largely implement, and the effectiveness is limited by types of accidents. According to Bosch's research (2023), the market size of all bicycle helmets in the Netherlands is roughly estimated at about 500,000 products sold per year, with the majority of helmets sold for race bikes and mountain bikes. Urban helmets constitute a smaller market segment. The definition of an urban helmet is vague and is interpreted differently within the industry (Bosch, 2023). Apart from less saturated colours and smoother shapes, there are few essential differences between the urban helmets and sports helmets. Functionality, especially safety, remains the most emphasised product features in the product description and promotion, which does not translate into willingness to purchase due to the high perception of road safety in the Netherlands.

Common brands in the market do not focus on bike helmets as their main product but venture into other areas. A significant proportion of these are sports gear brands involved in cycling, skiing, equestrian sports, motorcycling, and other activities. Some of these brands, such as ABUS, specialize in safety equipment and protective gear. There are also smaller independent brands with their unique designed helmets as their primary product, which usually gear towards a specific group of users by featuring unique selling points such as foldable structures or customizable services. Some fashion brands offer helmet-like products, but their protective effects are not proven.

One of the most popular trends is integrating smart functions such as turning light or collision detection. While the sales of bicycle helmets have increased quite a lot due to the popularity of E-bikes, that raises more possibilities in the smart function combination with e-bike. Some independent brands put more effort into developing unique structures for better portability and user experience.

Figure 3. Collage of Urban helmet on the market

3.2 Regulation Analysis

All bike helmet products in the Netherlands must comply with EU regulations, specifically EU1078 for standard helmets and EU1080 for children's helmets. These regulations outline the required protective and usage features to ensure safety and functionality.

Protective Features:

The helmet must cover key areas, including the forehead, rear, sides, temples, and crown of the head.
It should guarantee an unobstructed field of vision.
The helmet must not have any sharp edges or points that could cause injury.
It must pass the shock absorption test, ensuring that the maximum force measured by a dynamometer on the head model does not exceed safe limits (Figure 4).

Usage feature:

The helmet must be usable with spectacles.
There should be no significant interference with the user's ability to hear traffic, maintaining awareness of their surroundings.

Retention system:

The retention system must be adjustable to fit various head sizes securely.
The chin strap must be at least 15mm wide and should not include a chin cup.
Helmets should not feature any green-colored components in the retention system.
The retention system should be operable with one hand and able to be released under pressure, ensuring ease of use and safety in emergencies.

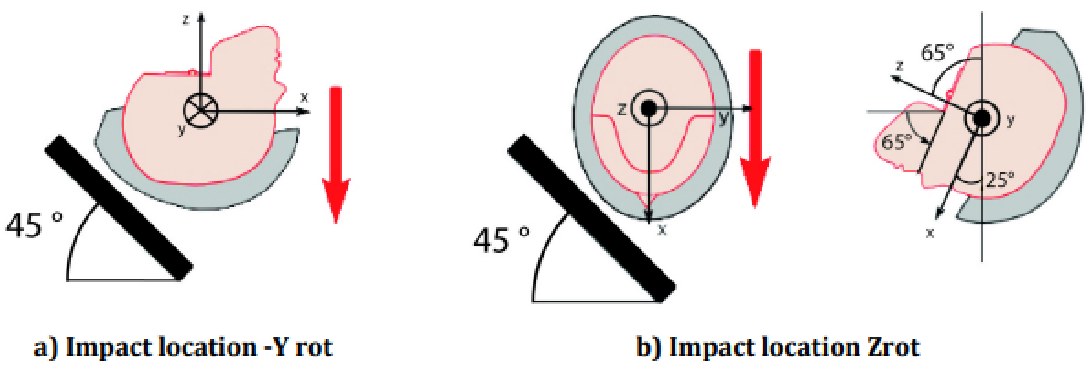


Figure 4. Illustration of test methods specified in the regulation

3.3 Structure & Material Research

The vast majority of bike helmets in the market contains the following parts: outer shell layer, energy-absorbing structure, inner comfort liner and retention system (figure 5). Some helmets also have additional parts such as visors or integrated glasses for different usage scenarios.

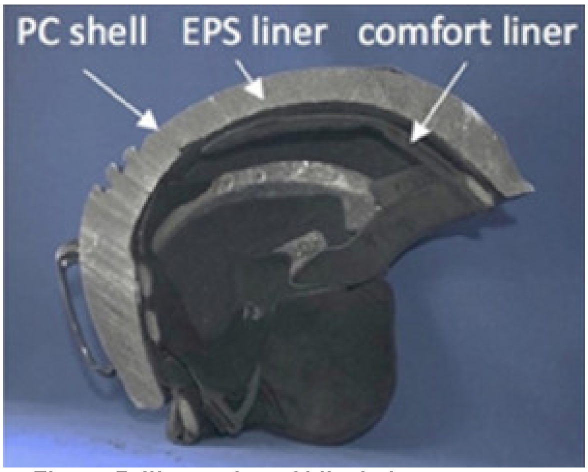


Figure 5. Illustration of bike helmet structure

Outer Shell Layer

The outer shell layer of helmets is typically made from composite materials like fiberglass or hard plastics such as polycarbonate or ABS. This layer is used to protect inner materials against rain and dust, and often feature aesthetical appealing colours and finishes.

An advanced process commonly used today is the in-mould process. In this method, a polycarbonate (PC) shell is formed by vacuum and then EPS (Expanded Polystyrene) is injected into the vacuum-formed shell for moulding. This process eliminates gaps between the shell and the protective material, reduces the overall weight, and provides better impact transmission features.

Energy Absorbing Structure

This part provides protective function for users and constitutes the main thickness of the helmet. It is mostly made of energy-absorbing foam that deforms upon impact to absorb energy. EPS (Expanded Polystyrene) is the most commonly used material due to its reliable performance in hard impacts, lightweight, low cost, durability, reliable manufacturing, and ease to ventilate. In addition to other alternative foam materials, some brands developed their alternative energy absorbing structure or materials. For example, Koroyd and HexR applies similar principle of using honeycomb-like network of polymer hollow structures that collapse upon impact. Compared to normal EPS foam, these materials offer lighter weight, better breathability and better protective efficiency due to their unique structures.

Most energy absorbing materials are disposable and need to be replaced after collision because the structural compression and changes in material stresses caused by the impact energy compromise their effectiveness.

MIPS (Multi-directional Impact Protection System) is an additional structure under the energy-absorbing materials. This system allows the head to rotate within the helmet shell at the moment of oblique impact in order to reduce the rotational motion damage (Figure 7).

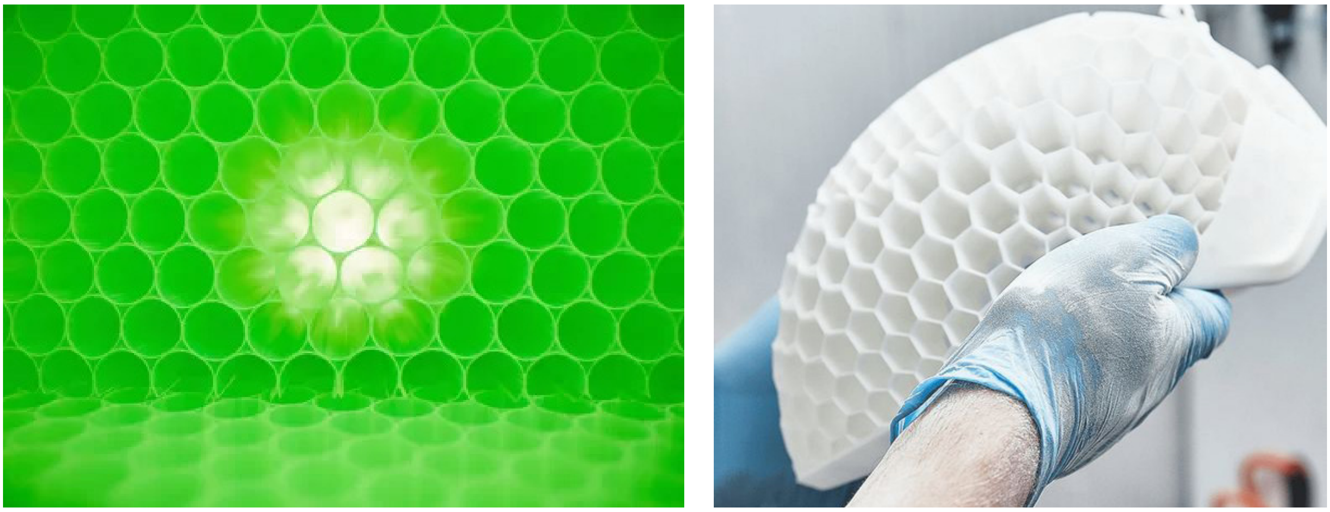


Figure 6. Various energy absorbing structure

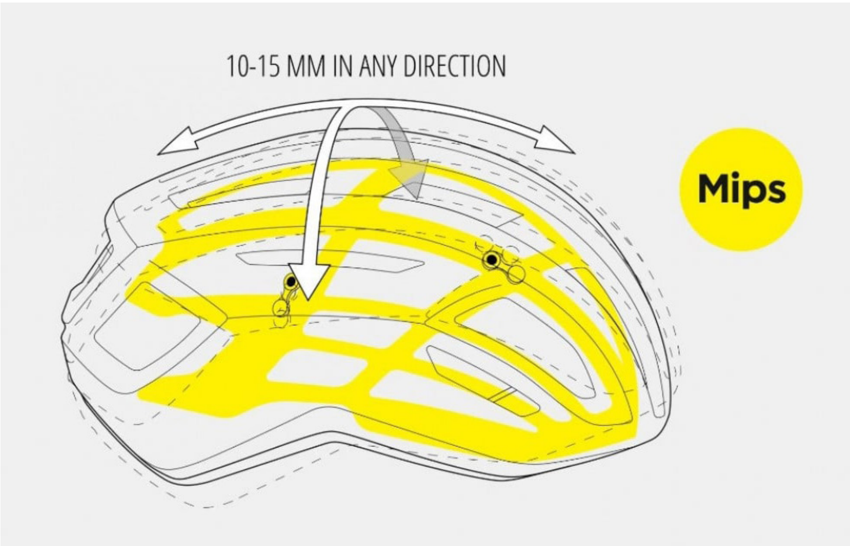


Figure 7. MIPS structure

Inner Comfort Liner

The inner comfort liner is attached inside the energy-absorbing structure of the helmet, creating a barrier between the helmet and the user's hair and skin. It is primarily composed of soft and absorbent fabrics and foam materials designed to enhance comfort and fit, accommodating various head shapes. However, the liner can also affect air permeability and may require regular cleaning.

Despite its role in improving comfort, the inner comfort liner is not always considered an essential component of bike helmets. In existing market products, some helmets feature removable liners for easy maintenance, while others omit the liner entirely. It is also common for helmet users to wear hairbands or caps underneath the helmet, serving the same purpose of enhancing comfort and fit, similar to what an inner comfort liner provides.

Retention System

The retention system wraps through the helmet and around the chin to keep the impact absorbing part of the helmet properly fastened on user's head. It usually contains two parts.

The retention mechanism at the back of the helmet is usually in the form of rotational dial or ratcheting buttons. By adjust the mechanism, the cradle connected with it will be snug against the back of head, under occipital protuberance.

The straps fixed on the helmet go around the ears and attach beneath the chin. The straps relate to buckles and are adjustable in multiple places, typically under the earlobes and at the jaw.

Figure 8. Retention system

Additional Parts

Some helmets include additional parts tailored to different usage scenarios or design purposes. These components enhance the helmet's protection, functionality, and overall user experience.

Protectional parts: Glasses (visors) are commonly used to protect the user's eyes from wind and dust, enhancing safety and comfort during rides. Chin protectors are specifically designed for mountain biking (MTB), providing extra protection for the chin and face, which is crucial in more extreme sports environments.

Functional parts: Headlights are widely integrated as functional parts of urban helmets, enhancing visibility in low-light conditions. Some helmets feature removable headlights that allow users to change batteries easily. Additionally, some helmets have ventilation holes that can be covered with additional structures or covers, allowing users to adapt to cold or rainy weather conditions.

Aesthetics parts. Aesthetic enhancements are more commonly found in other types of helmets. While these parts aim to improve the helmet's appearance, they also present an opportunity to make helmets more appealing and personalized, which could increase helmet usage among style-conscious users.

4 USER RESEARCH

4.1 Literature Review

4.1.1 Scenarios & User Habits

According to the statistics from CBS (2023a), the largest share of Dutch cycling path mileage is in built-up areas. Bosch's indicating that the most common scenarios for Dutch people to ride bikes are neighbourhood cycling (for groceries etc.), recreational cycling, and commute cycling (to school or work) (2023). The official statistics confirms this (figure 9), these three reasons account for most cycled kilometres and time travelled on average (CBS, 2023a). Commute riding has the fastest speed, while leisure or tourist riding are much slower than other cycling purpose.

Interaction with mobile phones is already an important share of our lifetime. Conflict arises between cycling and the distraction of playing mobile phones. Despite the fact that cycling while operating mobile phone has been illegal in the Netherlands since 2019, it has not completely deterred people from using their phones while cycling. Send/receive messages and navigation are two functions that people miss most during riding (Bosch, 2023). This dependence on mobile phones is particularly pronounced among younger age groups.

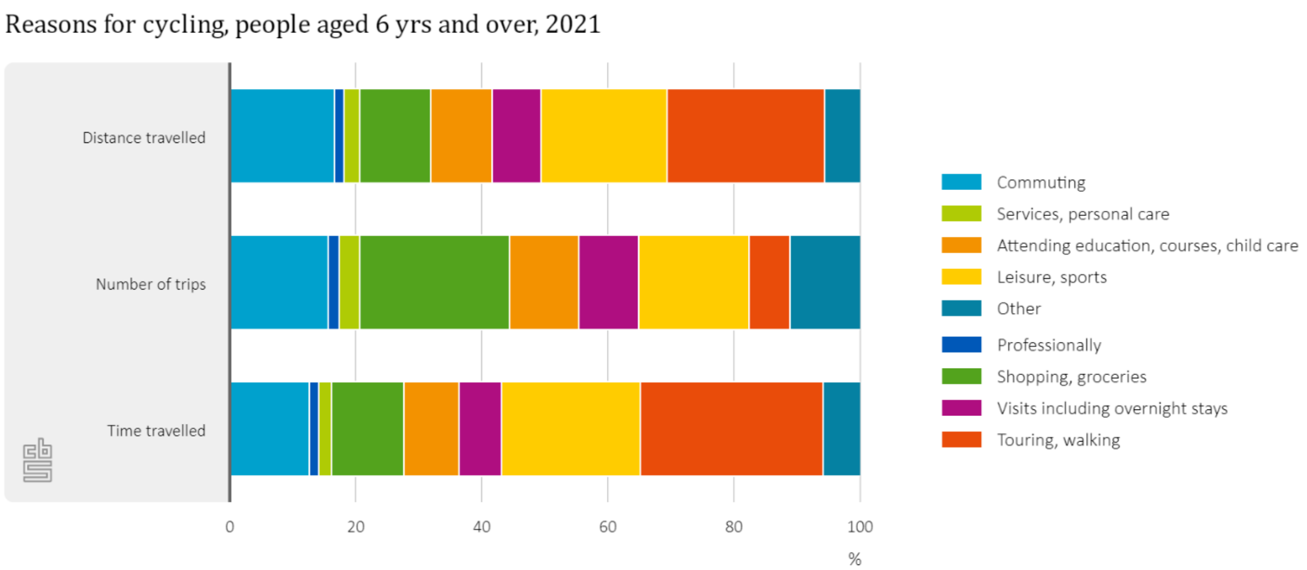


Figure 9. Reasons of cycling (CBS, 2023a)

4.1.2 Influence Factors of Helmet Using

Helmet wearing is influenced by multiple factors, the research of Ledesma et al. (2019b) divides these influence factors into four groups: benefits & risk deduction, disadvantages & barriers, group-norms, and situation dependence. Their result shows that frequency of helmet use is positively and strongly associated with F1 (Benefits & Risk Reduction) and F3 (Group Norms), and negatively with F2 (Disadvantages & Barriers), while the relationship with F4 (Situation Dependence) is very insignificant and close to zero. A strong positive correlation between the first and the third factor was also observed. Among these variables, F3 and F2 were more important predictors of helmet use than F1 (Ledesma et al., 2019b).

In this chapter we will analyse the factors that have an impact on helmet use according to these three categories.

Benefits & Risk Deduction

One of the most significant reasons for Dutch people not to wear a helmet is the low perception of risk. The Netherlands is one of the safest countries for cyclists in the world. Given the large number of cyclists on the roads, the safety-in-numbers principle (Jacobsen, 2015) increases the perceived safety of riding while decreasing the perception of danger, making people more reluctant to wear helmets. (In road safety, the principle of safety in numbers refers to risks for vulnerable road users. It implies that as the number of cyclists and pedestrians increases their crash risk decreases; or the increase in the number of crashes among these road users is smaller than would be expected considering the increase in their numbers in traffic) From the survey conducted by Bosch (2023), most Dutch cyclists perceived they are riding in a quite safe environment. The average safety perception is rated 5.06 of 7 (as the full marks for being very safe). This is also verified in my survey and interview, participants' perceived necessity of wearing helmet is generally below the median, and only small specific user group can notice a significant risk that led to the willing of wearing helmet. Therefore, we can say that the perceived benefits of wearing bike helmets is low in the Netherlands, which results in minimal positive correlations to assist bike helmet promotion.

Disadvantages & Barriers

At the same time, the barriers also strongly decrease people's willingness to wear a helmet in the Netherlands. According to ANWB's research, the difficulty of carrying and storing a helmet is the second highest scored reason of not wearing a helmet, which is also verified in Bosch's survey

The negative impact on personal appearance is also a significant factor preventing people from wearing helmets, including unattractive appearance with helmet or the effect on hairstyle.

Comfort is another major barrier to helmet use. Although significant research and development has been invested, tightness and breathability are still significant shortcomings due to protection effectiveness and the fitness of peoples' head shapes.

Group Norms

Various studies show that group norms have a strong effect on people's behaviour of helmet use. Within closer social relationships, the influence of peers and family is a significant factor in helmet wearing for all age groups (Finnoff et al., 2001) and particularly evident among young people (Seçginli et al., 2013). For those still in school, their parents' attitudes and behaviours are strongly associated with their decision to wear a helmet (Lajunen & Räsänen, 2001).

Moreover, Dutch cyclists are influenced by group norms on a larger scale. Due to the insufficient safety education an lack of social-norm, wearing a helmet is usually seen as not brave or unconfident to riding skills in the Netherlands. It is also forming a cultural identity distinct from neighbour countries, especially German riders. Comments linking helmet-wearing behaviour to nationality and culture are often seen under contents of promoting bike helmets in social media platforms. (figure 10). This observation is also verified in the survey I conducted (chapter 4.2.2).

Figure 10. Comments about helmet wearing in social media

4.1.3 Difference in Bike Types

Helmet use is also influenced by the type of bicycle being used. According to Bosch's research (2023), users of electric bicycles are more likely to use helmets, particularly if the helmet is included as part of the e-bike set. Helmet use is higher among personal bicycle riders compared to bike share users (Zanotto & Winters, 2017). Mountain bike (MTB) and road bike users are more likely to report helmet use, with 79% of race bike riders and 69% of mountain bike riders wearing helmets (Ministerie van Infrastructuur en Waterstaat et al., 2018). Helmets in conjunction with bicycles can increase user purchasing. But the connection between helmet ownership and use behaviour is unclear. Although having a helmet is a precondition for using one, several studies show that it does not automatically lead to high wearing rate (Ledesma et al., 2019c).

However, surveys and interviews indicate that in the Netherlands, most people see commute riding as daily transportation, sharply contrasting with their view of MTB or race bike cycling as sports. These two different perceptions create a challenge in translating the group-norms and high willing of helmet wearing from sport cycling to daily riding by helmet design.

4.2 Quantitative User Research

4.2.1 Research Questions

Based on the quantitative and qualitative research results of Bosch (2023) and the literature review insights, this survey aims at gaining a deeper understanding to people's opinions and their daily habits of protection and dressing. The following research questions are set:

R1 **what are people's opinions of bike helmet?**
(what are the social / culture norms of wearing bike helmet?)

R2 **What are people's daily riding habits?**

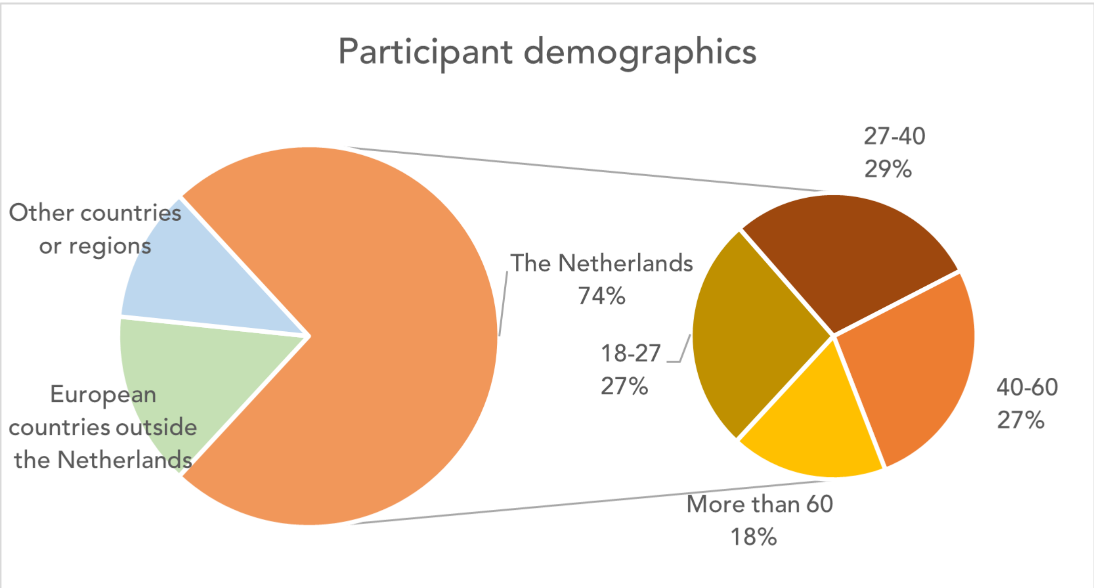
R3 **What are people's opinion and consumption preference to their outfits?**

R4 **What are people's dressing habits of headwear and bags during riding?**

R5 **How do people's group characteristics** (age, education, etc)
affects their opinions, habits and outfits?

4.2.2 Procedure & Results

To verify the above findings and conjectures, I conducted a quantitative analysis through questionnaires. Data were collected from 61 participants, mainly in Rotterdam centrum and Delft centrum, with a small portion of the questionnaires distributed on online platforms and via flyers with QR codes in residential buildings. All participants live in the Netherlands and use bicycle as one of their main modes of personal transportation. Every participant filled in the same questionnaire. 74% of the participants are Dutch, and the age distribution of Dutch participants are quite even (graph 1).



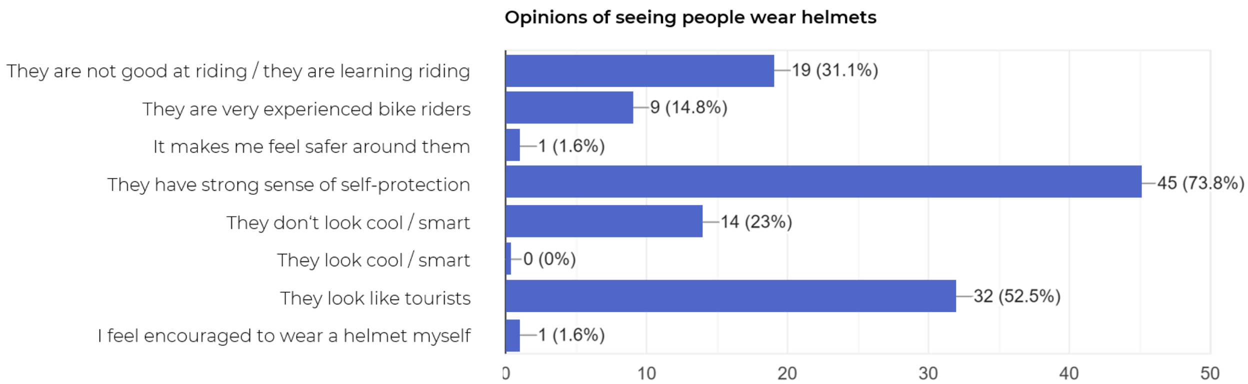
Graph 1. Demographics of survey participants

R1 is studied by asking participants to rate their perceived necessity of wearing bike helmet and then answer multi-choice questions by selecting the option that characterise the image of people wearing a bicycle helmet and the motivation factors for wearing helmet.

Participants' opinions on the necessity of wearing a helmet are low, with an average score of 3.36 on a seven-point scale (1 is totally unnecessary to 7 is absolutely necessary).

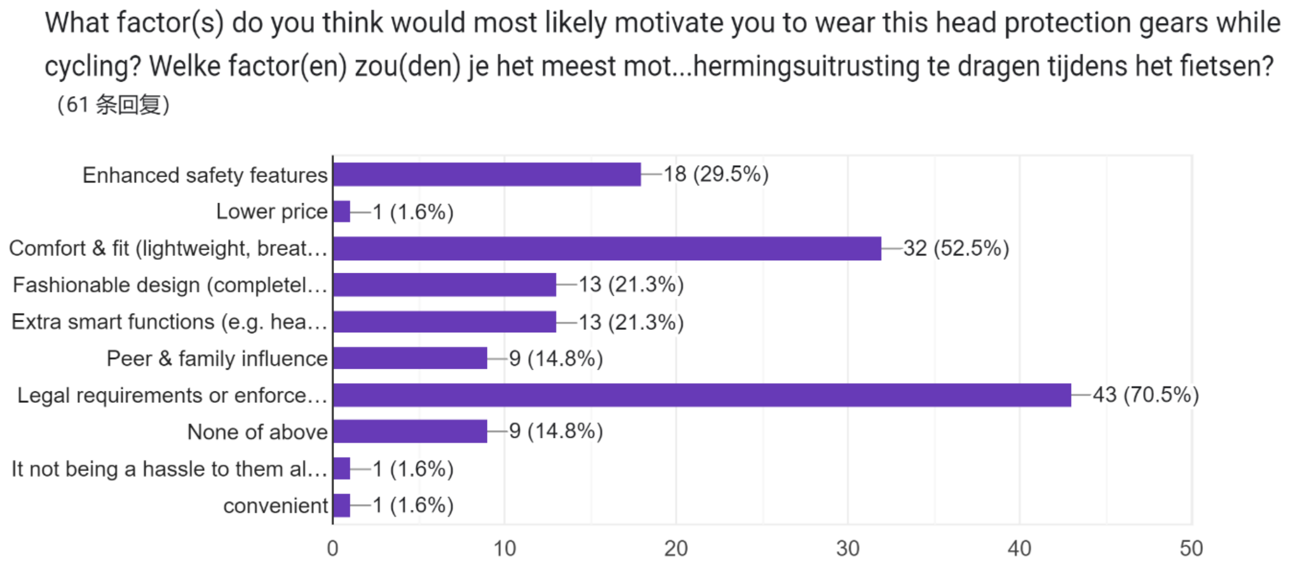
Though most participants agree that helmets convey a strong sense of self-protection (73.8%), this does not make people feel safer around helmet wearers or encourage them to wear helmets themselves. Only one participant agreed with that option. Over half of the participants (52.5%) believe that wearing a helmet makes one look like a tourist. Helmets also make people seem inexperienced in riding (31.1%) which could partly contribute to the reason of the low perception of safety. Some participants feel that cyclists wearing helmets look like experienced bike riders, it is likely because helmets are commonly associated with sport cycling, such as road cycling or mountain cycling. 23% of participants think wearing a helmet makes people look uncool or not smart, while none of the participants chose the opposite.

Those several pairs of opposite options revealed interesting results. The predominant view of seeing other people wearing helmets was negative. This result also shows the social norm of helmet wearing in the Netherlands.



Graph 2. Opinions to bike helmet wearing

Among all motivation options, legislation is still the most influential motivation of wearing helmet, followed by Comfort & fit. Price is the most insensitive factors for participants, with only 1 participant considering it motivative. The rest of the options were relatively evenly distributed. (graph 3)



Graph 3. Motivation factors of wearing helmet

R2 is studied by asking participants about the types of bikes they ride (possess), their use of helmets and other protective gear, and their safety habits.

Almost all participants own a normal commute bike (93.4%). 34.4% of participants ride an e-bike. The percentage of race bike and mountain bikes are quite similar around 16% -18 %, with fewer people ride cargo bikes (13.1%). About 80% of participants never wear helmets during riding, only 18% participants sometimes wear helmet. The proportion of participants using other protective gear is even lower. By cross analysing the data of bike types and protection wearing, I find that those participants who wear protection gears are highly overlap with mountain bike or race bike riders.

R3 is studied by questions about participant's concern of outfit and their daily dressing style.

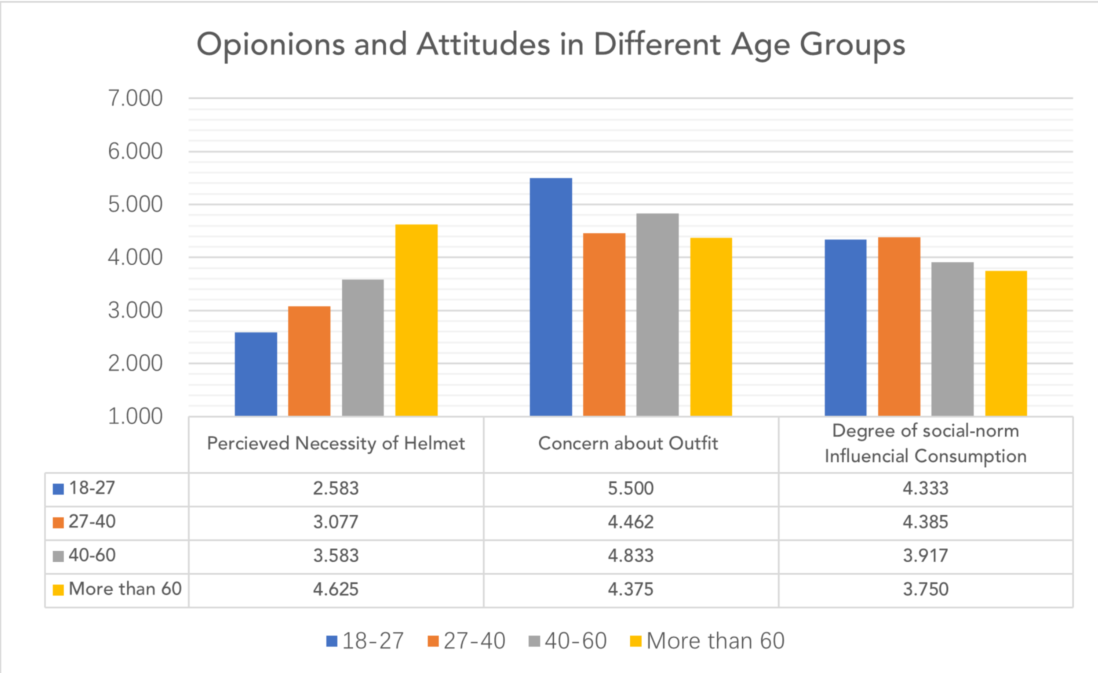
Most participants are concerned about their outfits with an average score of 3.36 on a seven-point scale (1 is "don't care at all" to 7 is "care a lot"). And the concern decreases with age. Among different dressing styles, most participants describe them as Minimalist style, following by elegant fashion style. The formal business style is the least popular outfit style. The other options show little difference in popularity.

R4: In this part, questions are set by asking participants to rate their frequency of headwear wearing and storage carrying. All questions were answered on a frequency scale from 1 "never wear" to 7 "always wear".

Participants generally have a high frequency of wearing jacket hoods, which is well adapted to the weather. Participants sometimes wear caps or hats, headphones, and glasses; and almost never wear helmets, hairbands and other headwear. Glasses usage frequency is polarized, participants either wear glasses very often or not wear at all. For storage, most people ride bikes with no bags. Backpacks are the bags people carry most frequently during riding and significantly more often than any other bags.

R5 is studied by analysing the data of the previous questions with age as an analyse parameter. The result shows that there are considerable differences between different age groups in cycling-related opinions and habits.

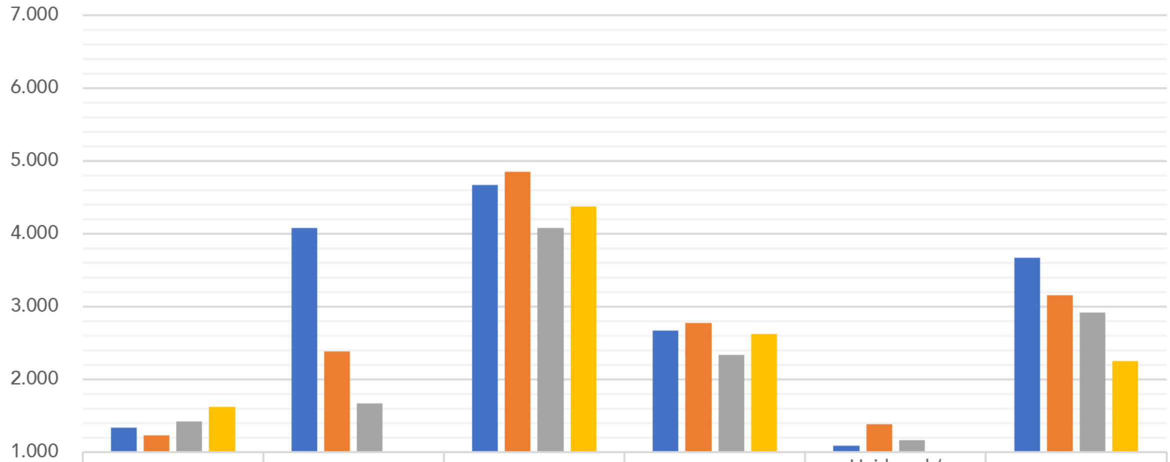
In terms of opinions and attitudes, younger age groups perceive less necessity of wearing helmet that could be related to their low risk-perception. The younger age group also have higher concern about outfit and high degree of social-norm influential consumption.



	Percieved Necessity of Helmet	Concern about Outfit	Degree of social-norm Influencial Consumption
18-27	2.583	5.500	4.333
27-40	3.077	4.462	4.385
40-60	3.583	4.833	3.917
More than 60	4.625	4.375	3.750

Graph 4. Attitudes in different age groups

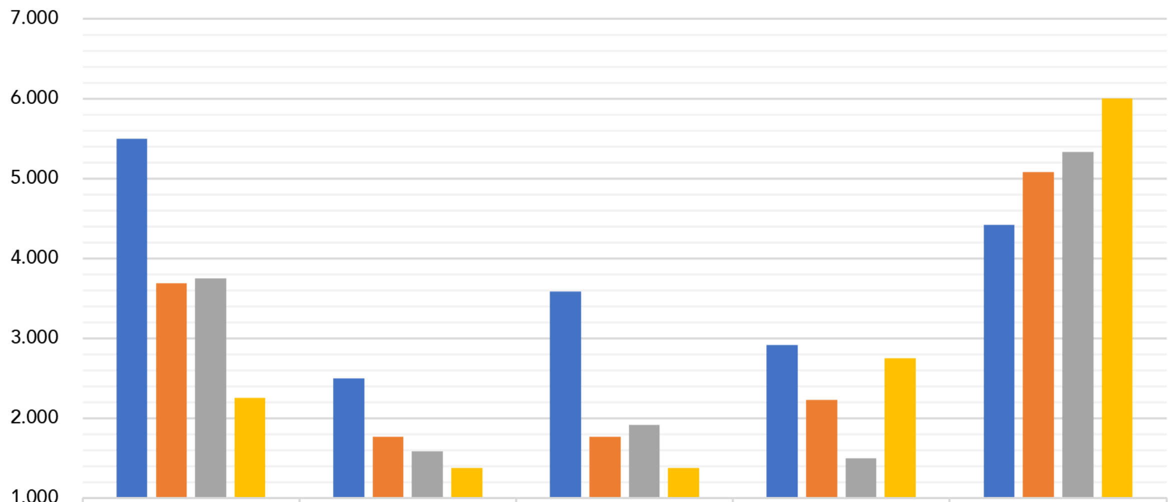
Outdoor jacket hoods are commonly worn with high frequency by all age groups. Younger age groups have a significant preference of wearing headphones and glasses compared to older age groups. Younger age groups have higher frequency of carrying bags, especially backpack and tote bags. Oppositely, higher age groups are less likely to ride with bags. There is an exception that the frequency of "riding with other bag" is particularly high among participants more than 60. Based on the result of interview (will be explained in chapter 4.3), one of the possible explanations is this group of participants categorized their bike bags into the "other bags".



	Helmet	Headphones	Jacket (Outdoor Jacket) Hood	Cap/Hat	Hairband / Headscarf / Other Headwears	Glasses
18-27	1.333	4.083	4.667	2.667	1.083	3.667
27-40	1.231	2.385	4.846	2.769	1.385	3.154
40-60	1.417	1.667	4.083	2.333	1.167	2.917
More than 60	1.625	1.000	4.375	2.625	1.000	2.250

18-27 27-40 40-60 More than 60

Graph 5. Frequency of headwear wearing during cycling in different age groups



	Backpack	Shoulder Bag	Tote Bag	Other Bag	No Bag
18-27	5.500	2.500	3.583	2.917	4.417
27-40	3.692	1.769	1.769	2.231	5.077
40-60	3.750	1.583	1.917	1.500	5.333
More than 60	2.250	1.375	1.375	2.750	6.000

18-27 27-40 40-60 More than 60

Graph 6. Frequency of bags and storage use during cycling in different age groups

4.3 Qualitative User Research

Interviews were conducted with 7 participants from different age groups. Four of them were interviewed after completing the questionnaire, while three were interviewed individually. The main purpose of interview is to understand participants' attitudes and motivations toward helmets, to identify people's preference to appearance features, and provide supplementary information to the questionnaire.

Respondents in older age group perceive the cycling environment as more risky. One respondent mentioned experiencing joint pains due to aging, which affects her ability to control her bike in specific scenarios such as steep slopes on bridges or when encountering speeding, non-compliant riders. The older participants generally feel complicated about helmet wearing or carrying, but they show relatively little resistance to helmets. Younger respondents displayed more assertive attitudes. Several admitted to risky behaviours like riding while drunk, running red lights, or sending messages with hands off the handles. Their attitude towards helmets is generally resistant, with one respondent even saying that he might laugh at his best friend if they wore a helmet.

Interviewees who do not wear helmets have little to no knowledge of the features or trends in the urban helmet category. They occasionally encounter discussions about helmet use but are rarely exposed to any commercial promotions of specific urban helmet products.

4.4 Conclusion & Insights

Common Features of All User Groups

The research by Ledesma et al. provides a constructive framework for understanding the factors influencing helmet-wearing behaviour, categorizing these factors into four distinct groups: social norms, disadvantages/barriers, benefits, and risk-reduction (Ledesma et al., 2019b). Among these, social-norm influence emerged as the most significant factor affecting helmet-wearing behaviour. Additionally, the influence of perceived disadvantages and barriers often outweighs or matches the perceived benefits and risk-reduction associated with helmet use.

For cycling scenarios, Dutch cyclists commonly ride in urban areas, with the most frequent purposes being neighbourhood cycling, recreational cycling, and commuting. Almost all participants primarily use regular bikes, while the e-bike and shared bike are increasingly involved in people’s daily transportation in the Netherlands. Interaction with mobile phones and other smart devices during riding is a prevalent need but varies significantly among different user groups.

In terms of other influencing factors, there is a general concern among users about their outfits, with minimalist style being the most popular. Outdoor jacket hoods are the most common type of headwear, highlighting the need to address weather-related challenges in bike riding. Participants also showed diverse preferences in their consumption behaviours, reflecting varying lifestyle influences and persuits.

Different Characteristics among Different Age Groups

Compared to other user group deviation, significant differences in helmet-wearing behaviour and attitudes were observed between different age groups. While bike accidents generally occur most frequently in the afternoon across all other age groups, younger users aged 18-24 experience most accidents during midnight, which can be used as a reference for the effective application time period of the design. Younger users have a stronger need for interaction with smart devices during cycling. In contrast, the middle age groups of 27-40 and 40-60 have more transportation options and rely less on bicycles transportation compared to younger and older people. E-bike usage is more prevalent among elderly users.

Age differences also affect attitudes towards outfits and consumption habits, including types of items carried and on-body storage during riding. Users aged 18-27 are more easily influenced by peers and opinion leaders, both in their immediate social circles and on social media, and they place a higher emphasis on their daily outfits. Oppositely, older users focus more on personal needs. And the middle-aged group 27-40 and 40-60 are more influenced by families. Younger users often associate their consumption with certain lifestyle pursuits as a trend that significantly influences their buying behaviour. They are more likely to wear headphones or glasses while riding and often carry bags, particularly backpacks. While older participant report that they mostly carrying no bags during riding.

While some other differences among age groups were noted, the limited sample size prevents drawing definitive conclusions about their significance. Nevertheless, these insights are valuable for understanding the distinctions between age groups and defining target users by considering age-specific needs and behaviours. This approach will help to maximize the effectiveness of promotional efforts aimed at increasing helmet use across different demographics.

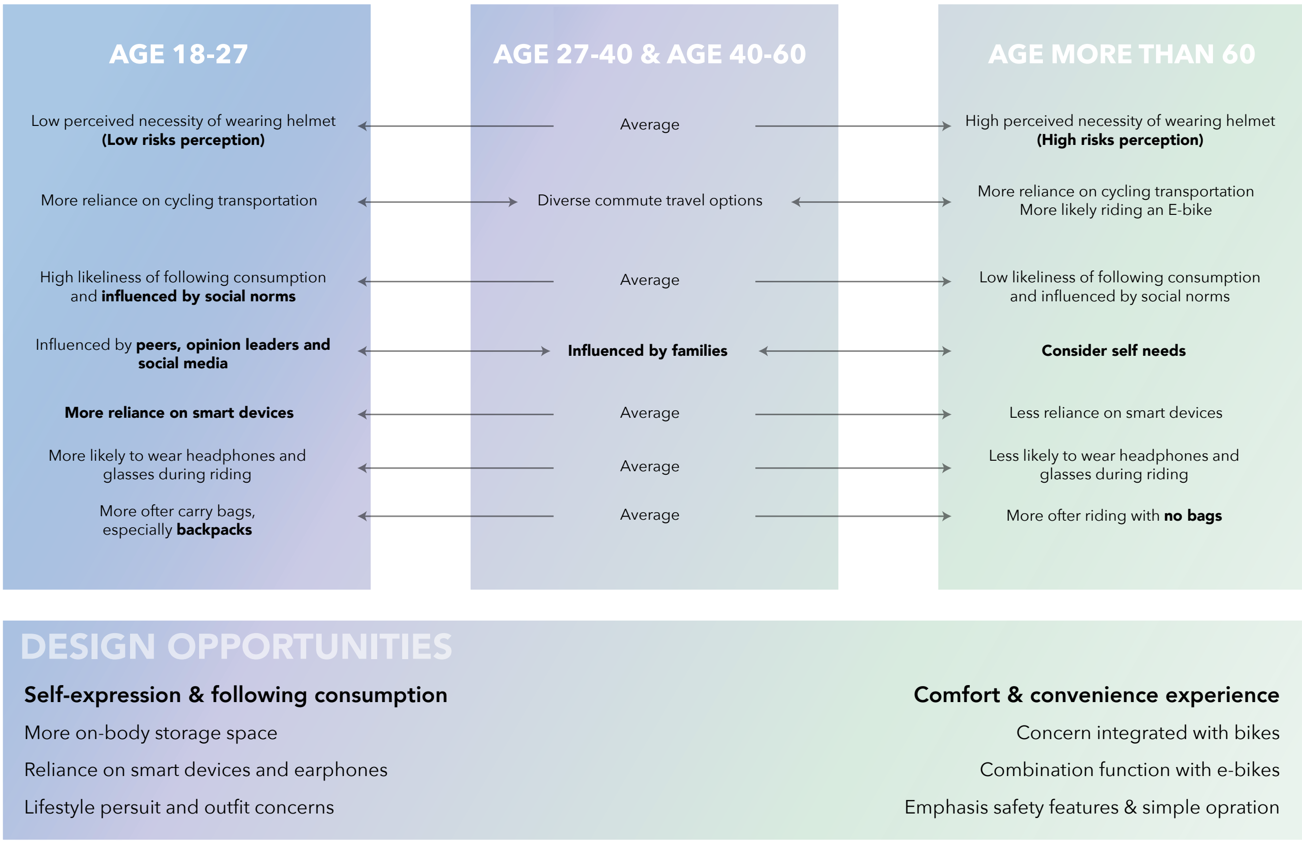


Figure 11. Characteristics of different age groups

5 DESIGN ENVISION

5.1 Target User Definition

5.1.1 Target User Selection

Based on the user research insights, the young urban resident user group (ages 18-27) has been identified as a key target for helmet design innovation for the reasons below: This group exhibits significant social influence but has a low perceived necessity for wearing helmets. They have distinctive behavioural features and preferences, such as high concern for outfits and a desire for smart functions. Compared to other user groups, young urban residents offer more opportunities for innovation in bike helmet design due to their unique characteristics and preferences. From an influential perspective, this target group is relatively independent and young, meaning their behavioural habits have the potential to last long and lead to a stronger societal influence. This influence can be beneficial in promoting helmet wearing over a longer timescale as well as across different demographics.

5.1.2 User Feature & Lifestyle Analysis

The target group of young urban residents, referred to as the "Vibrant Urban Youth" group, exhibits specific behavioural characteristics and preferences. This group primarily consists of college students or junior staff members who use cycling as their main mode of proximity transportation. during their daily cycling, they have habits of carrying storage bags especially backpack. They are highly concerned about their outfits and are significantly influenced by opinion leaders among friends and on social media.

Insights from surveys, interviews, and research on social trends and opinion leaders on social media reveal four key aspects of their lifestyle.

Socializing is a crucial part of their lives; they engage in strong interactions with peers and opinion leaders on social media, desiring self-expression, sharing, and recognition. This group's emphasis on social connections and visibility shapes their preferences and behaviours.

Minimalism lifestyle is another defining trait of young urban residents. Compared to other groups, they prefer a lifestyle emphasizing efficiency and simplicity. They value meaningful consumption, often prioritizing quality over quantity. This leads to a preference for efficient and sustainable items that can serve multiple purposes. Their consumption patterns reflect a desire for products that enhance their minimalist lifestyle while expecting for providing meaningful experiences.

Fitness & health act as their long-term goal. Beyond their occupations in work or study, they engage in various personal interests and hobbies, with sports or exercise taking up a considerable portion of their leisure time. They enjoy the joy and passion brought by physical activities, leading to a preference for vigorous experiences.

The "Vibrant Urban Youth" are also tech enthusiasts, characterized by their curiosity about advanced technological innovations. Their lives are heavily integrated with intelligent services, and they frequently interact with smart devices, including while cycling. They are eager for the changes that technology can bring to their lives, always enjoying the entertainment provided by smart devices.

By catering to their socializing, minimalist, fitness-oriented, and tech-savvy lifestyles, functional expectations will be carried out as promotion focusing on young urban residents.

5.1.3 Persona

Emma

Age: 23

Occupation: Master student & Product Design Freelancer

Daily lifestyle:

Lives a bit far from the city center. It always takes her a long time for commuting.

Uses her fancy bicycle for most transportation, including shopping, commuting, going to sport and socializing.

Often ride into bad weathers.

Sometimes ride at late night

Sometimes engages in risky cycling behaviours, such as cycling after drunk or playing with phones.

Cares a lot for outfits, usually dressed in minimalist style.

Hate clothes get wet but also hate wearing outdoor jacket all the days.

Always carries her backpack. It usually contains her laptop (or iPad), lunchbox, water bottle and a notebook.

Enjoys socializing, often share her life on social media.

Enjoys listening to music on headphones during riding.

Enjoys multiple sports, sometimes also travel by skateboards.

5.2 Problem Definition

The research by Ledesma et al. (2019b) divides the factors preventing people from using helmets into three groups: group-norm influence, barriers & advantages, and perceived benefits. To define the problem clearly, I have organized all research insights from previous sections and target user features into a comprehensive diagram (Figure 12). The centre of the diagram includes the three direct fundamental influence factor groups, while the outer area represents indirect influence factors from society, industry, and other sources. Each influence factor is marked as positive (promoting helmet use), neutral (little correlation with helmet use), or negative (discouraging helmet use). The diagram reveals that negative factors outweigh the positive factors, and there are many neutral factors that is potential to be utilized or transformed to have positive effects.

By extending the influence area of the three direct influence factor groups, the diagram is divided into three parts. The influential factors related to social norms shares a large area in the diagram. However, from product wise, only few factors from product features are available to influence that area.

Negative features of helmet products lead to strong perceived barriers and disadvantages. For the benefit part, our target user group perceives few benefits from wearing helmets. Helmet products continue to focus solely on safety without adapting to users' specific habits or lifestyles, nor do they interact with users and the environment effectively.

From the problem analysis above, I conclude the problem into three categories. Addressing these three areas can help in confirm the functional requirement of helmet design that aligns with the needs and preferences of young urban residents. The area in the bottom left is the potential functions that can increase the benefit perception, the bottom right area is the problems of the current products that need to be solved. The upper area is the group norm to shape for a bike-helmet promotional environment.

Social Norm Influences: There is a need to identify efficient ways to increase the positive impact of social norms at both the product and service system levels to make helmets more socially acceptable and desirable. Successful cases of affecting social norms from product design need for further research.

Product Shortcomings: Current helmets have certain shortcomings that create barriers and disadvantages, such as inconvenience of carrying or storing, preventing people from using them. These barriers need to be addressed through improved design and functionality.

Perceived Benefits: For the target user group, there are minimal perceived benefits to wearing helmets. By adapting to users' habits and adding potential functions, it is possible to create more perceived benefits and attractions.

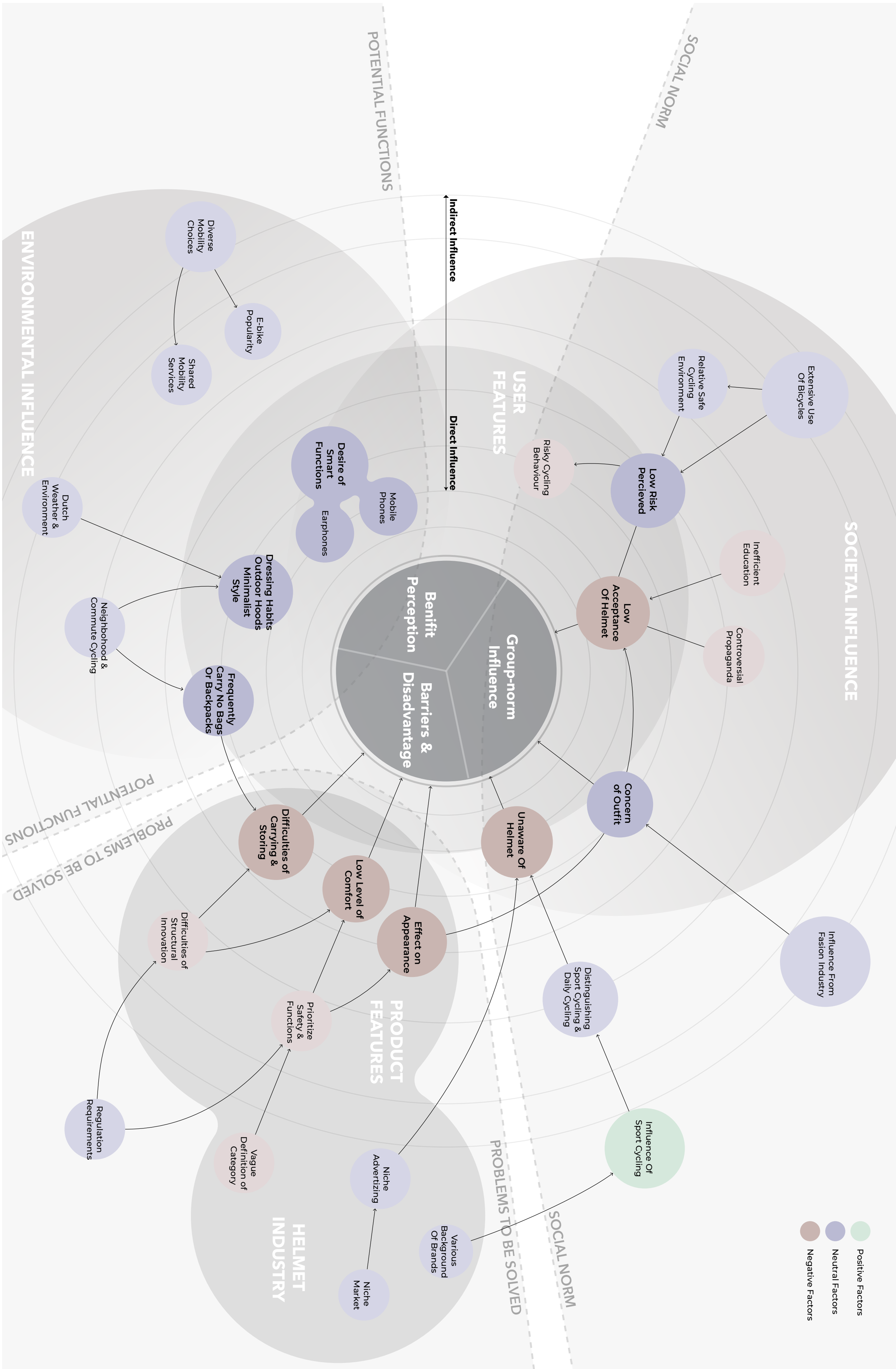


Figure 12. Problem definition

5.3 Case Study

Comparing to the other two areas of “potential functions” and “problems to be solved” in figure 12, the area of group-norm influences can rarely find connection to product or functional features. One of the few connections is appearance enhancement, which has proven difficult to innovate at a fundamental level due to the complex regulations surrounding helmet design. The other connection is the driving force of sports cycling, which is distinctly separated from daily cycling in Dutch society. This creates a significant challenge for the project: how to effectively influence social norms through product design approaches?

The question arising from the problem definition highlights that simple product functionality alone cannot address the challenge of shifting social norms. Instead, a strategic approach that integrates product design with service systems may offer a more effective method to influence social norms, especially when dealing with functional protective gear like helmets. To explore this approach, we can look at existing cases where products have successfully transitioned from purely functional items to trendy fashion statements.

Three representative products or brands have been selected as examples of how this transition can occur. These case studies demonstrate how innovative design strategies can elevate functional products into desirable items that resonate with social trends, providing valuable insights into how helmet design can potentially influence social norms and increase adoption rates.

Freitag is a brand renowned for its bags made from used truck tarps and other recycled materials. The truck tarps provide advanced functional enhancements such as excellent strength, water resistance, and abrasion resistance. Moreover, the use of recycled materials aligns with sustainable fashion trends. The vibrant colours and unique patterns of each tarp offer strong individuality and cater to consumers' needs for customization and self-expression. This distinctiveness is a significant advantage compared to competitor brands that use other recycled materials.

Stanley’s transition from a rugged, utilitarian brand to a trendy lifestyle product highlights the power of aesthetic appeal and emotional connection. By blending durability with nostalgic design elements, Stanley has elevated its products from basic outdoor gear to must-have items for modern consumers, aligning with a lifestyle that values both practicality and style.

Once regarded as purely functional footwear, Crocs transformed its image through bold collaborations, customizable accessories, and a strong embrace of the “ugly fashion” trend. By leveraging social media and influencer marketing, Crocs rebranded itself as a fashion-forward and fun choice, turning a simple shoe into a statement of individuality and comfort.

Case Study Insights

The product and service system design of Freitag, Stanley, and Crocs reveal similar components of design features for successfully shifting from function-driven products to fashion products.

Functional enhancement: Each brand offers significant functional improvements over their original product categories. Freitag uses durable, water-resistant recycled truck tarps; Crocs provide comfort and breathability; and Stanley products is enhanced for exceptional durability. These enhanced functional features create strong functional belief among target users and are widely spread in their respective fields.

Appearance attraction points: Based on functional belief, these brands add visual and customizable appeal. Freitag's Swiss style tarp pattern tailoring, Crocs' customizable Jibbitz accessories, and Stanley's bold colour with collaborations offer customization opportunities that increase user engagement and loyalty. This co-creation process and their unique aesthetic allows users to personalize their products, making them more attractive and increase the user stickiness of those products.

Lifestyle construction: All three brands successfully align their design features with ideal lifestyles that cater to current social trends. Freitag is one of the forerunners of sustainable fashion, Crocs have become symbols under context of home working during the epidemic, and Stanley products are associated with vigorous and pragmatic lifestyle. These lifestyle connections help the brands resonate more deeply with consumers, transforming practical items into integral parts of their daily lives and identities.

Indispensably, all those brands have a lot of co-branding promotion and exposure from opinion leaders which help a lot to building their brand influence and add on to their popularity. But from product design level, the three points above have provided a strong base for those products' lasting attraction to users and those brands' long-term prosperity.

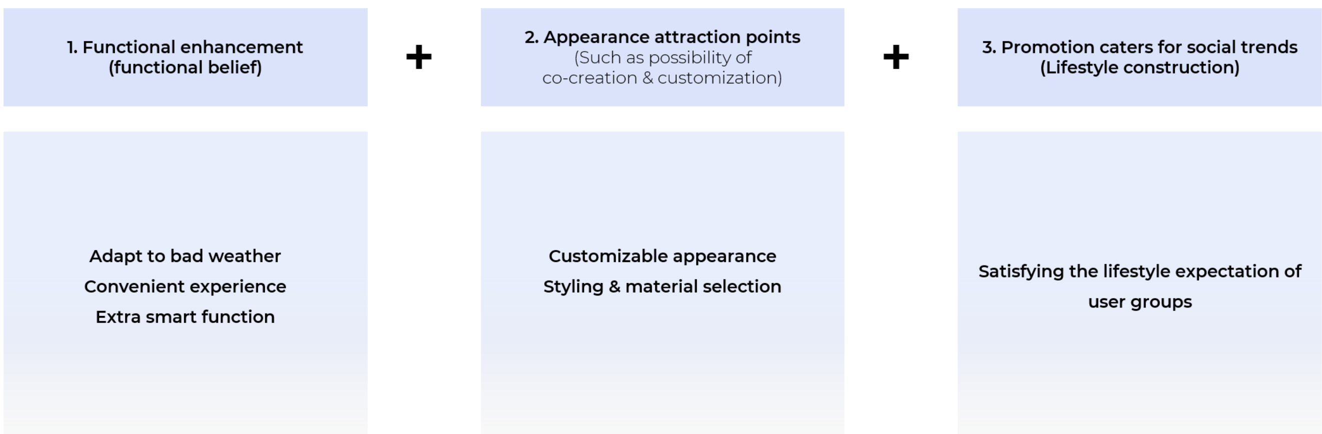


Figure 13. Case study insight: approach to shift from function-driven product to fashion products

5.4 Design Opportunities

5.4.1 Ideation

Based on the problem definition and insights from case studies, the functional expectations for the design have been concluded into four categories: personalization & self-expression, helmet function enhancement, adaptation to weather & environment, and smart functions. Personalization & self-expression aims at creating extra attractions to transform the target user's limitations of social norms. Helmet function enhancement focus on reducing the barriers and disadvantages inherent in helmets. Adaptation to weather & environment addresses the practical needs of target users in complex weather and environment conditions. Smart functions cater to the desire of the target user group during cycling.

The diagram (figure 14) shows the process of converting these functional expectations into possible solutions. By cross-composing among possible solutions, the ideation process generated five potential directions.

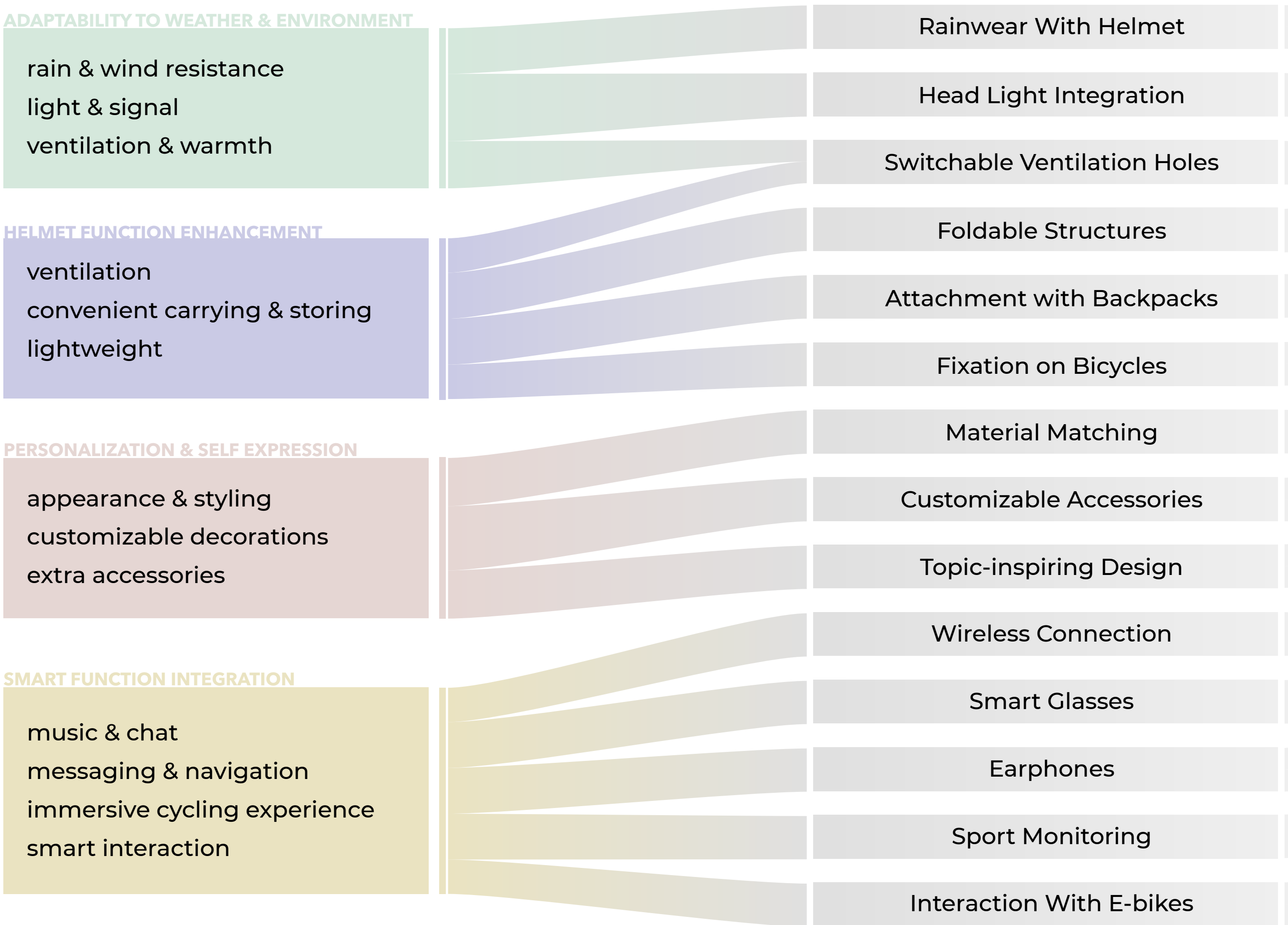


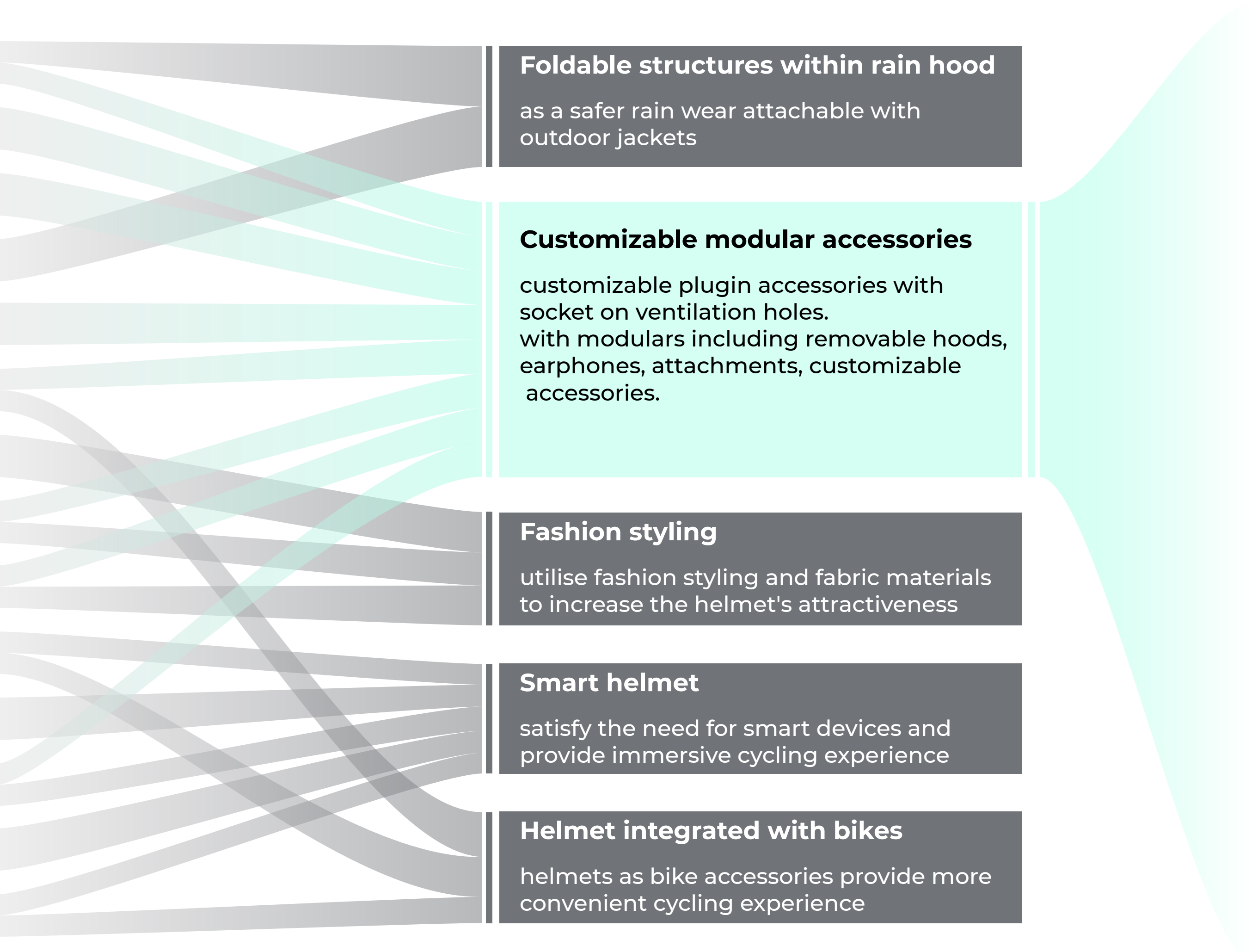
Figure 14. Ideation

5.4.2 Comparation Between Potential Directions

The five potential directions are compared across two dimensions: user suitability and product feature realization.

User suitability considers the coverage of functional expectations and the attractiveness to young urban residents. The function coverage should not only reduce the barriers to using helmets but also meet those desired functions of young urban residents to increase perceived advantages and influence social norms. Given the negative attitude towards current helmet products, more innovative and differentiated designs have a higher chance of standing out and attracting users.

Product feature realisation considers feasibility in the present or near future, including realizing difficulties and comparisons to existing market products. Helmet products must comply with strict safety regulations and ergonomic requirements, posing significant challenges during development and manufacturing. Additionally, the status of existing products with similar functions can indicate the cost and competitiveness of certain directions.



Process

	Product Features for User Suitability	Functionality for Realization
Foldable Structure	Effectively solve the pain point of storage & carrying Lack of customization or smart function to attract target users	Considering the safety regulations, achieving the expected weight and volume is challenging. Some helmets with creative foldable structures, like Closca, which still have a large volume after folded that cannot be easily integrated into hoods. It requires for investment on innovative structures to improve its feasibility.
Modular Accessory System	Covers all four categories of functional expectations. Modular functions and interaction need further consideration to ensure the simplicity and efficiency	Modular components show high feasibility with less difficulty in realization but combining ventilation holes and plug-in sockets may pose safety risks. There are mature solutions for replaceable light modules and visors. However, the matching and interaction between different modular components is rare in the market, requires efforts of developing.
Fashion Styling	Directly connects with the functions of personalization and self-expression Most attractive to people seeking for aesthetic satisfication	Fully feasible with current market capabilities, but it requires high-level fashion design skills. Many urban helmets feature advanced styling, using differentiated materials like fabric and feathers. Differentiation is challenging due to the abundance of attempts in the market, highly increasing the difficulty of standing out.
Smart Function Integration	Solve the pain point of smart function requirements during cycling Only attractive to people addict to smart functions	Easier to implement simpler smart functions, while more complex features like AR navigation and messaging require advanced hardware, software, and interaction design, posing cost challenges. Various smart helmets with different levels of smart function integrated exist in the market, increase the difficulty and questioning its efficiency of promote helmet. Higher-end smart helmets are often priced beyond the reach of average users, limiting accessibility.
Helmet Integrated with Bikes	Combines helmet functionality enhancement and smart functions. Matches e-bike riders carrying no storage best for offering improved convenience but lack of attractions to target user groups	Common in concept designs, but few market products offer similar functions. Integration with e-bikes is feasible but not extensively explored. This direction requires innovative structure to create a cohesive system that reduce the structural weight while enhance its strength, potentially offering unique benefits.

Figure 15. Comparation among potential directions

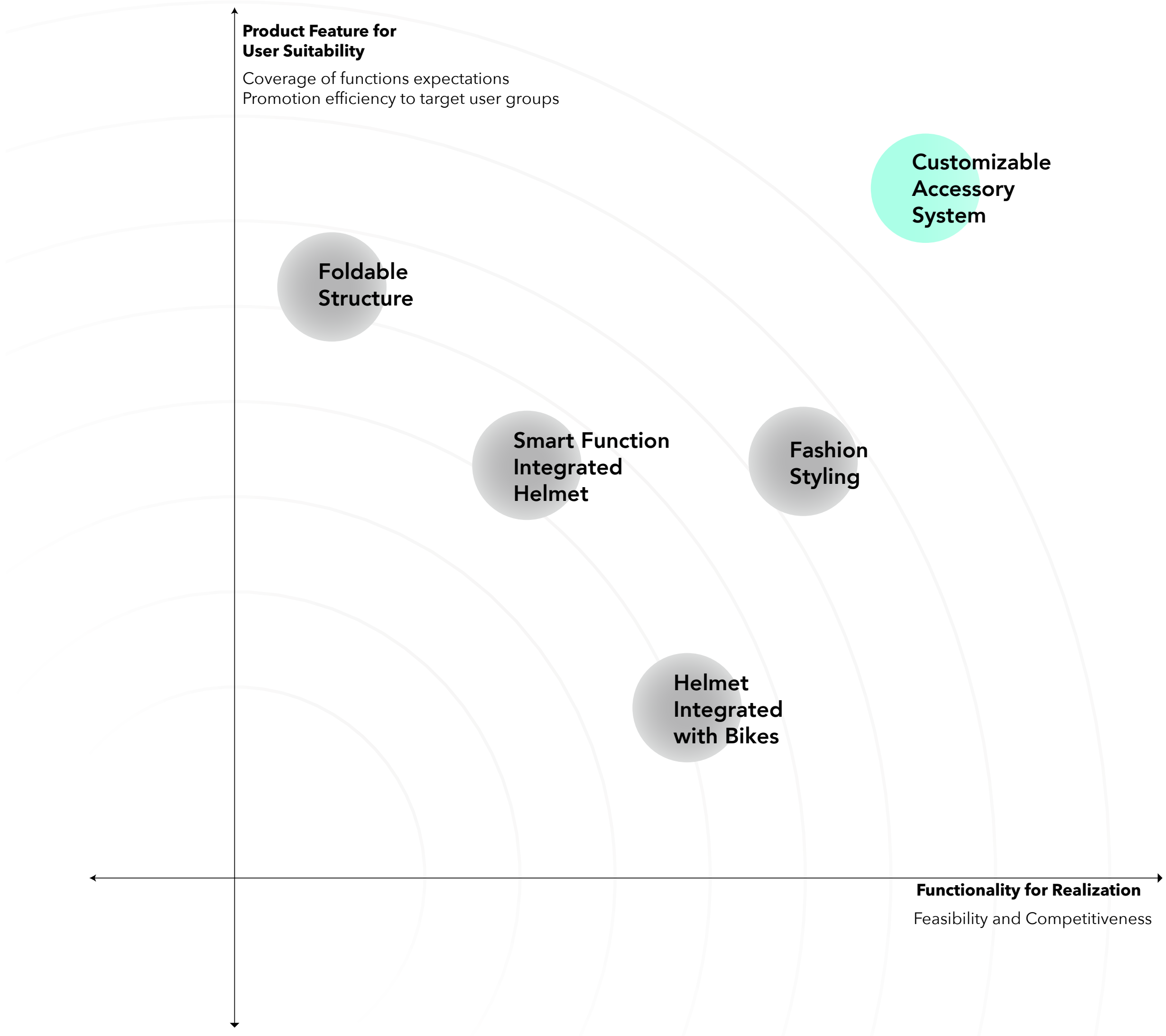


Figure 16. Comparation in 2-axis chart

The five design directions are compared in an axis chart within two different dimensions. The first evaluation dimension is product features for user suitability, including how much the function have cover the functions expectations and its promotion efficiency for target user groups. Considering the target of this project is commercially available in the near future, the other axis is for functionality for realization, which evaluate the feasibility (difficulty to realize) and competitiveness in the market in a time scale of 0-5 years in the future.

In the axis chart shows that the customizable accessories have highest score in both product feature for user suitability and functionality for realization. The foldable structure also have great attraction for target users while preformed poor in the realization due to regulations. The smart integrated helmet and fashion styling also only met part of the function expectation of target users. The direction of helmet integrated with bikes have good feasibility in the market while it may fit for other user groups such as elderly users and users in the stock market, which is not the best option for this project.

5.4.3 Conclusion

Modular Accessories are the most promising direction, covering all functional expectations, offering high feasibility, and providing innovative potential. This approach addresses user needs for personalization, functionality, and adaptability, making helmets more appealing to young urban residents.

Foldable Structures have unique advantages but face significant feasibility issues due to safety regulations, requiring innovative solutions to be practical.

Fashion Styling and Smart Helmets show potential vertically in their respective field but faces challenges in market differentiation due to abundant competitors in the market.

Integration with Bikes offers innovative features and a convenient experience. However, those features are more suitable for niche markets or future developments rather than facing young urban residents.

6 CONCEPT DEFINITION

6.1 Product Definition

The product consists of a clip-on socket and modular accessories. Functionally, the clip-on system is designed for universal use across multiple helmets via the clip-on socket or buckles. It should facilitate quick release and be integrated into the outer layer of the helmet or within the ventilation holes. The modular accessories are intended to address the primary functional expectations of the target users while maintaining light weight and simplicity in both quantity and morphology.

The clip-on system should integrate seamlessly with ventilation holes or the outer layers of the helmet and comply with safety regulations. It will feature quick-release functions for ease of use. The clip-on buckles are located in four different directions on the helmet: front, rear, top, and sides. This arrangement allows modular accessories to be attached in specific directions, enhancing convenience experience.

The modular accessories are designed to cover essential functions while keeping the system simple and effective. The primary modules include a rain hood, visor, headlight, rear light, and earphones with straps. The rain hood provides rain resistance, ensuring users stay dry during wet conditions. The visor offers protection from sunlight and rain and can interact with light modules for enhanced visibility. The headlight, attached to the front, improves visibility during nighttime or low-light conditions, while the rear light ensures visibility from behind, enhancing safety. Earphones with straps combine smart functions with convenience, allowing users to listen to music or take calls while cycling.

The clip-on system and modular accessories are designed to ensure the following key functions: customization, lightweight design, rain resistance, lighting, smart functions, and convenient carrying and storing. Users can personalize their helmets with various modular accessories without adding significant weight, maintaining comfort. The combination of a rain hood and visor provides effective protection against rain, while front and rear lights improve visibility and safety. Integrated earphones with straps cater to target users' habits. The rain hood and straps combine multiple function to facilitate easy carrying and storage.

The design ensures that all modules can be integrated without interfering with each other. For instance, the light module can work with the visor to create attractive lighting effects, and the hoodie should allow the rear light to penetrate, ensuring visibility when they are both in use. This modular design approach meets the functional requirements of customization, lightweight, rain resistance, lighting, smart functions, and convenience. By offering a combination of modules that can be easily attached and detached, the helmet provides a versatile solution tailored to the needs and preferences of young urban residents. This innovative approach not only enhances the functionality of the helmet but also makes it various in appearance to meet for the expectation of unique and customization.

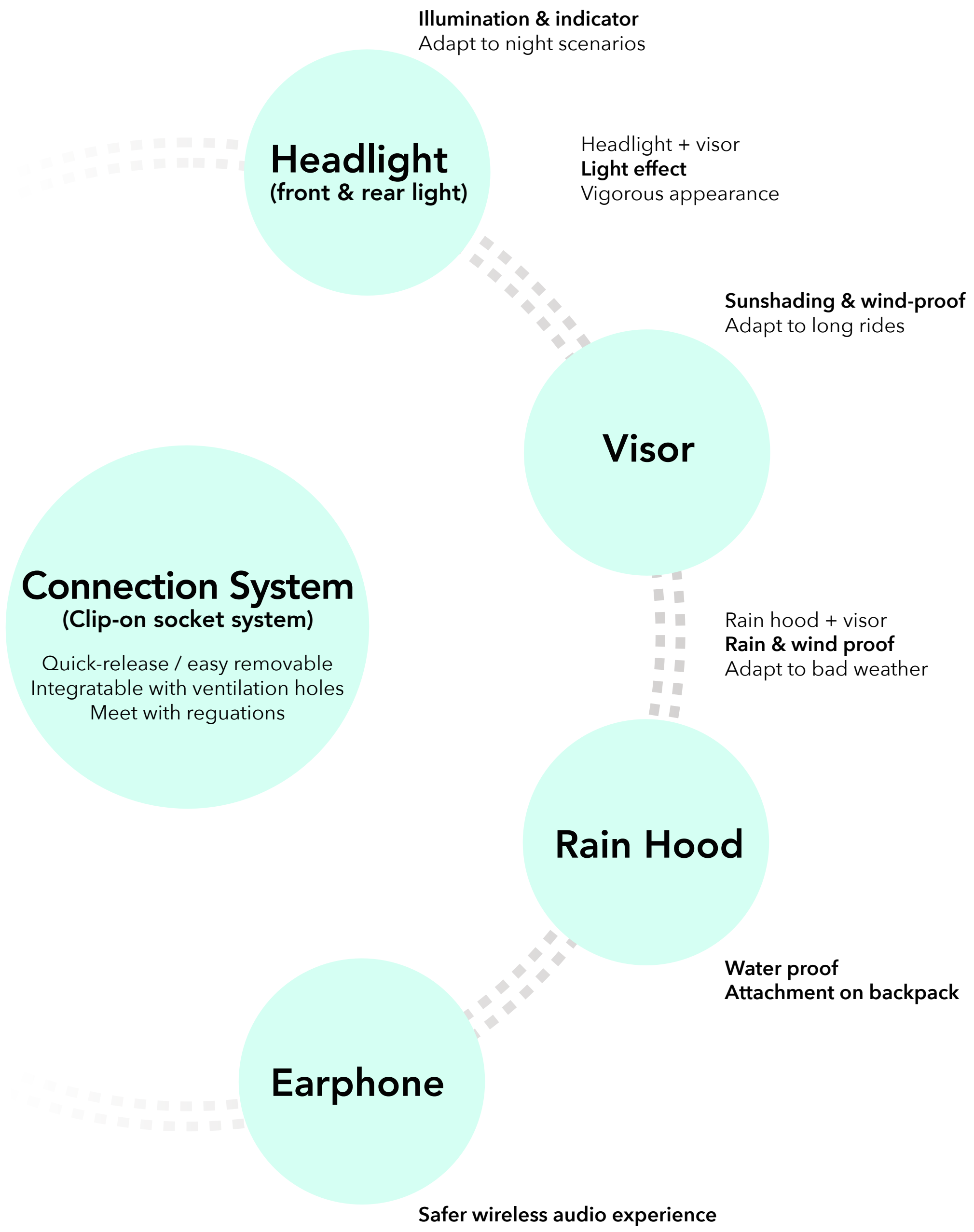


Figure 17. Product system

6.2 Styling Definition

Based on the target user definition and their lifestyle preferences, the styling of the helmet needs to meet the users' expectations of a simple yet dynamic and textured life. The style is defined as "vibrant concise," focusing on restrained decorations and avoiding complex forms to express an essential and vibrant feeling.

In terms of morphological features, the components should adopt a minimalist style, reducing excessive decorative lines. The design should use geometric outlines and integrate decorative elements only with necessary structural components, avoiding exaggeration. This approach ensures the helmet maintains a clean and straightforward aesthetic while still being visually appealing and functional.

Regarding CMF (color, material, and finish) features, the helmet should exhibit a neat and bright style. Using translucent or light-colored matte plastic materials can enhance the feeling of brightness and cleanliness and small-scale accents with contrasting materials and bright colors. It is crucial to unify the color palette and maintain consistency across all components and helmet, including the inner energy absorbing layers.

This styling definition aligns with the preferences of young urban residents who value simplicity, functionality, and modern aesthetics, as an approach to assist in creating the sense of their ideal lifestyle.

Figure 18. Moodboard for styling definition

6.3 List of Requirements

After a clear definition of product system and styling, the requirements of different are carried out for further development. The whole product system is divided into two different parts including the attachment system and accessory modulars.

All requirements are organized from different perspective, safety is the most basic requirements for a helmet, therefore, all the components should follow the safety rules and in line with the regulation. The functional requirements are another perspective that realize the planning in the product definition. The user experience is the third perspective that includes the interaction between user and product components and requirements of aesthetics features.

- Safety requirements
- Functionality requirements
- User experience requirements

Connection System

- Meet the safety regulations
- Securely attachment on the helmet
- The location of connection should be reasonable
- Able to operate both when wearing or not wearing the helmet
- Convenient to operate (easy-fixed and quick-release)
- Able to use with one hand
- Integratable with ventilation holes on the helmet

Accessory Modulars

- Usable with other modulars
- Easy to operate
- Facilitate riding experience
- Aesthetically unity as a serie of products
- Suitable for target users' outfits.

Headlight

- Contains Front & Rear light two parts
- Replaceable attery integrated
- Easy to switch on / off
- Compatibility with visors for light effects

Visor

- Ensure a clear view
- Protective against sunshine, wind and rain
- Compatibility with head lights for light effects

Rain Hood

- Guarantee users' vision
- Water-proof
- Reduce the wind effect during riding
- No blocking on headlight
- Attachable to backpacks
- Suitable for minimalism style dressing

Earphone

- Guarantee user's hearing to traffic
- Wireless connection
- Good sound quality

Figure 19. List of Requirements

6.4 Target Completion

The design concept is defined as one connection system with four different products, which can also consider as five independent product that is usable complement with each other, to develop in the time left. The initial goal, as planned in the project brief, was to develop fully functional prototypes as the final outcome of this graduation project. However, after an approximate estimate, it became clear that developing all five components into fully functional and aesthetically proven prototypes within the limited timeframe of the graduation project exceeds my capacity and would likely compromise the design quality. Consider the exceeded challenge, an adjustment for design goals and project develop management need to be carried out.

The primary goal of the project is to demonstrate that the design concept can meet the client's requirements, leaving room for further expansion and refinement by subsequent developers. The target completion management follows these key principles:

Prioritise core and basic functionality realization. Compared to the functions of the accessories, the core functionality of the design concept is the unified accessory connection system on the helmet. This system serves as a carrier for various accessories and enables customization according to user preferences, making it a fundamental aspect of the overall design.

Prioritise the unproven features realization. Among the target product features and requirements listed in Sections 6.1 and 6.3, the unified connection system, rain-proofing hood, and carrying capabilities are relatively unproven features compared to other functionalities like lighting or audio playback, which are already widely available on the market. Therefore, the prior focus should be on develop and validating these unique features.

Based on these principles, the target completion management plan prioritizes the development of the connection system and the rain hood as functional prototypes, while the other accessories will be developed to a level that demonstrates their appearance and intended functionality. A detailed target completion chart outlines the management strategy for each part of the product system.

	Feasibility Test	Aesthetic Development		Functional Development		
		Form-giving	Rendering	Material selection	Structure definition	Functional prototype
Connection System	○	○	○	○	○	○
Rain Hood	○	○	○	○	○	○
Headlight	○	○	○	○		
Visor	○	○	○	○		
Earphone	○	○	○			

Figure 20. Target completion management

7 PRODUCT DEVELOP PROCESS

7.1 Connection System

The development of the connection system, along with other accessory products, was conducted simultaneously. However, to make the report more organized and easier to understand, the development processes of the connection system and different accessories are explained separately. The LoR in section 6.3 outlined the key requirements for the connection system, focusing on three main aspects: security, convenience, and aesthetics. To meet these requirements, the development process is divided into three distinct parts: iteration on the connection structure, determining the location of the connection socket, and conducting a usability test with real target users based on the results of the first two development stages as validation.

7.1.1 Connect Structure Iteration

The development of connection structure generally followed the methodology of fish trap model, characterized by a continuous diverge-converge process across three stages of structural concept, formal concept, and material concept.

Before start prototyping, I considered possible scenarios and behaviours related to operating the connection structure. Users may need to attach accessories while wearing or holding the helmet, with either one or both hands available, which lead to a very high requirements of ease of use, especially with the possibility of operating the system with only one hand.

The analysis of connection methods appliable on helmets are conducted based on previous collected exist solutions and result of a brainstorming session conducted with three other design students. finally, several approaches are derived. After a comparation in terms of safety, ease of use and aesthetics, five potential solutions, including linear slide, rotate, magnet, Velcro, and press button, were selected to enter the prototyping session. Other options such as clipping on bands, though have more possibilities on aesthetic, is dismissed due to it is unable to be fixed securely.

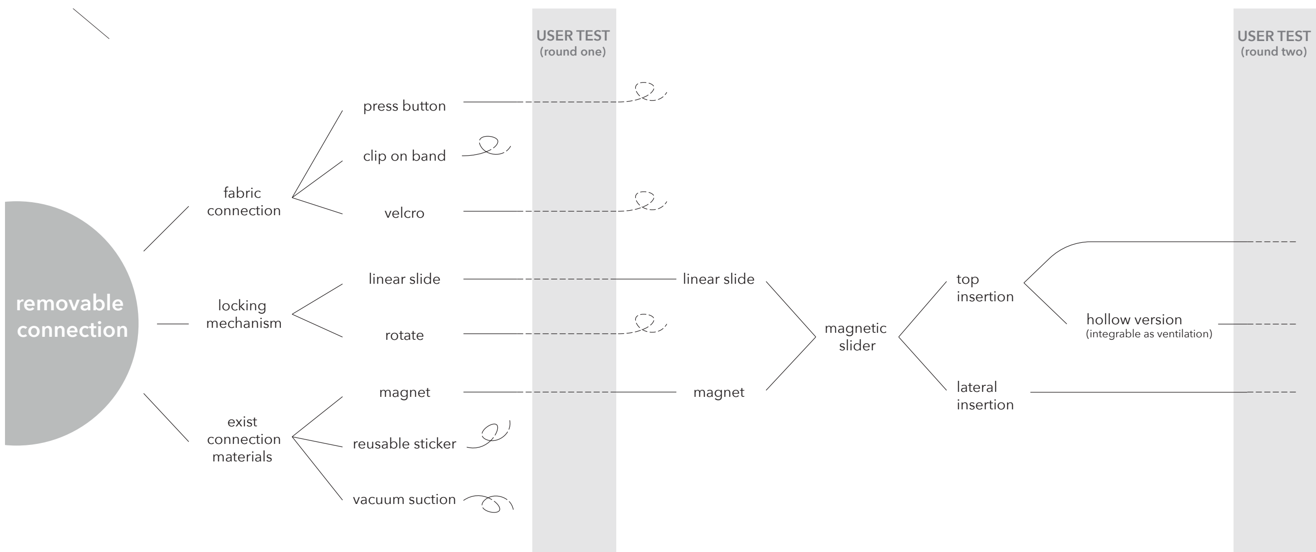


Figure 21. Illustration of selection & iteration process

Five prototypes are 3D modelled and produced using 3D printers. The difference in disturbing factors other than the structure difference among the five different prototypes are controlled to a minimum with several rounds of alterations in order to accommodate the deviating from physical printed models and original 3D models caused by model features and 3D printing process. (figure 22)

Figure 22. Iteration process of structure prototypes

Connection Structure Test

Following the prototyping phase, user testing was conducted to evaluate the effectiveness of the five candidate connection structures. To minimise the interference from varying model appearances, all five prototypes are standardized into a 45mm*45mm square in top view, and arrows indicating the direction are drawn on the top block that simulates the accessories to be fixed on. 3 participants (two Dutch participants and one Asian participant all currently living in the Netherlands more than two years) are invited to participate in this test. The testing process included the following steps:

1.Project Introduction: The participants are briefly introduced the background and current ideas to provide context.
2.Attachment Trials: Participants were asked to try attaching the prototypes.
3.Scenario Simulation: The base part of each prototype is fixed to a helmet. Participants were asked to connect the accessories both when wearing and not wearing the helmet.
4.Evaluation and Interview: Participants are asked to evaluate each connection structure across different dimensions and interviewed about the experience details.

Five candidate connection structures are evaluated from the following five different perspectives.

Ease: How easy it is for users to learn (when first-time use) and attach the mechanism.
Position: How easy it is for users to find the correct position to attach accessory to the socket.
Aesthetics: How much the users liked the appearance of the socket.
Solidity: How stable and secure the connection is when the accessory is attached.
Complexity: How complex is the connection structure

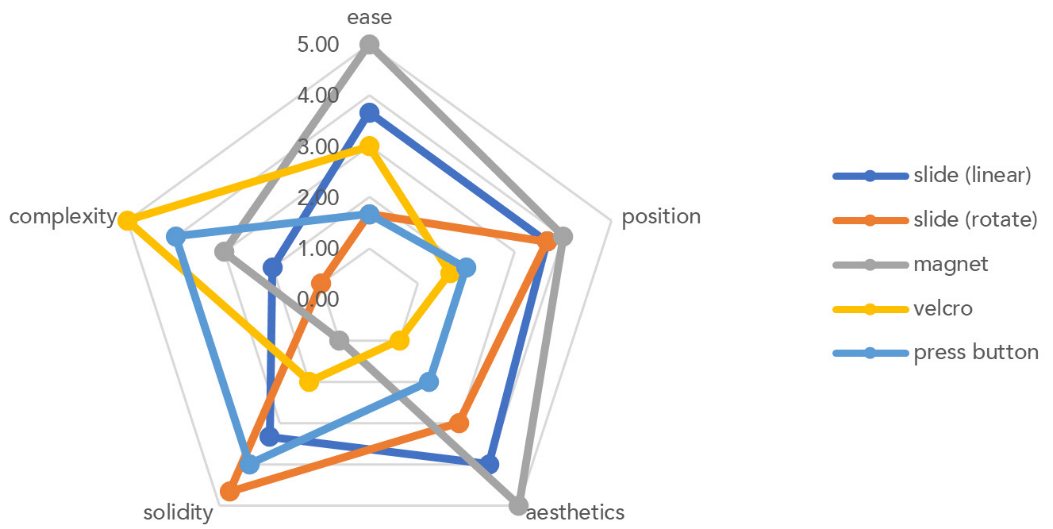
To simplify the evaluation process, participants are asked to rank each connection structure from best to worst in each category, assigned with a score from 5(best performance) to 1(worst performance) for each dimension.

Figure 23. Connection structure test process

The result of scoring is compared using a radar chart (graph 7). The linear slide option emerged as the most balanced option among all structures, whereas the other options all have noticeable shortcomings. The magnet connection performs best in the ease of use, aesthetics and position, but the worst in fixation solidity. Velcro shows obvious disadvantages in aesthetics, solidity and position. Press button performs poor in ease of use, position and aesthetics. The rotate structure is lack of ease with the most complexity of all five structures.

Although the number of participants is small, similar views are consistently expressed during the interviews. All participants emphasize their love for the click effect when slide in as efficient haptic feedback signal of a well-secured connection. Two participants express a strong dislike to Velcro concerning it can cause damage to clothing and it's hard to attach accurately. For those simpler structures, the strength of fixing is an important factor. Participants have doubt that the magnets may easily come off due to bumps or winds, while the press button is too hard to press in or remove it.

Considering these results, none of the structures fully satisfied the three key criteria of simplicity of construction, robustness of fixing and ease of use. This indicates that further development is required to find a solution that balances these attributes effectively. The goal is to ensure a simple and easy-understand structure that provides highly stable fixation while requiring minimal strength to operate.



Graph 7. Comparation between different connection structures

Based on the result of previous test, the linear slide idea and magnet idea are the two best performers, and they also complement each other's advantages. These two concepts have potential to combine for addressing the stability issues of magnets while retaining their convenience.

Through multiple iterations, including adjustments to the angle and structure of the slideway, and modifications to the shape and depth of the slots, the optimal connection structure is selected. As showed in figure 24, a slot matching the shape of the slide block was created at the end of the slideway. Magnets were embedded in both the slide block and under the slot at the end of the slideway. This structure uses magnetic force to secure the slide block in the slot, restricting its planar movement and improving performance in terms of simplicity, stability, and ease of use.

To connect, user need to slide the slide block into the slot, where it is pulled down and self-locked by the magnetic force, preventing any back-and-forth movement. To disconnect, user need to lift the slide block against the magnetic force and slides it back. This hybrid solution combines the advantages of both the slide and magnet structures, resulting in a robust, user-friendly connection system that meets the project's requirements.

After the development of the basic structural prototype, different optimized adaptations using the same structure are developed for various possible placement location. (figure 25) The structure can be adjusted with slide blocks access vertically or horizontally. For specific positions, such as the top of helmet, the structure can be hollowed to integrate with ventilation holes.

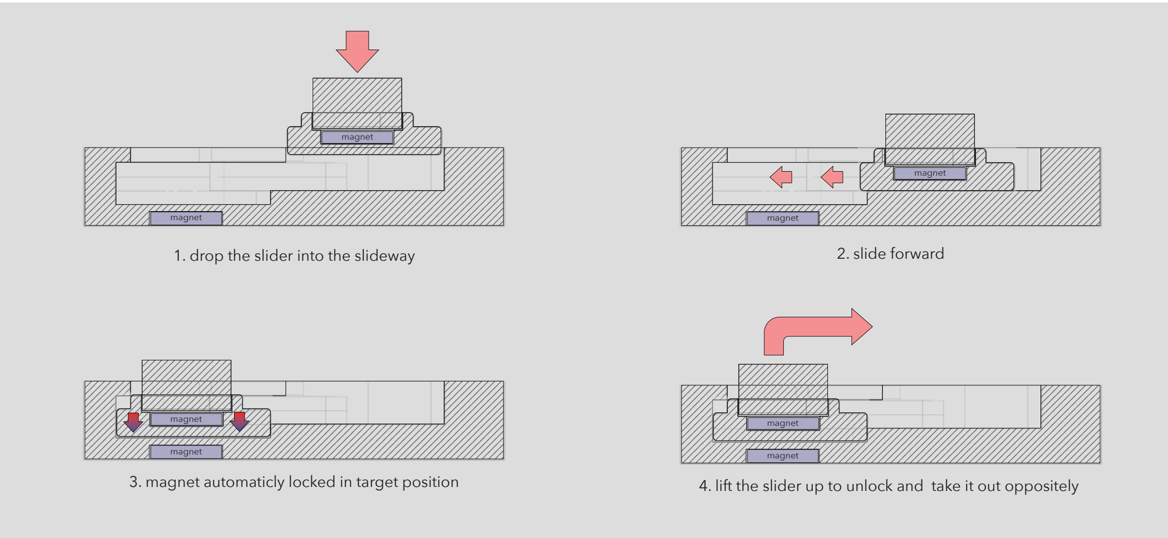


Figure 24. Structural illustration and instructions for use

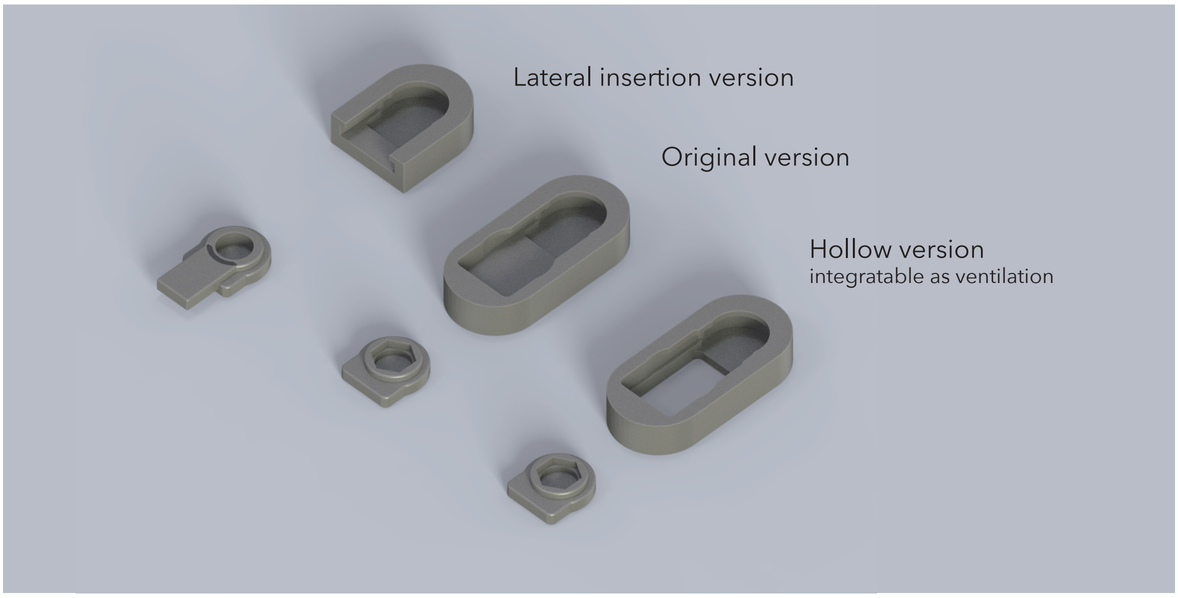


Figure 25. Optimized versions of connection structure

7.1.2 Position of Accessory Connection

The position of accessory connections significantly affects both user experience and the effectiveness of the accessories. The decision on the proper location for these connections was made based on two outcomes: the analysis of helmet structures and product requirements, and the insights gained from a focus group discussion.

The connection positions were determined by the intended location of the accessories. The four planned accessories are placed on the outside, front, back, and both sides of the helmet, which defined the general areas where the connection structures should be integrated.

Another crucial factor influencing the positioning is the structure of the helmet itself. For helmets made of EPS (Expanded Polystyrene), the top, front, and back areas can be hollowed out with appropriate reinforcement, maintaining sufficient structural strength. This also provides the opportunity to combine the connection structure with ventilation holes. However, care must be taken with the side areas where the straps are fixed to avoid the connection of straps dropping off.

To find out more defined positions, I conducted a focus group discussion with four design students with extensive riding experience. After an introduction of project background and the connection structure, block models and prototypes representing different accessories are provided. Participants can attempt to fix them with pins and double-sided adhesive tapes to simulate the connection and compare the fixation effects. Participants experience by them self and discuss the ease of access and operate while wearing helmet. In the whole discussion, all participants follow the principles of simplicity and try to use the least number of fixed positions possible.

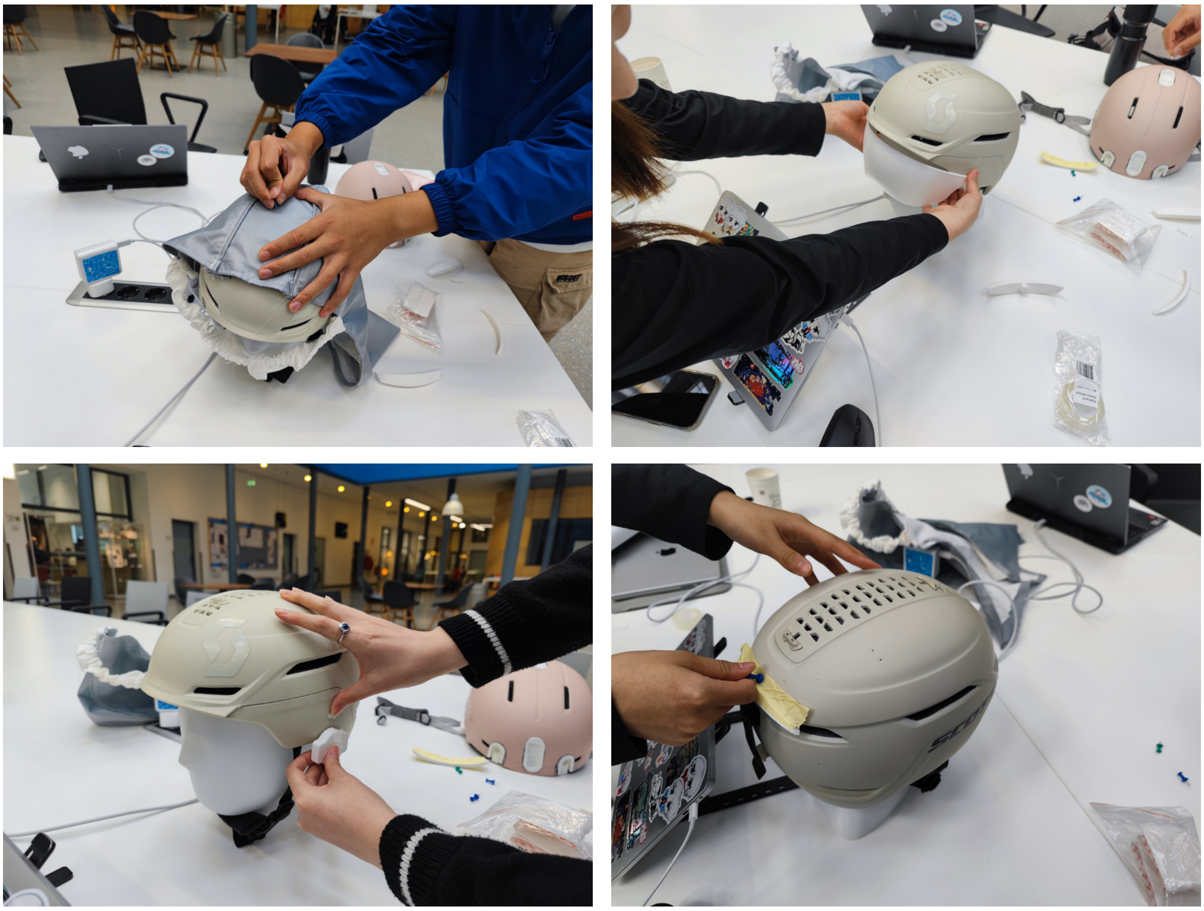


Figure 26. Process of location defining focus group

Based on participants' different opinions, the final result of connection position is summarized in figure 27. The darker the area, the more participants are preferred. The exact location of the final selection is marked inside the circle.

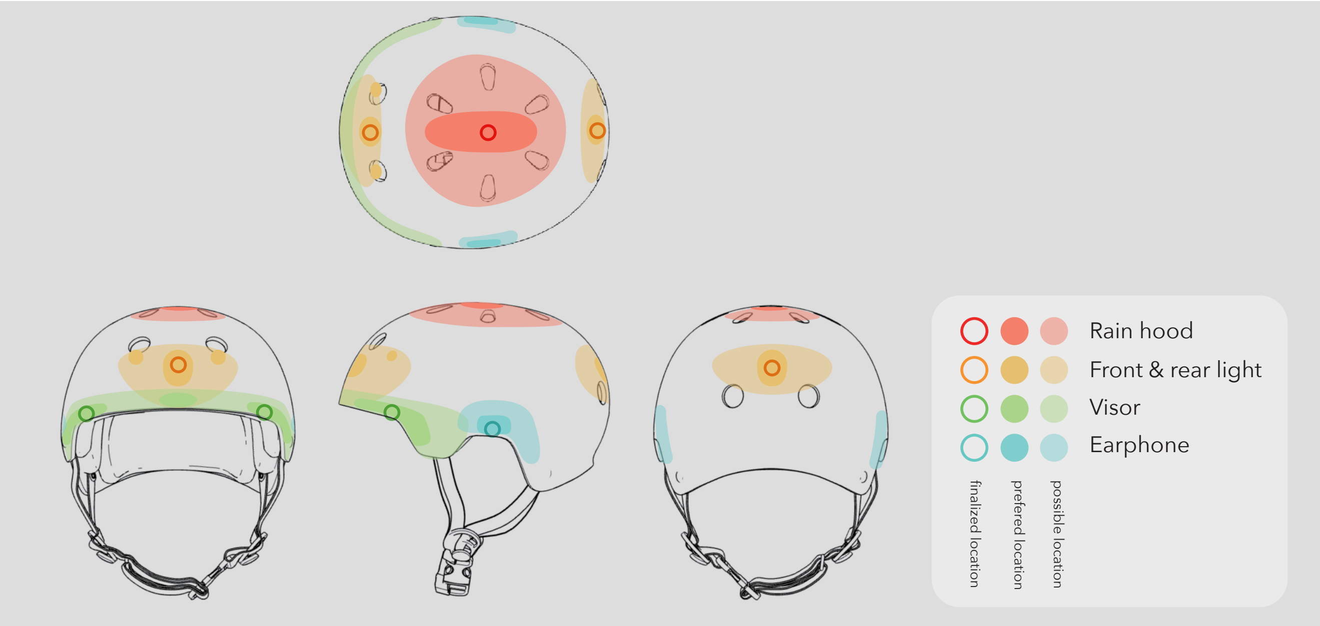


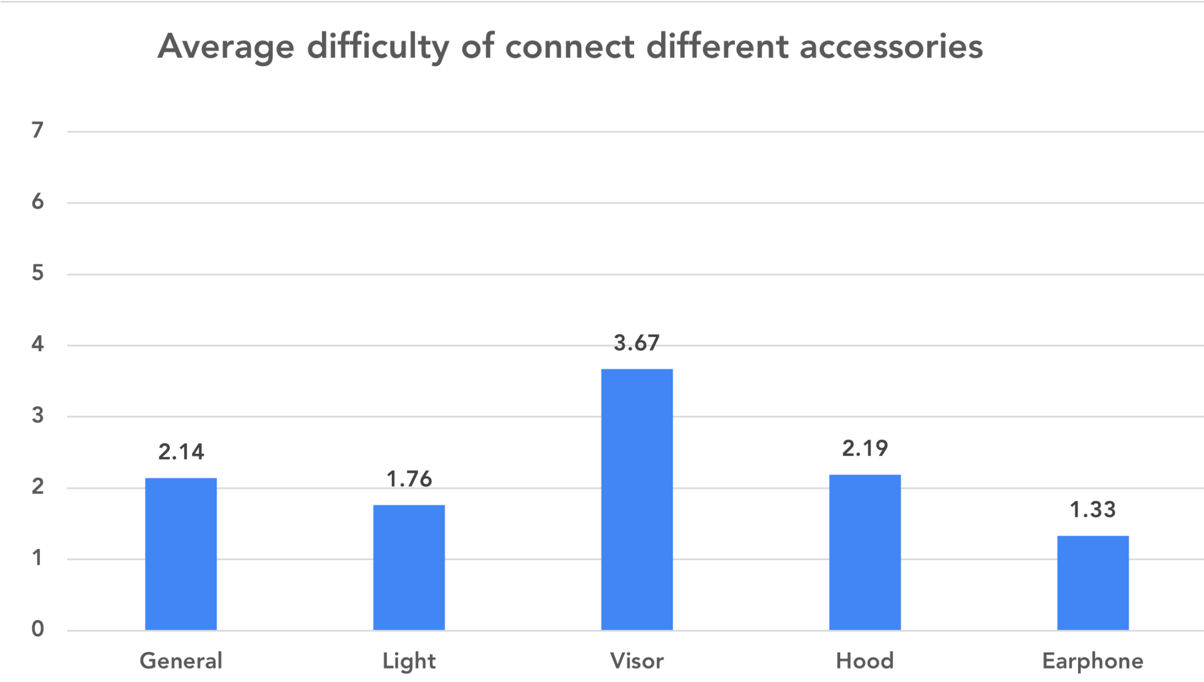
Figure 27. Illustration of outcomes and conclusion

7.1.3 Usability Validation

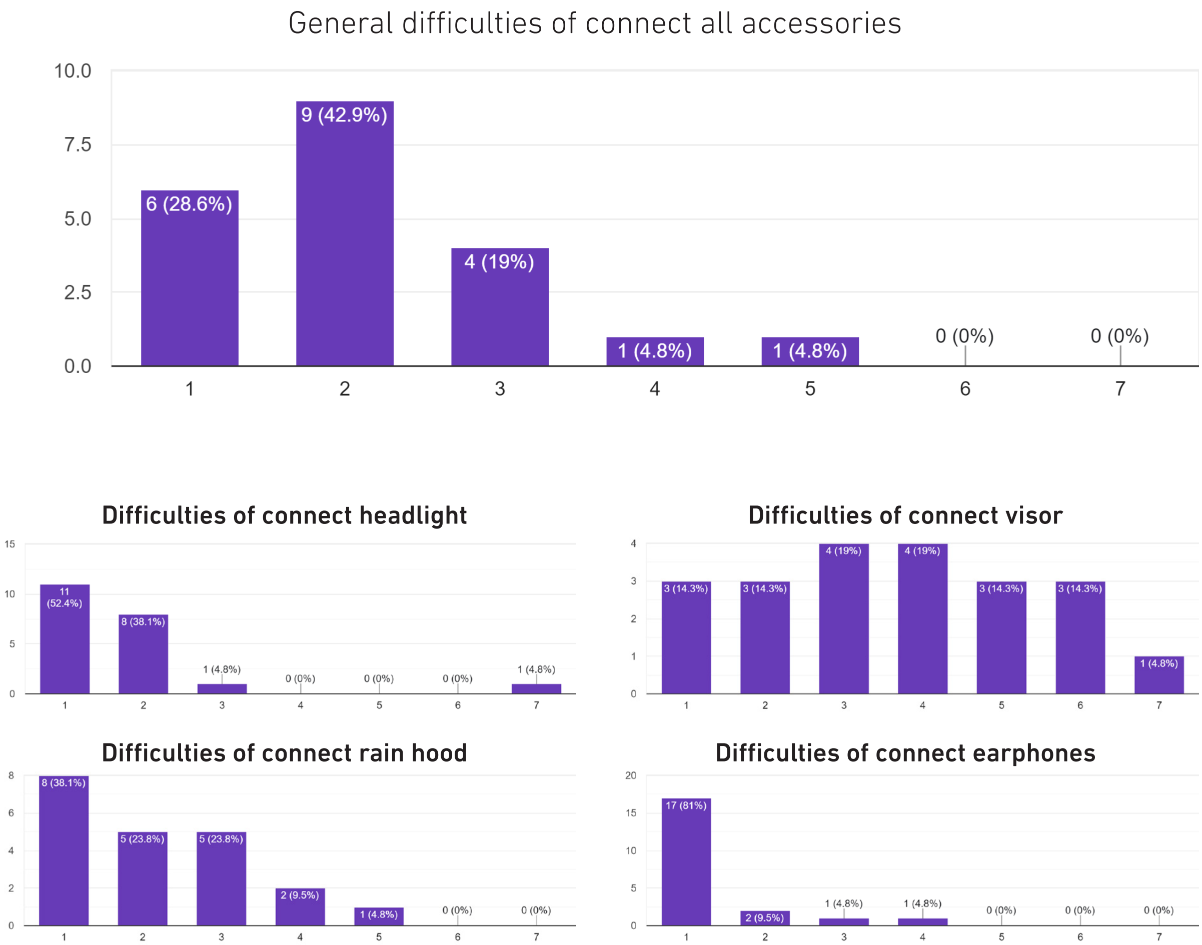
The tested prototype was developed using a standard urban-style helmet randomly selected from the market. The connection slots were integrated using adhesive fixing within pre-dug grooves created with a hand grinder. The usability validation of the connection system involved several small-scale pilot tests, and a larger validation test conducted alongside the efficiency validation test for helmet-wearing promotion efficiency. The test settings and procedures are detailed in Sections 8.1 and 8.2.

The results indicated that the overall difficulty of using the connection system was very low. However, the visor connection showed a higher level of difficulty compared to other parts, which is possibly due to insertion difficulties caused by thermal deformation during the gluing fixation process. Despite this, the test results confirmed that the placement of the connection slots was reasonable and effective. (Graph 8-9)

Feedback from the interviews conducted after the validation test revealed areas for improvement. Some participants noted that variations in friction could be misinterpreted as passive tactile feedback. Although all connection slots were produced using the same material and 3D printing process, slight differences in friction were observed, possibly due to minor accuracy errors inherent in 3D printing. These discrepancies could be resolved through iterations in material selection and manufacturing methods. Additionally, while some participants appreciated the crisp sound feedback that indicated the connection system was securely fixed, others found the click sound resonance with the helmet to be annoying, especially the connection slots for earphones. To address this issue, integrating soft shock-absorbing materials on one side of the magnetic attraction areas within the connection structure could help reduce unwanted noise, enhancing the overall user experience.



Graph 8. Average difficulty of connect different accessories



Graph 9. Difficulty distribution of general evaluation and specific accessories

7.2 Rain Hood

7.2.1 Tailoring & Fitting

Tailoring and fitting of the rain hood directly affects the appearance, comfort and protection effectiveness. The other addition functions also need to be carried out based on a sensible tailoring. Therefore, tailoring and fitting is the first thing to consider for the rain hood. The tailoring and fitting iteration is developed with paper prototypes, white cotton fabric prototypes and multiple fabric material prototypes on a head mannequin and a normal urban style helmet (figure 28).

Paper prototypes were used initially for rapid and extensive comparisons, especially in the early stages when I'm still unfamiliar with sewing techniques. The white cotton fabrics can show the difference between different tailoring methods better within less time and less interference. The fabric material prototypes are able to evaluate the impact of fabric texture and material matching on the hood's appearance.

The common styling of hoods can be categorized into three different types: two-piece cutting, three-piece cutting, and drape or stereo cutting. The two-piece cutting is mainly applied with elastic fabrics in hoodie and other casual style clothes. The three pieces cutting is predominantly used for outdoor jackets made with inelastic fabrics for better fitness and shield protection. Despite from that, some niche fashion stylings utilize special drape designs or stereo cuts. Regardless of the types of cutting patterns, all means of tailoring should obey the measurement of the mannequin for comfort and fitness, such as the perimeter of the helmet's semicircle, circumference of the back of the head, etc.

The iteration of the tailoring and fitting follows the diverge-converge process with multiple attempts and prototypes (figure 30). Compared to two-piece cut and draping cut, the three-piece cut is the most suitable cutting pattern. It offers advantages in terms of fit, material applicability (especially with non-elastic waterproof fabrics), and simplicity, making it the preferred choice for the rain hood design.

Figure 28. Illustration of outcomes and conclusion

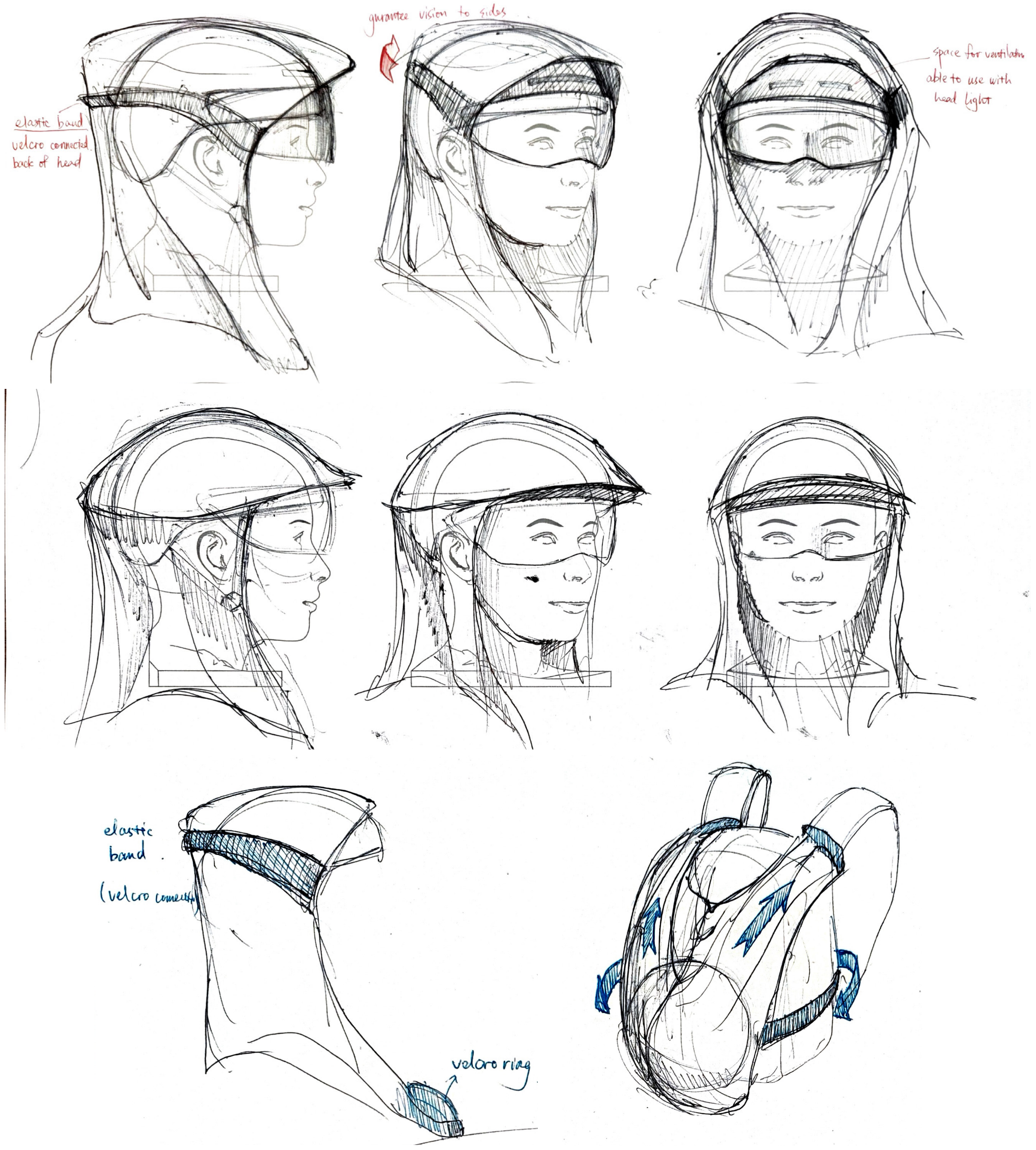


Figure 29. Ideation sketches of hood

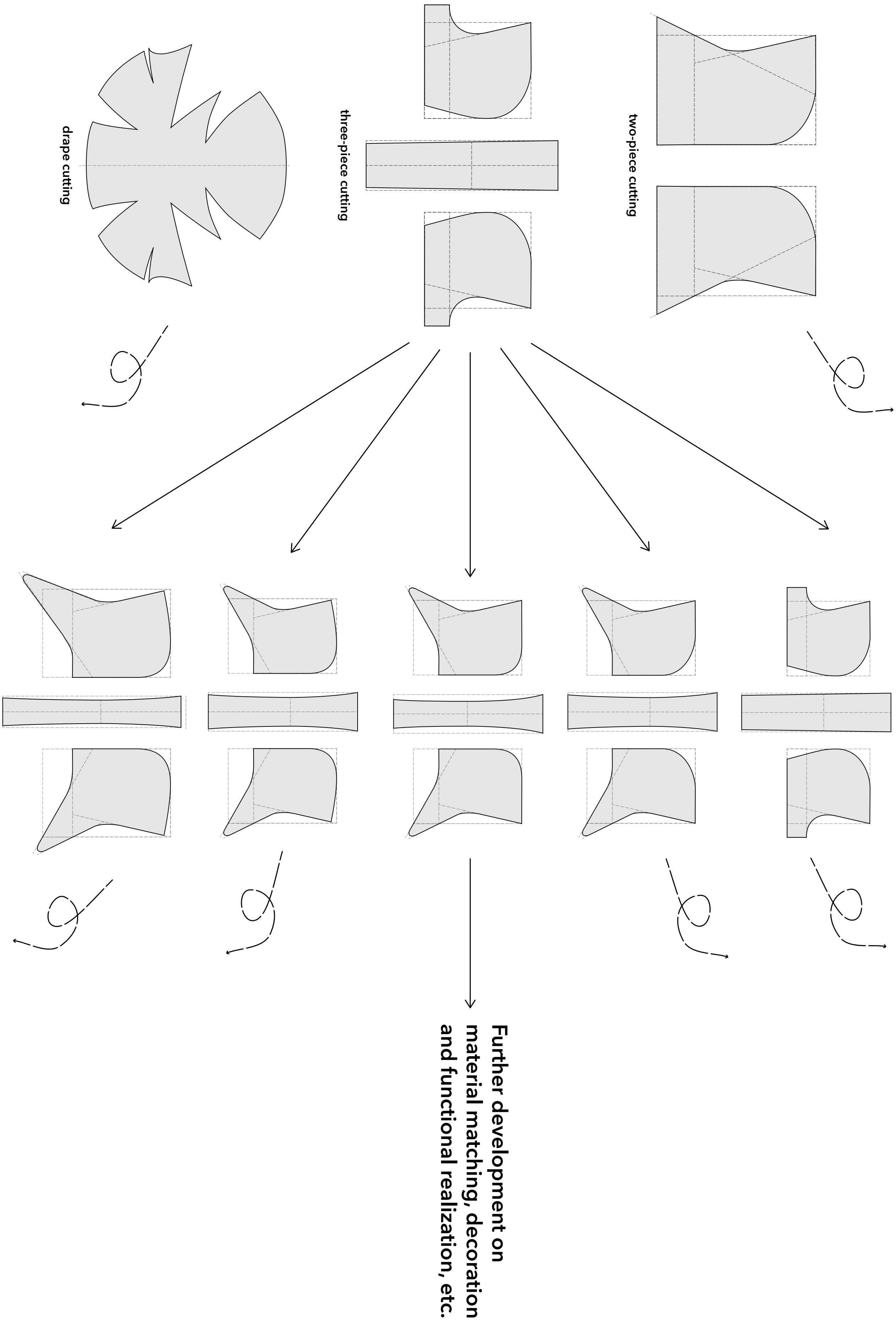


Figure 30. illustration of iteration process on cutting patterns

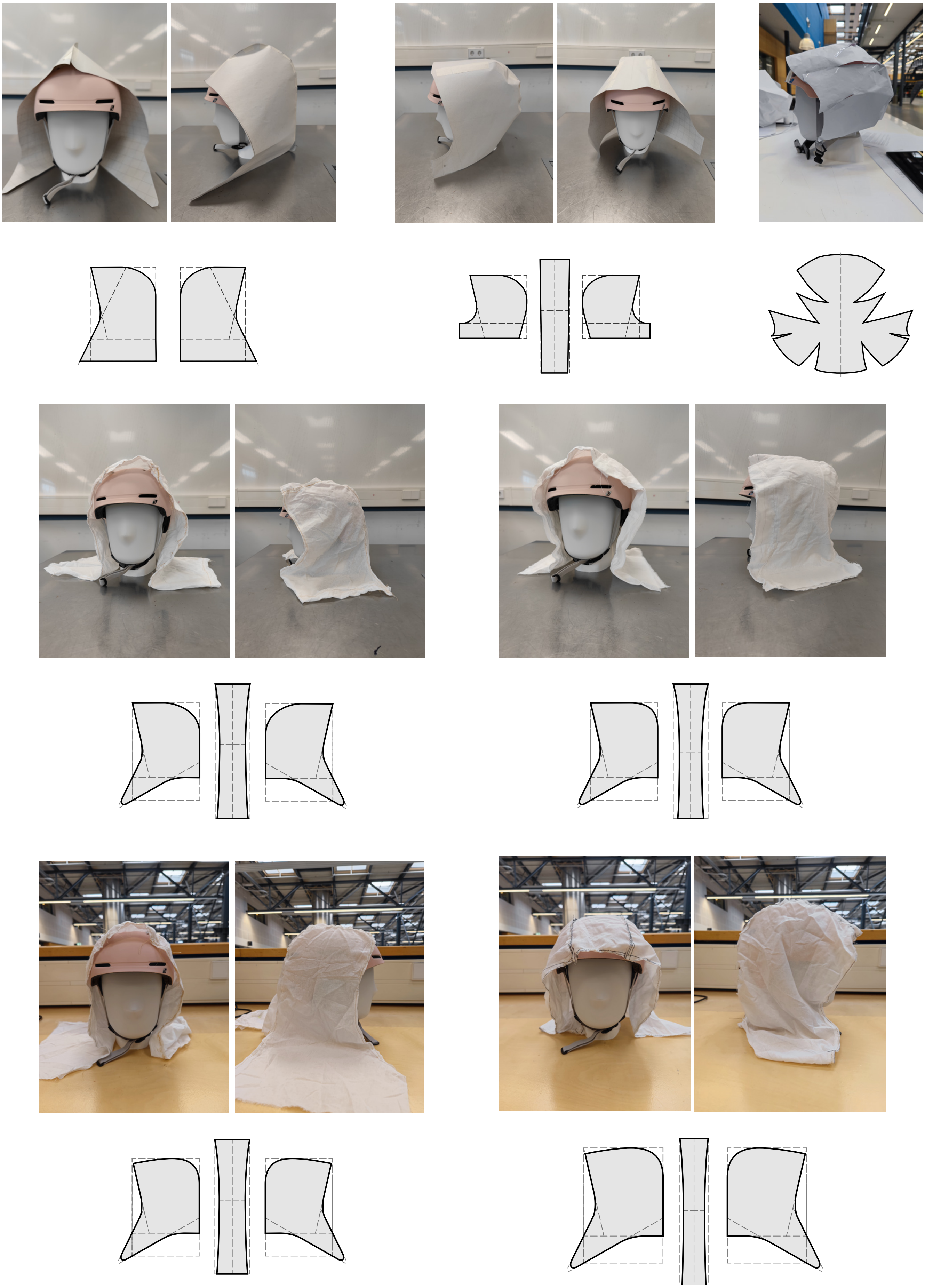


Figure 31. Prototypes of different cutting pattern attempts

7 PRODUCT DEVELOP PROCESS

Based on a basic cutting pattern of there-piece cut, various attempts are made to adjust the detail of cutting patterns for better fitness and more appropriate appearance (figure 31). These adjustments provided valuable insights that contributed to determining the final cutting pattern:

The inclination angle at the top of the head lead to more coverage on forehead while create more stack space on both sides of the face. ~
The inward contouring at the back of the head of cloth lead to tight fitness around the occipital area.
A smaller curvature at the turn of top back of the head lead to upright shape and reduces the feeling of stacking.
Change the width ratio of the side and top fabric pieces will reduce the garment fit and increase stacking.

The cutting pattern shown in figure 32 is selected as the best option proceed to the next step of development.

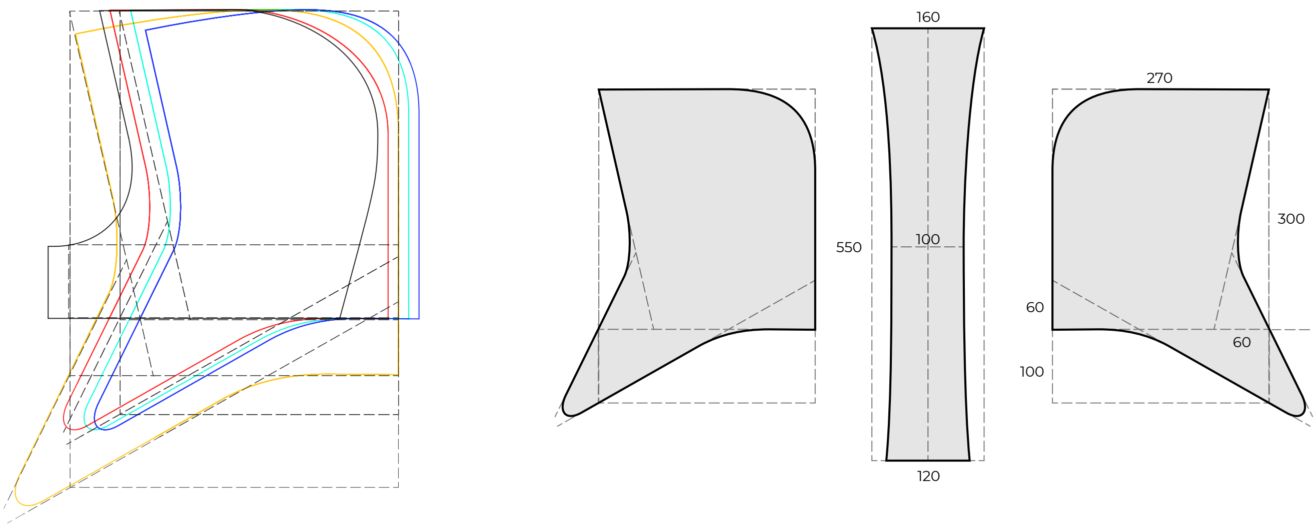


Figure 32. Selected cutting pattern

7.2.2 Material Matching & Sewing Methods

The material selection needs to meet the functional requirements first and foremost. To provide protection in severe weather, the outer layer fabrics should be waterproof and wear-resistant, while fabric of the inside areas that may have direct contact with skin should keep soft and skin-friendly for comfortable experience. For sections of the hood that cover the rear lights, the fabric should be light transmissive.

Under the guidance of Linda Plaude, a professional in fashion styling, the decision-making process for material selection starts after touching and feeling the texture of different fabrics. With hands-on experience at fabric stores, I collected and compared all fabrics that meet the above criteria and attempt to comparation between combinations of materials.

As shown in figure 33, the chosen materials include woven water-resistant fabrics as the main component of the hood, with the feature of wear resistant, waterproof, stiff, and inelastic. Light white cotton fabric, which is soft and elastic, easy to shape and breathable, are chosen as the lining of the hood. In addition to these to woven fabrics, two decoration fabrics are in more various textures of coated or plastic-like texture. The decoration fabric with reflective coating can increase the visibility at night, while the other translucent fabric can used in the area of rear lights, as well as for adding an outdoor-style decorative element.

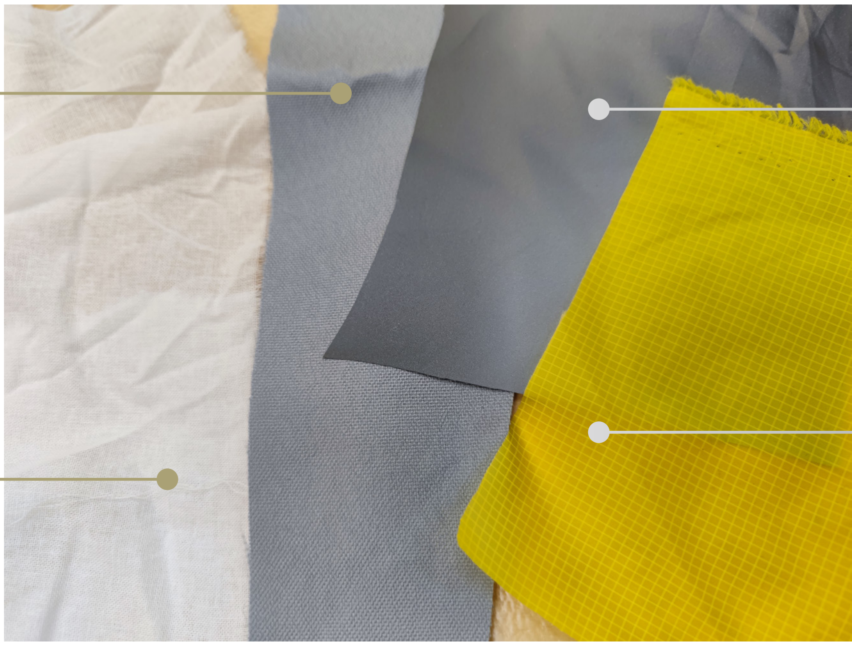


Figure 33. Material selection

In addition to the cutting pattern and material selection, sewing methods are also taken into consideration as an important factor influencing the final result of the appearance. After several round of iteration, I have tried different sewing methods including simple edgestitch, inner linen, etc.

The final decision is made after a number of competitions between different sewing method test, the connection between three fabric pieces is sewed with concealed stitches and topstich method for a natural fabric seam. the remaining exposed edges and elastic straps use 'facing' mathod to hem and fix with an extra layer of for better connection strength and aesthetics.

Figure 34. Material and sewing methods iteration

7.2.3 Functional Development

In line with safety regulations and the LoR in chapter 6.3, the hood as an helmet accessory should ensure the vision of users. And the function definition also requires the hood have the function allowing it to be fixed to backpacks.

After several rounds of ideation and iteration, the two functional expectations are realized through the use of one single elastic straps, which also serves as part of the hood's decorative design.

The strap is fixed to the hood in the area of both side near the user's line of sight. When attached together with Velcro, it can pull up the two pieces of fabric on the side of the eye to ensure the side vision during riding (figure 35). After riding, the strap can be used to attach the hood, together with the helmet to a backpack, then the whole hood becomes a cover outside the backpack (figure 35).

Figure 35. Strap design with vision guarantee and fixation functions

7.3 Headlight & Visor

Considering the close location of headlight and visor, the two accessories are developed together to achieve a cohesive overall design. Different from the hood or the connection slot, since the headlight and visor do not significantly differ in functionality from existing products, the form and aesthetics becomes an important part to focus on.

7.3.1 Form & Aesthetic Iteration

To determine the preferred style, interviews were conducted where participants were shown representative images of different styles of headlights. Among four different styles presented, all participants expressed a preference for the LED style with compact and delicate decoration. Participants favoured moderate brightness levels and preferred designs where light was reflected and diffused through semi-transparent materials rather than directly exposed LEDs.
That also reveals that user’s function expectation of headlight is not limited to the illumination of road environments but mainly considers the influence on one’s looking and warning the other transportation participants on the road that there is someone cycling here.

After defining the basic style, a large number of sketches (figure 36) and 3D models (figure 37) were returned for the target user to select from to define the form and aesthetics. And based on the results of the user's preference, a draft 3D model was produced.

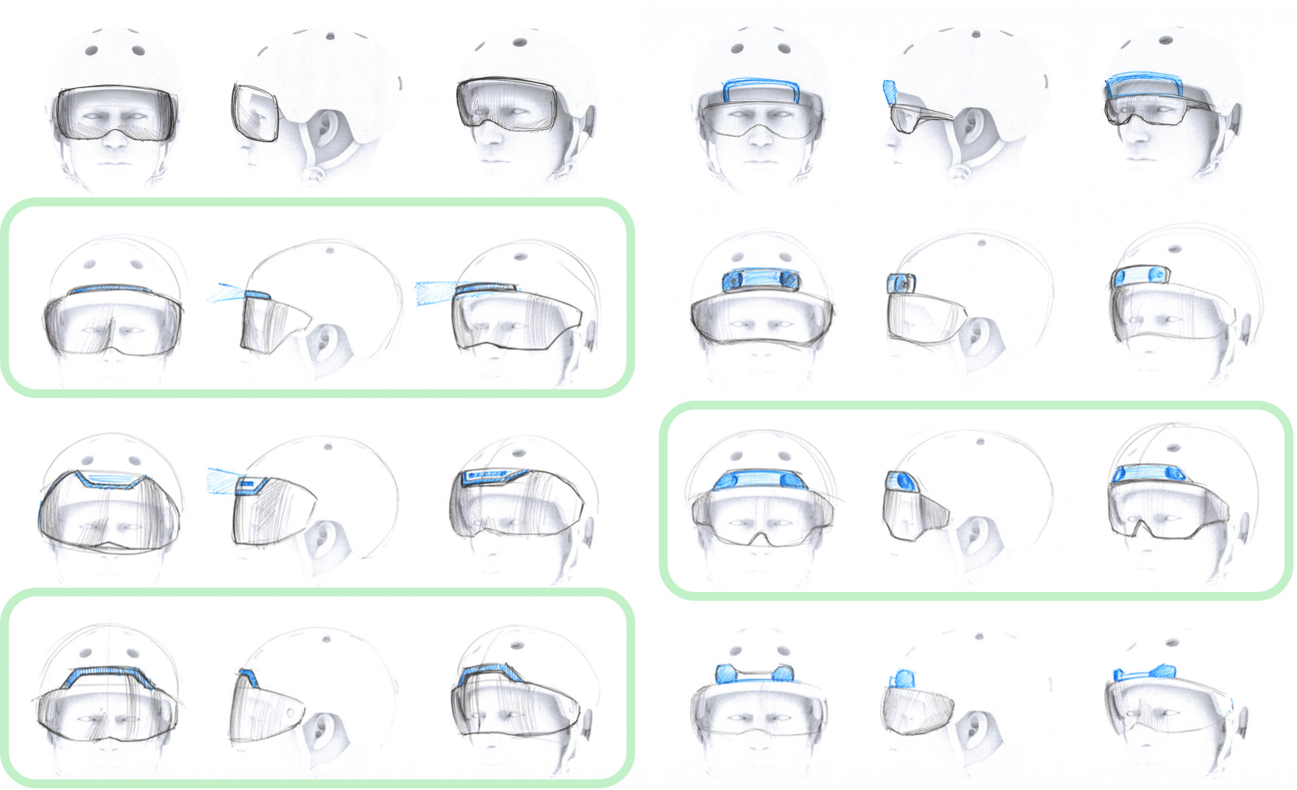


Figure 36. Sketch comparation

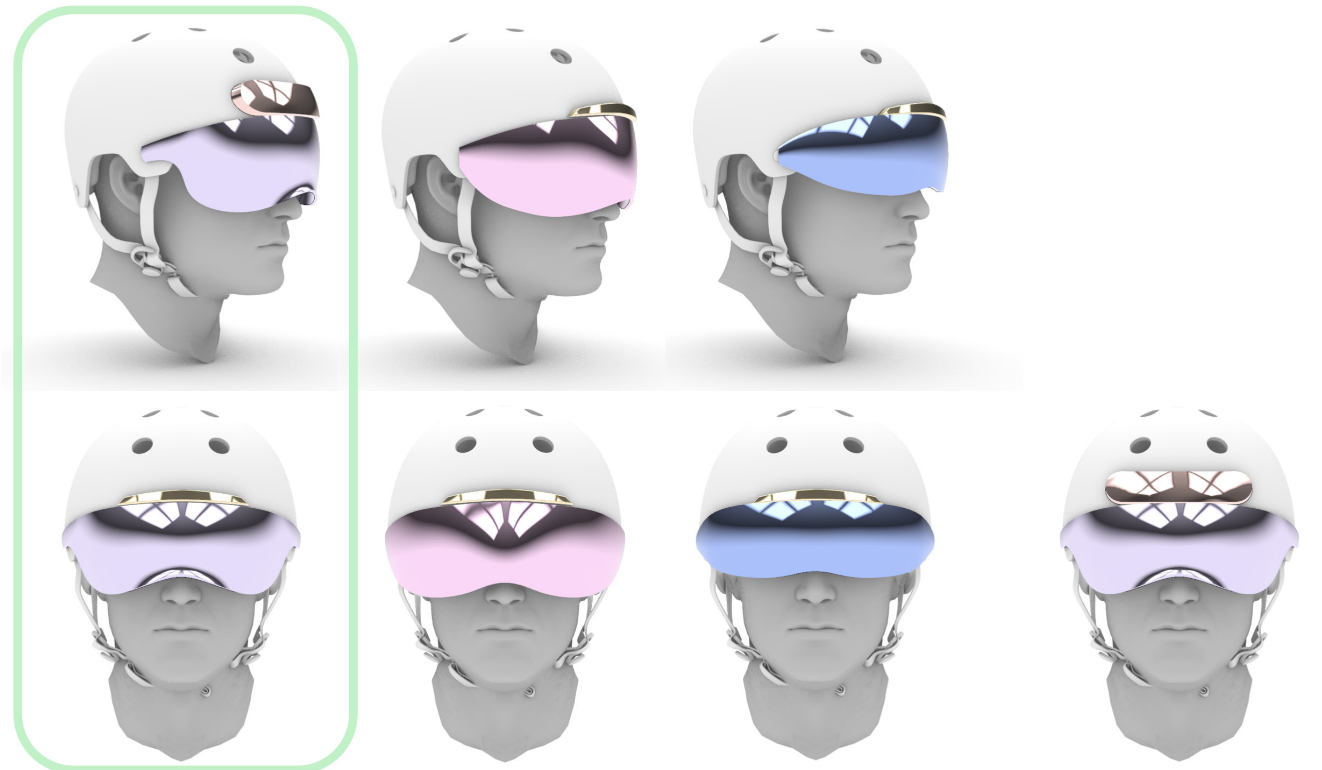


Figure 37. 3D model comparation

7.3.2 Appearance Model

Based on the results from the 3D model comparisons and the styling definitions, an appearance sample was created. The model continues with the selected shape from the aesthetic comparison, featuring LED and diffusion effects using translucent materials. The design adheres to the principles of essential and delicate aesthetics outlined in the styling definition.

The appearance prototype features two functional areas corresponding to the main user expectations: visual appeal with lighting effects (to signal that someone is cycling) and illumination for road environments. The indicator light is equipped with a translucent white light diffuser positioned in front of the light source, creating a soft and visually pleasing effect. The illumination light is made up of exposed high-brightness LEDs to enhance visibility. A central button controls the lighting modes, allowing users to switch between different settings by touching or pressing the button. (figure 38)

Aesthetically, the overall design is kept simple with symmetrical arrangement. The translucent lighting areas feature flowing and soft folding lines. The visor Inheriting the most popular curved shape that enhance the design's visual appeal. The headlight is constructed with a bright silver plastic casing and translucent white resin light diffusion fittings. The visor is designed using high-clarity resin with a gradient teal coating from top to bottom, providing shading and a hydrophobic effect. The overall form and CMF align with the styling definition described in Section 6.2, ensuring a cohesive and refined look that meets both functional and aesthetic expectations.

Figure 38. Two lighting modes of the light

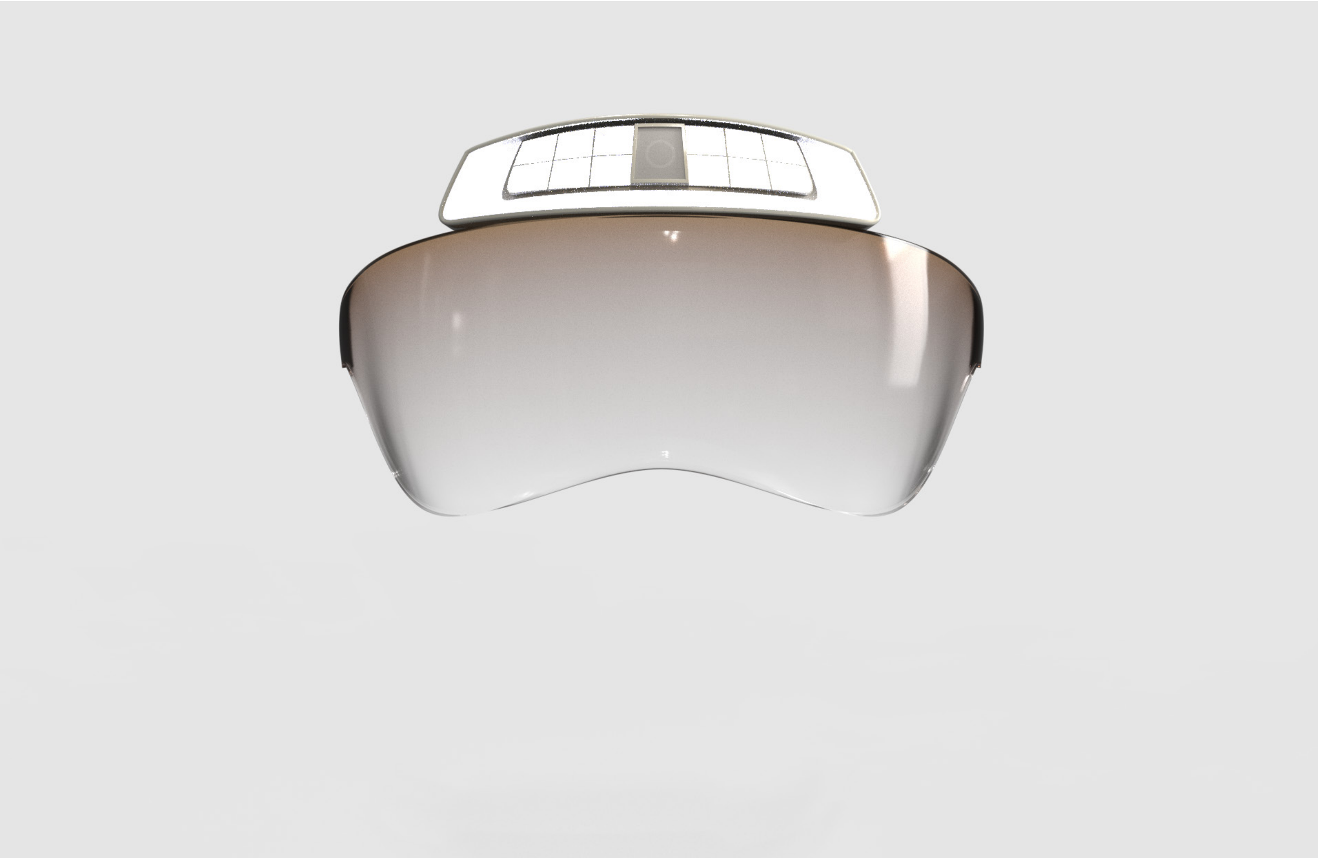


Figure 39. Rendering of headlight and visor

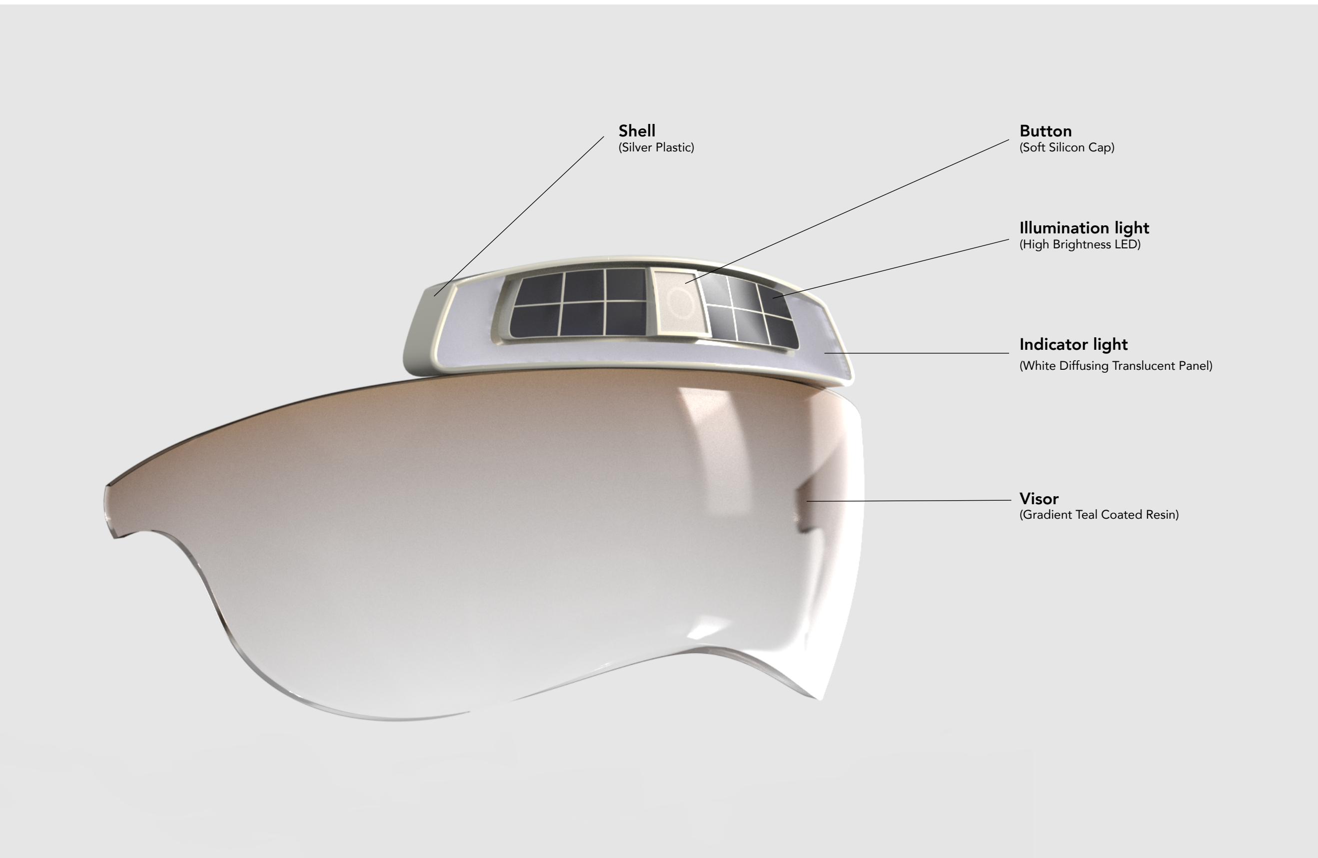


Figure 40. Component and material of headlight & visor

7.4 Earphone

Listening to music while riding is a common habit, especially among the target users, but it poses safety risks. the earphone accessory aims at providing the safest possible Bluetooth earphone experience for riding. To minimise the impact of headphones on hearing, two possible solution of bone conduction and air conduction is proposed.

Bone conduction involves fixing the sound-producing component on the temporal bone area, requiring a flexible structure. This method offers the best user experience with lower energy consumption and better musical effects but demands more development effort for the bridging and fixing structures.

Air Conduction uses normal speakers to conduct sound through air. This solution is simpler and more reliable but offers a poorer user experience due to potential issues such as sound leakage and lower sound quality.

Both two conductions are applicable and shows possibility of use. Due to time constraints, I chose the air conduction as the solution to finish the appearance model. The appearance model refers to the existing earphones and the electronic components widely used on market.

The earphones' functionality dictates that they need to be connected to the helmet using slots located on the top, with the speakers positioned close to the ears to minimize sound attenuation through air conduction. The design also includes space for electronic components similar to existing wireless earphones and features a button or touch area for user interaction.

As shown in Figure 41, the form follows a design style that is simple and fluid, with tensioned curves. The speaker is positioned in a protruding part at the bottom, ensuring clear sound delivery without blocking surrounding traffic sounds. The touch area is located on the outer side of the protruding part, allowing operation through two modes: simple touch and press down.

When the earphone is clicked into place, it automatically wakes up and connects to the user's phone. Touching or pressing the button enables more complex functionalities, enhancing the user experience while maintaining safety during riding.

Figure 41. Rendering of earphone

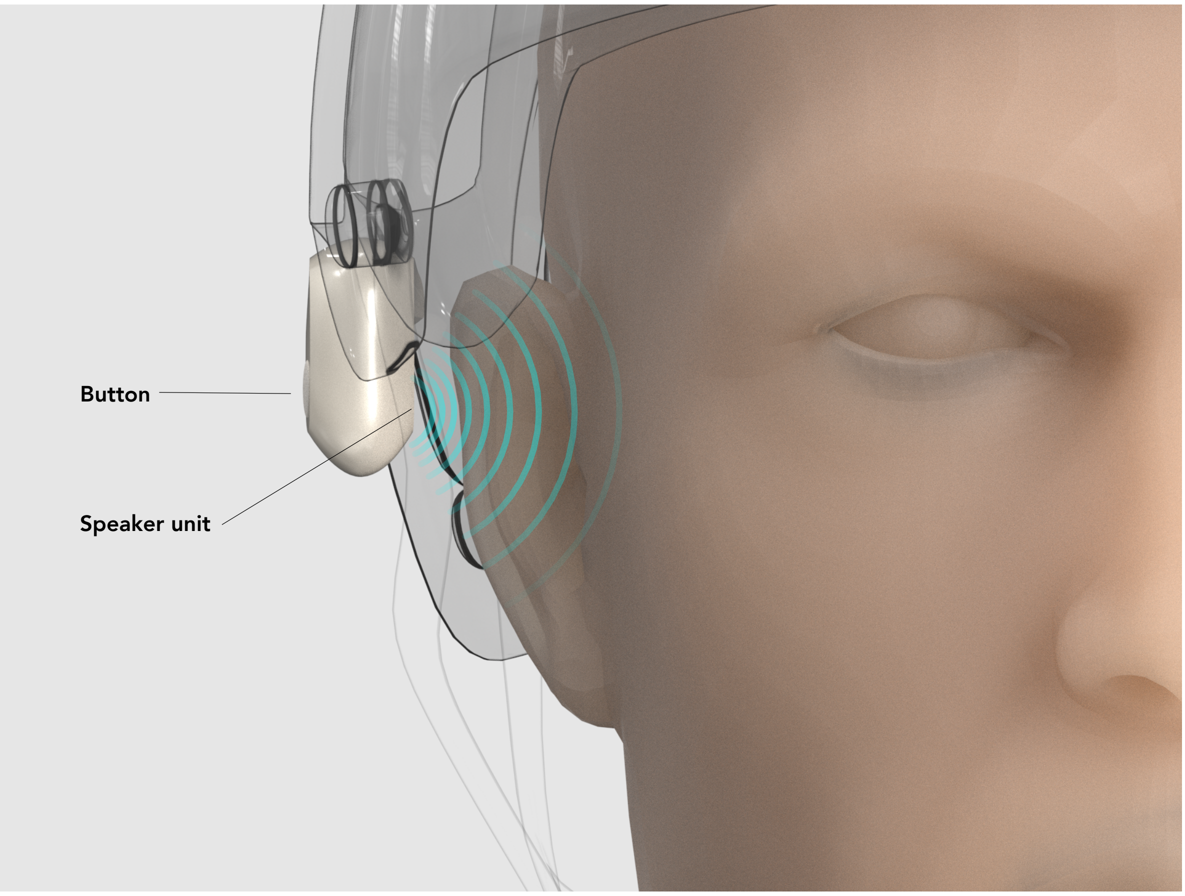


Figure 42. Air conduction audio playing

Figure 43. Rendering of helmet with accessories from different viewpoints

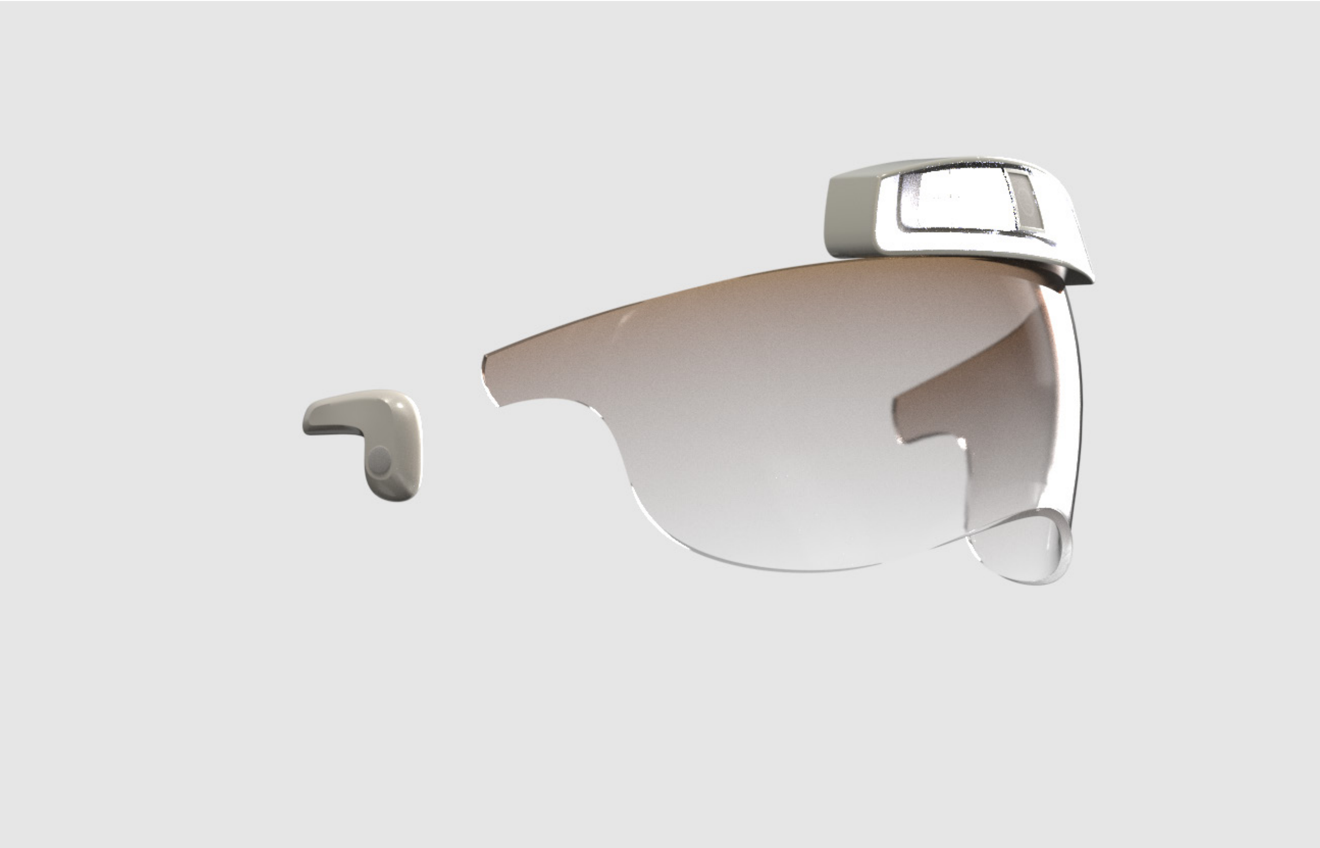


Figure 44. Accessory combinations

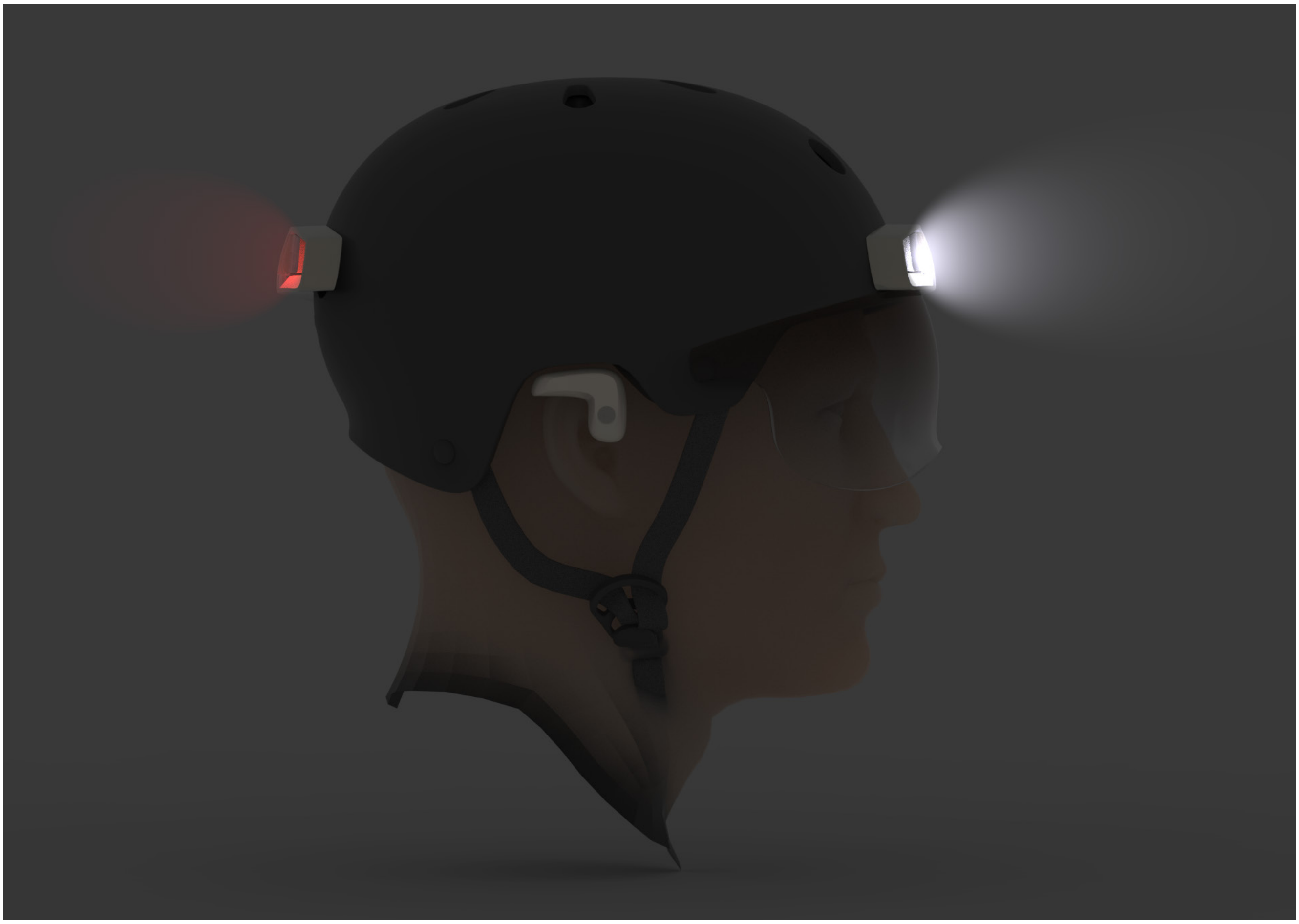


Figure 45. Front & rear light effect rendering in dark environments

8 EFFICIENCY VALIDATION

8.1 Test Setting

The efficiency validation test is conduct with the prototypes showed in figure 46 and several illustrations and sketches as explanation of the design. The tested prototypes include a head mannequin, a helmet integrated with connection slots, and the prototypes of accessories. the prototypes of headlight, visor and earphones are all morphological models 3D-printed in the same shape as the target accessories. the prototype of rain hood is a functional prototype made by water-resistant fabrics with elastic straps that is able to realize additional functions such as fixing.

Participants of this test are randomly recruited from the entry of Pulse and the bicycle parking area of X TU Delft (sport centre in Delft). None of the participants had prior knowledge of this design project, and their participation is completely voluntary.

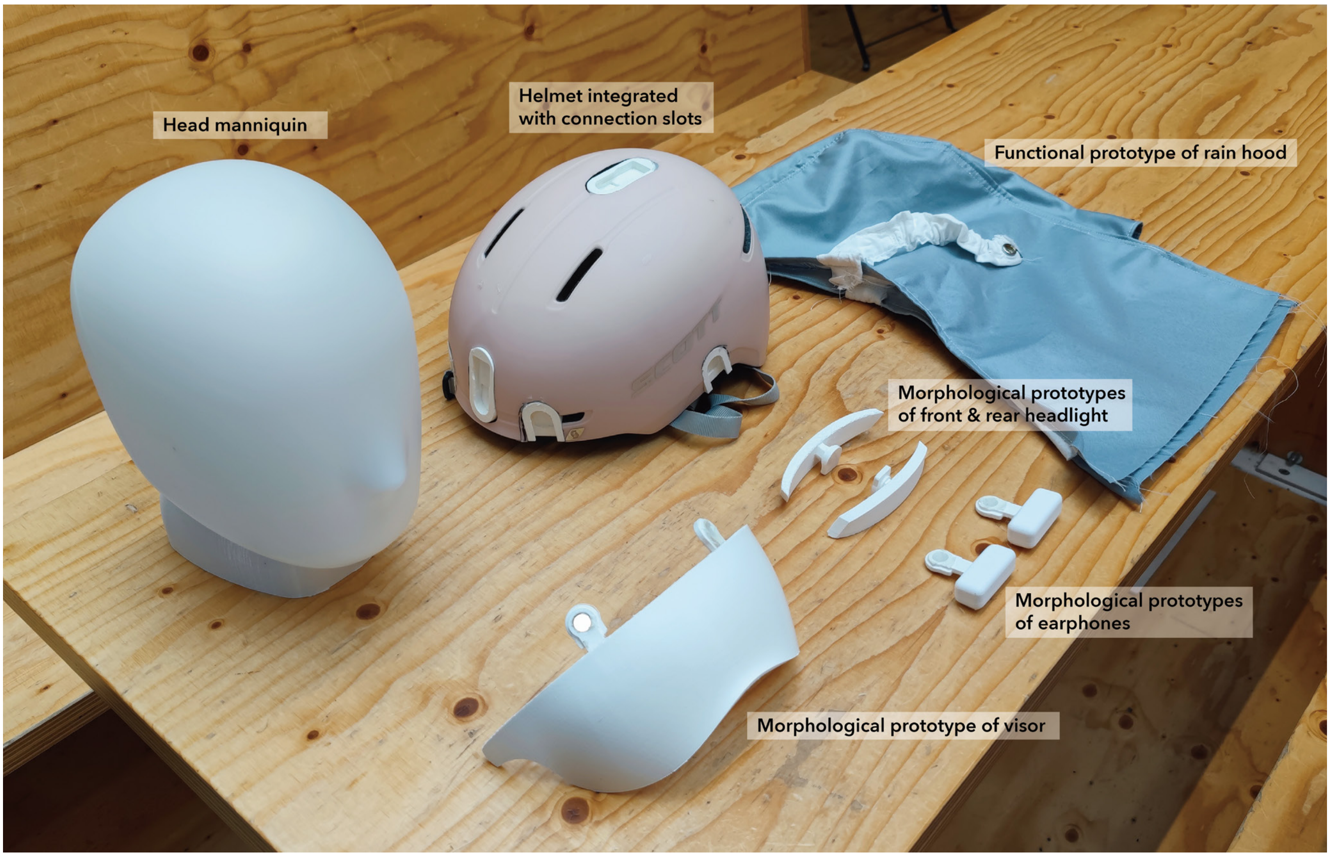


Figure 46. Prototypes used in testing

8.2 Validation Process

The whole test process is divided into four steps:

1. After read and signed the consent form, participants are asked to first fill in the first part of a questionnaire to collect necessary information and their frequency of wearing helmet.

2. Participants are introduced with the background of the project, the overall concept, and the different components. During the introduction, several illustration and sketches are shown to participants to help them better understand.

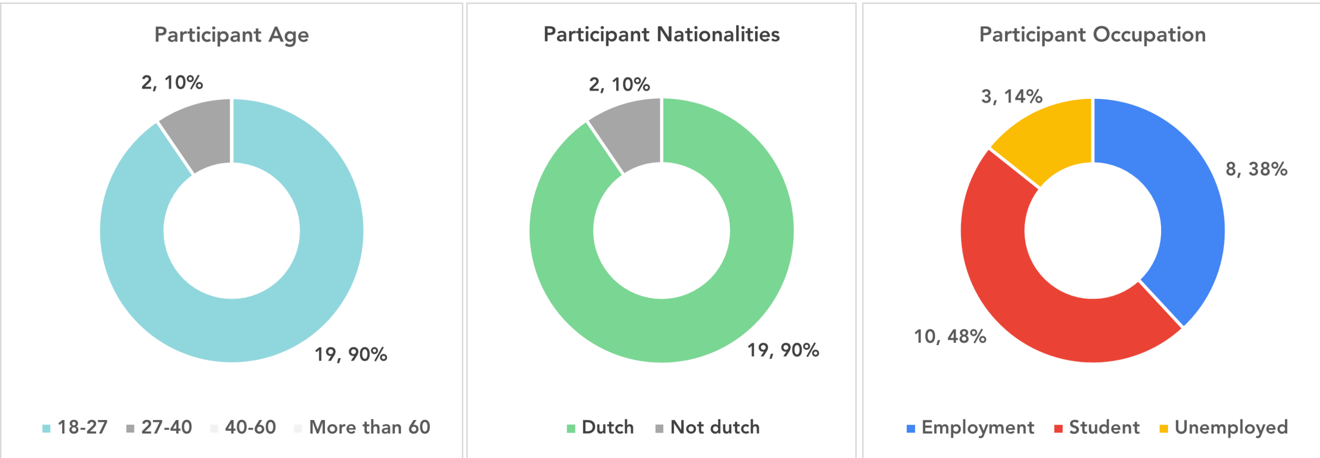
3. Participants were then asked to familiarize themselves with the usage of the helmet and accessories. They were instructed to attach and remove the different accessories in turn, both when not wearing and wearing (simulate the posture of riding).

4. After interacting with the prototypes, participants were asked to fill out the second part of the questionnaire to evaluate all products from the ease of use, comfort and its promotion effects. This was followed by a short interview to gather more detailed opinions and feedback on the design prototypes.

Figure 47. Test process

8.3 Results

A total of 21 participants attended the test, 19 of them are Dutch and all of them permanently residing in the Netherlands. One participant is 28 years old, only one year extend the age limit of the target group. Including this participant, 20 out of the 21 participants met the requirements of the target user group defined in Chapter 5. Participants' occupation situations are various, including student, employments and unemployment, which can diversely representation of target user group in its composition. The vast majority (16 participants) never wear helmets during riding, with the other 5 of them occasionally (once or twice out of ten rides) wear helmets in their daily life. In conclusion, the composition of the participants was in line with the definition of target user groups.

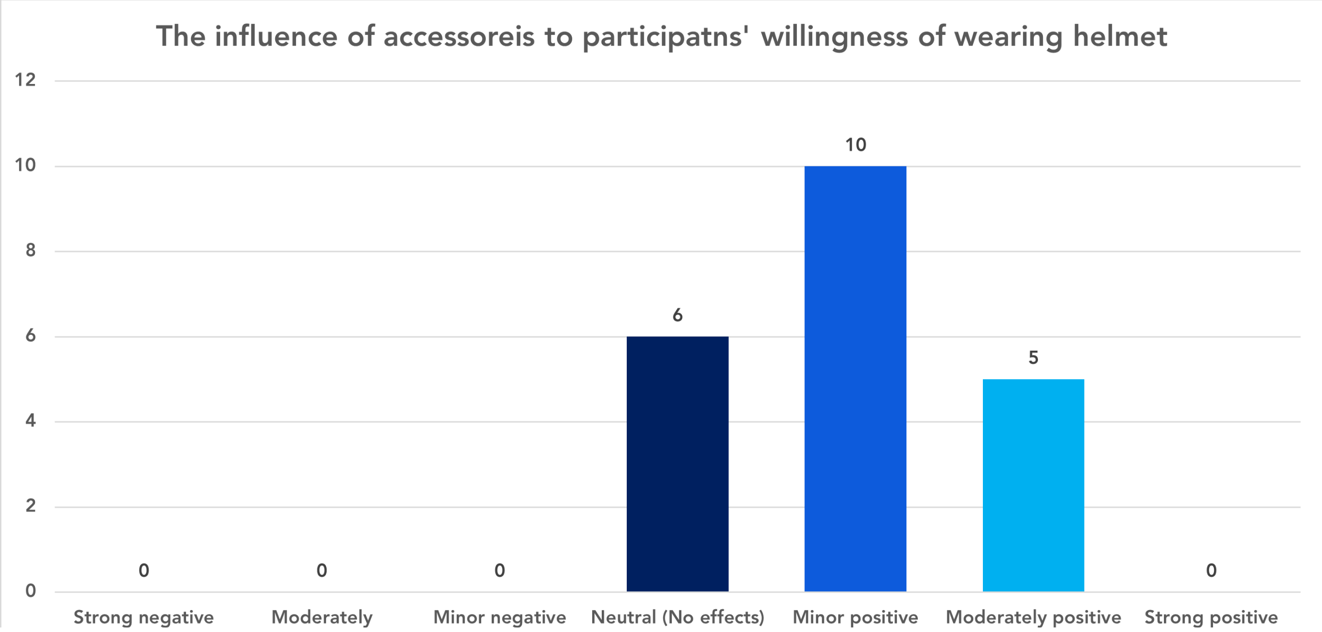


Graph 10. Demographics of test participants

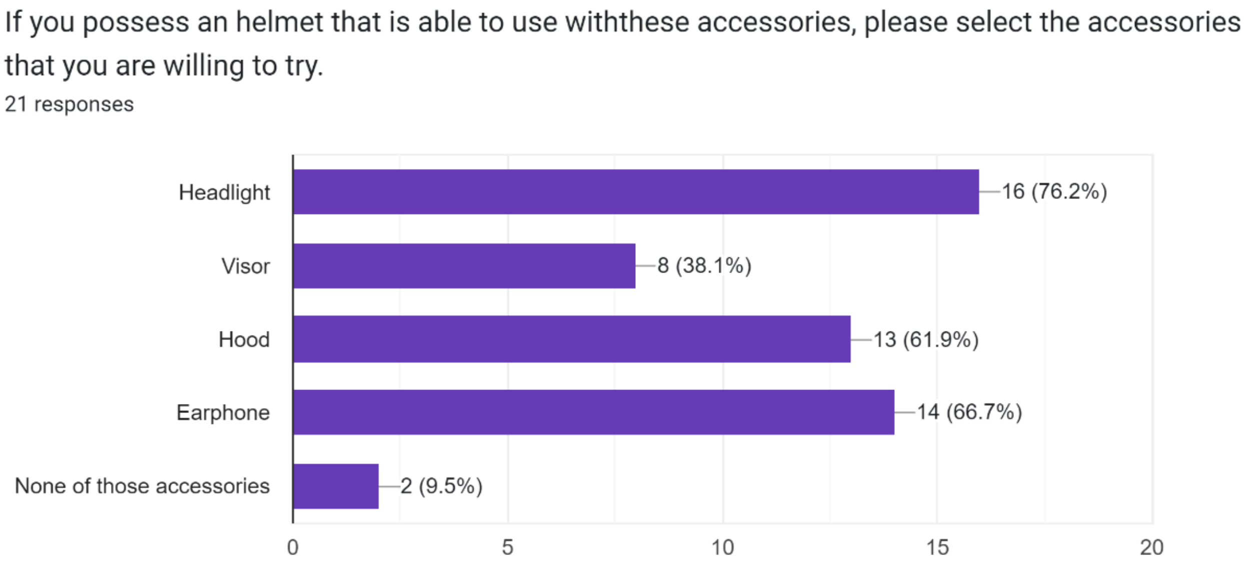
The ease of use and effect of comfort is proved in the test result. Except for the visor (the bonding and fixing process caused the deformation of 3D printed parts), all components are considered as a high stage of easy to use. Additionally, none of participants reported discomfort.

For the promotional efficiency, 15 of the participants acknowledge that the design has minor or moderately motivational effect on their willingness to wear a helmet, while the other 6 participants keep neutral and still resist wearing helmet. The reasons for these positive effects varied among participants. A majority agree that the functional enhancement can improve their riding experience that attract them to use. Five participants concerned about the positive impact on the appearance of helmet as a motivation factor.

Participants have various attitudes on different accessories. the headlight is the most popular accessories that participants are willing to try (76.2%), following by the earphone (66.7%) and the hood (61.9%). However, attitudes towards the earphones were polarized, some participants emphasised their need for a safe and compatible earphone that works well with a helmet, while the other participants think the existing earphones are good enough and have no significant influence on safety. The visor is less popular, the result may be related with the scenarios that participants used to ride in, which will be discussed in the next section.



Graph 11. The promotional efficiency of the accessory system



Graph 12. Participants' preference to different accessories

8.4 Discussion

The motivational effect of wearing helmet is confirmed among most participants with various underlying reasons. A significant factor was the optimization of the helmet's appearance through accessories. Participants note that the hood and visor can modifying the shape of the helmet to avoid looking dumb with helmet. The enhancement to the riding experience is another influential factor. The hood and earphones are the two favourite accessories in the interview. Participants says the accessories can improve their cycling in specific scenarios and make them more pleasant or enjoyable. This aligns with the analysis in Chapter 5, which suggested that enhancing experiences and influencing social norms through personalization and appearance optimization could create a stronger promotional force for helmet use.

However, the motivational effect was not universal. For example, Participant 01 acknowledged the usefulness of the accessories for riding scenarios but stated that they still would not change their mind about wearing a helmet. Participants 07 says he is only willing to try the accessories with helmet in winter or severe weather but have no chance to wear helmet in summer.

The overall functionality of the product system is also validated by participants. The connection system is found to be easy to understand and can be easily used with one hand after a brief familiarization period. Additionally, the rain hood's functions, such as fixation and maintaining vision, are recognized and appreciated by most participants.

In terms of the accessories' functionality, participants' expectation is various due to their different riding habits and scenarios. For example, participant 06 have rich experience with long rides and often go distance commute riding, who has worked as delivery person of Thuisbezorgd. She emphasises that hood and visor is very useful for her to keep out the dust and wind. In contrast, participant 02 who mainly cycles in neighbourhood areas, felt that the visor was only necessary in extreme weather conditions. This variation suggests that there is potential for further segmentation and definition of usage scenarios based on different rider profiles.

The validation tests still have certain limitations. Although I spend efforts to include a diverse range of participants, to cover the target groups, test participants are insufficient in number and are all recruited in delft campus region that have a high chance of be student or staff of TU Delft. Additionally, the test scenarios of wearing helmet did not fully replicate real-world conditions, consider the possible bumps, distraction or multitasking in the riding process, ease of use may not perform as well as indicated by the test results.

9 LIMITATION & REFLECTION

9.1 Future Development Recommendations

Finish Development of Products.

The planned products are not yet fully completed. While the connection slot and hood have been developed into functional prototypes, further steps are needed to optimize these components for commercialization. This includes additional testing and refinement of material selection and manufacturing processes to ensure they meet commercial standards. Meanwhile, the headlight, earphones, and visor remain at the appearance prototype stage. These products still require significant development in terms of materials, internal electronics, and interaction methods. Optimizing these aspects will be essential to transform the prototypes into fully functional products that are ready for market entry.

More Possibilities Based on the Product System

The four selected accessories are the most effective ones at promoting helmet use among those who typically do not wear helmets. However, additional functional and decorative accessories can be developed to meet niche promotional needs or to cater to loyal helmet users in a longer time scale, enriching the product system and enhancing helmet usability and commercial value. Future development could focus on diversification of product modelling materials and other accessories that address more experience-related aspects, such as storage solutions for fixation on bike or integrating power supply options within the connection system to expand from incremental markets to existing stock markets.

Service System and Commercial Development

Building a service system around the universal attachment system could significantly enhance user experience and motivate helmet use. A draft future develop plan applied with 3-horizon methodology is showed in figure 48.

Horizon 1: Target consumers who match the defined personas, promoting through opinion leaders to establish a connection between essential lifestyle trends and customizable functional bike helmet accessories. This strategy aims to open up new incremental markets for the product..

Horizon 2: Focus on maintaining the existing market while continuing to expand the incremental market by extending the product system and lifecycle. This aligns with the recommendations in Section 9.1.2, which suggest introducing new accessories and enhancing current functionalities.

Horizon 3: Evolve into a mature and recognizable product with ongoing product iterations aimed primarily at a loyal user base. Seek opportunities to leverage societal influences to drive new commercial growth points, fostering further integration into the market.

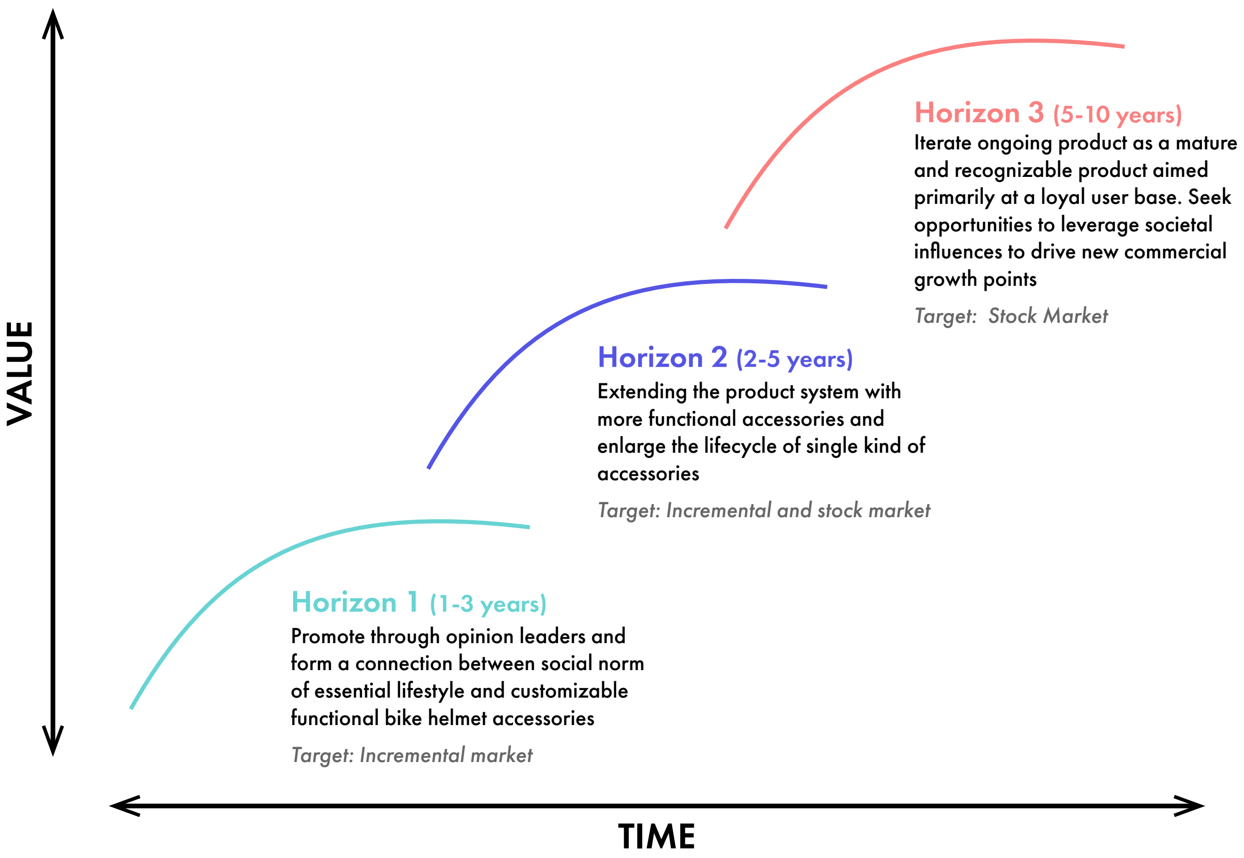


Figure 48. 3-horizons

9.2 Limitations

Insufficient time arrangement. The project planning faced several challenges, influenced by unforeseen circumstances, underestimation of complexity, and a series of cascading effects. At the project's outset, I underestimated the problem's complexity and was affected by external changes in project management. As the research progressed, it became clear that the issue of low helmet use in the Netherlands is not merely a behavioural challenge but a complex, systemic problem intertwined with social norms, education, and multiple industries. Identifying the most suitable entry point for product design within this complex landscape was a significant challenge, offering valuable learning experiences. However, delays caused by changes in the supervisor team and the extended research phase resulted in the main product development being pushed into July and August. This timing coincided with the summer vacation period, leading to uncertainties around the availability of facilities and difficulties in securing guidance from professionals, ultimately resulting in a less efficient product development and testing process.

Limitations in Testing. A larger-scale test with better simulation of real riding environments could have provided more robust validation. Due to time and budget constraints, the validation phase was conducted with a limited number of participants in static conditions, which does not fully replicate the dynamic nature of actual riding scenarios.

Lack of the data of colllision test. Due to practical constraints, no collision tests were conducted on the prototypes. While existing market examples with similar structural placements suggest that the design modifications should not compromise the helmet's structural integrity, direct collision testing is essential. Such tests would provide critical data on the safety performance of the helmet and accessories, offering guidance on the manufacturing of the EPS layer and the required solidity of the accessories. Conducting these tests in the future would be crucial to validate the safety standards of the product and to refine the design for commercial use.

9.3 Reflections

Different from all my previous design experience, this project presented a unique challenge, starting from a standpoint of social responsibility aimed at changing daily behaviours through product design rather than focusing purely on functional improvements. This work did not begin with a clear product definition like what I used to design for but instead grappled with a complex, systemic problem that proved far more difficult to influence as a product designer. The process taught me invaluable lessons about addressing multifaceted issues such as behaviour change and social norms through design.

Throughout the project, I engaged with professionals in fields related to behaviour change, the helmet industry, and other relevant sectors. Despite exploring various theories and methodologies, no existing model could be perfectly applied to generate a proven design approach, highlighting the complexity of influencing social norms through product design.

This project also provided a great exploration of different materials and processing methods, particularly through the design of the hood, which required working with fabric—a material I had never used as the main component of a product before. Designing with fabric introduced a completely different mindset, from the 2D-to-3D design process and various sewing methods to understanding the influence of material properties like elasticity, weave, and stiffness. This experience was incredibly inspiring and expanded my perspective beyond rigid product design.

I encountered challenges and struggles throughout the process, many of which were beyond my control. This project reinforced the importance of perseverance and creativity when faced with complex design challenges, highlighting that resilience and adaptability are crucial in navigating unforeseen obstacles in the design process.

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APPENDIX

DESIGN FOR our future

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Miao
Initials	Y.M
Given name	Yifan
Student number	5791774

IDE master(s)	IPD ✔ DfI ☐ SPD ☐
2^{nd} non-IDE master	
Individual programme *(date of approval)*	
Medisign	✔
HPM	☐

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2^{nd} mentor

Chair	Daan van Eijk	dept./section	HCD/AED
mentor	Ernest van Breemen	dept./section	SDE/MF
2^{nd} mentor	Antoinette Rozeboom		
client:	Erusmus MC		
city:	Rotterdam	country:	the Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2^{nd} mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Name Prof.ir. Daan van Eijk Date 20-03-2024 Signature

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

Master electives no. of EC accumulated in total ______ EC

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

	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Name ______ Date ______ Signature ______

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES		Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Name ______ Date ______ Signature ______

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Yifan Miao **Student number** 5791774

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

Project title Redefining Helmet Design with Fashion Styling

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)

Almost everyone in the Netherlands rides a bike, but few wear helmets, despite the fact that this greatly reduces the risk of craniocerebral injuries. This project focuses on research and design in the areas of fashion design, public health, and smart wearables, with the aim of using design to promote a change in user habits and encourage helmet usage.

Bicyclists are the primary stakeholders in this design project, serving as both consumers and end users. Their interest in the product is closely tied to their cognitive habits and user experience. Stakeholders in the helmet industry include manufacturers, designers, and potential collaborators from the fashion industry. They seek to increase profitability by expanding the user base and enhancing the product's value. Society is also an intangible yet crucial stakeholder; reducing unnecessary injuries in traffic can effectively decrease public health spending and alleviate the burden on the healthcare system, ultimately benefiting society as a whole.

Present-day helmets often prioritize product performance, emphasizing safety features and striving to be lightweight and breathable while lacking attractiveness. Additionally, helmets that prioritize aesthetics may not be practical for everyday wear. Therefore, leveraging fashion as a driving force represents a strategic intervention point to maximize the design influence and shape user behavior.

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introduction (continued): space for images

image / figure 1: Collage of urban bike helmets on the market

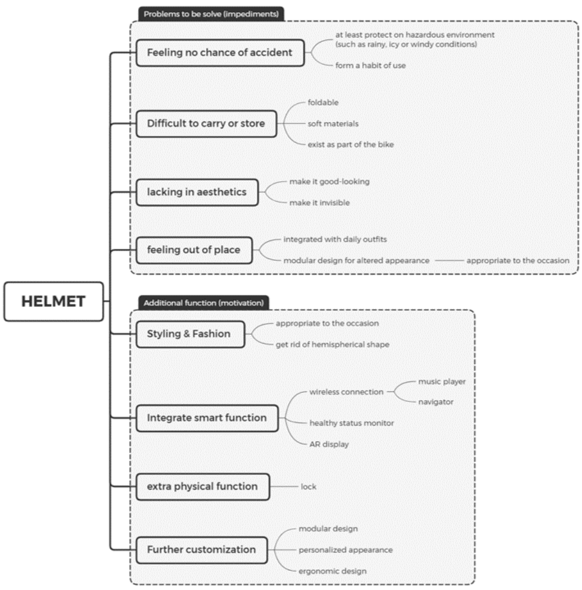


image / figure 2: Possible ways to solve current impediments and motivate people to wear helmet

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 ultimate goal for this project is to motivate people to ensure adequate head protection while riding. According to previous research, users' lack of perception of danger is the primary reason for not wearing helmets, alongside with the cumbersome usage process (difficulty in carrying, storage and comfortable wearing) and unattractive appearance being the other two main factors. The experience of use is the most criticised part of existing helmet products. Helmets don't fit in with everyday life, whether worn as part of an outfit or not. Leveraging fashion presents an opportunity to seamlessly integrate helmets into users' life, i.e. part of everyday wear.
In addition to solving the existing problems, I would also like to add new value to the product. The helmet could integrate with more functions, such as wireless connection with mobile phones, smarter body status detection, or as a smart control for e-bikes. More fashion and styling could be added to the helmet design to make it more attractive to target groups. These initiatives are mainly for young people, these users are willing to pay more money for get better protection experience (and protection effect at the same time). The helmet industry also benefit from the broadening of the user group and higher product value, which allow them to get higher profits and brand awareness. Due to better head protection, the society can also correspondingly reduce the burden of public health costs.

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:

Create a product design prototype to improve the experience of urban bike helmet and add more value to bike helmet to motivate people to develop the habit of wearing helmets for people who ride for transportation in urban area.

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)

The final design result can be regarded as a combination of two separate parts: the appealing fashion helmet appearance design and the matching structural design that realizes the head protection function.
At the initial stage of the design, due to my lack of experience in fashion design, I need to build up a relevant knowledge base, including research and study related to fashion, styling, form-giving, and textiles. At the same time, based on the results of previous research, I'll conduct further surveys, interviews, and market analysis and conduct user behavior research through observation and interviews, to define the target users through the establishment of personas.
After determining the design direction, I'll make prototypes for testing and iteration for its form, materials, and internal protective structures to ensure that styling form and function are compatible.
Considering the time constraints, the final presentation will feature a partially styled yet fully functional model with other more effective approaches as a display for the fashion outlook, which would include sketches, renderings, and potentially an AR filter, if feasible, to effectively communicate the design solution's essence.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	18 Mar,2024
Mid-term evaluation	20 May 2024
Green light meeting	29 Jul 2024
Graduation ceremony	19 Aug 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

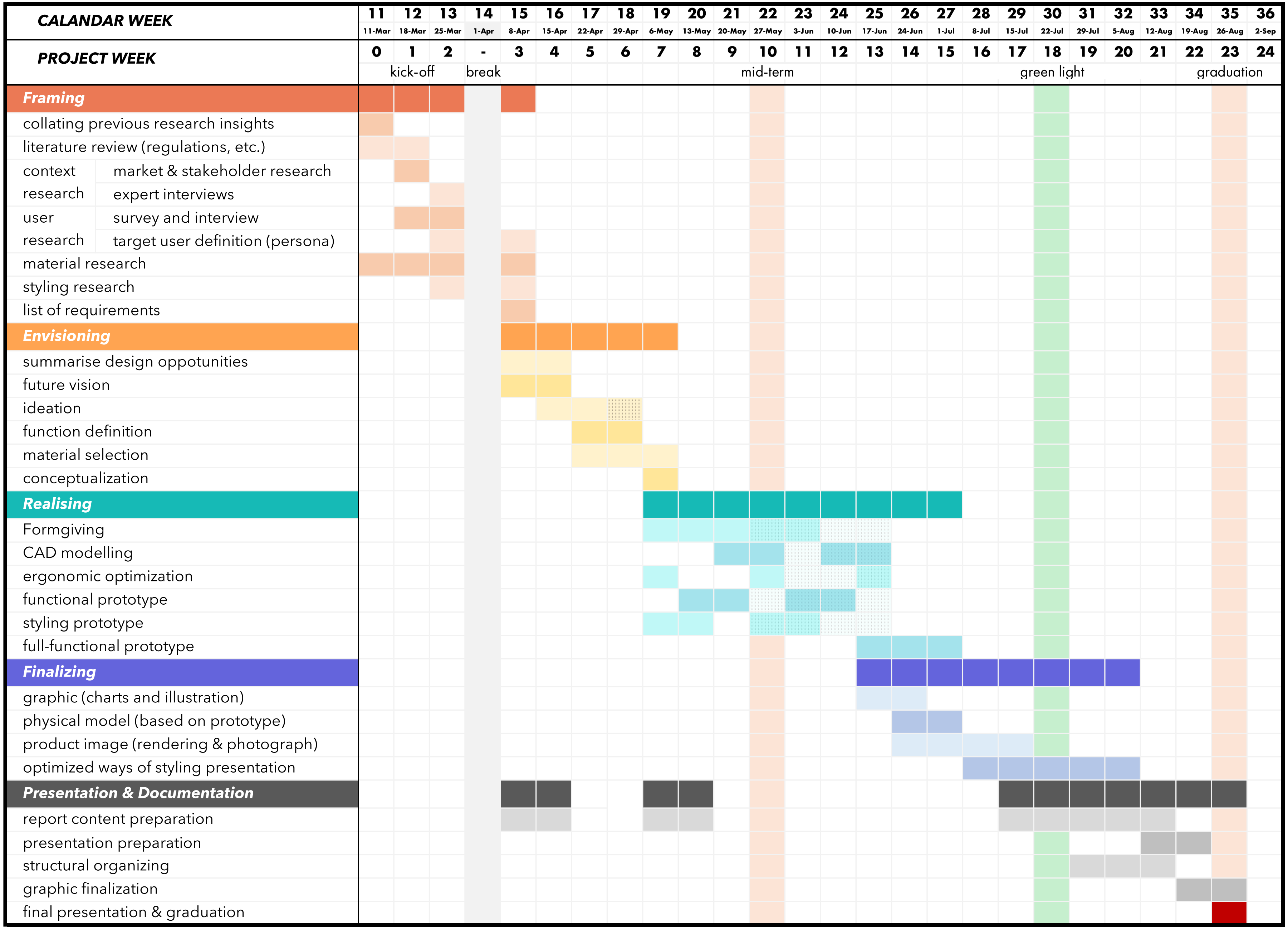
Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I have always been fascinated by research areas such as wearable devices and sports rehabilitation, which motivated me to enroll in the Medisign program. Through projects like the AED project and my prior bachelor's experience, I have gained valuable project insights that have enhanced my skills and prepared me for interdisciplinary challenges. During my time at IPD master, I have been expanding my knowledge base, actively engaging in courses covering biomechanics, digital fabrication, and textiles and fabrics. This has fully prepared me for the upcoming helmet design challenge.

I view helmet design not only as a matter of injury protection or public health concern but also as a project that aligns with my personal research direction and interests. While fashion and soft materials have always been an attractive domain with full of curiosity for me, it remains unexplored territory. The fusion of functionality and experiential styling in helmet design intrigues me, serving as an ideal entry point for exploring fashion design. This intersection perfectly aligns with my aspiration to contribute meaningfully to innovative projects addressing both practical and aesthetic dimensions.


CALANDAR WEEK
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
11-Mar 18-Mar 25-Mar 1-Apr 8-Apr 15-Apr 22-Apr 29-Apr 6-May 13-May 20-May 27-May 3-Jun 10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug 26-Aug 2-Sep
PROJECT WEEK
0 1 2 - 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
kick-off
break
mid-term
green light
graduation
Framing
collating previous research insights
literature review (regulations, etc.)
context research
market & stakeholder research
expert interviews
user research
survey and interview
target user definition (persona)
material research
styling research
list of requirements
Envisioning
summarise design oppotunities
future vision
ideation
function definition
material selection
conceptualization
Realising
Formgiving
CAD modelling
ergonomic optimization
functional prototype
styling prototype
full-functional prototype
Finalizing
graphic (charts and illustration)
physical model (based on prototype)
product image (rendering & photograph)
optimized ways of styling presentation
Presentation & Documentation
report content preparation
presentation preparation
structural organizing
graphic finalization
final presentation & graduation

Informed consent

18th August 2024

Dear Participant,
You are being invited to participate in a research study of bicycle helmet development and promotion in the Netherland. This study is being done by Yifan Miao at Delft University of Technology with cooperation with Erasmus MC.

Research Purpose & Risks of Participating

The purpose of this research study is to observe user's habits and ergonomic adaptations of design prototypes and existing products on the market and target to develop and promote head protection gears using in the Netherlands. This study will take approximately 30 minutes to complete. The data will be used for development of bicycle helmet product which might (or might not) be used for academic publication. The study will start with a pre-questionnaire collect your user habits and consumption preferences relevant to riding. In the study, we will be asking you to try different head protection products including design prototypes, and there will be a short interview after that to collect your opinions to those products. Additionally, we will take written notes and photos during the study. There are no heightened risks during these studies.

Anonymize, Storage & Access of the Data
To the best of our ability your answers in this study will remain confidential. The collected data will be anonymized in such a way that the name and personal information of the participants can no longer be identified. The raw data will be stored in a secure project folder on the TU Delft server, which only can be accessed by the involved researchers. The data is managed according to the data management plan (DMP) of this experiment. In publication, only the following results will be published:

- Typical setups of the experiment;
- The statistical results of the age, nationality;
- The statistical results of the questionnaire;
- Photos of participants trying prototypes in the experiment setup (Photos without personal identify, e.g. any faces will be blurred);
- Anonymized quoted comments.

The data will NOT be shared and re-used by default. But the participants can voluntarily donate the data to the research team in TU Delft for being anonymously used in future research.

Risks of Participating & Withdrawal from the study
Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. If requested, the collected data regarding your participation will be destroyed.

For any questions regarding this research the following researcher can be contacted:
Yifan Miao

PLEASE TICK THE APPROPRIATE BOXES		Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION			
1	I have read and understood the study information dated 15/04/2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2	I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3	I understand that taking part in the study involves: • Recording my basic information including age, gender • Filling in a pre and post questionnaires after each activity • Try different kinds of helmet products and design prototypes. • Photos and written notes of this study will be taken, and personal identifiers such as face will be blurred during interviews and observations.	☐	☐
4	I understand that the study will take approximately 30 minutes.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)			
5	I understand that taking part in the study involves no heightened risks.	☐	☐
6	I understand that taking part in the study also involves collecting specific personally identifiable information (PII) [age, nationality/ethnicity, photos, written notes] and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed.	☐	☐
7	I understand that some of this PIRD is considered as sensitive data within GDPR legislation.	☐	☐
8	I understand that the following steps will be taken to minimise the threat of a data breach and protect my identity in the event of such a breach. The published data will be not traceable to each individual (e.g. anonymizing all data collected, blurring faces out of photos, anonymizing discussion quotes, statistically processing measured data, etc.) and the shared data will be done in a secure server.	☐	☐
9	I understand that personal information collected about me that can identify me, such as my name will not be shared beyond the study team.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION			
10	12. I understand that after the research study the anonymized information I provide will be used for reports in relation to the development of bike helmet and might (or might not be) used for academic publication	☐	☐
11	I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE			
12	I give permission for the anonymized data that I provide to be archived in the TU Delft repository so it can be re-used for future research and learning	☐	☐
13	I understand that access to this repository is shared with Erasmus MC.	☐	☐

SIGNATURES

____________________	____________________	________
Name of participant	Signature	Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Yifan Miao	____________________	________
Researcher name [printed]	Signature	Date