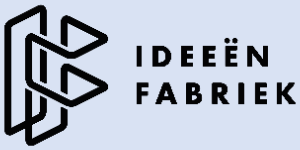
DESIGN OF A FRONT SEAT FOR THE BUDDY TANDEM TRICYCLE THROUGH USER EMPATHIZING

A conceptual design for a specific target user in a specific context of a new bicycle design.



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Tim Arts
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University of Twente
Faculty of Engineering Technology

Industrial Design Engineering
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Examination committee:
Prof.dr.ir. G.D.S. Ludden (chair)
Ir. W.F. Kets (supervisor)
Ir. M.C. Slot (external member)
Ing. J.P.M. Heeman-Thissen (company supervisor)

Client

Van Raam

Guldenweg 23

7051 HT, Varsseveld

info@vanraam.com

Educational Institution

University of Twente

Drienerlolaan 5

7522 NB, Enschede

info@utwente.nl

Examination on: 16th of September 2024

Abstract

This thesis investigates the design of a front seat for the "Buddy" tandem tricycle, focusing on key features that enhance comfort and confidence for elderly passengers (65+) with changing medical conditions. The research aims to identify the functionalities needed to effectively meet the needs of the target group and to understand why existing seat designs, such as those from HP Velotechnik or VanRaam, are not viable solutions currently. The subgoal is to create a prototype integrating these functionalities for further development by VanRaam. The design brief addresses the question: “What are the essential features for the front seat of the ‘Buddy’ tandem tricycle to maximize passenger comfort, confidence, and aesthetics?”

Using the Design Thinking approach, this study involves iterative low-fidelity prototyping and user-centred design. Key findings indicate that a functional seating angle of 123 degrees, side bolsters, lumbar support and adaptable ergonomics are crucial for meeting the target group’s needs. The iterative process reveals that both ergonomic and perceived comfort and stability are critical. Furthermore, aesthetic design plays a vital role in perceived comfort and stability as well.

While the study demonstrates the value of user-centred design, it also notes limitations due to the time-intensive nature of the iterative process. Future research should include materials, business case, bicycle access and durability tests.

Keywords: Design Thinking method, Ergonomics, Comfort, Stability, Aesthetics, User emphasizing, Prototyping

Preface

My study time is coming to an end with this master's thesis for the Industrial Design Engineering program, specializing in Human-Technology Relations. When searching for a master's assignment, I was contacted by Jolien to come by and have a conversation about the opportunities, and here we are. After about nine months, I can now present my master's thesis, "Design of a Front Seat for the Buddy Tandem Tricycle." The aim of this thesis was to provide the Ideeënfabriek and Van Raam with insights into which functionalities are essential for a front seat when empathizing with the target user is the primary research method. This was a meaningful design challenge that connected my master's program, "Human-Technology Relations," with the real world. My personal goal was to contribute something valuable to the company, learn how to undertake a design process in practice, and eventually obtain my master's degree in Industrial Design Engineering at the University of Twente.

The process provided me with the opportunity to put my coursework from the master's program into practice. Conceptual design methods aided me in realizing the importance of empathizing with a target user and understanding its limitations. The graphic language of products helped me in the aesthetic design of the seat, and Embodied Interaction was useful for empathizing and iterating during the design process. Interestingly, the bachelor's course, Design for Specific Users, also helped me a lot during this project.

Throughout the research and iterative design process, I took the opportunity to talk to numerous target users, experts, caregivers, and stakeholders—something that makes the design process enjoyable for me personally. I want to express my gratitude for the time and enthusiasm with which everyone participated. These people are the backbone of this thesis, and without them, I would have probably ended up designing a seat for myself. Their input will take the final result to the next level.

Finally, I would like to thank everyone working at Ideeënfabriek: Pau, Ruben, Iggy, Mitchel, Patrick, and Luc, as well as my company supervisor Jolien Heeman, for the critical feedback and questions when I needed them most. They helped me remain critical of my own work and supported me through various challenges. Last but not least, I would like to thank my UT supervisor, Wouter Kets, for his feedback, time, and positive attitude throughout the entire process. His guidance helped me maintain confidence and motivation when challenges arose. It's safe to say that without him, this thesis would not have been completed in the time it took.

I hope that this thesis brings joy to the reader.

Tim Arts
Enschede, August 23, 2024

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Chapter 1: Introduction

This chapter entails the initiation of the project by looking at the company, VanRaam, the client, Ideeënfabriek, and the previous research done on the “Buddy” bicycle, the bicycle of interest for this thesis. This provides a structured introduction into the topic of the thesis which will be further defined in the design brief section. A look into why the seat of the Buddy needs to be addressed based on research hypotheses formed by Ideeënfabriek, the client of the thesis, is provided. These hypotheses entail the target group of the Buddy, the newly to be designed bicycle, the ergonomics of the seat which are off and possible stigmatization and perceived safety issues. This will form the backbone of the research and development process described in this thesis.

1

1. VanRaam

In this chapter, a brief introduction into the company is given. VanRaam is a manufacturer of modified bicycles that specialises in the manufacturing of tricycles, mobility scooter bicycles, low entrance bicycles, duo bicycles, tandems, wheelchair bicycles and transport bicycles (figure 1).

Figure 1: VanRaam bicycle line-up

The core values of VanRaam consist of contributing to the integration and inclusion of impaired people within society by providing them with sustainable and contemporary mobility solutions. This is also embedded in their mission and vision (Van Raam, 2024).

VanRaam operates in a niche market compared to conventional bicycle manufacturers, offering bicycles at a higher retail price. Sales figures for VanRaam in 2023 varied significantly, as shown in the table below:

Bicycle	**Sales numbers quantity (2023)**
VanRaam Fun2Go	+/- 2200
VanRaam Twinny Plus	146
VanRaam Opair	309

Figure 2: Sales figures of certain VanRaam bicycles

These specific bicycles are highlighted because the assumption within Ideeënfabriek is that the Buddy bicycle has the potential to:

1. Replace the Twinny Plus bicycle.
2. Serve as an alternative to the Fun2Go for individuals who prefer active cycling over socializing when cycling together.
3. Provide an alternative to the Opair bicycle for individuals with challenges who want to actively engage in the cycling experience rather than just being seated.

Additionally, the Buddy bicycle has the potential to attract new customers to VanRaam, as there is no similar concept offered by competitors, potentially filling a gap in VanRaam's product lineup. This is visualised in the section “Target group”.

Projecting annual sales for the Buddy bicycle is challenging, but within Ideeënfabriek, a figure of 300 units per year is considered realistic. This estimate will be useful in later stages of the project when design for manufacturing becomes a focus. Taking this sales figure into account will help ensure that the design is scalable and feasible for production.

2. Ideeënfabriek

In addition to VanRaam, the client for this thesis is "Ideeënfabriek," the pre-development research and development division of VanRaam bicycles. Ideeënfabriek has extensive experience in developing prototypes in collaboration with students. These prototypes play a crucial role in VanRaam's strategy to innovate and stay competitive. At Ideeënfabriek, prototypes are always tested with the target group. Once a concept is validated and deemed ready for production and market introduction, it is handed over to VanRaam's R&D department for materialization and launch. It's essential to consider these themes from the project's initiation

Buddy Bicycle

The “Buddy” bicycle has been in development for several years now. During this time, several students have worked on different topics in order to establish the bicycle. The bicycle started its life as an alternative for a competitor bicycle named the “Hase Pino”. However, this is a bicycle tandem and therefore lacks stability. The choice was therefore made early on to design a tricycle. Within the product range of VanRaam there was also a need for a bicycle that gives the impaired person a sense of autonomy and sportiness/activeness. This is when the idea of the “Buddy” bicycle was first established. The first research that was done by a student was the wheel lay-out. It was found that a tricycle with two smaller wheels at the front was the preferred lay-out because of stability, sportiness and less stigma (Van Dort, 2023).

Figure 3: Hase Pino bicycle

Within Ideeënfabriek, several other students have already worked on the Biddy bicycle, or on related products. From these projects, some requirements and assumptions can be taken to be used for the design of the seat. These are the following:

- The target group is of age 65+ and has a changing medial condition
- The bicycle has to give a sense of safety to the user
- The first experience with the bicycle is very important
- The straighter the seating angle, the less sporty the bicycle is experienced
- Seating angle should be 45 degrees and the centre of mass of the front rider should be 7,5 centimetres from the front axle inward for the bicycle to remain stable.
- The seat has to have a backrest
- The bicycle should not be difficult to get in or out from
- The seat should have adaptable ergonomics
- The bicycle should give the user a sense of autonomy
- Ergonomics should be suitable for p5-p95 of the decided population
- Hip angle of rider should be at least 95 degrees
- Lumbar support should be available based on dimensions of population

Some of these assumptions are hard requirements that can be used as the foundations for the ergonomics of the seat design. It has to be seen whether all these assumptions are applicable to this specific project. However, it does provide for an insightful starting point for the design of the seat for the “Buddy” tricycle.

Secondly, in the month before my arrival at Ideeënfabriek, my daily supervisor did some end user test with the “Buddy” prototype with the current, competitor seat fitted at a functional seating angle of 112-116 degrees, with a sitting area angle of 12 -14 degrees.

The participants find the seating position on the bicycle uncomfortable, especially the posture required for pedalling feels awkward. The test was done at home with intended end users, they got the opportunity to cycle with the “Buddy” (Heeman, 2023). The main takeaways are listed below.

- Sitting in front gives a sense of autonomy and is preferred over sitting in the back, which feels passive.
- The feeling of stability and safety is highly positive, especially compared to traditional two-wheel tandems.
- The pedalling position is far from ideal as some find it challenging to exert enough force on the pedals.
- Sportier users, particularly those with disabilities or injuries, tend to prefer the "Buddy" over the "Fun2Go" bicycle.
- The current bicycle design might not be suitable for smaller adults and children due to the distance from the pedals and seat.
- Larger individuals, over 100 kg, may also find the cycling experience uncomfortable due to their size.
- The "Buddy" bicycle might be more suitable for individuals with mild mental or physical disabilities, offering a more active cycling experience with features like individual gearing and braking.

Figure 4: The Buddy prototype as it currently stands with the HP Velotechnik seat

Chapter 2: Design Brief

In this chapter, the design brief for the initial research phase will be established. It initiates the assignment by looking into assumptions from previous research at Ideeënfabriek from which the initial research questions are shaped. Also the scope will be defined in this chapter.

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1. The Assignment

As mentioned briefly in the previous section, the current seat fitted onto the prototype is found to be uncomfortable when testing with target users. Thus, this problem needs to be tackled. Next to this, the assumption within the Ideeënfabriek exists that the requirements for the seat of the "Buddy" differ significantly to the requirements for the seat of for instance, the Fun2Go and the EasyRider3 (figure 5). This has to do with the core values that the bicycle aspires to fulfil in order to be an addition to the current line-up.

Figure 5: VanRaam EasyRider3 seat and Fun2Go seat

The following assumptions need to be tested:

1. The ergonomics of the seat are not correct, as many test subjects were sitting awkwardly in the chair. The backrest angle appears to be the main issue.
2. The Buddy is a more sporty or active bicycle, so the seats need to meet different requirements.
3. Because the passengers' feet are the furthest point forward, significantly in front of the front axle, there might be a perception that the passenger could touch the ground when going over speedbumps or pavements. Therefore, it might be necessary to add some kind of protection to the bicycle for perceived safety.
4. The bicycle's length and size might create a stigma. Consequently, the aesthetics of the seat could either counteract or contribute to this stigma, affecting the overall appearance of the bicycle.
5. The target audience is defined as 65+ with changing medical conditions, however physically or mentally challenged persons might also be included as well as people recovering from surgery that are under treatment at an occupational therapist.

These assumptions are the initiation of the project. In the next section, research questions based on these assumptions will be established.

2. Research Questions

The main research question of the master thesis that will be performed at "Ideeënfabriek" is formulated as follows:

''What is the ideal cycling experience regarding the seat for the target audience sitting in the front seat of the ''Buddy'' tandem tricycle?''

The main question entails several aspects that are not yet defined. These aspects can be defined through the answering of sub questions in specific categories.

In order to answer the main question, several sub questions will be answered. In these sub questions the emphasis will lie on the human product interaction among others. The sub questions have been established in the initial phase of the project and are based on assumptions around the Buddy bicycle project from previous research conducted at Ideeënfabriek. The following sub questions have been established:

1. How is the target group defined?
2. What are the most important needs and wishes for the target group?
3. Wat are the ideal ergonomics for the seat with the target group in mind?
4. Does perceived safety affect the passenger of the Buddy and can this be influenced by the design of the front seat?
5. Is the Buddy stigmatising and can this be solved through design of the front seat?

3. Approach and Planning

In this section, the approach of this thesis will be elaborated. In order to add some context into the depth of this master thesis, NASA's framework for technology readiness will be used (figure 6) (Sauser et al., 2006). This framework is used because it provides a clear point of view to everyone in the project on the state of progress of the development and the necessary next steps that need to be taken in order to move forward in the direction of production. Initially, this project started at TRL level 0 where only basic observations have been made on the seating position issues of the Buddy bicycle. The aim is to reach technology level four with this project; thus getting to a partial scale model or prototype. In order to reach this, the following approach will be adopted.

Figure 6: NASA framework for Technology Readiness Level (TRL)

The main approach for this thesis is somewhat different to the most common approach in product design. Oftentimes, the double-diamond design method is referred to as being the most effective approach to product design (Design Council, 2005). However, at Ideeënfabriek it is desired to have a low fidelity prototype early on in the design. Therefore, the design thinking model will be the methodological approach. The design thinking approach puts the end user central in its approach in order to solve a problem or design challenge. The design thinking approach (Chasanidou et al., 2015) generally consists of five phases: Empathise, define, ideate, prototype and test. For this thesis these steps will also be followed. There is however a slight alteration to be made in terms of the report structure. The design thinking method is visualised in figure 7 in blue; the design & development phase entails the ideate, prototype and test cycle that will be followed multiple times. For the sake of this thesis, an introduction, design brief and final design & conclusions have been added.

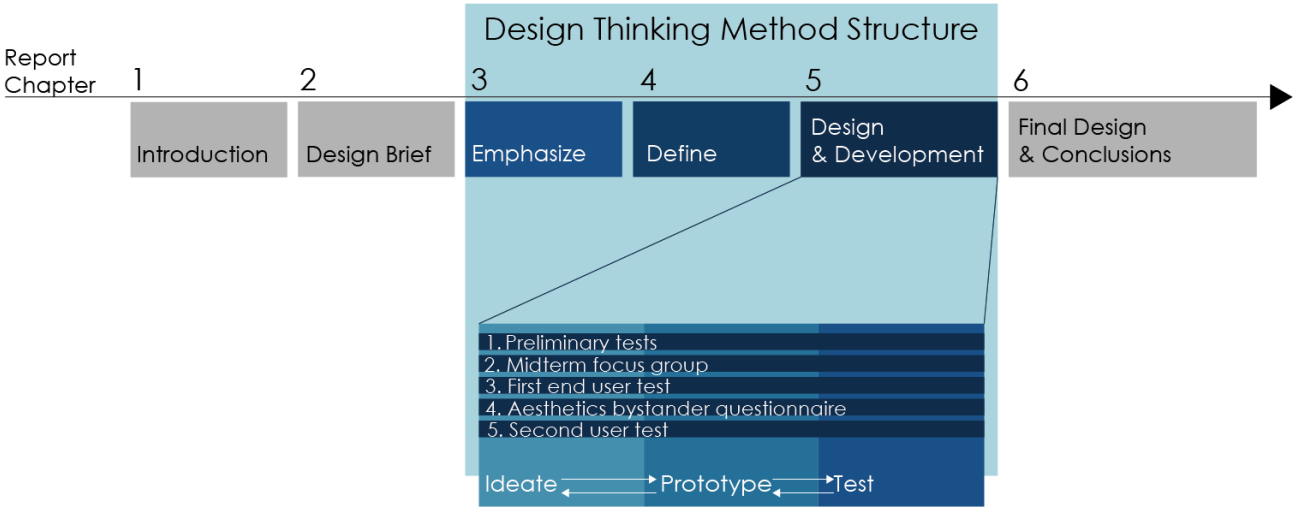


Figure 7: Approach for this thesis

Inherently, design thinking is an iterative process. However, in order to put emphasis on this, the key feature of the "designing better business" approach; understanding the point of view at any stage of the design process is imperative, therefore, the design and development phase is a non-linear process. Below, the three main parts will be elaborated.

Empathize
The Empathize phase consists of two parts, literature research and user interviews. The literature research has the purpose to establish a clear point of view for the formulation of the hypotheses that will be of use in the design process. The research will be done through a formulation of an initial main research question and corresponding sub questions. The research will be focussed on existing project knowledge and specific information regarding tandem seat design. The objective of the research is to clarify the target group, gather information about the market, ergonomics, stigma and safety, to eventually answer the preliminary research questions.

Define
The second part of the research phase is called define. In this phase the targeted end users are involved in the design process through direct engagement in the form of interviews to understand their priorities and to empathize with their lives. The focus will be on identifying the most relevant subject for the design of the seat of the "Buddy" tandem bicycle. The subjects that will be of interest come from literature research and are safety, ergonomics and stigma. The objective is to find out which of these three subjects will become the primary design theme to guide subsequent phases of the design process. This phase is done when a clear framework is established for the design and development phase as well as a clear formulation of the design challenge and corresponding to be verified assumptions.

Design and Development
The next phase of the project will be the design process. The design process is visualised in figure 7 and is based on the "design thinking" method. The design process will commence by using the outcomes of the empathize and define phase. The aim is to solve the design challenge that has been formulated. This will be done through an iterative process that includes preliminary tests, midterm focus group, aesthetics questionnaire, and two target user tests. Each of these subphases will consist of a ideate, prototype and test phase in order to test and cover as many topics as possible.

Conclusions and Recommendations
The finalization of this thesis will be drawing up conclusions and offer recommendations based on the prototype, tests and the general project outcome. The target is to provide finalised design guidelines and a "final" conceptual design integrating all the findings from this thesis that will help Ideeënfabriek and VanRaam moving forward with this project into future endeavours.

Methodological framework

The "Design better business" (Pijl et al., 2016) approach of continuous awareness throughout the cycle of a design process that leads to an everchanging design perspective will be imperative during this design phase. The reason for this is that It is easy to get lost in your own thoughts, this method can then aid you in being critical and ask the question: "why do this, and why do this now?" The design better business method does have overlap with the Design thinking method that is commonly used in product design; as they both incorporate an iterative design cycle with constant enhancement of the understanding of the problem and design vision. For this thesis, the design thinking method will be the main framework as it puts the end user central in the development of a product (Chasanidou et al., 2015). Next to this, for each section in this thesis, the MoSCoW method of design criteria prioritization (Hudaib et al., 2018).will be used in order to structure the outcomes of each section. These design criteria will be critically reviewed in every section and chapter of this thesis before being shaped into requirements in the final section.

Moscow method

The Moscow method will be used in this thesis in order to establish the priority of certain requirements based on the target user needs. The design thinking method allows for iteration based on user input. This user input however needs to be structured in order to make sense of all the data obtained from these interactions. The Moscow method is chose because of its ease of use (Hudaib et al., 2018) and ease of readability for everyone involved in the process. Furthermore, because this thesis is a preliminary research into the needs and wishes for the seat from a user perspective, specific measurable requirements will only limit development early on in the design process, hence these will only be of use in the final design section of the thesis. The Moscow method provides a tool that ensures confidence from the user, consistency, low difficulty and low effort, making it a suitable tool to establish the most important functionalities from the user involvement (Khan et al., 2015). The prioritizing will be done through the answering of the following questions: Must: "Which criteria are critical to success?", should: "Which criteria have high impact on success but are not critical?" could: "Which criteria have low impact on success?" won't: "Which criteria are beyond scope and for later development?"

Flexibility and Iteration

In figure 8, a broad overview of the approach is given with all the phases. This timeline does not show that there is time to spare. However, time planning is an iterative process thus this can be subject to change. This timeline gives a broad overview of the steps needed to be taken in order to integrate the design thinking method into the process. At this point in time it is rather difficult to make a proper estimation of how time-consuming every step will be, what is clear however is that the iterative design and development will be the core of this thesis and will therefore take up close to 20 weeks of the timeline.

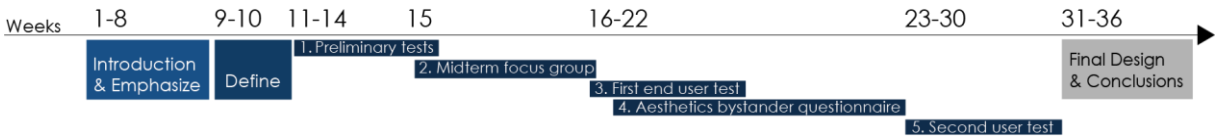


Figure 8: Broad overview of planning for this thesis

4. Scope

The primary focus of this thesis is the initial design phase of a prototype seat for the “Buddy” bicycle for the passenger. The scope will be defined by addressing the main and sub-questions, and this section aims to further elaborate on the scope by delineating the included and excluded elements of the study.

The initial part of this thesis will delve into the target user, how are they define and what are their specific needs and wishes for the to be designed seat. This research phase will include the following topics:

- Target group definition
- Stigma and Appearance
- Safety
- Ergonomics

Afterwards, the design phase will commence, following the design thinking method with constant iteration, prototyping and testing. Excluded from this phase is material iteration, prototyping and testing, the focus initially is to explore which functionalities are an absolute must have for success based on user involvement. Also, design for manufacturing will not be done in this part, as this will be done much further on in the development of the seat. This part of the thesis aims primarily to test hypotheses from the research and emphasis phase with target users to see which functionalities are a necessity to effectively cater for the target group.

The final part of the thesis will provide a conclusion which addresses the design requirements based on the research performed for the eventual design for the passenger. Included in these requirements are the functionalities that have been tested during the design phase as well as requirements that have been set in earlier research. Also, a final representation of the ideal seat with aesthetics will be provided together with a ballpark cost estimation that will aid the concept choice. What will not be provided are the following elements: Material recommendations, design for manufacturability, Finite element method force calculations and a proper business case with cost estimation, as this is too preliminary.

Chapter 3: Empathize

In this chapter, the point of view of the current situation with respect to the project will be explored, defined and understood. This will act as the starting point for this master thesis. Firstly, the target group will be defined. At the end of this chapter a set of assumptions will be defined that will be the guidelines for the initial ideation and prototyping. The initial problem statement is defined and researched through literature research. These early problems are based on previous research at Ideeënfabriek and through some assumptions that are made. In order to challenge these assumptions, a literature study on ergonomics, stigma and safety will be done. Based on this, the initial assumptions will be analysed to see whether they are still relevant and if the problem needs to be reframed. In this phase, the actual focus and scope of the research will be defined. This section will then be concluded with a list of design criteria from which the design process can be initiated.

1. Literature Research

Target Group Analysis

Initially, the target audience for the "Buddy" bicycle was defined as elderly people aged 65+ with changing medical conditions by Ideeënfabriek. An example of this is Parkinsons disease. This illness can be divided into stages. For a full breakdown, see Appendix C, the target group for this specific bicycle would be people suffering from Parkinson's stage three and four where they become more and more dependent. However, after discussions and testing, the scope expanded to include:

1. Elderly recovering from mobility-impairing injuries (e.g., brain injury, hip replacement).
2. Younger individuals with physical or mental challenges (e.g., Down syndrome).

To better understand how to address these diverse needs, a Venn diagram was created. This diagram highlights both the overlapping and distinct characteristics among the three groups. It serves as a visual tool to identify common features that can guide the design process while prioritizing the primary target group.

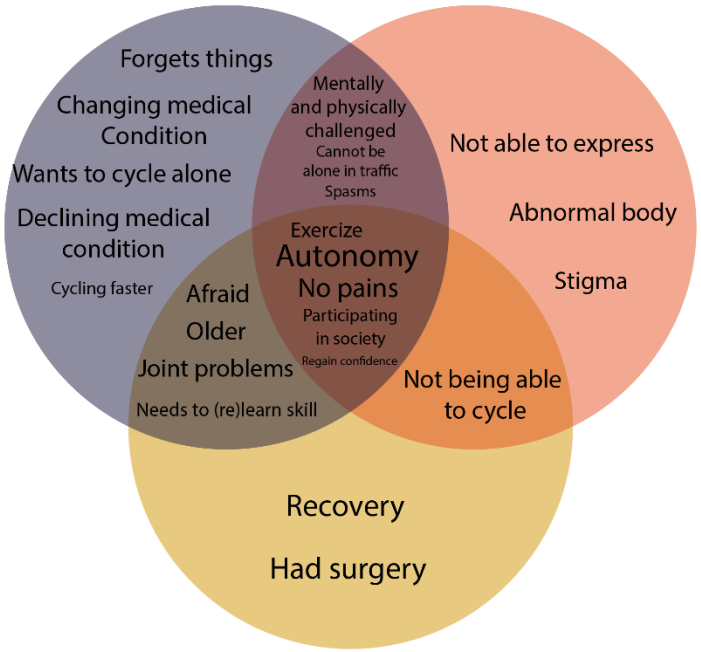


Figure 9: VENN-diagram of the three potential target groups, Blue is 65+ changing medical condition, Red is younger challenged people. Yellow is People who are recovering from surgery

The Venn diagram reveals several shared needs across the groups, such as stability, ease of use, and confidence while cycling. These commonalities suggest that by focusing on the 65+ group, the design can also meet many needs of the other two groups. For instance, designing for stability and safety not only supports elderly users but also benefits those with Down syndrome or those recovering from injuries.

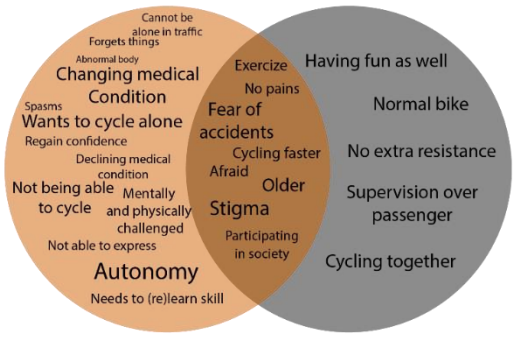


Figure 10: VENN-diagram of supervisor-passenger needs

However, distinct needs are also evident:

- The 65+ group often requires enhanced ergonomic adjustments due to reduced mobility.
- Younger individuals with Down

syndrome may benefit from simplified controls or visual cues.
- Those recovering from injuries need temporary support features that can adapt as they heal.

Market analysis shows that the 65+ group is the largest potential market. In the Netherlands, nearly 2.8 million people fall within this age range, expected to increase to almost 5 million within ten years (CBS Ouderen, 2024). Around 210,000 of these individuals suffer from dementia (154,000 people) or Parkinson's (53,000 people) (Ministery of Welfare and Environment, 2018)
The secondary groups include 13,300 people with Down syndrome (Stichting Downsyndroom, 2024) and those recovering from strokes (521,500 people) or hip arthritis (359,000 people, with 24,000 hip replacements annually) (Volksgezondheid En Zorg, 2024); (Hipreplacement, 2024). Additionally, 811 occupational therapy practices represent a market for caregivers purchasing the bicycle (Dutch cargiving autorothy, 2024)

Given the significant overlap of needs, focusing on the 65+ group allows the design to address the broadest range of users. The Venn diagram analysis supports prioritizing this group while still considering the needs of secondary groups without compromising overall functionality. This leads to these design criteria. The first is critical to success where as the other has low impact on success of the seat.

Design Criteria

The seat shall cater to the needs and wishes of elderly with changing medical conditions

The design of the front seat shall include people with down syndrome and people recovering from surgery

Stigma and Appearance

“Many well meaning interventions fail; not because they are not helpful, but because they are not appealing. To improve day-to-day hardship, designers must do what clinical solutions do not: treat those in need as regular customers, whose emotions drive decisions” (Vaes et al., 2014). In other words, for the design of the seat it is imperative to get involved with the target group in order to tackle product related stigma. This is critical for addressing product-related stigma, as empathized by Keates and Clarkson (2002), who argue that inclusive, stigma-free design should be a core activity within the design process (Keates & Clarkson, 2002). Kouprie and Visser also illustrate this necessity (Figure 11).

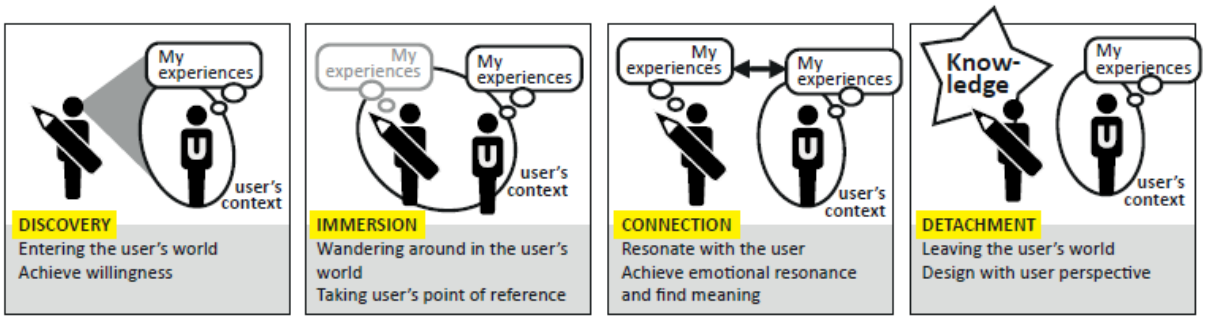


Figure 11: User empathizing (Kouprie & Visser, 2011)

Stigma encompasses various definitions, including "an often visible perceived mark or spot," "belonging to an individual or group," "situated in a particular social context," and "something that violates standards and/or induces aversive emotions in others" (Vaes et al., 2014). The Cambridge Dictionary (2023) defines stigma as "a strong feeling of disapproval that most people in a society have about something." Stigma usually manifests in bystanders rather than users, especially for those using medical or assistive devices due to physical or mental challenges (Vaes et al., 2014). Such devices are often overlooked by designers, who focus primarily on technology, functionality, and basic usability, neglecting the experiential aspect, which could otherwise provide emotional benefits such as empowerment, autonomy, and a sense of safety (Vaes et al., 2014).

There is however another way of looking at stigma: The "Product Appraisal Method for Stigma" (PAMS) suggests that as long as the user's goals are met by the product, the user may minimize the impact of stigma, encapsulated under "consequences of product use (meaning)" in the PAMS model. The user's goals reflect their intentions and desired outcomes (Vaes et al., 2014). Thus, designing to counteract stigma requires addressing other stakeholders as well, as they perceive stigma, whereas the user needs fulfilment outweighs stigma up to a limit, this limit is difficult to pinpoint without user empathizing. In the next section, the bicycle design will be reviewed in terms of stigma.

Appearance of the Bicycle

The Buddy bicycle's design includes three aspects that could contribute to stigma. Firstly, individuals who lack stability or confidence may avoid tricycles or recumbent bicycles due to associated stigmas (Hagemeister et al., 2018). Krause et al. (2013) note that people often assume tricycles have many disadvantages without having tried them (Krause et al., 2013). Cognitive dissonance plays a role, as individuals recognize that a tricycle could solve their mobility issues but hesitate to use one due to stigma. Acceptance of tricycles increases if they are perceived as non-senior products and marketed as "sporty" or "fun" (Krause et al., 2013).

Figure 12: VanRaam EasyRider3

An entrepreneur in the Netherlands with the company "Tworby" has observed a shift away from tricycle stigma due to safety concerns (Van Den Berg, 2023). This shift might be due to changing perceptions over time, but there is insufficient evidence to draw firm conclusions. For this thesis, it is assumed that the tricycle aspect of the Buddy bicycle is not the primary source of stigma as people seek for functionalities that cater to their needs rather than holding themselves back by the visual appearance of a product.

Secondly, the recumbent position of the front seat can also lead to stigma. Recumbent bicycles are often perceived as technical and lack status, associated with being for "challenged" individuals. Interviews with bicycle fitters at Van Raam revealed a preference for upright seating, aligning with findings that a recumbent position is seen as vulnerable (Daams, 1999). However, the Buddy is mainly a tandem, not a recumbent bicycle, so the front seat's position is not considered the most stigmatizing aspect.

Finally, the size of the Buddy bicycle, being a tandem tricycle, raises the question of stigma associated with tandem bicycles. Vaes et al. argue that tandem bicycles empathize the impairment of one rider, leading to societal and bystander perceptions of dependency. Despite some awareness that tandems can break down barriers (Buletin Mutiara, 2023), this awareness is not widespread. Thus, the tandem aspect might be the most stigmatizing feature because it highlights the passenger's inability to cycle independently.

These three factors cannot be considered in isolation, as the Buddy integrates all three into a new concept. Therefore, assumptions based on isolated aspects may be misleading. Thus, target group interviews are essential to understand perceptions of stigma and the reasons behind them.

Non-Stigmatizing Design Toolbox

In order to initiate design to counteract stigma, Jacobsen (2010) has identified three strategies:

1. Disguising stigmatizing features.
2. Redirecting attention from stigmatizing features to other aspects.
3. Transforming stigmatizing features into elements that convey prestige or status.

These guidelines can help minimize stigma in the Buddy bicycle's design, particularly the front seat. Vaes (2014) presents a non-stigmatizing design toolkit, emphasizing the need to address product, user, and culture interventions. Relevant product interventions include making the seat an eye-catching object to distract from its assistive function. User interventions aim to empower individuals, enhancing their abilities, while culture interventions focus on changing public perceptions. Incorporating these strategies in both design and marketing is essential for success and can also aid to counteract perceived stigma in the design of the Buddy tandem bicycle.

Gestalt

Designing to reduce stigmatization involves considering the "gestalt" of an artifact, encompassing colour, material, surface structure, taste, sound, appearance, and overall function (Demirbilek & Sener, 2003). Gestalt can be divided into four semantic functions (Monö, 1997). Specifically in the context of the “Buddy”, this implies the following.

- **To describe**: defining the product's purpose and function.
- **To express**: conveying product properties such as autonomy, stability, sportiness, and quality.
- **To signal**: prompting specific user reactions, like caution, comfort or safety.
- **To identify**: linking the product to its purpose, brand, and system. For this, a Brand identity prism can be helpful.

For the Buddy's front seat, the gestalt should describe the seat's function for the passenger, express autonomy, stability, activeness, and quality, and avoid signalling impairment. It should also align with the VanRaam brand.

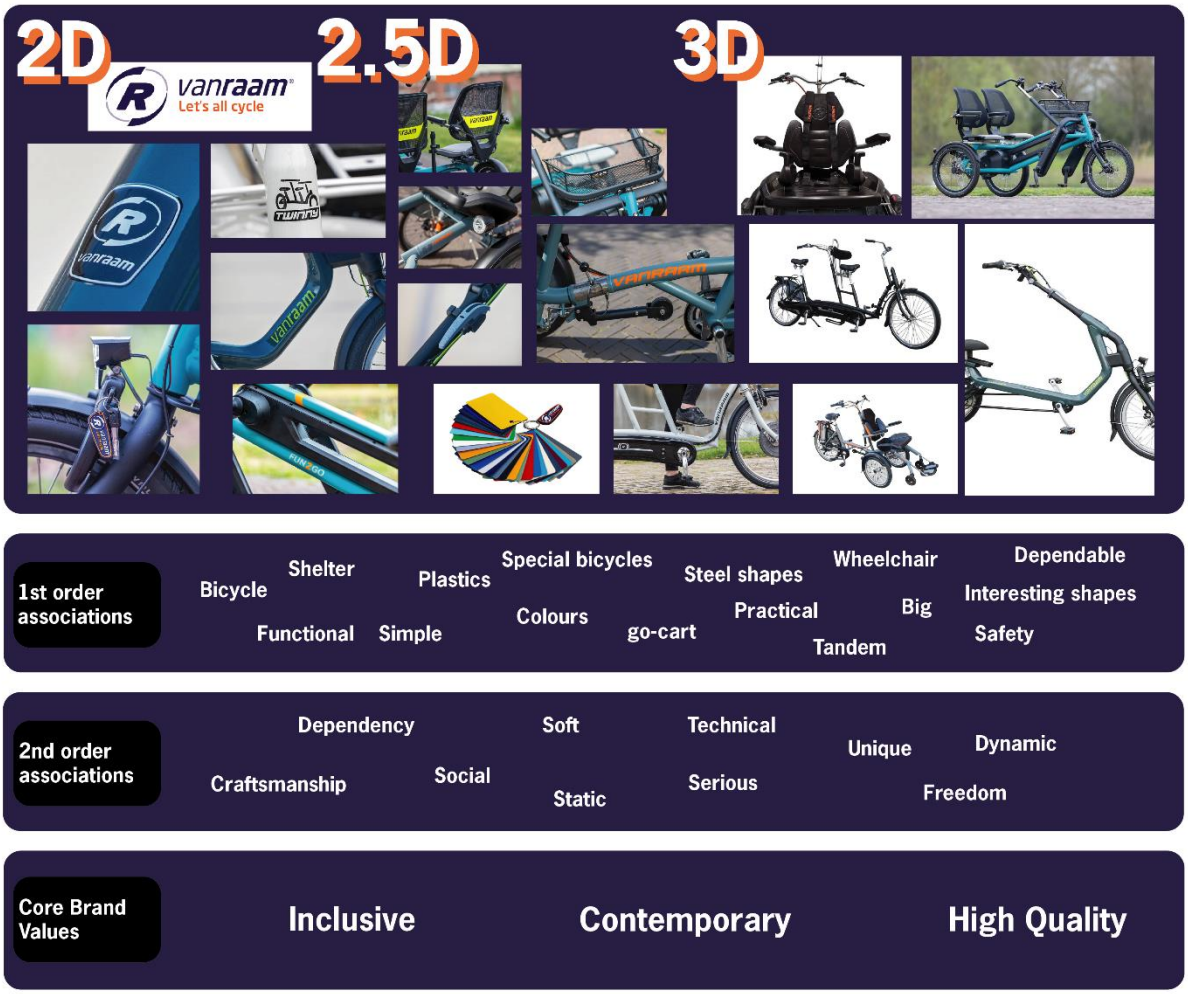


Figure 13: Brand Translation Prism for VanRaam

Gestalt is commonly used in graphic design but applies to 2D and 2.5D product design (Mulder, 2023) Understanding visual language through a brand translation prism (Figure 13) helps ensure the design fits the VanRaam brand without isolating any single aspect. if a design fits with the VanRaam brand it can be considered a bicycle with a particular design that doesn't necessarily indicate impairment.

Modern rhetoric (Mulder, 2023) aids in explaining why specific designs or visualizations are persuasive, using ethos, pathos, and logos. For the Buddy bicycle:

- Ethos: The seat is ergonomically designed for specific human anatomies.
- Pathos: The seat's appearance matches user expectations, needs, and wishes.
- Logos: Literature supports the seat's comfort and stability.

Pathos, focusing on visual language, is crucial. Colour theory and visual balance contribute to stability and comfort. Red signifies activity, blue denotes premium quality and self-confidence, green implies safety and relaxation, and black evokes a premium feel ((Aslam, 2006; Hiler, 1946; Yu et al., 2021). Visual balance, whether symmetrical or asymmetrical, enhances stability (Lundgren, 2020).

MAYA Principle

The MAYA (Most Advanced Yet Acceptable) principle balances typicality and novelty in product design. This principle explains why consumers prefer a mix of familiar and new elements, influencing market success (Ceballos et al., 2019). A study on apparel design supports a negative correlation between novelty and typicality (Hekkert et al., 2003). For the Buddy's seat, involving target users and bystanders in the design process ensures the right balance between tradition and innovation. This can in turn be linked to the stigma section; where an appealing and familiar aesthetic design can aid in minimising product related stigma.

Conclusion

To eliminate stigma in the design of a new seat for the Buddy bicycle, the following points are crucial:

Design Criteria

- The seat design shall avoid a reclining position, as recumbent bicycles have a negative image and are not preferred for non-stigmatizing design.
- The seat shall be designed in a way that disguises, redirects attention from, or transforms stigmatizing features, addressing cultural and user-related stigma.
- The seat shall incorporate Gestalt theory principles, focusing on stability, comfort, activeness, and visual balance.
- The design shall follow the MAYA (Most Advanced Yet Acceptable) principle to ensure aesthetic appeal and user acceptance.

2. Safety

At Ideeënfabriek, there is concern that the exposed position of the passenger on the "Buddy" bicycle could be problematic. Therefore, the focus is on perceived safety for the passenger, which is crucial to the bicycle's design.

Perceived Safety

For the passenger to feel safe, perceived safety is key. This concept involves a rider's sense of security while using the bicycle. Perceived safety is often defined as the "degree to which individuals anticipate potential hazards in traffic" (Meir & Dagan, 2020) or as "how safe users feel while using a system" (Jahanshahi et al., 2020). For this thesis, it is defined as "the degree to which individuals feel safe in traffic while riding the bicycle, anticipating minimal accidents."

One way to measure perceived safety is by evaluating accident rates among the target group. However, since no specific research has been done on this bicycle, alternative methods are needed. Testing the bicycle with the target group and familiarizing them with the design has been shown to increase confidence, thereby enhancing perceived safety (Meerstra, 2021). Interestingly, for tricycles, perceived safety is generally high because users often feel secure while cycling, though this might be due to overconfidence rather than actual safety (Hagemeister & Tegen-Klebingat, n.d.). Therefore, boosting user confidence is central to improving perceived safety.

Conversations with Van Raam fitters and the owner of ACE Bicycle Technique provided useful insights. For instance, many recumbent cyclists order headrests, not for comfort, but because they feel it offers protection in case of a rear impact, even though it doesn't actually help in an accident. Similarly, some users prefer armrests because they give the feeling of being "inside" a vehicle, providing psychological comfort. These preferences highlight the importance of perceived safety features, even if they don't directly contribute to actual safety.

The asymmetric design of the Buddy bicycle also impacts perceived safety. During tests, one user mentioned feeling safer because the passenger couldn't exit into traffic from the left side, providing a sense of control and trust. This design aspect, along with the distance of the passenger's legs from the front axle, which could increase insecurity in a crash, needs further investigation to determine its impact on perceived safety. In summary, while perceived safety is difficult to quantify, it is crucial for the passenger's confidence and overall sense of safety. This confidence is rooted in factors like stability, protection, and comfort, and these aspects will be explored through testing and interviews during the thesis research.

Design Criteria

- The seat shall give the passenger confidence which in turn leads to safety

3. Ergonomics

The most crucial aspect of front seat design is its ergonomics, though this can be complex. Traditional ergonomics focus on a static seated position, but for VanRaam, the challenge is greater due to the diverse and unique needs of its consumers. Despite this, the primary ergonomic goal remains: users should experience no pain or discomfort, avoiding any risk of injury.
This section explores key ergonomic principles to ensure comfort and safety. The analysis will be based on literature, target audience data, previous VanRaam projects, and existing seats for recumbent or specialty bicycles.

Current Seat and Layout

The Buddy bicycle currently uses the “Ergo Mesh Premium” seat (Figure 14). This seat features mesh fabric for ventilation and adjustable padding to create a "bucket" seat shape. Its functional seating angle is 112.3 degrees, with a 14.4-degree seat angle. The seat height is 160 mm relative to the bottom bracket, and it is 936 mm from the seat to the bottom bracket.

Figure 14: HP-Velotechnik seat

The seat is hammock-style, with adjustable tension straps. While the sitting and back support angles can be adjusted (11 and 14 degrees respectively), the seat's length and lumbar support are fixed. Adaptable ergonomics are crucial (Van Dort, 2023), and current seat designs offer some interesting solutions:

1. **Hase Vario Comfort Cushion**: Uses Velcro-attached individual cushions, allowing for customizable back support (Figure 15).
2. **Hase Pino Seat**: Features height and length adjustment through an extendable frame (Figure 16).

Figure 15: Hase Seat cushion with Velcro-inserts

These examples will inform the design of a new seat for the Buddy.

Figure 16: Extendable poles on the Hase Pino seat

Seating positions

To determine the optimal seating position for the Buddy bicycle, we must consider two general types:

1. **Recumbent Seating Position:** Here, the functional seating angle is at least 135 degrees. This position includes two variations: one with the bottom bracket above the rider's center of gravity and one below. The latter is preferred for this project because it simplifies pedaling and makes entering and exiting the seat easier.

2. **Upright Seating Position:** In this position, the functional seating angle is less than 115 degrees and is commonly found on VanRaam models. This position offers a clear view and a comfortable, active posture.

Expert opinion suggests a 135-degree angle for recumbent bikes, similar to VanRaam's ideal of 45 degrees measured differently (Van Dort, 2023). Angles larger than 135 degrees are sportier, while smaller angles are more relaxed. Current seating angle on the Buddy is around 110 degrees but could be optimized further. The seat angle on the HASE Pino, for example, is more aligned with the bottom bracket than the Buddy's.

Staarink (2014) found that a static seating angle of 90 degrees and a semi-active angle of 115 degrees are effective, with 123 degrees being the most relaxed and stable. Angles beyond 123 degrees may lead to instability, requiring more effort from the neck muscles (Staarink, 2014), VanRaam research also supports a functional seating angle of 108 to 115 degrees for comfort (Haasjes, 2024), with a 4-degree seat area angle recommended for optimal hip angle.

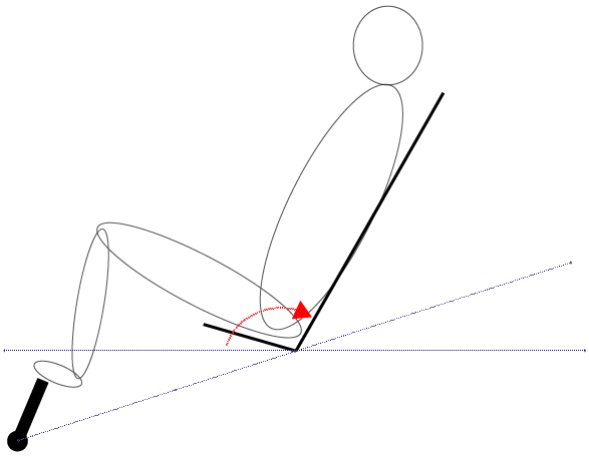


Figure 17: Functional seating angle, red arrow. Upper image is initial Functional seating angle. Below is the functional seating angle moving forward in this thesis

In conclusion, the most stable seating angle is 123 degrees, though individual preferences may vary between active and relaxed positions. Further examination of hip angle, lumbar support, S-Curve support, seating pressure, and seat access will follow, leading to a final decision on the seating angle based on user preferences and ergonomic considerations.

Seated anatomy

Understanding the seated anatomy of the target group for the tandem bicycle is crucial. The spine, which comprises the Cervical, Thoracic, and Lumbar sections, plays a significant role in determining a comfortable and supportive seat. From previous research, we know the lumbar support is vital for maintaining a stable seating position, but specific measurements for this support have not been clearly defined. This section aims to address this gap.

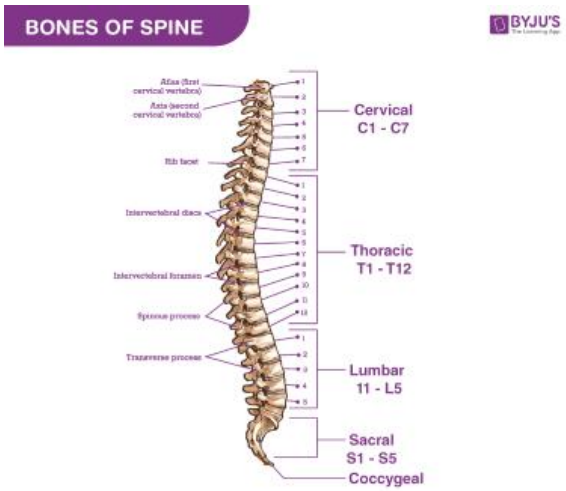


Figure 18: The spinal column

A 1995 study examined spine shapes in seated positions to define relevant lengths for a given seating posture. The study used a functional seating angle of 109 degrees, with a hip angle of 8 degrees and a back angle of 101 degrees, involving 102 participants (both men and women) aged 25 to 75. This led to a set of measurements for seat design, which were applied in research by Van Raam to determine ideal back support for the EasyRider3 (Haasjes, 2024). This research provided baseline measurements for back support (see Figure 18).

- The minimal support is from L2-T8
- Everything above T8 should fade away towards the rear by 20,4 mm
- Everything below L2 should have an angle of 11,5 degrees.
- The minimal length that the seat should support for is p5 (Dutch elderly DINED) = 1517 mm
- The maximal length that the seat should support for is p95 (Dutch elderly DINED) = 1917 mm
- The height from the support from t8 to S1 shall be 253 mm (p5-p95)
- The radius of the curve for optimal S-curve support shall be R = 475 mm (p50)
- The seat shall not be hard in the spinal column, for at least 22,5 mm width
- The width is assumed to be 440 mm (Armpit width, p50) however, this needs to be further researched.

These measurements will serve as a starting point for designing the Buddy bicycle seat. However, it is crucial to note that the functional seating angle in this study varied between 105, 115, and 123 degrees. For optimal stability, the Buddy front seat will use a 123-degree angle. Since there is no clear data on how functional seating angles affect spine and seat measurements, these will need to be validated through user test inputs. A 1994 study found that a wider backrest (480 mm) improves lateral stability in automotive contexts (Reed et al., 1994). A full overview of human measurements whilst seated can be found in appendix P.

Hip angle

The second ergonomic aspect of the front seat is the hip angle. Research on the Fun2Go seat highlights that for elderly users, a hip angle of at least 95 degrees is crucial. This angle helps prevent excessive hip bending and supports a backward-leaning posture for maximum support, rather than leaning towards the handlebars, which can disrupt the spine's natural S-curve (Boer, 2023); (Staarink, 2014).

Figure 19: Hip angle determination (Boer, 2023)

To determine this hip angle, a rotation point at the hip joint needs to be determined. Previous studies, including the Fun2Go research, used the midpoint of the cycling movement as the rotation point, estimated at the Hip Joint centre near the top of the Trochanter major. This rotation point is essential for maintaining the relevant 95-degree hip angle.

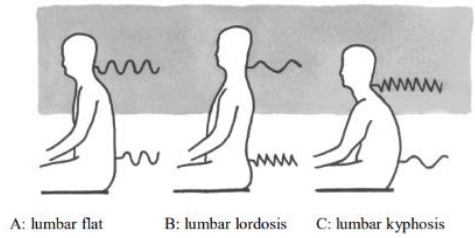
Shoulder support

Ergonomics research highlights the importance of back and shoulder support in semi-reclined seating positions, such as those found in recumbent bicycles. While specific studies addressing a 123-degree seating angle are limited, relevant literature on spinal load and vehicle ergonomics provides insights that can be applied.

Wilke et al. (1999) found that reclining postures, reduce intervertebral disc pressure in the lumbar spine. However, the study does not directly address the shoulder or upper back support necessary in such positions (Wilke et al., 1999). During the visit to ACE Velo technic it also became apparent that the more reclined the position is, the bigger the need for a proper upper back support in order to relax the shoulder and neck muscles. Another study on postures in a desk environment found that the further reclined a supported backrest is, the better the weight of the person in the seat is distributed when a proper upper back support is present (Nag et al., 2008).

Overall, while specific guidelines for a 123-degree seating angle in recumbent bicycles are scarce, existing ergonomic principles stress that adequate upper back and shoulder support is key to ensuring comfort and biomechanical efficiency in semi-reclined positions.

Lumbar Support



Lumbar support is crucial for rider stability and comfort. Proper lumbar support maintains the spinal S-curve, reducing muscle tension and improving stability (Staarink, 2014). Key considerations include: A neutral S-Curve; Adequate lumbar support ensures a neutral spinal curve. Too little or excessive support can lead to incorrect postures and discomfort and pressure distribution**:** Optimal lumbar support should create peak pressure in the lumbar area but avoid excessive pressure that can cause discomfort.

Common issues related to inadequate lumbar support include:

- **Kyphosis:** Insufficient support can result in a rounded back, leading to high pressure on intervertebral discs and increased neck strain.

- **Lordosis:** Excessive support can cause lower back tension, though this is less common in seated bicycles.

To address these issues, lumbar support for the Buddy bicycle should follow specific guidelines:

A study on the ideal seat support should be positioned between the T9 and L2/3 vertebrae, approximately 150 mm high and 120 mm wide, with the center located 200-250 mm from the sitting area (Staarink, 2014). Another study on automotive lumbar support suggested that the support should be firm but sufficiently padded to avoid discomfort due to high pressure. Ideally, it should be adjustable in prominence and vertical position. The depressed contour should range from flat to convex, with a prominence adjustable up to 30 mm and a radius between 250 and 400 mm. The vertical position of the apex should be adjustable between 195 and 295 mm above the seat cushion (Reed, 2013). Since the latter includes the envelope of the first, this is assumed moving forward.

These design parameters will ensure that the lumbar support is both comfortable and effective for the target user group. Given that the natural spinal curve in elderly users is less pronounced, a less prominent support may be more appropriate.

The design of lumbar support for the Buddy bicycle is integral to ensuring rider comfort and stability, particularly for elderly users. The guidelines provided, based on both literature and ergonomic standards, will serve as a foundation for developing an adjustable lumbar support system that caters to the varying needs of the target audience. By incorporating these design considerations, the Buddy bicycle will be better equipped to enhance the riding experience, offering both comfort and stability, which are critical for user confidence and safety.

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Lateral stability

Adding lateral support to the seat could improve stability, a consideration supported by automotive seat design research. Reinforced bolsters in automotive seats have been shown to offer better support and reduce fatigue (Kamp, 2012). For the Buddy bicycle, evaluating the effectiveness of side bolsters in enhancing stability and comfort will be important.

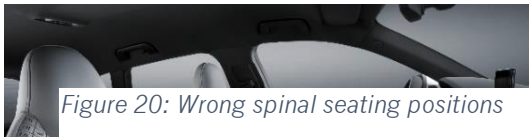


Figure 20: Wrong spinal seating positions

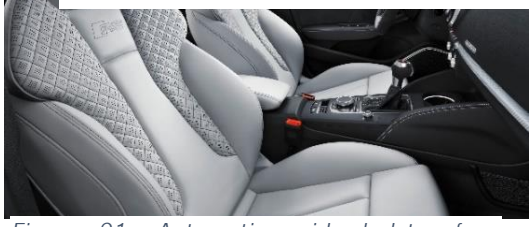


Figure 21: Automotive side bolster form inspiration for the seat stability

The side bolsters should be positioned around the lower torso to allow for body rotation while assessing traffic situations, thus enhancing the user's sense of autonomy. Testing will be necessary to determine if side bolsters provide adequate support and stability.

Dimensioning of side bolsters is hard to find, in literature. A study on bolster height and radius did research into this field where it turned out that bolster height comfort is highly dependent on the radius and vice versa (Lee et al., 2021) For this study the main focus is the added value of the side bolster without going into depth of measurements.

Seatbelts

Seatbelts, often used to enhance lateral and longitudinal stability in bicycles, may conflict with the Buddy bicycle's design philosophy of user autonomy. While seatbelts are an option for users who need extra stabilization, they may undermine the Buddy's core concept of self-steering and cycling. If side bolsters do not offer sufficient support, other stabilization solutions will need to be explored.

Getting in and out of the seat

Improving the ease of entering and exiting the seat is important for the target audience.
Physiotherapists suggest that swivelling after sitting is easier than simultaneous sitting and swivelling (Ergomobility, 2023). Secondly, a 2005 study on foot placement when standing up, concluded that space underneath a seat is necessary in order to ease the task of getting up from a seat, this is something to keep in mind and might offer a challenge in combination with the layout of the Buddy bicycle (Kawagoe et al., 2000).

The Buddy bicycle features an adjustable, fold-away handlebar, but it should be evaluated whether this is adequate or if the seat itself needs to rotate, similar to the Fun2Go model.

Figure 23: Rotatable seat on the Fun2Go

Conclusion from Ergonomics research

The ergonomics research highlighted key design criteria for the seat to ensure comfort and stability. However, it's important to note that some findings are hypotheses that need verification for this specific application. The conclusions are summarized in the table below. The criteria suggest that for optimal ergonomics, attention should be given to hip angle, seating angle, lumbar support, and accurate measurements. imperative for the success of the design of the seat.

Design Criteria

- The hip angle shall not exceed 95 degrees to facilitate comfortable pedalling and force exertion, especially for elderly users.
- The seat shall maintain a functional seating angle of 123 degrees for optimal stability.
- Lumbar support must be included to enhance stability when seated.
- The Lumbar support shall be placed between 195 and 295 mm above sitting area with maximum of 30 mm prominence.
- The seat shall accommodate the target group's anatomical measurements (P5 to P95 range).
- The seat shall include side bolsters positioned around the lower torso region to increase stability.
- The seat materials shall prioritize comfort by addressing heat transfer, water vapor, support, and freedom of movement, regardless of the chosen material route (conventional, ER3/Fun2Go, or 3D printed options).
- The seat shall incorporate adaptable ergonomics inspired by existing recumbent seats to better suit individual users.
- The seat design shall include a rotatable mechanism to assist users in getting in and out, though it requires testing with the target group to ensure feasibility due to potential mobility issues.
- The design shall not rely solely on the handlebar movement as a means for entry and exit without considering additional support mechanisms or ergonomic adjustments.

The requirements regarding ergonomics that have been described in the previous section can be visualised using a package drawing. A package drawing is something that has been established in the automotive industry and is defined as “the arrangement of the driving position and that of the occupants, and all components and systems in the vehicle. Essentially, it is a visual requirement specification.” (De Silva, 2013) The package drawing includes the p5 female and the p95 male. Furthermore, all measurements that came from literature have been added. This first version will be the blueprint for the initial prototype and is prone to change according to the needs and wishes of the end user. Under the package drawing, a table can be found with the additional information of certain measurements

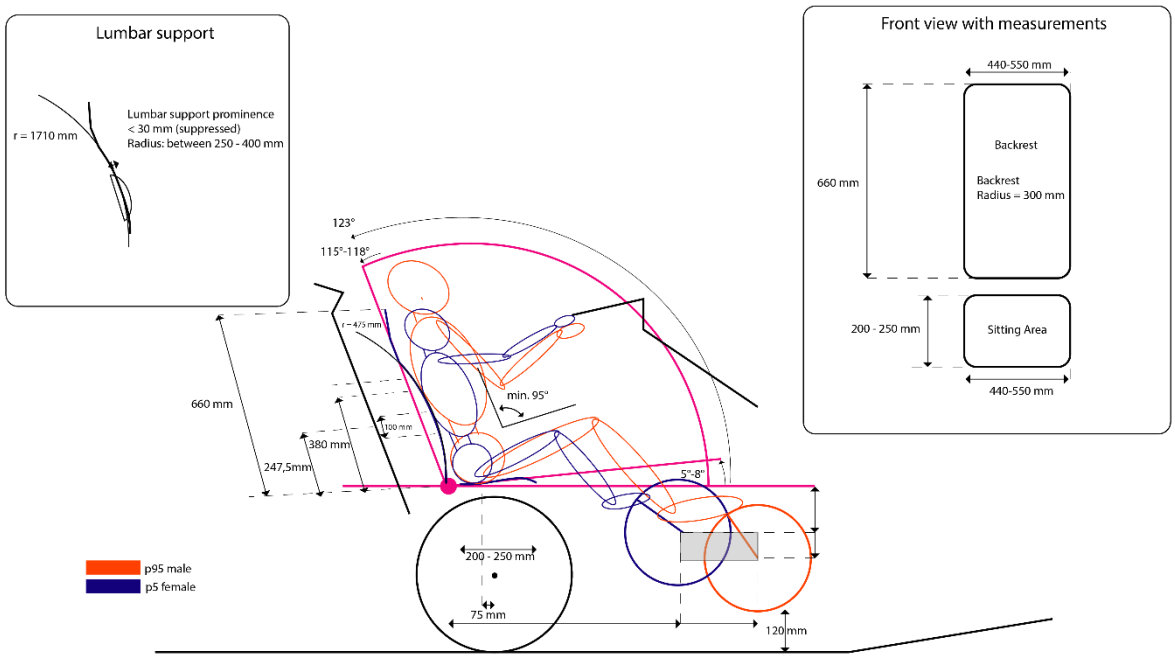


Figure 24: Package drawing of the ergonomically correct measurements and envelopes according to literature

	What?	Old	Ideal (theoretical)
1	Functional seating angle	112-116 deg	123 deg
2	Sitting angle	12,3-14,4 deg	> 4 deg
3	Back angle	97,6-103,7 deg	118 deg
4	Sitting area length	250 mm	< 250 mm
5	S-curve radius	R = 1710 mm	R = 475 mm
6	X distance to crank	936 mm	t.b.d.
7	Y distance to crank	160 mm	t.b.d.
8	Lumbar support height	Not applicable	195 – 295 mm
9	Lumbar Support Prominence	Not Applicable	< 30 mm
10	Hip angle (smallest)	87,25 degrees	95 degrees
11	Lumbar support effective height (t8-S1)	310 mm	253 mm
12	Crank length	160 mm	t.b.d.
13	Width seat	410 mm	440 - 480 mm
14	Entire backrest length	660 mm	660 mm
15	Radius backrest from top	Not applicable	R= 300 mm

Seating Pressure

Pressure distribution on the seat is crucial for comfort. Proper lumbar support ensures even pressure distribution (Makhsous et al., 2003). Research by Staarink highlights that active, tense muscles distribute pressure better than relaxed muscles, which tend to create higher localized pressure (Staarink, 2014).

Figure 25: VanRaam EasyRider3 seat

Seat design involves:

- **Top Layer**: Affects tensile stress; materials with less deformation are preferable to avoid the "Hammock effect" (Iizaka et al., 2009)
- **Load Structure**: A spring mechanism can reduce reaction forces by increasing the contact surface area.
- **Upholstery**: Softer, elastic materials like foam can enhance comfort but may reduce stability.

Foam, such as Sunmate foam, has shown lower pressure distribution compared to gel-based materials (Apatsidis et al., 2002), making it a promising choice for the Buddy bicycle.

VanRaam's existing Easy Rider seat could also be a suitable option. Additionally, materials used in recumbent bicycle seats often feature mesh and foam for better heat and moisture management, which will be considered in further development.

Materials

his section explores potential materials for the Buddy seat by consulting with Van Elburg Stoffering, examining existing seats, and reviewing literature.

Van Elburg Stoffering recommended using a solid load structure with foam upholstery and a top layer of mesh or artificial leather. They suggested "Koudschuim" (Polyurethane foam) for its durability and elasticity, though it requires a waterproof top layer due to its water absorption.

Current seats, such as the HP Velotechnik, use:

- **Top Layer**: Mesh and Cordura for washability, durability, and breathability (HP Velotechnik, 2024).
- **Load Structure**: Aluminium tubing with adjustable tension straps (HP Velotechnik, 2024).
- **Upholstery**: Spacer fabric for breathability and lightweight cushioning (HP Velotechnik, 2024).

One option for the materials could be to integrate the current production techniques into the to be designed seat. The VanRaam EasyRider3 and Fun2Go seats use a solid foam sitting area and a separate backrest, offering ease of access but less breathability. The backrest is made from a mesh that is injection moulded into a glass filled nylon frame which in turn is connected to the load structure that offers adaptability and is connected to the frame. The sitting area of the ER3 seat is injection moulded closed-cell EVA foam. Inside of the foam there is a hard plastic load structure. The Fun2Go seat is made from a glass reinforced nylon base with an EVA foam insert for added comfort.

Figure 26: ER3 and Fun2Go seat

An alternative is 3D printing, which allows customization of firmness and geometry, though it requires a base plate made of ABS. Create it reel's technology enables flexible design, with TPU prints allowing varied firmness levels (Programmable Foam, 2024)

A study on wheelchairs highlights the need to avoid materials that impede heat and moisture transfer, ensure pressure distribution peaks at the Ischial Tuberosities, and avoid excessive padding that restricts posture adjustment (Apatsidis et al., 2002).

Three material routes are considered: conventional materials, the ER3/Fun2Go approach, and innovative 3D printing. The chosen material should ensure comfort, heat transfer, moisture management, and support. The next section will explore the anatomy of the target user.

Conclusions

This material research section implies that the seat is subject to several mechanical properties that decide the comfort of the seat. The most important criteria are given in the “must” section of the criteria and are based on the literature review.

Design Criteria

- The seat design shall ensure even pressure distribution, focusing on comfort by minimizing deformation to reduce reaction forces and tensile stress (e.g., avoiding the "Hammock effect").
- The top layer shall be selected to minimize tensile stress, and load structure must reduce reaction forces effectively.
- The material selection shall prioritize breathability and ventilation to address heat and moisture issues during use.
- The design shall balance stability and comfort, considering the use of mesh or foam-based upholstery depending on the target user’s needs.
- The seat shall explore innovative manufacturing methods, such as 3D printing with customizable firmness levels, allowing tailored support and geometry.
- The seat shall incorporate materials like "Koudschuim" foam for upholstery, with a waterproof top layer to enhance comfort and durability.
- The design shall not include alternatives like rigid or hard-shaped seats meant for sport-oriented recumbents, which require core stability and are unsuitable for the target user.

4. User interviews

Finally, user interviews were done to gather insight into what the problems are according to the projected target user with regard to the bicycle and its seat. Secondly, the aim was to find out what the main focus of the thesis will be.

The interviews were conducted with five different people/duos who already had experience riding the Buddy in a previous test. Two duos were caregiver/passenger, one person was the passenger and with two other people, only the caregiver was present. This mix of people provided insights from both sides of the equation.

Figure 27: The bicycles used for the questionnaire

The interview consisted of an informal conversation about the experience when riding the bicycle together with getting to know the very specific situations of all the interviewed people. Afterwards, four images of competing bicycles were shown one at a time and the question was asked what associations the people had and why when seeing the bicycle in the most broad sense (figure 27). Then, the questions where asked, out of the four bicycles on display, which bicycle they would like to be seen riding mostly? And, “Which bicycle would they most like to ride themselves?”. The final question was if the exposed front end raised any safety concerns. After the questions there was also the possibility to view the bicycle and to ride it.

Initially, the plan was to test two different seating angles, however due to weather constraints, this fell through. However, in order to do this, the bicycle had been slightly modified (Add image); the seat was located in such a way that the angle of the back support could not be exceeded further that 116 degrees. However, for the test I wanted to test the difference between the upright position which is 110 degrees and the laying-down position which is 135 degrees. Therefore, the bar that attaches the seat to the frame was modified in such a way that the seat could be located at a larger angle. After the modifications, the seat could reach an angle of 140 degrees..

Afterwards, the interviews were coded into categories of interest, from this the following conclusions have been drawn:

- Stigma does not appear to be a problem with the target group
- Not everyone spoken to fits the primary target group
- Safety does not come from shelter, rather from stability
- Stability gives confidence
- Tricycle takes time getting used to
- It does not matter what the bicycle looks like as long as it fits function. However, when taking it too far by exaggerating the position of the passenger, stigma does become a problem.
- There is a difference in active and sporty cycling and many people want the Buddy bicycle to be active and to cycle as a normal bicycle.
- The Buddy would appear more normal if it looked more like a sporty bicycle
- There is no consensus over sitting upright or laying down position, this has to be tested with two different concept directions
- The Buddy is seen as more active and sporty than the fun2go and the Twinny thus deserves to be a model in the range of VanRaam
- Generally, the Buddy is one of the most liked bicycles in the group of four different bicycles.

From these insights, the conclusion has been drawn to continue the development of the front seat though focussing on comfort, which can be perceived and should be ergonomically correct, confidence, which in term leads to a sense of safety, and finally, aesthetics that play a vital role in evoking a feeling of comfort, confidence, autonomy and activeness in the design of the seat.

5. Expert interviews

In this section, two interviews conducted with experts will be described. They are done to gather insight into the criteria that the seat needs to meet. The interviews are listed below.

Interview Bicycle fitter Van Raam

The first expert interview conducted was with one of the fitters of VanRaam who has tons of experience with specific needs and wishes of persons with disabilities that have the desire to keep cycling. The aim of this interview was to collect information on specific needs and wishes. Secondly, this specific bicycle fitter had also helped during testing on the "Buddy" bicycle before my project so it was also helpful that he was familiar with the bicycle. Therefore, some insights could also be gained from him view on the previous user tests with the Buddy bicycle.

The main takeaways from this interview are the following:

- A softer material for the seat has to be used compared to the Easyrider
- The ergonomics of the seat need to be adaptable
- A rotatable seat would be very convenient for getting in and out of the front seat
- Bottom bracket and seat cannot be seen separately
- In general, a recumbent position is less pleasurable for the user than an upright position

Interview ACE Velotechniek

The second expert interview conducted was with the owner of a Recumbent bicycle shop in Winterswijk. The owner had tons of experience with these bicycles and used to build them himself. The aim for this interview was to find out whether users of recumbent bicycle want some protection to feel safe and secondly to gather insight into the ergonomics of the recumbent bicycle also by looking at products on offer in the store.

The main takeaways from this interview are the following:

- A Recumbent bicycle needs to have a seating angle of 135 degrees
- Some people choose a headrest for the perception of safety
- There exist some clever solutions for adaptable ergonomics
- Hip angle becomes an issue when the bottom bracket is below the centre of gravity of the rider.

Target Group and Bicycle

Now that the target group has been established, a critical point is to see the connection between the target group needs and wishes and the current product line-up of VanRaam and even competitor bicycles.

Within the current VanRaam line-up, the Buddy is envisioned as an alternative for the Opair, Fun2G0, KiV0 Plus and Twinny plus. These bicycles however, have specific qualities which not necessarily cater the target group. The competitive matrices of the Buddy compared to the current VanRaam lineup gives an interesting result (figure 28). The competitive matrix has been scored though application of knowledge gained from expert interviews and target group interviews.

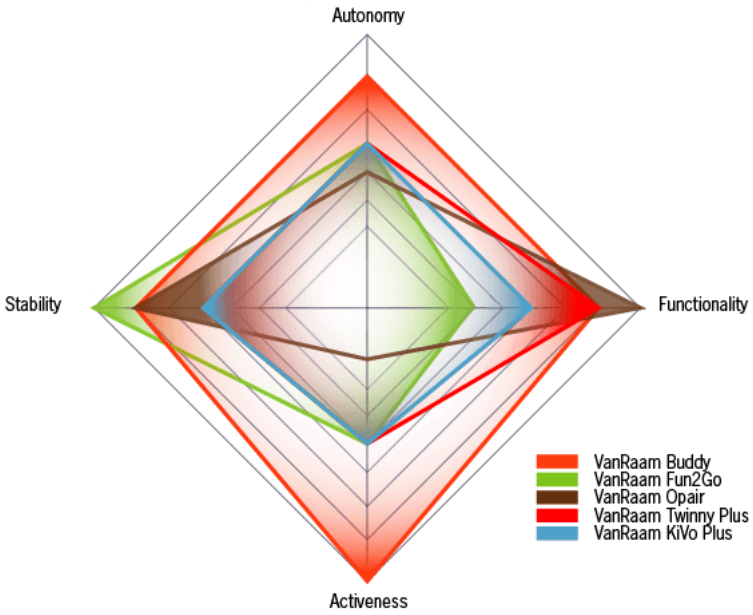


Figure 28: VanRaam bikes analysis in competitive matrix

The Buddy, marked orange, scores better particularly on the autonomy and activeness values. This has to do with the outcomes from the user interviews and the general feelings all other bicycles evoke. Autonomy is a tricky concept here; all bikes in this overview are bikes for people who cannot cycle autonomously anymore. Hence, autonomy is about the sense of autonomy and is based on the user interviews and expert interviews. In this matrix, the Fun2Go is marked as more stable than the other bikes, this has to do with its wide appearance, making it appear more stable. The Opair is indicated as being more functional; this has to do with the fact that this bicycle can also be used as a wheelchair and because it can be split, it is easier to store as well. Compared to the Twinny plus and the KiVo plus, both tricycle tandems, the buddy scores better in all areas, as its lower design makes it appear more stable and active. The main argument for more sense of autonomy is the possibility to sit in front of the supervisor on the Buddy. All in all however, the Buddy is the only bicycle within VanRaam that offers good stability, functionality and sense of autonomy whilst at the same time evoking a feeling of activeness for the target user.

When assessing the possible competitors from outside of VanRaam; four bikes are of interest (figure 29)

Figure 29: Clockwise: Hase Pino, Huka CoPilot3, Bambuk E-Trike, Urban Strada

When comparing these bicycles to the “Buddy”, it becomes apparent that some competitors offer similar levels of stability and functionality, based on the appearance

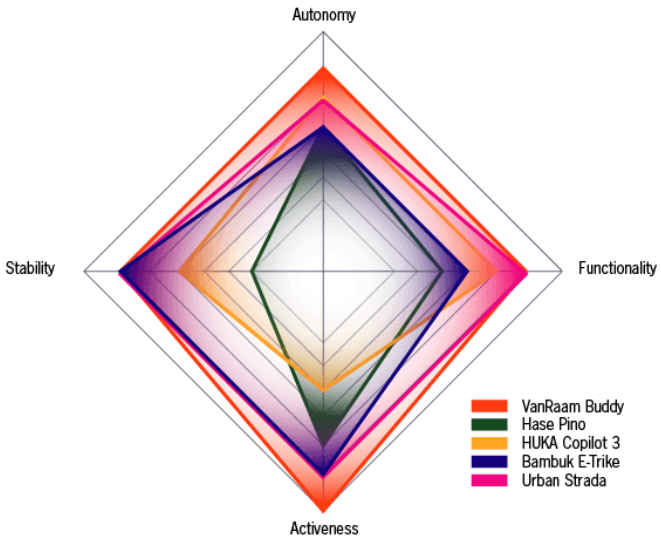


Figure 30: Buddy compared to outside competition

of the bicycle. However, in terms of activeness and autonomy, all bicycles score lower since on some bicycles, the passenger is seated at the rear and on all bicycles, the passenger is not able to steer. Thus, the unique selling point of the “Buddy” bicycle is the combination of a sense of autonomy, functionality, stability and activeness that cannot be found in competing bicycles.

Design Criteria

- The seat design shall support a sense of autonomy, allowing the passenger to sit in front of the supervisor and have some control over the ride, enhancing the feeling of independence.
- The seat shall reinforce the active and sporty image of the Buddy, aligning with the target users' preference for a more dynamic cycling experience compared to competitors.
- The design shall maintain functionality comparable to other VanRaam models like the Opair and Fun2Go, balancing features such as ease of entry, comfort, and storage.
- The seat shall include features that enhance the appearance of stability, such as a wider base or visible support elements, since stability is a key aspect that influences user confidence.
- The design shall incorporate elements that visually communicate activeness and autonomy, differentiating the Buddy from other models and competitors.
- The design shall not prioritize features that are better suited for bicycles targeting users with lower levels of autonomy or activity, as this goes against the active, engaging nature of the Buddy.

6. Conclusion

In this section, the research phase will be ended with some general conclusions that will be transferred into hypothesis that lay the foundations of the design criteria that will be established in the next chapter. To conclude this section, the questions asked initially will be answered as well as forming hypotheses for the subsequent course of this thesis.

1. **How is the target audience defined?**

The target audience of the Buddy bicycle is defined as 65+ people with changing medical conditions that are not able to cycle through traffic alone anymore. The reason for this is that in terms of numbers, the potential market for this target group is the largest. Secondly, the needs and characteristics that define this target group are rather unique, however they also have sufficient overlap with the other two projected target groups; thus focussing on this target group also includes a major part of the needs and wishes of the other projected target groups.

2. **What are the most important needs and wishes for the target group?**

According to the user interviews performed, the most important need for the "Buddy" bicycle seat is the sense of stability and the fact that not everyone can fit comfortably in the seat. Smaller individuals struggled as well as larger ones. Finally, the target users prefer the "Buddy" to be more active and to cycle as much as possible like a normal bicycle. In terms of appearance they like it to look more active and sporty as well.

3. **Wat are the ideal ergonomics for the seat with the target group in mind?**

According to the literature study, There are specific measurements that a back support needs to fulfil. Furthermore, the minimal hip angle whilst pedalling should not exceed 95 degrees. The functional seating angle is found to be most stable when it is 123 degrees. The sitting area should then be at >4 degrees compared to the horizontal x-axis. A lumbar support is needed in order to create maximal stability. Then, the material should minimise the tensile stress and reaction forces exerted on the body of the passenger. Then, a lumbar support and side bolsters in the lower torso might add to stability of the passenger whilst riding and should thus be included. Then, a rotatable seat could be included to enhance the general experience of the target user. Lastly, in order to cater effectively to p5-p95 of the target group, adaptable ergonomics are of great importance. Not lastly because some individuals within the target group have abnormal bodies that also need to be able to ride the "Buddy" bicycle. However, all these measurements and conclusions are based on literature only. It is imperative to test these with a prototype with the target user.

4. **Does perceived safety affect the front driver of the tricycle and can this be influenced by the design of the front seat?**

From the user interviews, it can be concluded that perceived safety comes not from protection, rather from stability that gives the passenger and driver confidence in the ability of the 'Buddy" bicycle to handle the situations in traffic sufficiently. Fundamentally, people realise that a bicycle is inherently not very safe, however with sufficient stability, the bicycle does give confidence to its user thus the user perceives

the bicycle as more safe. Therefore, the seat of the bicycle must offer stability and confidence to the passenger.

5. **Is the tricycle stigmatising and can this be solved through design of the front seat?**

The user interviews made clear that stigma is not a major issue concerning the “Buddy” bicycle. It is proven in literature that people are willing to diminish the effect of stigma when the product enhances their abilities, which is the case with the “Buddy” bicycle; people who are not able to cycle through traffic alone get a sense of cycling through traffic alone. However, the seat should still communicate certain attributes to the user that evoke a sense of autonomy, stability, activeness and quality. This can be done by looking at the Gestalt theory. It is also desirable in terms of Stigma to not put emphasis on the impairment of the passenger. As long as this is not done in the design of the seat, stigma is not an issue for the seat and possibly also not for the bicycle itself.

Next to these hypotheses, some early design criteria have been formed in this chapter of the thesis. These criteria will be iterated and tested over the course of this thesis. The design criteria will follow the MoSCoW method (Hudaib et al., 2018). This method provides a structured overview into which requirements must, should, could and won't be included in the seat (figure 31) . This is a streamlined version of all the design criteria that can be found at the end of each section. These design criteria are not yet prioritized, this is done in this section. The prioritization has been made based on user interviews, expert interviews and interpretation of literature review. The prioritization is done by asking the following questions: Must: "Which criteria are critical to success?", should: "Which criteria have high impact on success but are not critical?" could: "Which criteria have low impact on success?" won't: "Which criteria are beyond scope and for later development?"

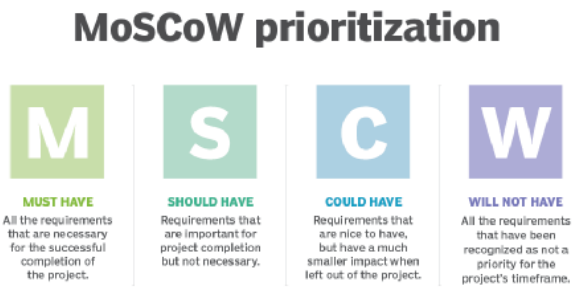


Figure 31: Moscow method

Must have:

- The seat must cater to the needs and wishes of elderly with changing medical conditions
- The seat design must prioritize stability, as this is directly linked to user confidence and safety.
- Ergonomics must be adaptable to suit a range of user preferences and needs.
- The seat must accommodate the target group's anatomical measurements (P5 to P95 range).
- Seat must have a functional seating angle of 123 degrees
- Seating position must facilitate a minimal hip angle that does not exceeds 95 degrees
- The seat must have a lumbar support for optimal stability
- The seat must include side bolsters positioned around the lower torso region to increase stability.

Should have:

- The material of the upholstery should provide freedom of movement to the user in order to switch positions
- The seat should incorporate Gestalt theory principles, focusing on stability, comfort, activeness, and visual balance.
- The design should follow the MAYA (Most Advanced Yet Acceptable) principle to ensure aesthetic appeal and user acceptance.
- The seat should be designed with a sporty and active aesthetic to align with user expectations for the Buddy bicycle and to reduce stigma..

Could have:

- The seat could rotate to make accessing the bicycle more convenient
- The design could incorporate elements that visually communicate activeness and autonomy, differentiating the Buddy from other models and competitors

Won't have:

- The design of the front seat won't exclude people with down syndrome and people recovering from surgery
- Seat won't cause unpleasant pressure points around the shoulder/scapula region
- Seat won't have seatbelts fitted as standard
- The design will not rely solely on the handlebar movement as a means for entry and exit without considering additional support mechanisms or ergonomic adjustments.
- The design will not prioritize features that are better suited for bicycles targeting users with lower levels of autonomy or activity, as this contradicts the active, engaging nature of the Buddy.
- The seat won't include a headrest to enhance the perception of safety for users who prefer it.
- The seat materials won't be addressed that prioritize comfort by addressing heat transfer, water vapor, support, and freedom of movement, regardless of the chosen material route (conventional, ER3/Fun2Go, or 3D printed options).
- Three different material routes could be taken for the material of the seat won't be addressed

Now that the initial research questions have been answered and the initial design criteria have been established, some hypotheses need to be established that can be answered in the design phase of the seat can be established. The following hypotheses have been established based on literature research.

Comfort

1. The ideal functional seating angle is 123 degrees with a sitting area angle of >4 degrees in terms of comfort and stability.
2. The sitting area must be made out of a solid material instead of a hammock structure to minimise seating pressure
3. The prototype of the seat should offer maximum adaptability in order to cater the target audience and to test as many aspects as possible.
4. The most important aspect of the seat for the "Buddy" is that it is ergonomically perceived as comfortable and gives the passenger stability.
5. The minimal hip angle of the passenger cannot exceed 95 degrees whilst pedalling from the front seat.
6. The accessibility of the front seat needs to be examined with the target user, if the handlebar movement is insufficient, a rotatable seat needs to be installed.

Confidence

1. A Lumbar support is needed for the seat to offer maximal support and stability. The lumbar support should be adaptable for p5-p95.
2. Side Bolsters are needed in order to improve stability for the passenger. They will be placed around the lower torso of the passenger.

Aesthetics

1. The design of the front seat can evoke a certain feeling to the target user and should by no means cause for more stigma than the functionality of the Buddy bicycle allows.

Chapter 4: Define

In this chapter the design challenge will be redefined based on the emphasizing performed in the previous chapter. This will provide research questions for the subsequent parts of this thesis. In this chapter, also the terms “comfort” and “confidence” will be elaborated.

4

1. Design Challenge and Research questions

The design challenge is based on the main and sub questions as defined in section 2. During the research phase, sub question one; How is the target audience defined?; has been answered. Next to this, a clear image of the needs and wishes for the target group has been shaped; this is however an iterative process and will be under scrutiny with every test and iteration step. With this, sub question two has also been answered. Sub question three, "What are the ideal ergonomics for the seat with the target group in mind?", has been answered only theoretically and needs to be answered through user testing and validation in the design process. In the initial research phase, the sub questions were based around the assumption that perceived safety and stigma are major issues for the Buddy bicycle. Therefore, sub questions four and five; "Does perceived safety affect the front driver of the tricycle and can this be influenced by the design of the front seat?" and "Is the tricycle stigmatising and can this be solved through design of the front seat?" are not relevant moving forward with the project. Finally, looking at the main question, formulated in the initial phase of the project: "What is the ideal cycling experience for the target audience sitting in the front seat of the "Buddy" tandem tricycle?" This question needs to be reformulated, moving forward in the project. The main question in this thesis will be:

''What are the desired features for the prototype of the front seat of the ''Buddy'' tandem tricycle to give the passenger maximal comfort and confidence whilst also addressing appearance?''

To answer this question, sub questions need to be established in order to structure the design process. These sub questions are defined as follows.

1. Are the ideal static ergonomics found in literature found to be correct, thus perceived as comfortable, when testing with target users in a dynamic setting?
2. How to give the target user a maximal sense of stability that is better than the current seat, with the design of the front seat?
3. How can the seat communicate stability, autonomy, activeness, comfort and stability through its appearance better than is done with existing seats?

These questions are however difficult to measure. Thus in order to do this, some specific design targets need to be established, this will be done in the next section. Firstly however, it is imperative to define what Comfort and Confidence mean within this context. This will be done in the next sections.

In order to answer these research questions, it is imperative to define what "comfort" and "confidence" mean within the specific context of this thesis. Thus, two simple research questions have been established:

1. What is Comfort in this specific context?
2. What is Confidence in this specific context?

2. What is comfort?

Originally, the word comfort comes from the late-Latin word “confortare” which means to strengthen greatly. In product design however, a uniform definition is not evident (Tutton & Seers, 2003). Thus, it is important to look at the different aspects of comfort. Barnard et. Al. give a four way framework that together entail “comfort”. These frameworks are the following (Barnard et al., 2004). This framework for comfort is used because it offers a structured and comprehensive way to address the complex, multi-faceted nature of comfort in product design. By applying this framework to the "Buddy" bicycle seat, it ensures that all relevant dimensions of comfort are considered, leading to a well-rounded and user-centred design:

1. **The passenger bubble**, this is a specific case for aviation and is thus not applicable for the “Buddy” tandem as this is about isolation without disturbance which is contrary of why the bicycle is being developed in the first place.
2. **The health model**. This model entails the absence of discomfort, potential dangers, annoyance and on physical wellbeing. This is an important aspect of the design of the passenger seat for the “Buddy” as well.
3. **The community model**. In this model, the passengers on an aeroplane all share the same experience. For the “Buddy” this is not the case, however, it can be argued that because the passenger has the possibility to cycle themselves it does make them part of the community of cyclists and should therefore have similar experiences in terms of comfort.
4. **The Aesthetic-Economical model**. This model makes comfort being perceived as being in an interesting, advanced and beautiful environment and critically, for a reasonable price. For the “Buddy”, it is not necessarily the case that the passenger is in a closed-off environment; a large part is of the unique selling point of the “Buddy” bicycle is to have freedom that cannot be experienced on a conventional tandem or a Fun2Go bicycle. However, this model can still provide insight into texture and material use and design for look and feel in order to give the passenger an experience as comfortable as possible.

Next to these frameworks, different points of view on comfort also exist. These points of view are useful for finding measurables in terms of comfort that can be integrated into the requirement specifications. Firstly, there is the physical point of view that describes the psychological comfort, bio-mechanical comfort and comfort for people with health problems. In this point of view, comfort is about level of acceptance and correct ergonomics, fitting to the health model as described above. This fits the definition of comfort that is: “The pleasant and satisfying feeling of being physically or mentally free from pain and suffering, or something that provides this feeling” and “A feeling of freedom from worry or disappointment.”

The second point of view is the psychological point of view that argues that comfort is a state of quiet enjoyment. This implies that in order to be comfortable, the passenger of the “Buddy” needs to be satisfied in firstly, basic material needs, like a proper seat with support, pedals and a handlebar. Secondly, the passenger also needs to experience aesthetic comfort; a subjective form of comfort that depends on taste and on personal perceptions of forms, materials, colours, textures and others. This could imply that some level of customizability is desired. This has to do with autonomy in

design; this highlights the importance of enabling users to make choices in design that empowers users to select products or configurations that align with their personal preferences and comfort needs (Rosala, 2020). Another study found that for the material selection in the design for emotional comfort, attributes like 'stiffness', 'strong wrapping', 'softness', 'wear-resistant' or 'breathable' were named as preferable. Secondly, as sustainability is becoming more relevant in material design nowadays, in another open-question section the participants were asked for 'attributes for eco-friendly materials'. The respondents answered quite vague, e.g. 'low carbon-footprint, recyclable or bio-degradable', 'fair-trade, vegan', 'natural materials' or 'durable'. A big challenge will be to include these attributes in visual cues. (Quattelbaum et. al., 2021).

Thirdly, there is the conformity comfort, which has to do with the feeling of belonging to a group and not being an outsider. This is closely related to the PAMS model as described in section 2 that describes the evaluation of a product related to product stigma. If the product is causing too much stigma, the conformity comfort will be diminished, resulting in a product that is not perceived as comfortable by the passenger. This conformity comfort is thus really important in order to feel safe for the passenger. This also fits the sociological point of view where each individual is still conditioned to belong to a group.

Finally, there is the technological point of view where all technical and functional aspects of artefacts are important as well as the visual, tactile, aesthetic, and symbolic aspects. The technological point of view also highlights the gap between designed and manufactured parts that have been designed with comfort in mind and have measurable properties and the perception of comfort which is highly subjective.

This subjective nature of comfort is illustrated by the "correlation between product attractiveness and perceived comfort" (Quattelbaum et al., 2021). In this research, the suggestion is made that attractive products are generally perceived as more comfortable by the target user, because they interact better with them. In short, companies could benefit from products that have high emotional comfort for the end user, this also stands for the seat of the "Buddy" bicycle, as ergonomics only take you thus far. The reason why emotional comfort is as important as ergonomical comfort is because people in general are not able to produce proper proprioceptive feedback from ligaments, joints, and the spine, making ergonomic features challenging to review (Stavrakos, 2016). However, aesthetic features that can be related to comfort are easier to pinpoint. This then suggests that aesthetics may outweigh ergonomics in terms of user preference, as users are often guided more by aesthetics than longer-term ergonomic factors. However, more research is needed to prove this, which is beyond the scope of this thesis. This is something that is also backed by the findings of Kamp et. Al. (2012). Their research concludes that hard seats with high side bolsters are perceived as sporty, whereas softer seats are associated with luxury. It has to be seen whether this can also be applied to the design of the passenger seat for the "Buddy"; it does however provide an initial design direction. Another aspect that can aid the design of the passenger seat is the study of Quattelbaum et. Al (2021), that looked into emotional comfort versus actual comfort in car seats and concluded that "options to adjust the seat", "height of the side bolsters", and "overall seat width" had the largest influence on emotional comfort.

Thus, for the design of the seat for the "Buddy" bicycle, the term "comfort" entails several aspects. Firstly, from a health model, the seat needs to give no discomfort,

annoyance or potential dangers. This can be checked through a failure mode and effect analysis and a perception scoring. Secondly, from a psychological point of view, the seat needs to fulfil basic needs that the target users demand from the seat, such as support in the correct areas and good stability, both at a reasonable price. Finally, conformity comfort also needs to be experienced as this makes for a safe feeling whilst using the bicycle which has to do with blending in with a group and not standing out. All of this is summarised in figure 32.

Which framework?	**Requirements**	**How to measure?**
Health Model	• No discomfort • No annoyance • No potential dangers	• Questionnaire on perception • Failure Mode and Effects analysis
Community Model (Conformity comfort)	• No stigma in design • Inclusive design • Design should not set the user apart from a group	• Questionnaire on stigma with target group and bystanders • Questionnaire on perception with different designs
Aesthetic-Economical model **(Technological point of view)**	• Support in the correct areas • Good stability • Customization • Comfortable materials • Not too expensive	• Concept choice • Questionnaire • Measurement on stability • Material selection • Business case

Figure 32: Frameworks for measuring comfort

3. What is confidence?

The second terms mentioned in the design question is confidence. Confidence is a critical part in order to make this bicycle a success among the target group. In the interviews conducted in the initial phase of the research, it became apparent that confidence for the target user comes mainly from feeling stable in the bicycle (section 3.4). However, the term stable is also difficult to define in this case. The situation is similar to comfort; there is a difference between perceived stability and actual stability. Perceived stability is something that can be quantified through perception scoring and can give a good insight into the relative perceived stability when comparing two seats. However, in order to quantify stability even further, lateral and longitudinal stability should also be examined. This can be done in an experimental way; both for the lateral, and longitudinal displacement of the passenger whilst cornering and braking. When quantifying the direction in these directions and measuring whether the displacement has decreased in similar conditions, the seat is proven to be more stable.

4. Conclusion and Framework design

In this section, the framework for the design phase will be defined. It initiates with the three main themes of this thesis, being: **Comfort, Confidence and Aesthetics**. These three themes need to be properly defined in order to make them measurable and useful for the design of the "Buddy" seat.

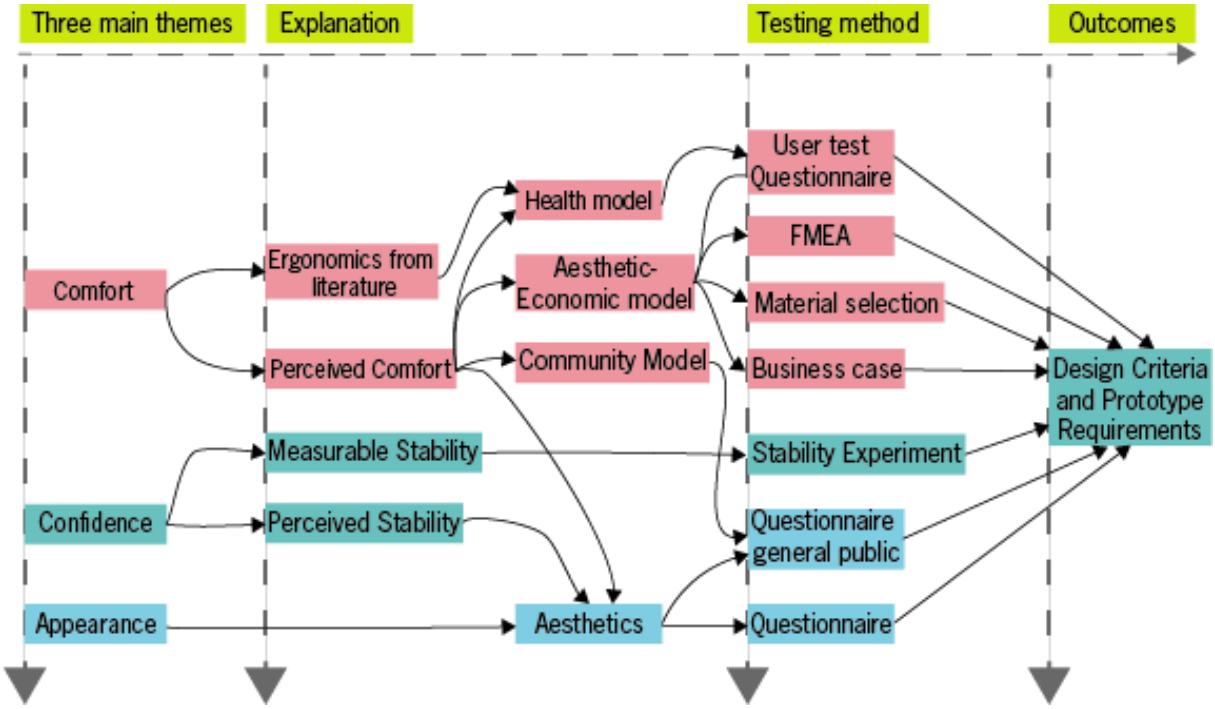


Figure 33: Framework for translating the three outcomes of the previous parts into requirements and design criteria for a final prototype.

With this framework, the design phase can commence. The focus will be on gathering the design requirements for the eventual final design of the seat through several testing methods. These methods can then be structured in the design thinking process by iterating.

This framework aims to give an overview into the link between the three main topics coming from the previous chapters: comfort, confidence and appearance. Comfort and confidence can both be linked to appearance via perceived comfort and confidence through aesthetics. Trough the use of this framework, ambiguous terms like comfort and confidence can be made measurable and can therefore structure the design to ensure that the main needs for the target group are being met.

Chapter 5: Design & Development

In this section, the design and development phase of the prototype, using the design thinking method will be described. This phase consists of five subphases. These phases each have their ideation, prototype and test phases as described in the approach section. When these tests are conducted, design criteria and hypotheses for the final concept can be established. The chapter commences with six preliminary tests. Then, a midterm focus group will be described. Then, a first target user test will be conducted. For this, a prototype needs to be designed. Fourthly, an aesthetics bystander questionnaire will be conducted. Finally, a second user test will be conducted. Each phase begins with to be tested hypotheses and finalises with design criteria. This chapter will conclude with an overview of the main functionalities to include in the design of the seat according to the research. This section is finished once a clear understanding about which functionalities to include is shaped.

1. Preliminary tests

Explaining building and testing hypotheses

This section details six explorative tests designed to address uncertainties identified in the previous section. The tests to be conducted are as follows:

1. Functional seating angle
2. Lumbar support
3. Sitting area
4. Bucket seat
5. Hip angle envelope
6. Lateral stability

These tests will be conducted with employees at Ideeënfabriek or the Civon Innovation Centre. This choice is due to convenience and the current stage of the project, where involving target users would be too cumbersome. Target users will be included in a later stage with a proper prototype. Each tests has the aim to address the hypotheses formed in section 3:

Test 1:

- The ideal functional seating angle is 123 degrees with a sitting area angle of >4 degrees in terms of comfort and stability.
- The prototype of the seat should offer maximum adaptability in order to cater the target audience and to test as many aspects as possible.
- The most important aspect of the seat for the "Buddy" is that it is ergonomically perceived as comfortable and gives the passenger stability.

Test 2:

- A Lumbar support is needed for the seat to offer maximal support and stability. The lumbar support should be adaptable for p5-p95.
- The most important aspect of the seat for the "Buddy" is that it is ergonomically perceived as comfortable and gives the passenger stability.

Test 3:

- The sitting area must be made out of a solid material instead of a hammock structure to minimise seating pressure
- The most important aspect of the seat for the "Buddy" is that it is ergonomically perceived as comfortable and gives the passenger stability.

Test 4:

- Side Bolsters are needed in order to improve stability for the passenger. They will be placed around the lower torso of the passenger.

Test 5:

- The minimal hip angle of the passenger cannot exceed 95 degrees whilst pedalling from the front seat.

Test 6:

- The most important aspect of the seat for the “Buddy” is that it is ergonomically perceived as comfortable and gives the passenger stability.

The remaining two hypotheses will be tested at a later stage:

- The design of the front seat can evoke a certain feeling to the target user and should by no means cause for more stigma than the functionality of the Buddy bicycle allows.
- The accessibility of the front seat needs to be examined with the target user, if the handlebar movement is insufficient, a rotatable seat needs to be installed.

Each test will involve five subjects, following Norman and Nielsen’s qualitative research recommendations (Nielsen & Landauer, 1993). Additionally, comfort and stability ratings from each subject will be statistically analysed. While reliable statistical results typically require a minimum of 20 subjects, conducting these tests will still provide valuable insights into the significance of the outcomes. A detailed breakdown of the tests, including test plans and hypotheses, can be found in Appendix G.

Test 1: Functional Seating Angle

Goal

The objective of this test is to determine the most desired seating angle for the "Buddy" bicycle by comparing two seating angles based on comfort and stability ratings from participants.

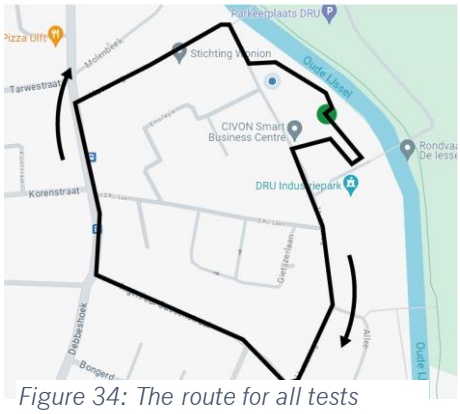


Figure 34: The route for all tests

Methodology

- **Participants:** 5 subjects of varying ages and heights.
- **Procedure:** Participants will cycle for 5-10 minutes in two different seating positions and provide comfort and stability ratings for each position.
- **Evaluation:** Ratings will be collected and qualitative feedback will be sorted into an affinity diagram to draw conclusions.

Reasoning for Conducting the Test

- **Emphasizing:** Understanding user preferences ensures that the final design meets the comfort and stability needs of the target audience.
- **Ergonomics Optimization:** Identifying the ideal seating angle helps in designing a seat that promotes proper posture and reduces physical strain.
- **Literature Hypotheses check:** To see whether the most stable functional seating angle of 123 degrees according to literature is also applicable in this specific context.

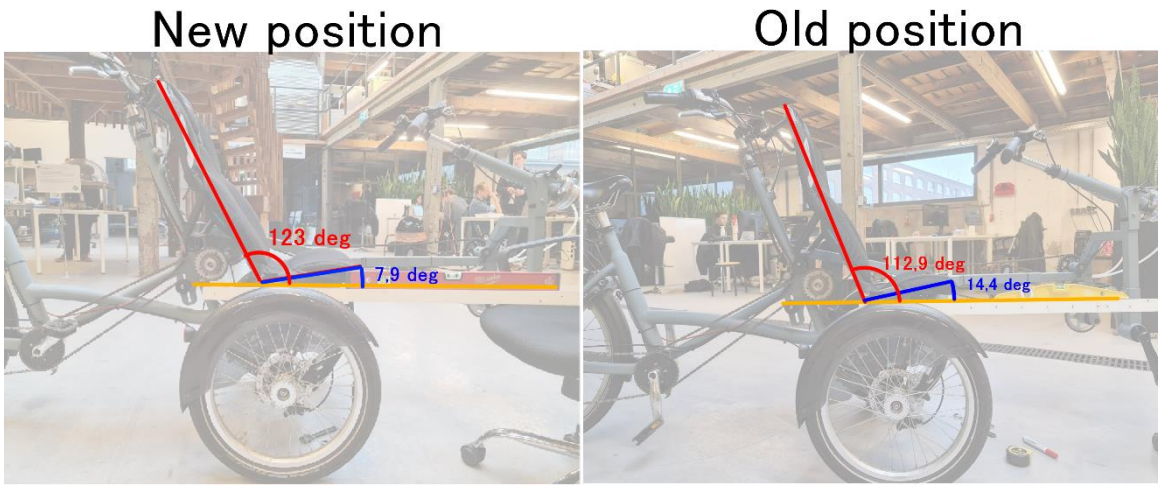


Figure 35: Two different seating angles

Test Plan

1. **Initial Setup:**
    a. Configure the bicycle with two seating angles:
2. **New Position:** Functional seating angle of 123 degrees
    a. Back angle: 123 degrees
    b. Sitting area angle: 7.85 degrees
3. **Old Position:** Functional seating angle of 112.9 degrees
    a. Back angle: 112.6 degrees
    b. Sitting area angle: 14.4 degrees
4. **Participant Procedure:**
    a. Have participants cycle for 5-10 minutes in both positions.
    b. Collect comfort and stability ratings for each position.
    c. Gather qualitative feedback and remarks.
5. **Data Collection Template:**

Person	Age (yr)	Gender	Height (cm)	Old Back Angle: Comfort	Old Back Angle: Stability	New Back Angle: Comfort	New Back Angle: Stability
1	24	m	183	7	8.5	7.5	8.5
2	22	m	188	4.5	5.5	6.5	8
3	24	m	186	8	8	9	9
4	22	f	166	7	8	8.5	9
5	71	f	175	7	7.5	8	7

Statistical Analysis

Metric	p-value	CI	A priori power	Significant difference?
Comfort	0.0046	0.05	0.239	Yes
Stability	0.098	0.05	0.239	No

Results Interpretation

- The ideal back angle of 123 degrees was preferred by 4 out of 5 subjects.
- The subject who preferred the old back angle was shorter than 170 cm, indicating that this angle might be less comfortable for shorter individuals due to the need for greater core control.
- Overall, the functional seating angle of 123 degrees received higher comfort ratings and was generally preferred.

Limitations

- **Sample Size:** With only 5 participants, the statistical significance of the results is limited, although a trend might be spotted from these results.
- **Subjectivity:** Individual comfort and stability perceptions can vary, influencing ratings and feedback.

Conclusion

The test indicates a clear preference for the functional seating angle of 123 degrees among most participants, suggesting it as the desired seating angle moving forward with the project. However, for shorter individuals, adjustments to the pedal and handlebar positions may be necessary to enhance comfort.

Additionally, the sitting area support is more critical with this back angle and needs to be adapted accordingly. A headrest might also be necessary to better support the passenger. This seating angle also allows for better compliance with the 95-degree hip angle limit, ensuring ergonomic benefits. Despite the positive direction indicated by the data, the small sample size and individual variations highlight the need for further testing to validate these findings comprehensively

Test 2: Lumbar support

Goal

The objective of this research is to determine whether integrating a lumbar support into the seat of the "Buddy" bicycle enhances comfort and stability. This will be assessed through qualitative research involving five subjects of different ages.

Figure 36: The seat with Lumbar support

Chosen lumbar Support

The lumbar support added to the seat is the McKenzie slim line ergo support lumbar role which has a half circle shape and is not too firm (McKenzie Slimline). This is done because elderly people tend to have a less pronounced S-Curve, so the in theory a less pronounced lumbar support will be the most viable option. The Lumbar support has the following measurements:

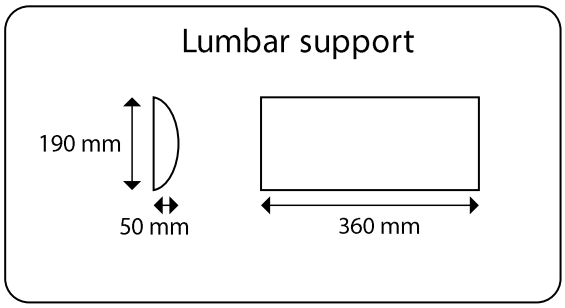


Figure 37: Lumbar support dimensions

Reasoning for Conducting the Test

- **Emphasizing:** Understanding the impact of lumbar support on comfort and stability can lead to improved user experience, particularly for longer rides where discomfort can become a significant issue.
- **Informed Design Decisions:** Gathering qualitative feedback from actual users helps in making data-driven decisions about potential modifications to the bicycle seat, ensuring that any changes meet the needs and preferences of a diverse user base.
- **Literature Hypotheses check:** To see whether a lumbar support actually provides more comfort and stability for the user as is suggested in literature.

Methodology

- **Participants:** 5 subjects of different ages (specific demographics detailed below).
- **Procedure:** Each participant will cycle for 5-10 minutes using the "Buddy" bicycle, both with and without lumbar support. Before cycling, eacht participant is asked to place the lumbar support as they think is correct at the backrest. This is then measured from the central point in the seat
- **Evaluation:** Post-cycling, participants will rate comfort and stability in both scenarios. Qualitative feedback will be collected to provide arguments in favor and against the lumbar support.

Test Plan

- **Initial Setup:**
  - Ensure the bicycle and seat (with and without lumbar support) are ready for use.
  - Remove bolster foam to allow lumbar support to sit flush with the seat.
- **Participant Details and Ratings:**
  - Collect basic information: age, gender, height.
  - Have participants rate comfort and stability on a scale from 1 to 10 for both configurations.

Data Collection Template

Participant	Age (years)	Gender	Height (cm)	Comfort With Support	Stability With Support	Comfort Without Support	Stability Without Support	Ideal Comfort With Support	Ideal Stability With Support	Ideal Comfort Without Support	Ideal Stability Without Support	Lumbar Support Height (mm)
1	24	M	183	8	9	7	8.5	9	8.5	7.5	8.5	250
2	22	M	188	6	7	4.5	5.5	9	9	6.5	8	231
3	24	M	186	5	8	8	8	6	9	9	9	280
4	60	F	180					7.5	8	7	7	192
5	22	F	166	8	9	7	8	4	6	6	6	187
6	71	F	175	8	8.5	7	7.5	9	10	8.5	9	-
7	56	M	170					7	6	8	7	

Statistical Analysis

Metric	p-value	Confidence Interval	A priori Power	Significant Difference?
Comfort	0.57	0.05	0.319	No
Stability	0.175	0.05	0.3567	No

Results Interpretation

Although the lumbar support did not show a statistically significant improvement in comfort and stability ($p > 0.05$), qualitative feedback suggests a preference for the lumbar support. Four out of seven subjects preferred using the lumbar support, citing increased stability and comfort. However, some issues were noted regarding the positioning and size of the lumbar support in relation to the seat's sitting area.

In terms of Lumbar support placement the mean is 228 mm, which is nearly identical to the findings from literature, 225 mm with 50 mm adjustability. This value will thus be kept moving forward in the project.

Reasoning for Integration of Lumbar Support

- **Qualitative Feedback:** Most participants noted an increase in stability and comfort with the lumbar support. This feedback indicates potential benefits that quantitative measures might not fully capture.
- **User Preference:** The majority of participants preferred the lumbar support, suggesting that despite the lack of statistical significance, there is a perceptible improvement in the cycling experience.
- **Comfort and Ergonomics:** Proper lumbar support can enhance spinal alignment and reduce strain, which is particularly beneficial for longer rides as indicated in literature.

Limitations

- **Sample Size:** With only five subjects, the sample size is too small to generalize the findings broadly. The statistical power is low, limiting the ability to detect significant differences.
- **Subjectivity:** Comfort and stability ratings are subjective and can vary greatly between individuals.
- **Demographic Range:** While the ages of participants vary, the sample may not represent the broader population of potential users. Gender and height distribution is also limited.
- **Seat Modification:** Removing the bolster foam to fit the lumbar support may have affected overall seat comfort, independent of the lumbar support itself.
- **Documentation:** The lumbar support placement measurements have not been documented properly as images have not been taken from this event. In order to be sure about this, a new test needs to be conducted

Conclusion

Despite the lack of statistical significance, the qualitative feedback indicates that lumbar support could enhance comfort and stability for the "Buddy" bicycle seat. Adjustments to the position and size of the lumbar support should be made to ensure better compatibility with the seat's geometry. Therefore, it is recommended to offer a lumbar support that can be adjusted according to user preference.

Test 3: Sitting area material

Goal

The objective of this research is to determine whether integrating the sitting area from the VanRaam Easy Rider 3 onto the "Buddy" bicycle enhances comfort and stability. This will be assessed through qualitative research involving six subjects of different ages.

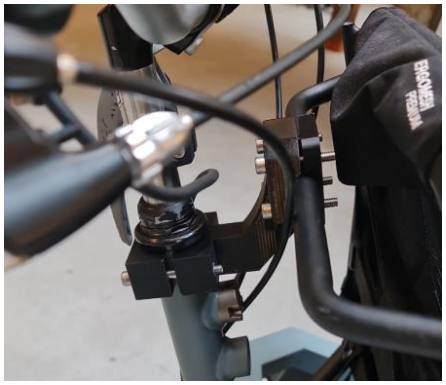


Figure 38: Clamp to connect the backrest to the frame

Methodology

- **Participants:** minimal 5 subjects of different ages (specific demographics detailed below).
- **Procedure:** Each participant will cycle for 5-10 minutes using the "Buddy" bicycle, with and without the ER3 sitting area.
- **Evaluation:** Post-cycling, participants will rate comfort and stability in both scenarios. Qualitative feedback will be collected to provide arguments in favour and against the ER3 sitting area.

Figure 39: The ER3 sitting area on the Buddy bicycle

Reasoning for Conducting the Test

- **Literature hypothesis check:** Understanding the impact of the ER3 sitting area on comfort and stability can decide the design direction, as the ER3 seat is harder and flatter than the HP Velotechnik seat. It also has a different load structure (figure 40).
- **Informed Design Decisions:** Gathering qualitative feedback from actual users helps in making data-driven decisions about potential modifications to the bicycle seat, ensuring that any changes meet the needs and preferences of a diverse user base. This is also based on the materials part in the literature research.

Test Plan

- **Initial Setup:**
  - Disassemble the existing HP Velotechnik seat and install the ER3 sitting area from the VanRaam EasyRider 3.
  - Manufacture and install the necessary connections to the frame and headset tube to secure the ER3 sitting area.
- **Participant Details and Ratings:**
  - Collect basic information: age, gender, height.
  - Have participants rate comfort and stability on a scale from 1 to 10 for both configurations.

Data Collection Template

Participant	Age (years)	Gender	Height (cm)	Comfort With ER3	Stability With ER3	Comfort Without ER3	Stability Without ER3
1	24	M	183			7	8.5
2	22	M	188	7	8.5	5	8
3	24	M	186	5	8	9	9
4	22	F	166	9	9	7	9
5	71	F	175	7	9	8	7
6	21	M	185	8	7		

Statistical Analysis

Metric	p-value	Confidence Interval	A priori Power	Significant Difference?
Comfort	0.5	0.05	0.239	No
Stability	0.5	0.05	0.239	No

Results Interpretation

The ER3 sitting area did not show a statistically significant improvement in comfort and stability ($p > 0.05$). Subjects found the ER3 sitting area too short and too slippery and too hard, which affected their overall perception of comfort and stability. These issues were largely due to the sitting area's placement and material.

Limitations

- **Sample Size:** With only six subjects, the sample size is too small to generalize the findings broadly. The statistical power is low, limiting the ability to detect significant differences.

- **Subjectivity:** Comfort and stability ratings are subjective and can vary greatly between individuals.
- **Demographic Range:** While the ages of participants vary, the sample may not represent the broader population of potential users. Gender and height distribution is also limited.
- **Seat Modification:** Modifications required to fit the ER3 sitting area may have impacted the overall seat comfort independently of the ER3's design, such Is the stability and the placement of the seat.
- **Foam differences:** Foam is a material that exists in thousands of different shapes and hardness levels. To draw a hard conclusion after comparing to only one foam is too premature.

Conclusion

Despite the lack of statistical significance, the qualitative feedback suggests that the ER3 sitting area has potential but requires modifications. The seat was found to be too short and slippery, which are issues that can be addressed through design adjustments. Given the participants' preference for a more bucket-like sitting area, a hammock-like structure may be more suitable. However, at this stage only one foam and top layer has been tested. In order verify this even further, different foams and slipperiness levels should be tested against the Hammock style seat. For now, the hammock style seat is concluded to be the better option as it had more elasticity, better damping and more longitudinal stability for the user.

Test 4: Side Bolsters

Goal

The objective of this research is to determine whether adding side bolsters to the seat of the "Buddy" bicycle enhances comfort and stability. This test aims to guide the potential addition of bolsters and to evaluate the backrest of the EasyRider 3, which allows significant sideways movement of the passenger, without mounting the actual ER3 backrest.

Figure 40: The side bolsters on the Buddy bicycle

Methodology

- **Participants:** 5 subjects of different ages (specific demographics detailed below).
- **Procedure:** Each participant will cycle for 5-10 minutes using the "Buddy" bicycle, with and without the side bolsters.
- **Evaluation:** Post-cycling, participants will rate comfort and stability in both scenarios. Qualitative feedback will be collected to provide arguments in favor and against the side bolsters.

Reasoning for Conducting the Test

- **Enhanced Stability:** Side bolsters are hypothesized to increase lateral stability, which can enhance the passenger's sense of security, especially in turns and uneven terrain.
- **User Comfort:** Proper lateral support can mimic the comfort of a bucket seat, making the ride more enjoyable and reducing the need for the passenger to constantly adjust their position.
- **Design Decisions:** Understanding the impact of side bolsters will inform whether the backrest of the EasyRider 3 should be used or if a custom solution is more suitable for the "Buddy" bicycle.

Test Plan

- **Initial Setup:**
  - Construct and attach the side bolsters to the existing seat. These bolsters are made of 3D-printed clamps, wooden panels, and polyurethane foam for comfort.
  - Ensure the bolsters can be rotated and adjusted to fit the body of the subject.
- **Participant Details and Ratings:**
  - Collect basic information: age, gender, height.
  - Have participants rate comfort and stability on a scale from 1 to 10 for both configurations.

Data Collection Template

Participant	Age (years)	Gender	Height (cm)	Comfort With Bolsters	Stability With Bolsters	Comfort Without Bolsters	Stability Without Bolsters
2	24	M	183	8.5	9.5	6.5	8
3	24	M	186	9.5	9.5	9	9
4	22	F	166	9.5	10	8.5	9
5	77	M	173	8	9	8	7
6	21	M	185	8.5	9	7.5	8.5

Statistical Analysis

Metric	p-value	Confidence Interval	A priori Power	Significant Difference?
Comfort	0.027	0.05	0.239	Yes
Stability	0.01	0.05	0.239	Yes

Results Interpretation

The addition of side bolsters resulted in statistically significant improvements in both comfort and stability ($p < 0.05$). Participants provided positive feedback, noting enhanced stability and comfort similar to that of a bucket seat. Comments included:

- *"No need to correct yourself in order to remain stable in the seat."*
- *"Like sitting in a comfortable chair at home, but without feeling sleepy because of the activity."*
- *"Cannot move from side to side anymore, which gives a secure feeling."*

However, the bolsters made core rotation difficult, meaning passengers must rely more on the supervisor in traffic. This issue could be mitigated with more subtle bolsters.

Limitations

- **Sample Size:** With only five subjects, the sample size is too small to generalize the findings broadly. The statistical power is low, limiting the ability to detect significant differences.
- **Subjectivity:** Comfort and stability ratings are subjective and can vary greatly between individuals.
- **Demographic Range:** While the ages of participants vary, the sample may not represent the broader population of potential users. Gender and height distribution is also limited.
- **Bolster Design:** The current bolster design is an extreme version; more subtle designs may yield different results. Exact measurements of proper bolster design are difficult to find in literature. In this study, only the added value of

the side bolster is examined, moving forward with the project, also bolster dimensions should be specified.

Conclusion

The addition of side bolsters significantly improved both comfort and stability for the "Buddy" bicycle seat. Despite the positive feedback, the difficulty in core rotation suggests that a more subtle bolster design may be preferable. This test also indicates that the backrest of the EasyRider 3 is not suitable for transfer to the "Buddy" bicycle. Moving forward, a bucket seat-like structure with adjustable, less intrusive bolsters is recommended to ensure both comfort and stability without compromising the passenger's ability to move as needed.

Test 5: Hip angle envelope

Goal

The objective of this experiment is to determine the necessary adaptability of the seating position relative to the bottom bracket to effectively accommodate the 5th to 95th percentile (p5 to p95) of the target audience, specifically Dutch adults aged 60 and above.

Figure 41: Test set-up

Methodology

- **Participants:** 2 subjects, one at the 15th percentile (158 cm) and one at the 95th percentile (182 cm), representing the target audience.
- **Procedure:** Measure the adaptability required for the seating position to ensure both participants can pedal comfortably while maintaining a minimal hip angle greater than 95 degrees.
- **Data Source:** Use the DINED database tool for "Dutch adults 60+ mixed" to establish the height range of the target audience.

Reasoning for Conducting the Test

- **User Comfort and Safety:** Ensuring that the seating position can be adjusted to fit a wide range of body sizes is critical for user comfort and safety, preventing discomfort and reducing the risk of injury.
- **Inclusivity:** Designing a seating position that caters to a diverse audience range ensures that the bicycle can be used by a larger portion of the target population, making the product more inclusive.
- **Optimal Ergonomics:** Achieving the correct seating position and pedal distance is crucial for maintaining proper ergonomics, which can enhance the overall riding experience and efficiency.

Test Plan

Initial Setup:

- Establish the height range for the target audience using the DINED database.
- Select two participants whose heights approximate the p5 and p95 percentiles.

Experiment Setup:

- Adjust the seating position and measure the distance from the centre of the seat to the bottom bracket for each participant.
- Ensure that both participants can spin the pedals easily and achieve a minimal hip angle greater than 95 degrees.

Data Collection:

- Use the following conversion factors and dimensions to determine the necessary range of adaptability:
- Stature height p5 / Stature height p15=0.968\text{Stature height p5 / Stature height p15} = 0.968Stature height p5 / Stature height p15=0.968
- Add 2% extra safety to the calculated dimensions.

Measurements and Calculations

Metric	P5 minus 2%	P5 (151.7 cm)	P15 (158 cm)	P95 (181.3 cm)	P95 plus 2%
X distance (Seat to Bottom Bracket)	76.8 cm	78.4 cm	81 cm	95 cm	96.9 cm
Y1 distance (Floor to Bottom Bracket)	30.4 cm	31 cm	32 cm	36 cm	36.7 cm
Y2 distance (Seat to Bottom Bracket)	19.6 cm	19 cm	18 cm	14 cm	13.3 cm

Results Interpretation

Both participants (158 cm and 182 cm) were able to pedal comfortably and maintain a minimal hip angle greater than 95 degrees, indicating the seating position's adaptability within the defined range. This supports the conclusion that the current design can accommodate the p5 to p95 of the target audience.

Limitations

- **Sample Size:** Testing only two participants limits the generalizability of the findings. A larger sample would provide more robust data.
- **Subjectivity:** The perceived comfort and adaptability can vary between individuals, even within the same height range.
- **Database Limitation:** The DINED database provides an average range, but individual variations in leg length and torso height are not accounted for, which could affect comfort.

Conclusion

The experiment demonstrated that the seating position on the "Buddy" bicycle can be adjusted to accommodate individuals from the 15th to the 95th percentile of the target audience in terms of height. Both participants were able to pedal comfortably, maintaining the required hip angle, which confirms the seating position's adaptability. Moving forward, it is recommended to conduct further tests with a larger sample size to validate these findings and consider individual variations in body proportions for even more tailored ergonomic adjustments.

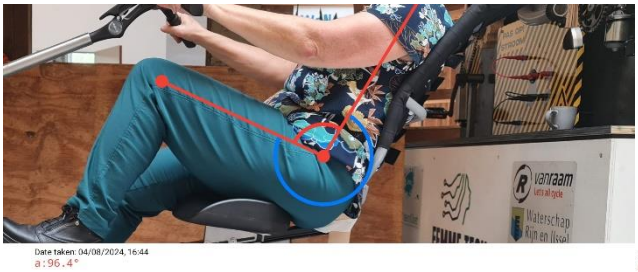


Figure 43: p15 woman

Figure 44: p95 male

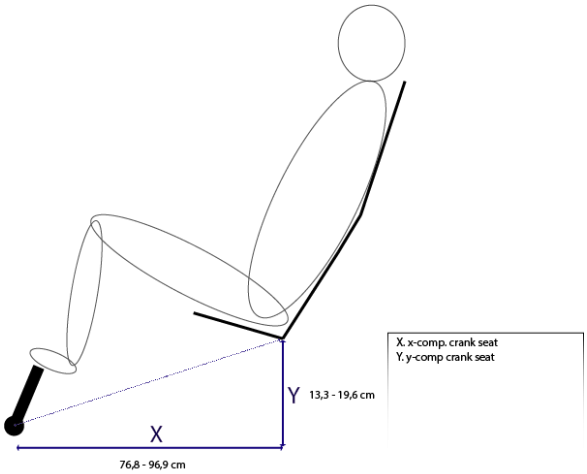


Figure 42: Experiment setup

Test 6: Stability experiment

Goal

The objective of this test is to quantify passenger stability while riding the "Buddy" bicycle during cornering and braking, comparing configurations with and without side bolsters and lumbar support.

Methodology

- **Participants:** one subject will ride the bicycle in both configurations (with and without side bolsters and lumbar support).
- **Procedure:** Measure the core displacement (in degrees) of the passenger during cornering and braking manoeuvres.
- **Evaluation:** Compare the average core displacement between the two configurations to assess stability.

Reasoning for Conducting the Test

- **Enhanced Stability:** Understanding the impact of side bolsters and lumbar support on stability can lead to design improvements that enhance passenger safety and comfort.
- **Design Validation:** This test provides empirical data to support the inclusion of side bolsters in the bicycle design, ensuring that any modifications are based on measurable benefits.
- **Safety Considerations:** Improved stability reduces the risk of falls and injuries during cornering and braking, which are critical moments for maintaining balance.
- **User Experience:** Enhanced stability can make the riding experience more enjoyable and secure for passengers, increasing the overall appeal of the bicycle.

Test Plan

1. **Initial Setup:**
    - Attach side bolsters and lumbar support to the existing seat.
    - Ensure both configurations (with and without side bolsters and lumbar support) are ready for testing.
2. **Participant Procedure:**
    - Have participants ride the bicycle through a set course involving cornering and braking.
    - Measure the core displacement of the passenger during these maneuvers using motion capture or similar technology.

Data Collection Template:

Configuration	Core Displacement (degrees)
Without Side Bolsters and Lumbar Support	9.6
With Side Bolsters and Lumbar Support	3.6

Results Interpretation

The configuration with side bolsters and lumbar support showed a significantly lower average core displacement (3.6 degrees) compared to the configuration without (9.6 degrees), indicating improved stability during cornering and braking.

Limitations

- **Sample Size:** The test needs more participants to provide statistically robust results.
- **Subjectivity:** Individual variations in balance and riding style can affect core displacement measurements.
- **Measurement Accuracy:** Ensuring consistent measurement of core displacement is challenging and may introduce variability.
- **Unknown Fall Threshold:** The results do not indicate the value at which the bicycle would fall over. Without this critical threshold, the significance of the measured core displacements remains uncertain.
- **Real-World Variability:** Controlled test conditions may not fully replicate real-world scenarios, where additional factors can influence stability.

Conclusion

The test demonstrates that the inclusion of side bolsters and lumbar support significantly improves passenger stability during cornering and braking, as evidenced by reduced core displacement. These findings support the design direction of incorporating side bolsters into the "Buddy" bicycle. However, further testing with a larger sample size and additional real-world scenarios is recommended to validate these results and better understand the stability limits. Additionally, determining the core displacement threshold at which the bicycle would fall over is crucial for fully assessing the safety implications of these design modifications.

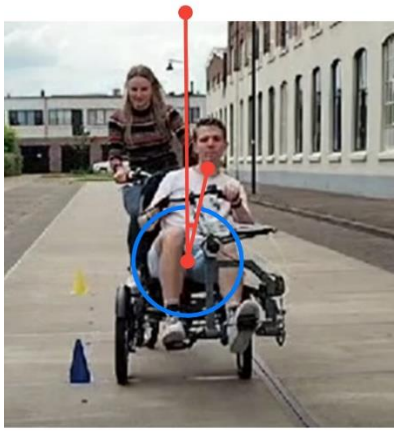
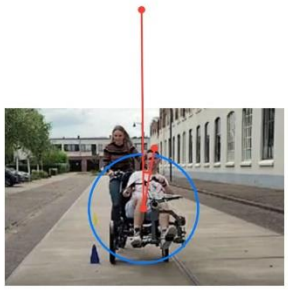
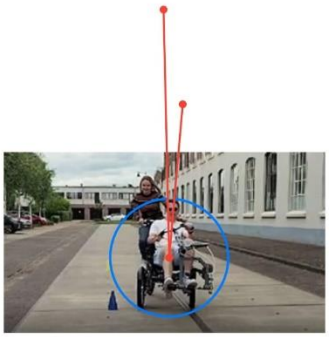
 Date taken: 05/29/2024, 11:00 a:12.8° t1.1	 Date taken: 05/29/2024, 11:11 a:10.9° t1.2	 Date taken: 05/29/2024, 11:17 a:5.2° t1.3
T1.1	T1.2	T1.3
 Date taken: 05/29/2024, 11:20 a:2.3° t2.1	 Date taken: 05/29/2024, 11:25 a:6.3° t2.2	 Date taken: 05/29/2024, 11:28 a:2.3° t.2.3
T2.1	T2.2	T2.3

Figure 45: Stability test outcomes

Conclusions from tests

These preliminary tests have provided useful insights into the criteria the seat needs to fulfil in order to be comfortable and stable. The conclusions are summarized below.

- **Seating Angle**: Preferred angle is 123 degrees for comfort and stability.
- **Lumbar Support**: Adjustable lumbar support is recommended for enhanced comfort and stability.
- **Sitting Area**: A hammock-like sitting area with modifications to length and surface to prevent slipperiness is preferred.
- **Lateral Support**: Side bolsters improve comfort and stability but should be less intrusive to allow for core rotation.
- **Adaptability**: The seat needs to be adaptable with respect to the bottom bracket.
- **Stability**: Side bolsters reduce torso rotation, indicating improved stability; further assessment of core displacement threshold is needed for safety.

These conclusions can be translated into the following design criteria:

Design Criteria

Must Have:

- The seat must have an adjustable seating angle, with 123 degrees being a key reference point.
- The seat must include adjustable lumbar support to cater to different user preferences and enhance comfort and stability.
- The seat must be designed to prevent slipperiness and be ergonomic, taking inspiration from a hammock-like structure to improve comfort.
- The seat must have side bolsters that enhance stability without significantly impeding core rotation or the ability to move.

Should Have:

- The side bolsters should be adjustable to cater to various user preferences and ensure they do not overly restrict movement.
- The design should allow for adaptability with the bottom bracket, either through the seat or the bicycle frame.

Could Have:

- The seat could include additional ergonomic features based on user feedback to further enhance comfort.
- The design could include optional features such as additional padding or accessories for further customization.

Won't Have:

- The seat won't have a fixed lumbar support, as adjustability is crucial for comfort and compatibility.
- The seat won't have rigid or non-adjustable bolsters, as they may impede movement and reduce comfort.

2. Midterm Focus group

A group of elderly voluntary caregivers stopped by at Civon for an event. They were asked about their first impressions when looking at the “Buddy” bicycle whilst stationary. Some even sat down on the front seat and one male and one female rode a lap together on the DRU industrial estate.

The questions asked were mainly about the first impressions of the bicycle and the seat, also some questions were asked about some associations that the people had with the bicycle. Finally, some general feedback was given on the bicycle.

This event was to get some feedback from the “supervisors” that have experience with taking care and cycling together with impaired people. No major conclusions can be drawn from this event, it does however provide some feedback and insight for the design process of the seat and the “Buddy” in general.

The people were male and female in ages 68 until 77 years. Some had experience with riding on a bicycle as a supervisor, others had no experience.

The Buddy bicycle was generally perceived as a nice new bicycle concepts. People said the bicycle looked, stable tough and more practical than the Fun2Go. The caregivers wanted a lot of support and possibility to secure the passengers in place. Generally, they thought the bicycle is meant for impaired people in a wheelchair, thus they want a rotatable seat. The seat feels comfortable, lumbar support can be added the bolsters do not need to be too big but have to offer some support. Therefore, the following design criteria need to be put into consideration The full session can be found in Appendix R:

Design Criteria

Should have:

- The seat should have a lumbar support and side bolsters for better comfort and stability

Could have:

- The seat op the Buddy bicycle could be rotatable for easier access for people that are less mobile and autonomous.

3. First User Test

The third part of the design & development phase entails the first user test in which the design criteria that have been established in the previous parts . These criteria can be found in Appendix H. In order to test these criteria, a prototype needs to be created, this will be covered in the next part.

New proto vs. current seat

After the initial partial tests have been concluded and some initial aesthetical designs have been made; the project needs to move forward into the target user phase and for this a physical prototype is needed.

For the test with end users, realistically, two paths could be taken. The first part is to keep the existing seat as a basis and change it according to the previous findings. The second option is to design a new seat from scratch; this gives freedom of adding the exact ergonomics as found in literature, downside is however that it will cost significantly more money. The question is also raised what the added value of a completely new prototype would be. In order to clarify this an overview is provided in figure 47.

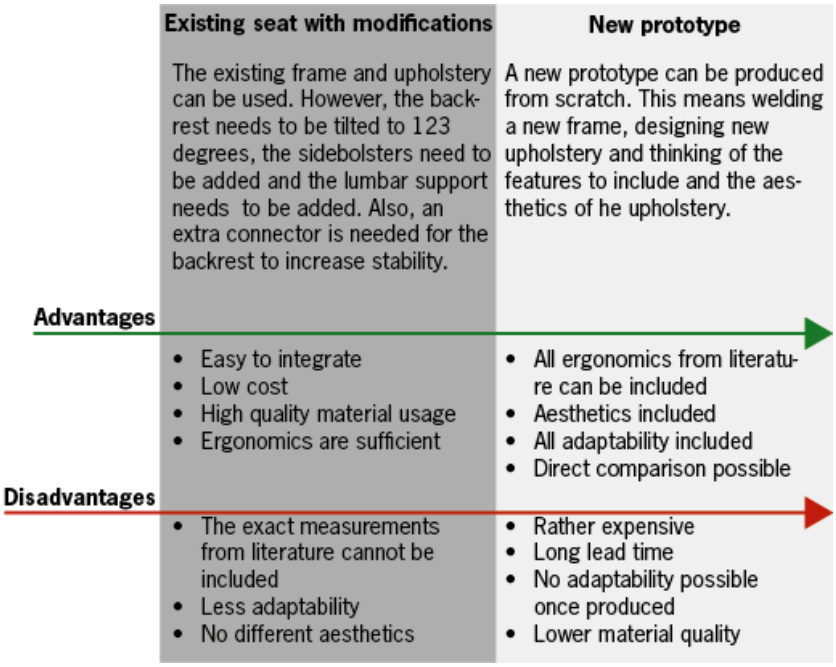


Figure 46: Different prototype directions

Eventually, the paramount arguments were the cost and lead time for not choosing to design a new prototype from scratch. A new prototype would cost approximately 1500 euros and would take three to four weeks to design and manufacture; time that was not at hand. On top of this, using the current seat as test prototype would mean next to no cost of production. Thus, the Existing seat with modifications has been chosen as the test prototype. In the next section the process of conversion will be elaborated.

Modifications to current seat

In order to test the ergonomics as described in the requirement specifications, the seat needs to be modified. The following changes have been made:

1. **Lumbar support**

The Lumbar support has been placed between the tension straps and the mesh fabric of the HP Velotechnik seat. During the initial tests with the lumbar support, it had been placed between the subject back and the mesh of the seat. The conclusion was that the lumbar support was too pronounced in this way. By hiding it behind the mesh, it becomes less pronounced and subjects are less likely to judge the lumbar support because it cannot be seen. The prominence of the lumbar support is now 10-30 mm, corresponding with earlier findings (Reed, 2013).

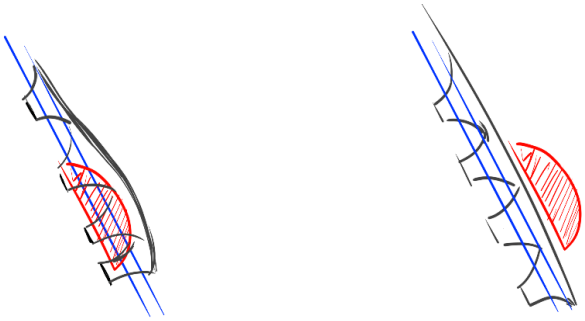


Figure 47: New Lumbar support position

2. **Connection to frame**

In order to add stability to the backrest, an extra support clamp has been 3D printed from PETG material, see figure 49.

Figure 48: Connection behind backrest to frame

3. **Side bolsters**

The side bolsters used for this prototype are an evolution of the bolsters used for the preliminary test. They have been made smaller in depth, and are now upholstered with black fabric in order to make them more uniform with the current design of the seat.

The bolsters are connected to the frame of the seat via a 3D printed clamp that has been modelled in Solidworks, see figure 50.

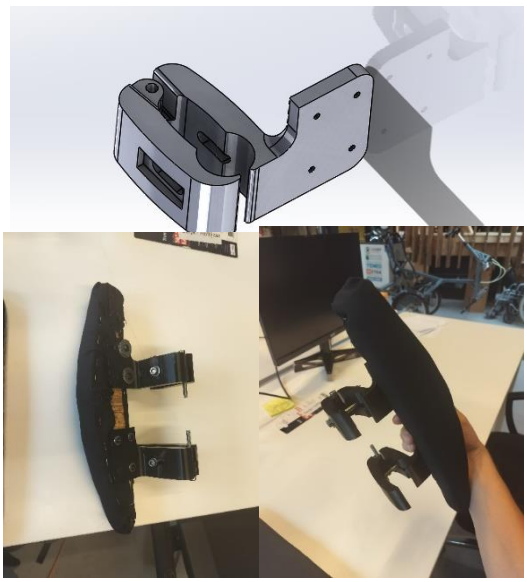


Figure 49: The clamp for the side bolsters

4. Functional seating angle

The functional seating angle has been changed from 114 degrees to 123 degrees, which is the most stable position according to literature. This is done by cutting away a part of the seat frame in order to create some space for the seating angle. The seat itself allows for the change in seating angle, see figure 51.

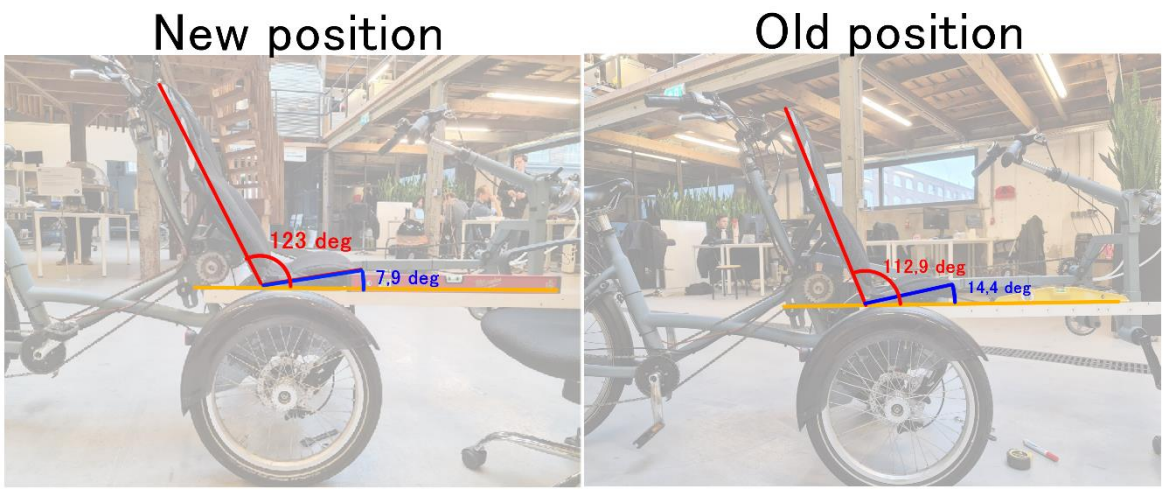


Figure 50: The new functional seating angle

Aesthetics ideation + Conceptualization

Next to the functionality, the Aesthetics are also of interest for the design of the seat of the Buddy bicycle. From the define and empathize phase it became apparent that stigma is not really a problem, however aesthetics can still communicate comfort, stability and other values that might be desirable. In order to explore this, initial aesthetic sketches have been made based on the research of the define and development phase.

In order to gather even more insight into the aesthetics, a meeting has been held with one of the visual designers at VanRaam Ideeënfabriek. The conclusion of this meeting was in order of design, really put emphasis on the fact that VanRaam customers do not expect “flashy” design. It has to evoke a sense of reliability, dependency and quality. This is in line with the brand translation prism as defined in section 2. In terms of colour usage, if has been advised to use as neutral colours as possible in the design of the seat as the colour mainly comes from the frame; colour mismatch is something that should be avoided.

Then sketching commenced. The focus was really on the aesthetics, without focussing too much on functionality. After the initial ideation sketches, the decision has been made to focus the aesthetics onto the feeling that the seat needs to evoke. The different feelings were, Sportiness, Activity, Comfort and Stability. In order to do so, mood boards have been created to gather inspiration into these ambiguous terms.

Figure 51: The four mood boards

These mood boards are the inspiration for the ideation in each of those directions. Then these ideation sketches will be conceptualised and shown to the target user through sketch rendering. In figure 52, some ideation is shown based on the mood boards.

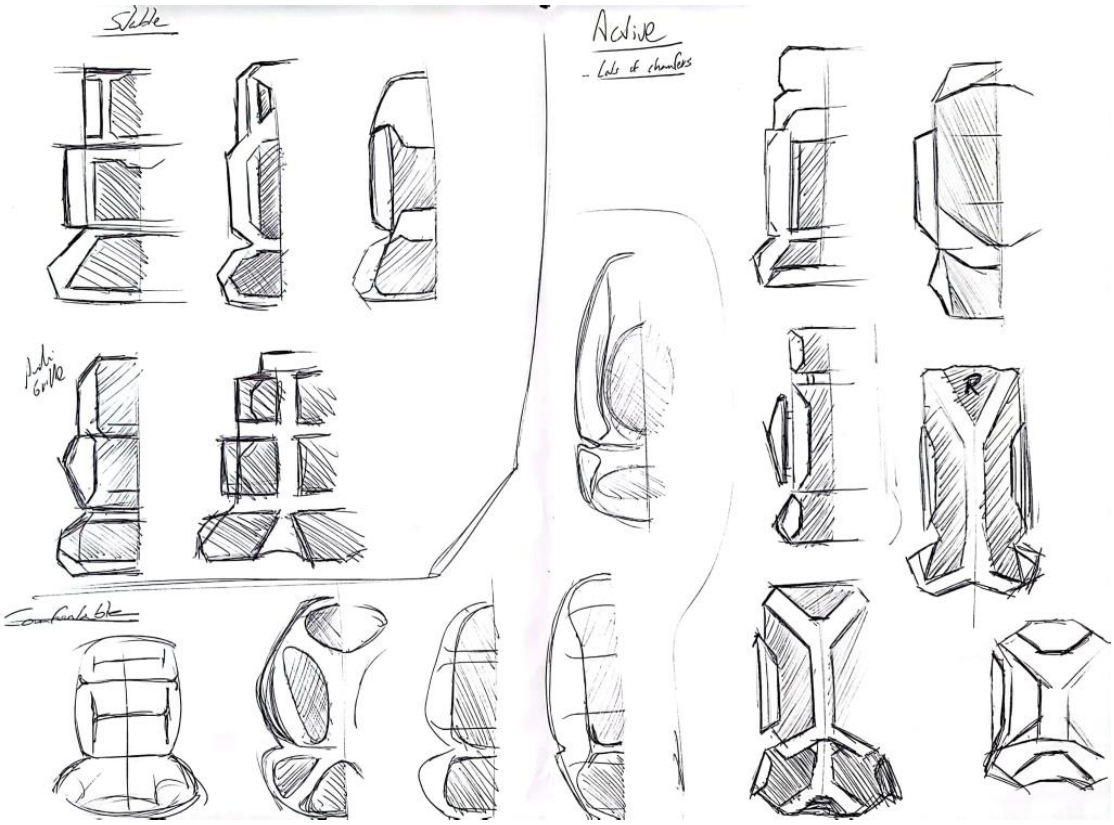


Figure 52: Different ideation sketches.

Eventually, four concept directions have been established (figure 54). These concepts will be tested with the target user during the initial user test before deciding which direction will be the desired direction for moving forward with the design.

Figure 53: The comfort seat, the Active seat, the Sporty seat and the Stable seat

Clockwise, these are the different concepts:

1. Comfortable seat: The idea behind this seat is to create continuous lines in order to create a visual coherent, relaxing and comforting experience. Also, the side bolsters are wide and appear to be hugging the passenger. In terms of materials, there are the black parts, which is some kind of mesh, and there is a grey part which is another top layer material.
2. Active seat: This seat uses a lot of chamfers and Y-shaped lines that might resemble rugged outdoors equipments. This makes the seat visually “busy”, there is a lot happening. The side bolsters are separate to evoke a feeling of functionality before form. This is also done in the sitting area.
3. Sporty seat: This seat uses the VanRaam Easy Rider 3 line and a generally narrower design that resembles a race bucket seat as found in sportscars. Also the exaggerated side bolsters add to this appearance.
4. Stable seat: The final seat evokes stability by not adding a lot of styling elements and essentially keeping it simple. The most striking feature is the three section approach with the middle section having exaggerated, lower place bolsters that aim to evoke a sense of stability.

User test

For the development of the seat for the passenger of the Buddy bicycle, it is imperative to emphatise with the target user. With this test, the finding in the literature research and early design phase testing can be checked and tested if the assumptions made and conclusions drawn are also applicable for the target group.

The aim of this user test is to gather insight into the preferences in terms of comfort and stability of the seat for the target user (65+ with changing medical condition) and whether the requirements set after preliminary tests are also correct for the target user. Next to this, also some insight in to the aesthetic wishes of the target user will be explored.

The subjects will all be people within the target group. For this they should be at least 65+ of age and suffering for some sort of (changing) medical condition that makes them not able to navigate through traffic independently.

The hypotheses that will be checked in the next section are the following:

1. The functional seating angle of 123 degrees is preferred also by the target group in terms of comfort and stability.
2. A lumbar support improves stability for the target group, however it should not be too pronounced.
3. The distance from the seat to the bottom bracket from the seat is decisive for the sense of comfort.
4. The side bolsters improve the stability, sense of stability, comfort and sense of comfort for the target user.
5. The construction and material for the sitting area is sufficient an should not be changed massively.
6. The appearance of the seat has influence on the perception of comfort and can evoke certain feelings for the target user.
7. A rotatable seat can be a necessity for entering the bicycle.
8. The current prototype with modifications is sufficient for the time being.

Test Plan (Protocol)

- Introduce everyone and introduce test plan and informed consent.
- Ride for 10 minutes in both positions
    - First new position then old position
    - In between the two positions, the seat needs to be positioned back to the old setting. This will take 10 minutes. In this time, one of the two colleagues can ask questions to the end user.
    - Before leaving make sure everyone is fitted properly to the bicycle
    - During the ride, let the passenger steer and brake while researcher/supervisor gives directions
- Afterwards a questionnaire with user feedback This questionnaire also asks for an opinion on the four aesthetics sketches as presented in an earlier section.

Conclusions from user test

Figure 54: Affinity diagram of outcomes user test

Figure 55: One of the user tests

General conclusions form the first user test:

1. **Distinguishing Seating Positions**: People with Parkinson's disease find it difficult to distinguish between different seating positions when riding for the first time.
2. **Stability and Comfort**: The bicycle feels more stable and comfortable compared to EasyRider3 and Fun2Go models.
3. **User Confidence**: The bicycle gives users confidence, making them feel secure and safe.
4. **Seat Accessibility**: People with Parkinson's disease find it challenging to get in and out of the seat; a rotatable seat might be beneficial.
5. **Seat Material**: Current seat materials are satisfactory; no comparison was made.
6. **Pedal Distance**: Distance to the pedals is crucial for stability and comfort.
7. **Adaptable Ergonomics**: Different design requirements are necessary for people with vision impairments, particularly regarding the seating angle.
8. **Side Bolsters**: Side bolsters are comfortable and ergonomically beneficial.
9. **Aesthetics**: A simpler design with minimal distractions is preferred by people with Parkinson's disease; the product should communicate activity.

These conclusions are then transformed into design criteria using the MoSCoW method of prioritization:

1. **Stable and Comfortable Design**: The bicycle must maintain or improve on the stability and comfort that make it preferable to EasyRider3 and Fun2Go models.
2. **Adjustable Pedal Distance**: The design must allow for adjustable pedal distance to ensure stability and comfort for different users.
3. **Simple Aesthetics**: The bicycle must have a simple design to avoid distractions, especially for users with Parkinson's disease.

1. **Rotatable Seat**: The seat should be rotatable to facilitate easier access for people with Parkinson's disease.
2. **Adaptable Seating Angle**: The seating angle should be adaptable to cater to the needs of users with vision impairments and other specific requirements.
3. **Confidence-Building Features**: The design should include elements that enhance user confidence and the perception of safety.

1. **Enhanced Side Bolsters**: The design could incorporate side bolsters that are adjustable to enhance ergonomic comfort further.
2. **Optional Ergonomic Features**: The design could include additional ergonomic features that can be customized based on user needs.
3. **Material Comparison**: Future iterations could involve a comparison of different seat materials to optimize comfort and durability.

1. **Overly Complex Design**: The bicycle won't have a complex design that could distract or overwhelm users with Parkinson's disease.
2. **Non-Adjustable Seating Angle**: The seat won't have a fixed seating angle, as adaptability is necessary to meet the needs of a diverse user base.

4. Bystanders aesthetics questionnaire

In order to gather some insight into the aesthetics of the to be designed seat, a survey was set up. The aim of the survey was to explore reactions on different concept directions within the “active” appearance subgroup as defined in section 3 and gather some significant results from which the final design can be derived from. The four different concepts can be found in figure 57.

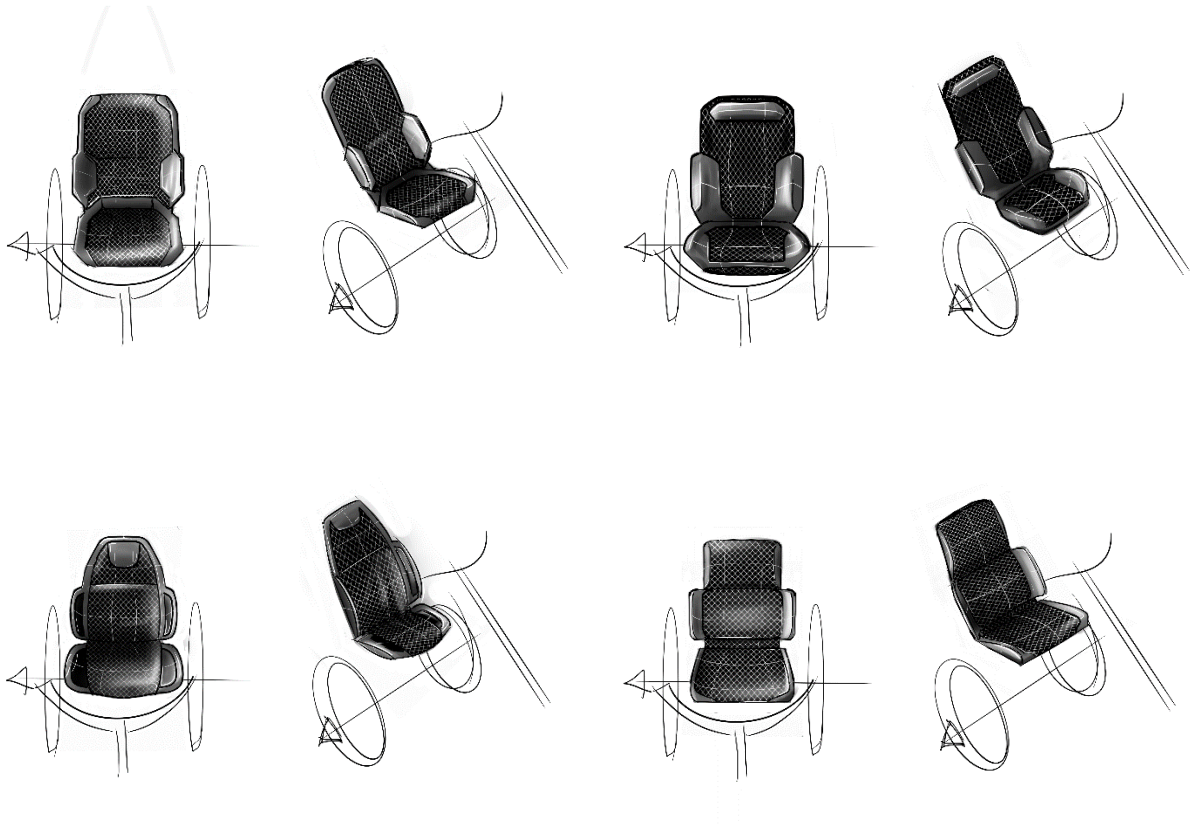


Figure 56: The four active concepts for the survey

The general stability and comfort of the appearance was scored on a Likert scale from 1 to 5. Next to this, a one word association was asked for every concept. The final question was which concept direction for aesthetics was preferred and why. This gave the following results:

Firstly, the questionnaire had 53 responses with 35 male and 18 female responses. The average age of the respondents was 40,7 years, with the youngest being 13 and the oldest respondent had an age of 75 years. The following results were obtained:

	Concept 1	**Concept 2**	**Concept 3**	**Concept 4**
Word association multiple choice	Sporty (43,3%)	Sporty (35,8%)	Relaxed (41,5%)	Clinical (41,5%)
Own word association	• Elegant • Sporty • Comfortable	• Comfortable • Luxurious • Sturdy	• Comfortable • Wide • Sporty	• Functional • Minimalistic • Large
Comfort rating (avg)	3,62	**3,89**	3,75	3,36
Comfort rating (median)	4	4	4	3
Stability rating (avg)	4,01	**4,23**	3,66	3,79
Stability rating (median)	4	4	3	4

Figure 57: Outcomes of the survey

Using an ANOVA analysis and a Tukey's HSD analysis, it can be concluded that from the ANOVA test, no significant result can be obtained for the comfort ratings, however a significant result for the stability ratings was obtained. When proceeding with the post hoc HSD analysis, it has been found that for the comfort ratings the between groups results showed that seat 2 was seen as significantly more comfortable than seat 4. For the stability ratings, seat 2 was again found to be significantly more stable than seat 3. All in all, one can conclude that in terms of appearance, seat 2 is the favourable direction to take when looking at numerical data in terms of comfort and stability. An important note is that seat 3 is the least stable seat in terms of appearance and seat 4 is the least comfortable seat in terms of appearance. For the full statistical analysis, see appendix L.

Next to this numerical data, there were also questions in the questionnaire on word associations. Table x. already provided with an overview of the number one association of the four choices per concept seat. It becomes apparent that the first two concept appear most sporty compared to concept 3 and four. However, the aim was to design a seat that conveys a sense of activity. However, questions can be raised whether people actually know what “active” is when directly compared to “sporty”, whereas sporty might be more clear to the general public and I therefore more easily picked as the favourable associative word. Next to this question, also the question was asked to describe each concept in one word, this lead to very different associations, however for each concept, there were some general words that appeared to be fitting for that concept (figure 58). The final question of the questionnaire was for the respondents to pick their preferred concept out of the four. 45,3% chose concept 2, which are 24 respondents. This is a significant result thus it can be concluded that in terms of aesthetics and appearance, for this population, concept two is the preferred option. Finally, when looking at why people choose concept 2 as the preferred concept, mostly they fancy the larger side bolsters and the more sporty look which makes it appealing to them. The main conclusion is then that the direction of concept two is the desired concept direction. The entire questionnaire can be found in Appendix J.

From the user tests and the questionnaire, the following aesthetics design criteria are established:

- **Active Lifestyle Communication**: The design must communicate an active lifestyle to appeal to users who value activity and engagement.
- **Continuous Lines**: The design must incorporate continuous lines to ensure a cohesive and visually appealing appearance.
- **Simple Design**: The design must be kept as simple as possible, avoiding unnecessary features to prevent overwhelming users.
- **Perceived Comfort**: The design should incorporate side bolsters to enhance perceived comfort, ensuring users feel secure and supported.
- **Non-Clinical Appearance**: The design should avoid a clinical look to make the bicycle more inviting and user-friendly.
- **Subtle Adventure Elements**: The design could include subtle elements that hint at adventure, without overwhelming the user with an adventurous aesthetic.
- **Aesthetic Stability**: The design could incorporate aesthetic features that contribute to the visual stability of the bicycle, enhancing user confidence.
- **Overly Adventurous Design**: The design won’t communicate too much adventure, as this could be intimidating or inappropriate for the target user base.
- **Unstable Aesthetic Elements**: The design won’t include aesthetic elements that make the bicycle appear unstable, as stability is crucial for user confidence and safety.

Figure 58: The most liked concept from the questionnaire

Figure 59: Further ideation

Designer VanRaam input

For the design of the seat, two aesthetic industrial design engineers have been consulted in order to gather insight into what VanRaam might want for the design of the front seat for the Buddy tricycle. They gave the following remarks:

Firstly, the dots were placed at the most liked concepts. Then, the general remarks that white versus black is too high in contrast; they suggested a uniform colour and make subtle change in materials and textures in order to create interesting shapes and overall designs. Secondly, the bottom left concept was found to be most inline with VanRaam styling; frame has to be more graphical than the seat. However, this is also a “dull” design. Finally, they advised to stay away from sharp corners, thus make edges a little more rounded off. With this information in mind, 2 concepts have been chosen to develop further. Eventually, one will be chosen as the final design direction for the seat in this thesis.

Figure 60: The dots indicate VanRaam designer preference

Iteration prototype design direction

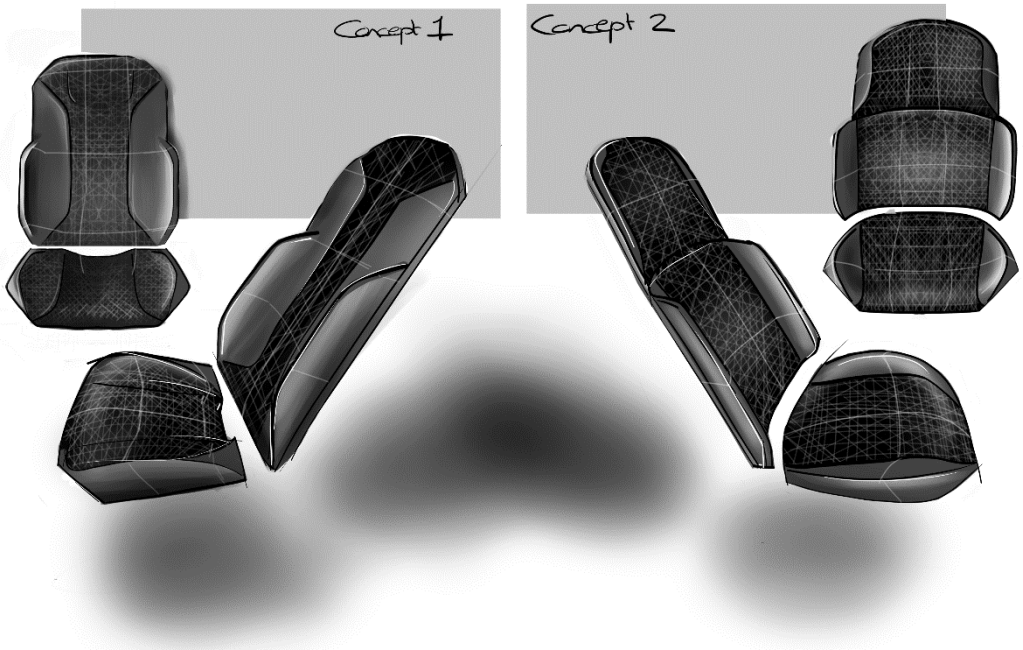


Figure 61: Concept generation from ideation

From the designer input in the previous section, two concepts have been developed for the aesthetics of the seat. (figure 62). For the aesthetics, it has been chosen to make a clear division between the sitting area and the backrest. This is done because of the implementation of functionalities later on like rotatable seats.

Concept 1: Chamfers

Concept one put emphasis on the side bolsters by making them appear wider that they actually are. The same is happening at the sitting area, where the “bucket” seat is pronounced through the use of a negative chamfer. The seat consists of two parts, however the lines follow the Gestalt principle of closure so the two parts are aesthetically linked together. For both concepts, a neutral colour has been chosen after consultation with another designer at VanRaam; the consensus was that colour will come from the frame of the bicycle and adding colour to the seat can only lead to colour mismatch. Furthermore, concept one aims to evoke a sense of activity by having a sporty look to it through the chamfered lines

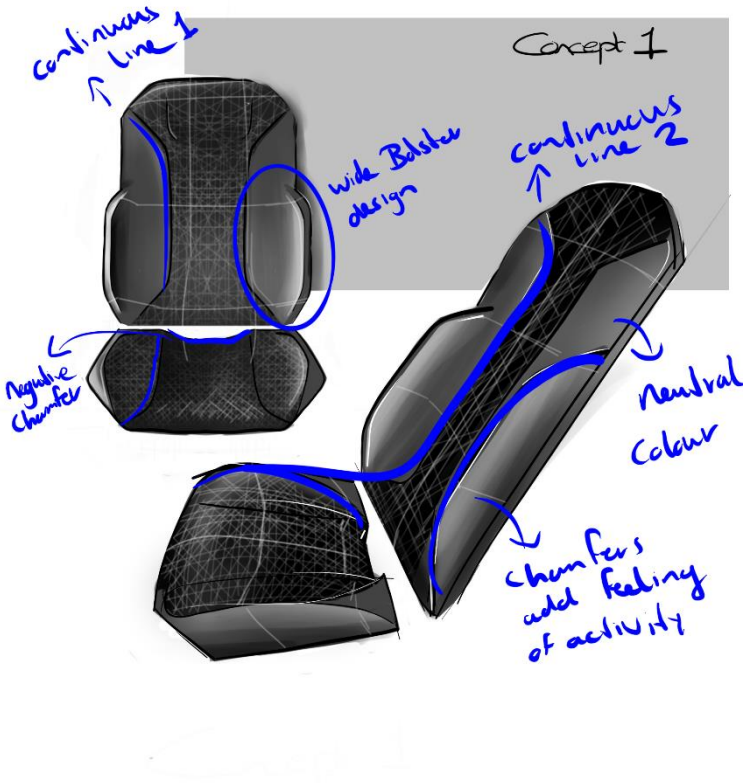


Figure 62: Concept 1

Concept 2: Three parts

The second concept consists of three parts visually and appears much more straight due to the vertical lines. Also, the sitting area is much more straight. The side bolsters are longer and thinner than on the other concept, but no thinner than the prototype to still offer sufficient support. However, despite its clear structure and simplicity, Concept 2 lacks the visual flow and sporty character of Concept 1. While its minimalist design offers a practical and clean appearance, it doesn’t evoke the same sense of activity or dynamic energy. This makes Concept 2 more suitable for users who prioritize straightforward functionality over aesthetic vibrancy and sporty appeal.

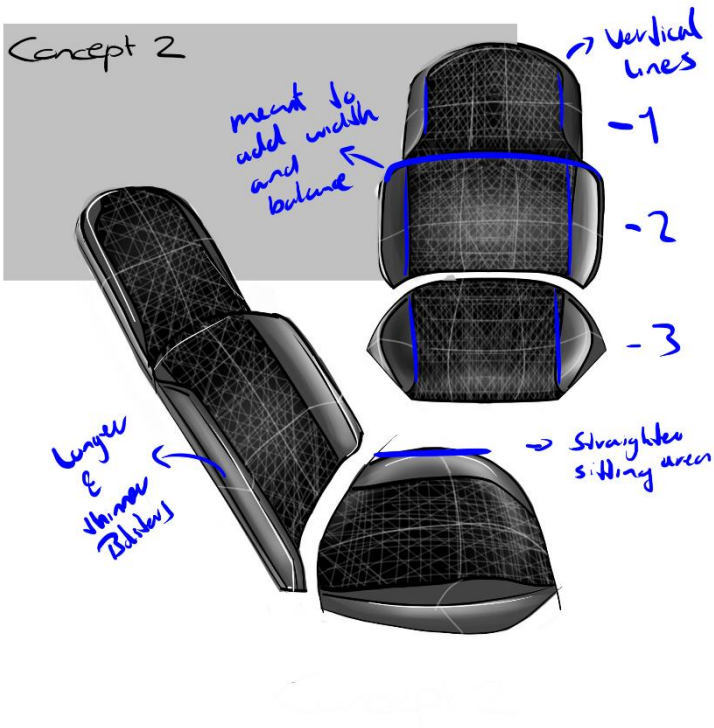


Figure 63: Concept 2

Concept choice

Criteria	Weight	Concept 1: Chamfers	Concept 2: 3 parts
Active Lifestyle Communication	2	++ (2)	+ (1)
Continuous Lines	1	+ (1)	+ (1)
Simple Design	3	+ (1)	++ (2)
Perceived Comfort	3	++ (2)	+ (1)
Non-Clinical Appearance	1	++ (2)	+ (1)
Subtle Adventure Elements	1	+ (1)	0
Aesthetic Stability	2	++ (2)	++ (2)
VanRaam Brand Connection	2	0	++ (2)
Total	Max score: 32	**21**	**21**

Figure 64: Concept evaluation

Ultimately, the concept scoring did not yield a clear preferred design, necessitating a design review with two designers at VanRaam. During this meeting, it was empathized that aligning the selected concept with VanRaam brand values is crucial for further development. The discussion concluded that Concept 2 aligns best with VanRaam core brand values, namely, inclusivity, contemporality, and high quality. Concept 1, by contrast, was criticized for appearing overly sporty, which does not align with VanRaam identity.

In evaluating comfort, the community model highlights the need for an inclusive design approach. Concept 2, being more restrained in its design language, was deemed more suitable in this regard. However, Concept 2 did receive critiques during the discussion, particularly regarding its large, uninterrupted material surfaces. It was suggested that this issue could be mitigated through the use of horizontal stitching, with the colour of the stitching further enhancing the design.

In summary, Concept 2 was selected for further development based on its aesthetic coherence with VanRaam's brand identity and the consensus reached during the design review.

5. Second User Test

The second and final user test will predominantly function as a validation step for all the functionalities of the seat that have been of interest in this thesis together with the aesthetics development.

Final prototype design

In this section, the final prototype design will be elaborated. Firstly, the iteration direction based on the previous phases is defined, before providing an overview of the prototyping options with corresponding TRL levels. Then, the ideating, prototyping and testing will commence.

Iteration directions

Because the chosen direction does not seem to be causing major problems and is generally received well by the target group. It is also a matter of not having to reinvent the wheel; the geometry of the seat that is currently fitted to the Buddy bicycle comes close to the ideal geometry as presented in literature. This has to do with the adaptability of the current seat. Therefore, I argue to move forward with this design and to include the side bolsters into the design as well as an enhanced Lumbar support as was tested in the new seating position. The functional seating angle will remain 123 degrees with the option to change this back to a minimum of 105 degrees in order to not exclude specific target groups from the use of this bicycle. The main reason for this is that the intended target users do not notice major differences between the two positions, however the new position with the functional seating angle is more stable according to literature.

The rotatable seat, aesthetics, lumbar support and bolster placement are the main focus of further iteration. Thus, in order to decide what the final deliverables will be, an overview has been created in figure 66.

What?	Number	NASA TRL	Advantages	Disadvantages
Full frame prototype and upholstery prototype	1	0 to 5	• Nice end prototype • Direct comparison between old and new seat • Focus on aesthetics, comfort and stability in one prototype	• Expensive (1500 eu) • Time consuming • Too many unknowns at this stage on for instance material
Existing frames with add-ons and new upholstery	2	0 to 4	• Upholstery is a good check on aesthetics and visual comfort • Existing frame is solid basis for	• Limitations to dimensions of existing frame • Upholstery still expensive (500 EU)

			ergonomics and comfort with add-ons • Existing frame is easily integrate able onto existing frame • Life size prototype	• No easy comparison between two seats
No change to current seat with add-ons and visual render	3	0 to 3	• Existing frame is solid basis for ergonomics and comfort with add-ons • Existing frame is easily integrate able onto existing frame • Cheapest option • Least time consuming	• No life size aesthetics prototype • Sometimes difficult for people to read a sketch • Sketch is non-tangible • Current seat not novel
Modifications to seat frame geometry and visual render	4	0 to 3/4	• Existing frame only needs slight modifications • The frame is more representative of the literature findings in this way • A visual render can give a good image of the desired aesthetics	• Sometimes difficult for people to read a sketch • Sketch is non-tangible • When modifying the existing frame there is no way back • No feel of materials and aesthetics in real life
¼ scale prototype of aesthetics and no change to current seat plus add-ons	5	0 to 3	• Existing frame is solid basis for ergonomics and comfort with add-ons • Existing frame is easily integrate able onto existing frame • Cheapest option • Least time consuming • Scale prototype is more easy to understand than a	• Scale prototype is time consuming to manufacture • Scale prototype might look like a toy too much • No life size aesthetics prototype

			sketch	

Figure 65: Different deliverable options

In the end, modifications to seat frame and visual renders have been chosen as the final deliverables for this thesis. In the end, only the sitting area will be modified to tailor for the rotatable seat; the backrest will remain in tact.

For the manufacturing of the rotatable seat, two concepts have been considered. The first concept keeps the original mounting points of the sitting area from the HP Velotechnik seat, whereas with the second concept, the seat is welded onto a connection. Secondly, also the rotation bearing differed in the two concepts (figure 67). The first concept uses a rotation bearing that is 95x70x20mm in size, whereas the second concept uses a rotation mount as used also on deck chairs of boats. This rotation mount is 175x175x25mm, thus a little higher than concept one. However, figure 67 shows that there is little difference in height between the two concepts; on the contrary, the height is needed in order not to interfere with the from wheel whilst getting in and out of the seat.

Next to this, after speaking to one of the employees at Ideeënfabriek, it became apparent that the smaller rotation mount would likely not be strong enough in order to deal with lateral forces that occur when mounting and dismounting of the seat happens. Next to this, the small rotation mount has no built in locking mechanism, whereas the larger one does. These two facts decided that the second concept would be more feasible. Thus the choice was made to move forward with concept two.

Then, for the final version, concept two needed to be slightly adapted for manufacturability. Because the upper connection to the seat frame has to be from aluminium as it will be a weldment connection. The part will be made from four parts, see appendix M, that can be welded together. Also, the connection to the bicycle frame needed to be stiffer, thus this part has been thickened from 2mm to 5 mm. Eventually, the CAD image can be seen in figure 68.

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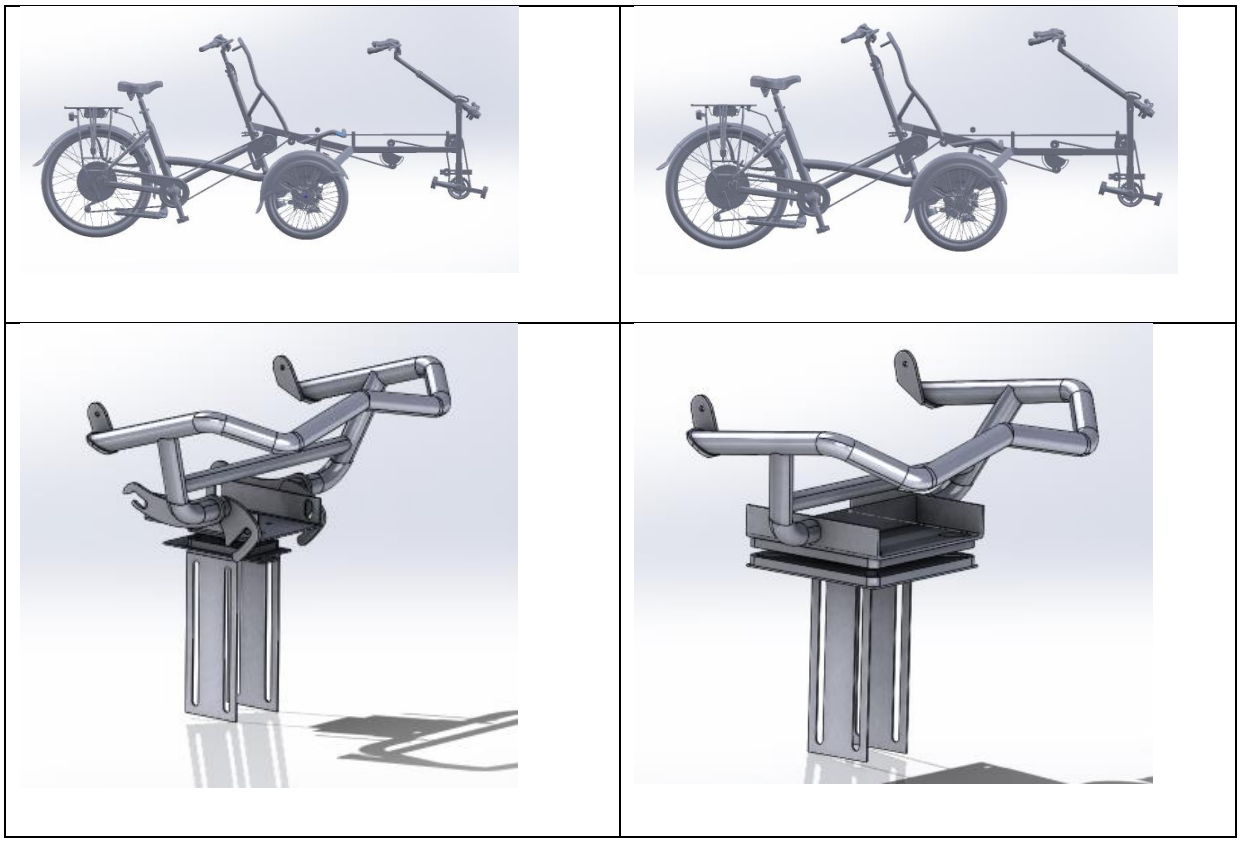


Figure 66: two different concepts for integration of rotatable seat onto the current prototype

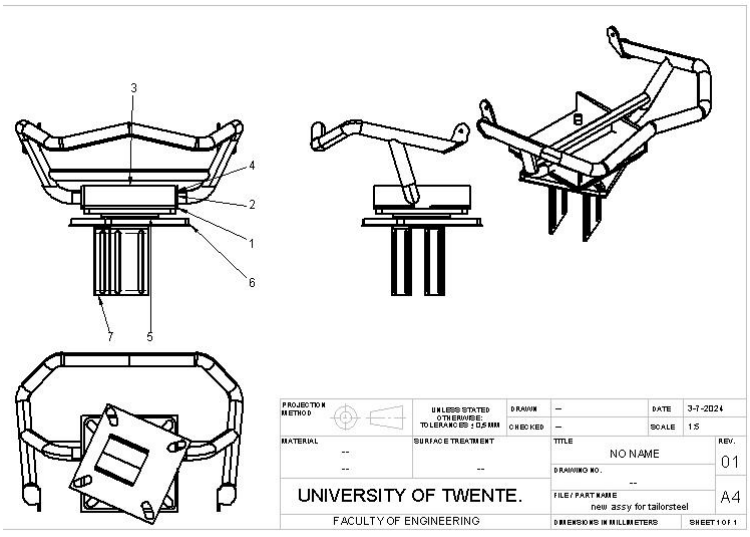


Figure 67: Solidworks drawing from rotation assembly

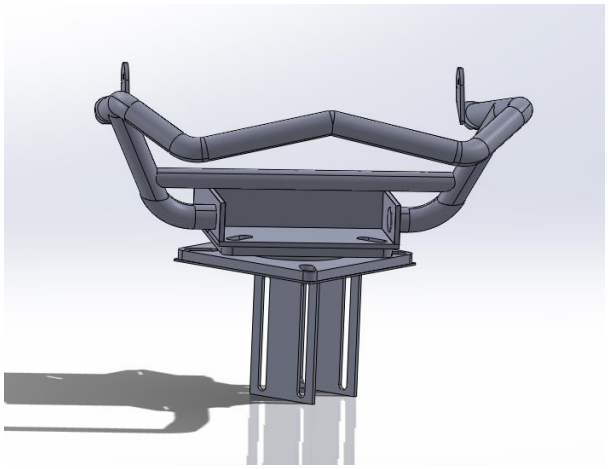


Figure 68: Final version of rotatable seat for the current prototype in CAD

Manufacturing of the rotatable seat

Once the parts were delivered, the manufacturing could commence. In order to properly fit the new parts onto the "Buddy", the following has been done:

1. The aluminium parts that will connect to the seat have been welded together

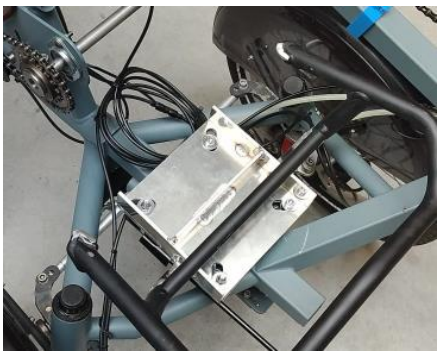


Figure 69: Welded together parts

2. The existing sitting area of the seat has been modified in order for it to be able to be fitted to the aluminium connection parts that have been welded together in the previous step. For this, the height of the seat needed to be corrected, otherwise, the sitting area would be too high on the bicycle, diminishing the active and stable feeling of the Buddy bicycle. Next to this, the mounting points have been ground away to make room for the aluminium mounting point.

Figure 70: Above: new seat, Below: Old seat

3. The connection to the frame consisted of two "L" profiles with slots in them to connect to the frame. These L profiles have been welded together the create an "U" profile that is then welded to the under part of the rotation bearing. This was firstly done with a weak connection to establish the exact position of the rotation bearing with respect to the "U" profile and the frame. Once a satisfactory result was obtained, it was welded together correctly.

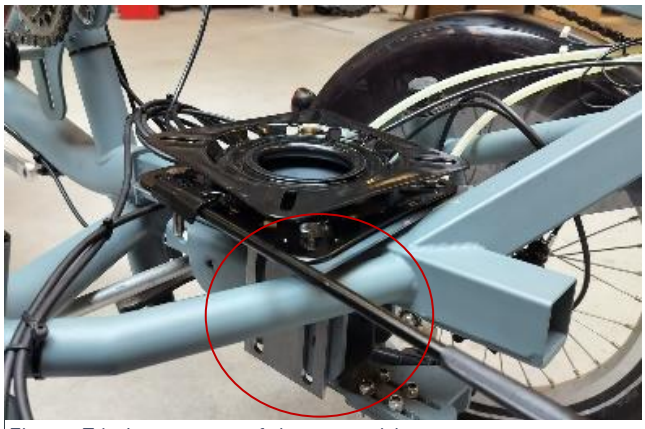


Figure 71: Lower part of the assembly

4. Then, the sitting area was welded to the aluminium profile via one point connection in order to establish the angle of the sitting area with respect to the horizontal axis. This angle needs to be similar to previous in order to eliminate a confounding variable. Once this was the case, the seat has been properly welded together to the aluminium mounting bracket.

Figure 72: Merger of the sitting area frame and the mounting bracket

5. Then, the entire sitting area assembly has been assembled, using 8 bolts and nuts and 16 washers to keep everything in place.

Figure 73: The assembled seat

6. Then, the backrest needed to be connected to the to the frame four centimetre higher than before to facilitate the rotation of the sitting area. For this, a new clamp for behind needed to be constructed. This can be seen in figure 75. Also, the pivot point of the HP Velotechnik seat needed to be ground away on both the sitting area and the backrest to factilitate the rotation.

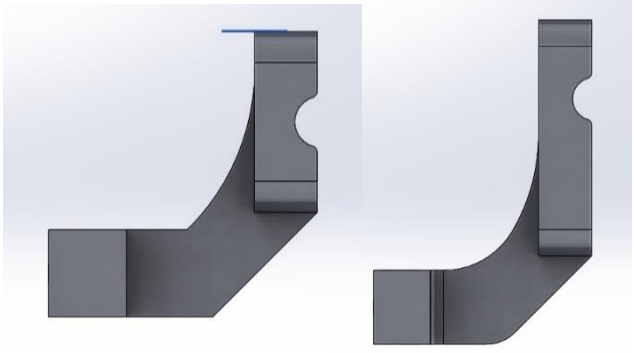


Figure 74: Left, old connection, right, new connection

7. The final step was to slice the existing upholstery in half. This was done at an upholstery firm in Ulft in order to obtain a neat result. The final result can be found in figure 76.

Figure 75: 45 degrees rotation

Because of the rotation, the sitting area had to be placed 4cm more forward and 5 cm higher. This has to do with the placement of the drivetrain behind the seat of the Buddy. There is a chainring located awkwardly; thus for now, this is the only option. Still however, realistically, the seat can only rotate 45 degrees. In the testing phase, it has to be seen whether this is a sufficient amount of rotation for the target user to comfortably enter and exit the bicycle.

User test set-up

The goal of this final user test is to determine whether the rotatable seat is essential for the overall comfort and autonomy of the Buddy bicycle's cycling experience. Additionally, participants will review final sketches of the seat's aesthetics and provide feedback. The purpose of this test is to ensure that the chosen design direction aligns with the needs and preferences of the target group. This test also serves as a validation to confirm which functionalities should be included in the final design based on user input. The test will be done with the prototype as described in the previous section (figure 77)

Figure 76: The final prototype with side bolsters, lumbar support and rotatable sitting area

Subjects

The subjects will all be people within the target group. For this they should be at least 65+ of age and suffering for some sort of (changing) medical condition that makes them not able to navigate through traffic independently. Ideally, 5 subjects will be used, this makes all the ratings not very statistically significant, however according to Norman & Nielsen, 5 subjects are sufficient in order to tackle 75% of the usability problems and different feedback points. (Nielsen & Landauer, 1993). The subjects are selected from a daycare division of an elderly home in Zevenaar, where the are predominantly focussed on Parkinsons disease patients that still live at home.

Hypotheses

- The rotatable seat is a necessity for getting in and out of the bicycle and thus adds comfort and confidence to the target user.
- The stability is still sufficient with the rotatable seat
- The 45 degree rotation is sufficient for the target user
- The aesthetics provide a feeling of comfort, stability and activity to the target user
- Placing the sitting area forward leads to more discomfort for the target user.

Ethical approval

Bring an informed consent form for every volunteer, which has to be signed by researcher and subject. All data will be stored carefully and securely, without mentioning of names.

Test Plan (Protocol)

- Introduce everyone
- Ride for 10 minutes on the bicycle
    - Focus is observing the getting in and out of the bicycle
    - Before leaving make sure everyone is fitted properly to the bicycle
    - During the ride, let the passenger steer and brake while researcher/supervisor gives directions
- Afterwards a questionnaire with user feedback
    - Polar questions on the integration of the rotation seat and the final design

User test conclusions

Based on the polar questions, the conclusion can be drawn that:

1. The rotatable seat mechanism as was used in this test does not work as intended
2. The stability of the seat is still good, despite the new sitting area construction
3. The aesthetics of the seat do evoke a feeling of comfort and stability to the user.

Based on the interviews after the test drives, the following conclusions can be drawn.

1. The rotatable seat mechanism did not work as expected, however, a rotatable seat is still desired to make entering and exiting the bicycle easier.
2. Across all subjects, the seat was generally found to be comfortable, particularly due to its softness and back support. This suggests that the seating design is largely effective in providing comfort during use.
3. Despite the aforementioned challenges, the overall riding experience was described as fun and enjoyable by the users.
4. Side bolsters were effective in keeping users stable, especially those with medical conditions that cause them to move around more. This underscores the importance of such supportive features in maintaining user stability and comfort.

Figure 77: User test 2: testing the rotatable seat

Looking at the hypotheses, the following conclusions based on observations can be drawn:

- The rotatable seat is a necessity for getting in and out of the bicycle and thus adds comfort and confidence to the target user.

This is only true if the rotation mechanism is designed in such a way that a 90 degree rotation is obtained from the seat and this is clearly visible for the end user. For the design of the Buddy, this proves a challenge as the wheels will always be in the way duo to the nature and lay-out of the bicycle.

- The stability is still sufficient with the rotatable seat

This is correct, the stability is not influenced by the addition of the rotation mechanism according to the subjects

- The 45 degree rotation is sufficient for the target user

This is insufficient as the wheels are in the way and people are used to getting in of the bicycle in a certain manner that that the 45 degree rotation simply feels unnatural.

- The aesthetics provide a feeling of comfort, stability and activity to the target user

According to the polar questions they do provide these attributes.

- Placing the sitting area forward leads to more discomfort for the target user.

This has not been noted by the subjects. The height of the seat was however a problem. This is due to the fact that is was placed 4 cm to incorporate the rotation mechanism. See appendix O.

Discussion and limitations

The test conducted only had a sample size of n=3 duo to time constraints. These people did however have experience with the Buddy bicycle. Because of the small sample size, not every usability problem will be tackled through the tests. However, because all three subjects encountered the same issue, telling that there was a fundamental problem with the rotatable seat mechanism. The reason why this rotatable seat did not work could be down to the following causes:

1. The subjects did not notice that the sitting area was rotatable because the backrest was still in its original place. This, in combination with the side bolsters made the sitting area rotation "invisible" to the target user.
2. The previous encounters with the bicycle have taught the subjects how the getting in and out works thus this is how they assumed they had to enter and exit the bicycle.
3. Visually, the entire bicycle does not facilitate the addition of a rotatable seat; there is a small entrance so the subjects decide that this is the way to enter the bicycle, although this is more complicated for themselves than the bicycle facilitating the entrance; they still try to do everything themselves. This links also to point 1.

This final user test did however provide observational evidence that people are sitting more relaxed in the front seat; something which they are also reporting when asked. According to them the seat is comfortable and stable and provides them with confidence and cycling pleasure. One important sidenote to make is that some subject also suffered from ataxia; making it hard for them to put into words what the feel, thus making giving feedback sometimes challenging (Ataxia, 2024). Therefore, observation was an important tool in all the user tests.

The findings from this user test underscore the importance of refining the rotatable seat mechanism to ensure its functionality and visibility to users. Given the clear demand for this feature, future iterations should focus on achieving a full 90-degree rotation without interference from the bicycle's structure. Additionally, the study suggests that while the aesthetic and stability aspects of the seat are well-received, further attention must be given to enhancing ease of access, particularly for users with limited mobility.

Future research should expand the sample size and include a broader range of users to validate these findings and explore other potential usability issues. Moreover, incorporating iterative testing phases could facilitate continuous improvement of the design, ultimately leading to a more user-friendly and accessible bicycle.

6. Conclusions

The iterative process of the design thinking method proved instrumental in identifying and prioritizing functionalities that directly impact the user experience. By engaging with users at multiple stages, the design methods not only validated the importance of certain features but also revealed areas where improvements were needed. This user-centred approach ensured that the final product would meet expectations of the target user.

From the literature research, certain assumptions come forward that needed to be tested through practical application. However, to operate as time effective as possible, preliminary test were conducted. These tests proved fruitful and provided directions for the design of the seat than could later be validated with the target user. Afterwards a focus group with care givers that had experience with cycling with the target group was held. This lead to the insight that the seat might benefit from a rotatable seat, whereas the stability and comfort found from the preliminary tests proved to be a good addition to the seat. In the first user test is was observed that the improved functionalities of HP Velotechnik seat, which was used as the prototype, did provide the desired stability and comfort to the target user, although it was very difficult for the user to distinguish between the different seating positions due to their medical condition. Furthermore, in order to not exclude people, the seating angle should be adaptable. Also, the rotatable seat came to the table again, with users emphasizing the importance of this feature because entering and exiting the seat proved difficult. Finally, aesthetical insights have been gathered during this user test that have been used to develop the aesthetics through the implication of an aesthetics bystander questionnaire. This was done to examine the aesthetics as perceived through people that would merely observe the seat, rather than use the product. This, together with the findings of the user test and discussions with VanRaam designers, lead to a final concept that is simple through the usage of continuous lines, evokes a feeling of comfort, stability and activity. For the final user test, the decision was made to integrate a rotatable seat that could rotate 45 degrees to see what this would do to the overall cycling experiences. This lead to the insight that a rotatable seat will only work and be an added value when it can rotate 90 degrees and the combination of bicycle and seat design nudges the target user into using this feature. The final user test again indicated improved comfort and stability trough the use of a different functional seating angle, lumbar support and side bolsters.

This project validates the effectiveness of a user-centred, iterative approach in developing a product that meets user expectations. Future designs should continue to prioritize user feedback and testing, expand the sample size, and include diverse users to ensure broad applicability. Balancing functionality, comfort, and aesthetics is critical to achieving widespread user acceptance and a successful market launch.

Functionalities Identified as Absolute Necessities

Based on this iterative testing process, the following functionalities were identified as absolute necessities for the Buddy bicycle:

1. **Ergonomic, comfortable Support**: Proper hip angle, seating angle, and lumbar support were confirmed as essential for maintaining comfort, it has t be seen whether this is also the case for prologued use.

2. **Stability support:** In terms of stability, the lumbar support and side bolsters add stability to the passenger of the seat. These functionalities are integral to the final design and are based on the iterative testing phase conducted in this chapter

3. **Adjustability**: The ability to adjust the seat's position and angle was deemed crucial, providing users with the flexibility to customize their seating to their comfort preferences. Also, the adjustability with relation to the crank is imperative in providing a comfortable cycling experience.

4. **Aesthetics**: The aesthetics of the seat are not merely there to provide a design that reduces stigma, it also aids the user in feeling comfortable and confident by adding stability and comfort as implicit design features to the design.

5. **Material comfort**: The material of the sitting area is paramount in deciding the comfort seat. It has been found that a hammock structure is perceived a pleasant and comfortable.

Chapter 6: Final Design & Conclusions

In this final section, the main conclusions and recommendations that can be taken from this thesis project will be elaborated. This is done in through the presentation of design directions for the final conceptual design that incorporates all findings combined into a program of requirements and a package drawing that can be used moving forward with the project. A final design for further development will also be chosen. Furthermore, in this section also the limitations of this thesis, further research recommendations and a cost estimation will be presented. Before moving to the final conclusion of this thesis.

1. Requirement specifications

In order to establish the requirement specifications, the design criteria from earlier in this thesis will be evaluated and made measurable as best as possible. A complete overview of all design criteria can be found in Appendix B. Underneath, the measurable requirements are presented.

Requirement	No.	Measurable Criteria	How to Measure	Numerical Target/Range
Ergonomics and Comfort				
The seat must cater to the needs of elderly with changing medical conditions.	1	Comfort and Stability must be included and rated positively.	User testing with diverse elderly participants; feedback surveys.	70% Positive ratings can be obtained from Likert scale questionnaire where the questions are perceived comfort and perceived stability compared to competitor seats
The seat must be ergonomically sound for p5-p95 of the Dutch elderly 60+ population (DINED)	2	Ergonomics must be adaptable to user preferences and needs.	Measurement of adjustment ranges	See package drawing (figure 80)
The seat must provide lumbar support that caters to everyone in the p5-p95 range	3	Presence of adjustable lumbar support	Measurement of lumbar support adjustability range; user comfort tests.	Lumbar support adjustment range: 100 mm, 247,5 mm from the neutral point. Radius between 250-400 mm, prominence <30mm
The seat must have an adjustable functional seating angle, with 123 degrees as a key reference.	4	Angle adjustment range with a key setting of 123 degrees.	Mechanical testing of seat adjustment; verification through angle measurements.	Adjustable angle range: 110°-130°, with default at 123°.
The design must allow for adjustable pedal distance for user stability and comfort.	5	Pedal distance adjustability range covering P5 to P95 anthropometric data.	Measurement of pedal adjustability range; user trials for comfort.	Pedal distance adjustable: X-direction: 630-845 mm Y-direction: 305-375 mm
Seating position whilst pedalling should maintain a minimal hip angle not exceeding 95 degrees.	6	Hip angle measurements during seating position analysis.	Biomechanical analysis; seat angle testing with target users.	Hip angle ≤ 95°.

The seat should be easy to access for the target user.	7	Time taken to complete getting in and out of the seat and perceived comfort	User tests	Improvement compared to initial design of bicycle and seat combination

Stability

The seat must provide longitudinal stability	8	Surface friction coefficient and structural support inspired by hammock designs.	Slip resistance tests; ergonomic evaluation by seating experts.	Coefficient of friction ≥ to be determined; Sitting are angle 5-8 degrees
The seat must provide lateral stability to the target user	9	Side bolster dimensions that provide support while allowing movement.	User trials, bicycle stability measurements	Bolster dimensions to be specified
The seat design must prioritize stability for user confidence and safety.	10	Stability under various user conditions (P5-P95); ability to maintain balance during typical motions.	User trials.	Seat must be perceived as stable by target user.

Aesthetics

The design must communicate an active lifestyle to appeal to target users.	11	Design elements that evoke activity, such as dynamic lines and sporty aesthetics.	User perception studies; visual design analysis.	Statistically significant results
The design should be in line with VanRaam brand identity	12	VanRaam brand identity: Quality, functionality, accessible	Conversation with designers at VanRaam	Not applicable
The design must incorporate continuous lines for a cohesive appearance.	13	Use of uninterrupted lines in the design.	Conversation with designers at VanRaam	Not applicable

Materials

The seat materials should address comfort factors like heat transfer and support.	14	Material properties related to comfort, heat dissipation, and support.	Material testing for breathability and support; user trials for comfort.	Heat transfer coefficient: to be determined moisture wicking capacity: to be determined
Sitting area must minimize pressure under ischial tuberosities of passenger	15	Load structure design.	Seating pressure experiment with different load structures and material compositions	Measurable seating pressure to be determined

In terms of the materials and load structure of the eventual sitting area, it was still uncertain which the HP Velotechnik design was preferred compared to the EasyRider3 sitting area. Therefore some additional literature research has been done in order to come to a requirement:

Pressure distribution on sitting area

Staarink, did the following discovery: When seated, the pressure distribution between the buttocks and a cushion depends on the relative resistance to deformation of each. If the cushion is more resistant, the buttocks deform more; if less resistant, the cushion conforms to the buttocks' shape. The goal is to minimize pressure under the ischial tuberosities and avoid deformation.

Foam cushions, show that as foam thickness increases, pressure decreases under the ischial tuberosities (figure 78) . However, if the foam is too thick, it can bottom out, limiting further deformation and leading to increased pressure.

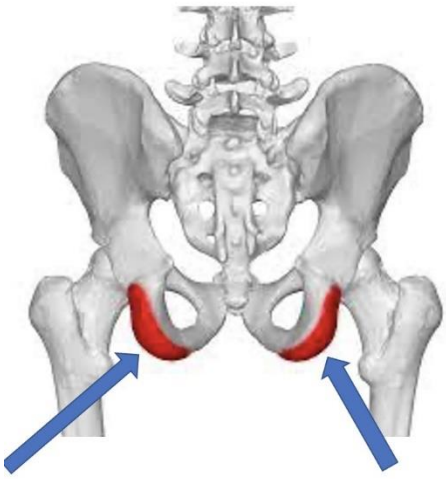


Figure 78: ischial tuberosities

When foam is placed on a hard surface, the pressure is highest directly under the tuberosities due to localized deformation. However, placing the same foam on a "trampoline" structure; a flexible fabric stretched over a frame, similar to a hammock; results in nearly a 50% reduction in maximum pressure. This is because the hammock-like support distributes the load more evenly and requires less deformation of the foam, preserving the natural shape and pressure distribution of the buttocks.

Hammock structures are advantageous because they minimize the deformation required by the foam, leading to lower and more evenly distributed pressure. This reduces the reactive forces that could otherwise deform the buttocks and compromise their natural pressure distribution capability. The hammock's ability to conform to the body shape while maintaining structural integrity enhances comfort and reduces the risk of pressure sores.

A well-designed cushion system should leverage the natural pressure distribution capabilities of the body. Hammock structures are superior to rigid foam setups because they require less foam deformation, maintain the body's natural contours, and significantly lower the pressure on critical areas like the ischial tuberosities. This makes hammock-based supports a better option for preventing discomfort and pressure-related injuries (Staarink, 2014).

Package Drawing

These requirements are then visualised in a package drawing: This package drawing visualises the requirements that are the backbone for the design of the Buddy seat. Included are measurements of the lumbar support and side bolsters that have been used in this thesis and are not criticized. The rotation angle is added because it can only be useful if the seat rotates 90 degrees.

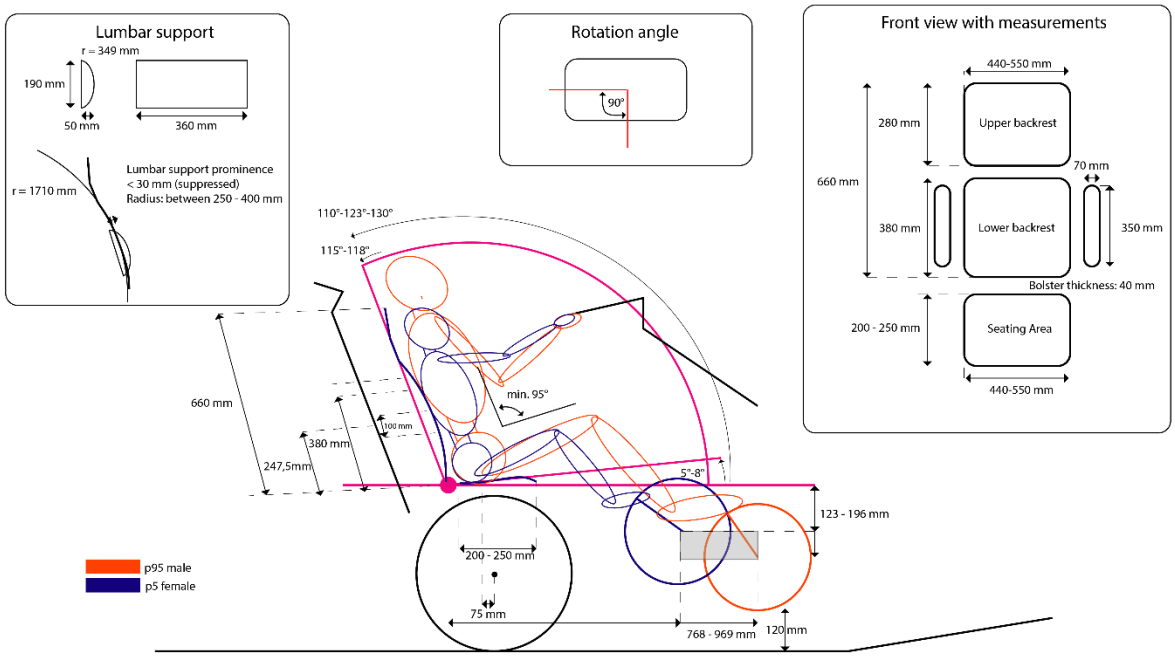


Figure 79: New package drawing based on the findings of this thesis

Ideation

From these requirements, a brief ideation session on functionality is done. In the next section an overview of the feasible ideas is presented in a morphological overview.

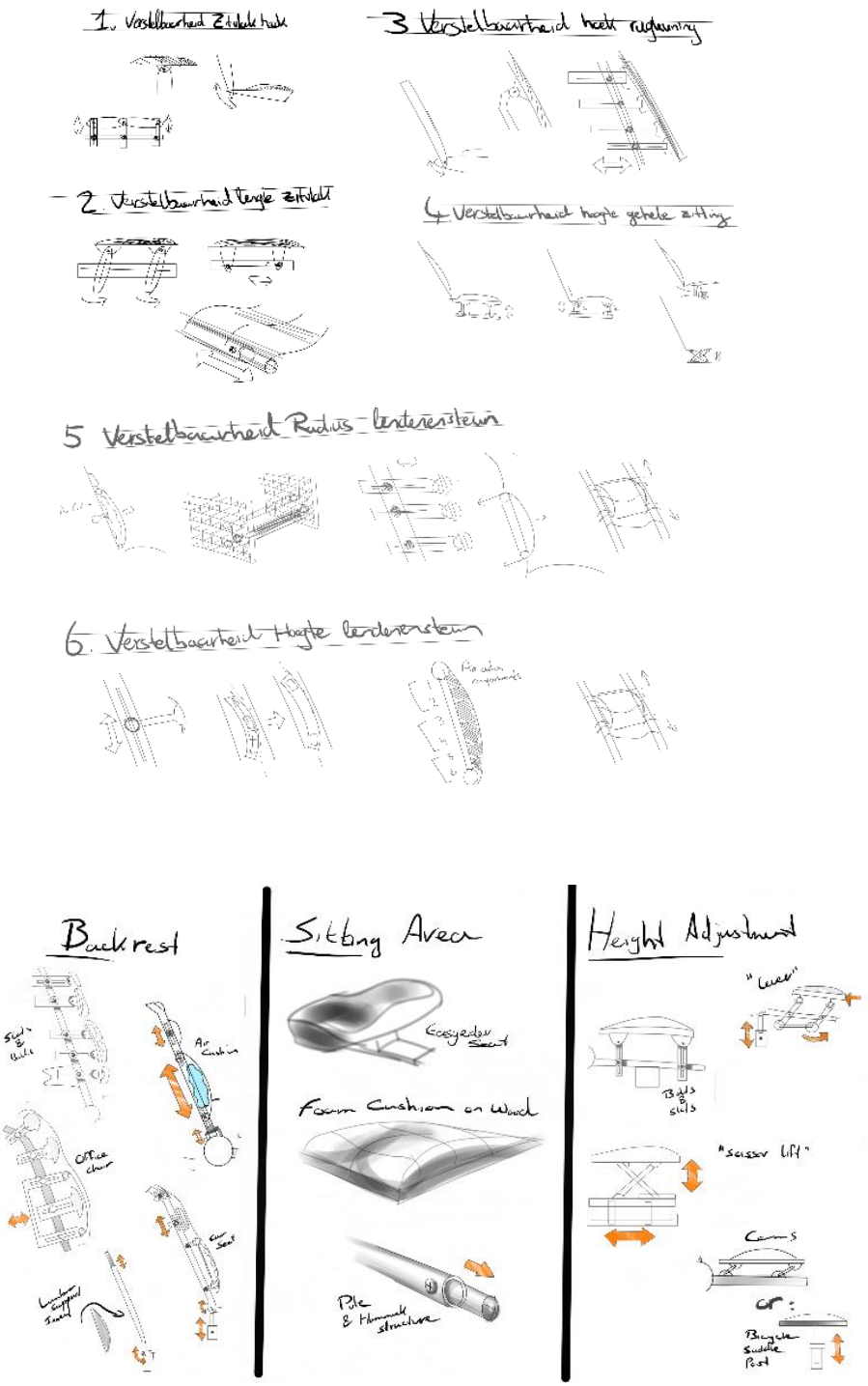
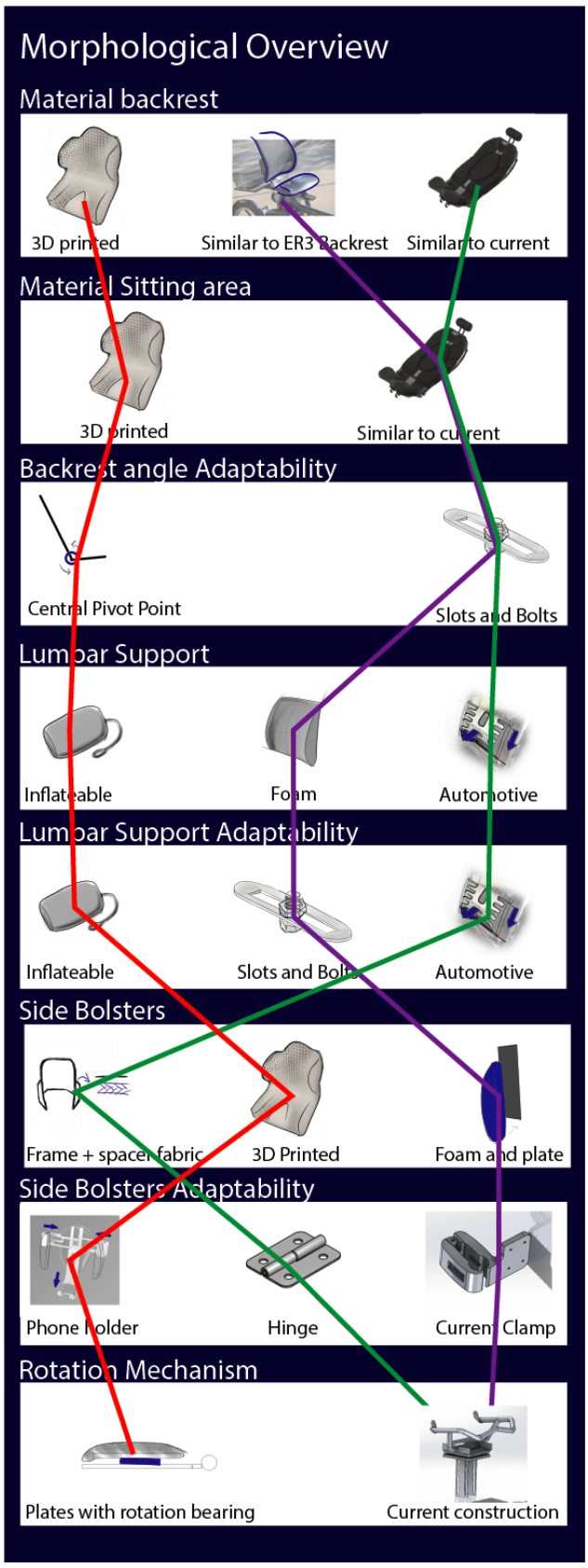


Figure 80: Functionality ideation sketches

2. Morphological overview



The morphological overview presents eight different aspects or functions that have been the central theme in terms of functionality for the seat. The most important difference is the material of the backrest and sitting area. Because no real material study has been provided in this thesis, this is still a very open end. From the user tests however it became apparent that harder foams are not the way to go and that a “hammock structure” or “bucket seat” is found to be very pleasant by the user. In terms of solutions for the functionalities like the side bolsters and lumbar support, these solutions are conceptual and will need to be prototyped in further development. For now, these functionalities do however present the opportunity to develop three concept directions. These are presented in the next section. For the rotatable mechanism, it is imperative that this can reach 90 degrees in order to make it functional for the target group. This overview is designed to aid in concept generation for the next part.

Figure 81: Morphological overview

Conceptualization

From the morphological overview, four different concept directions can be established based on the functionalities included in this overview.

Concept 1: 3D Print

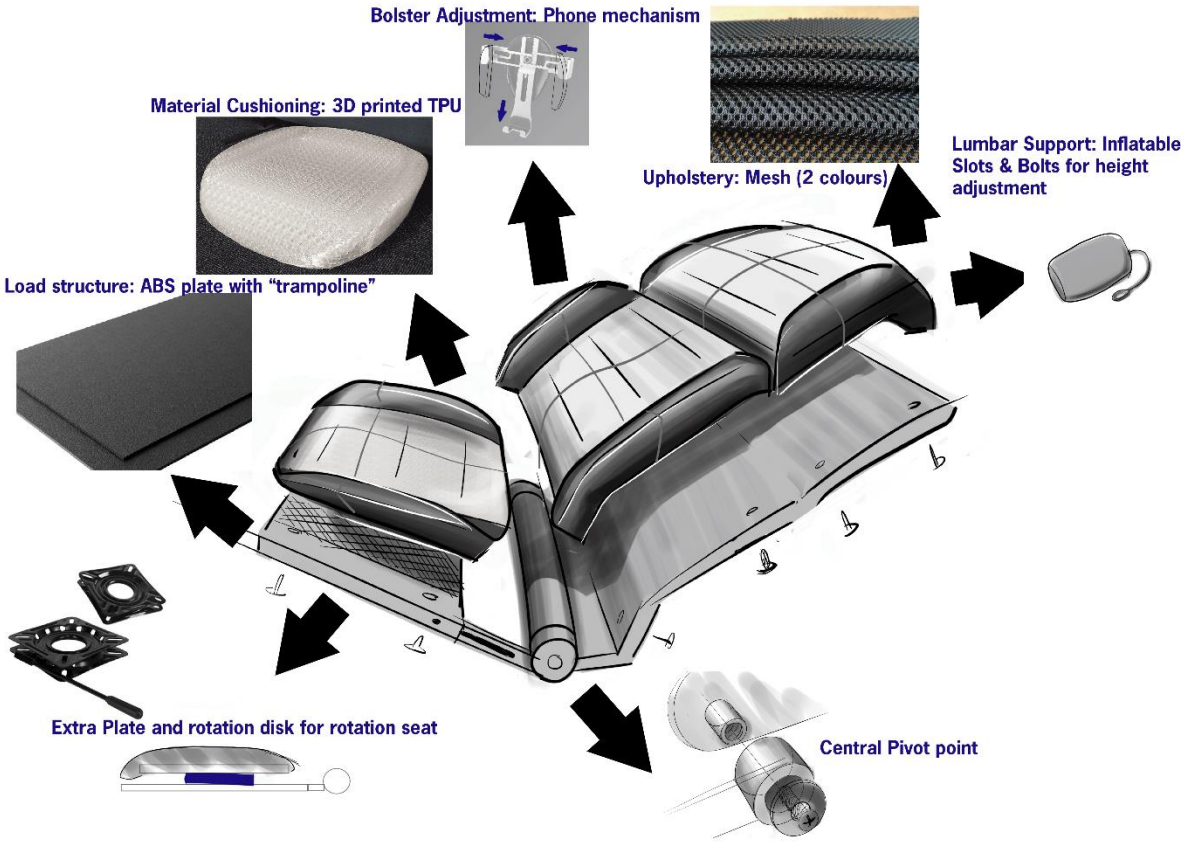


Figure 82: Concept 1

Concept 2: Alu Frame

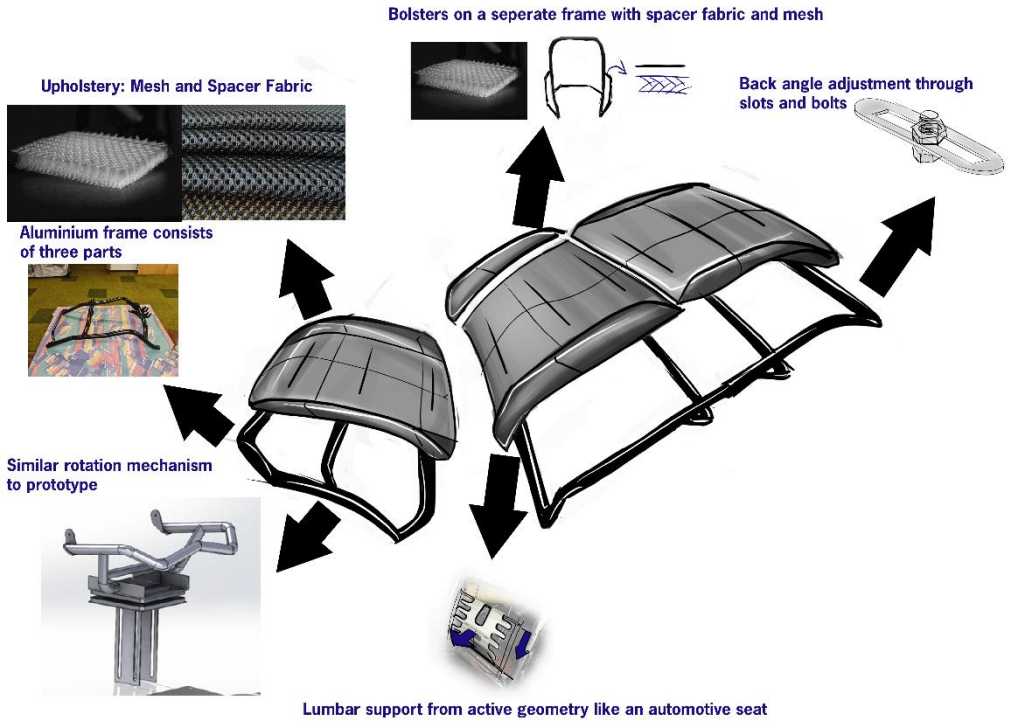


Figure 83: Concept 2

Concept 3: VanRaam Backrest

Figure 84: Concept 3

3. Concept choice

The concept selection process will be conducted through requirement-based scoring, with requirements derived from the design criteria iterated throughout this report, as outlined in section 6.1. However, scoring based on these requirements is rendered ineffective because all functionalities in the morphological overview are considered equivalent in performance. Additionally, as the aesthetic selection was addressed in Section 5.4, these criteria do not offer a clear preference for any particular concept through the scoring process.

Given this limitation, the focus shifts to examining how cost considerations may influence the final concept selection. Therefore, a more systematic approach has been adopted: first, the estimated cost for the three concepts from the previous section will be analysed. Then, the next step is to identify the least expensive option while retaining critical functionalities. This cost-optimized solution will then be compared with the three initial concepts. The concept with the greatest alignment with the cost-efficient design will be deemed the most suitable for the company to pursue.

Cost price concept choice

In this section, each functionality and its different solutions will be examined on their cost price in order to come to the cheapest option whilst still retaining the desired aesthetical look thus conforming to the aesthetic-economical model of comfort. This option will then be compared to the three concepts presented before to come to a final design with the desired functionalities. For this cost price concept selection method it is assumed that every design for each functionality works equally well.

Eventually, the cheapest option consists of the following design options:

Backrest	Similar to ER3 materials
Sitting area	Similar to HP seat materials
Backrest angle adaptability	Slots and Bolts
Lumbar Support	Inflatable with pump
Lumbar Support Adaptability	Inflatable with pump and height adaptability through slots and bolts
Side Bolsters	Frame + Spacer Fabric
Side Bolster adaptability	Current clamp for surface and cylindrical shape
Rotation mechanism	Current construction 90 degree

Figure 85: Cheapest concept

The entire ballpark cost estimation can be found in Appendix K.

When comparing this assembly to the different concepts, it becomes apparent that this concept has the most similarities with concept three. Inevitably, the cost price including material, manufacturing and assembly of concept three is also the lowest in the estimation, making this the most appropriate concept to move forward with as final concept at this stage. However, a major disclaimer needs to be placed that no real material study has been performed at this stage. When all materials are

established and the functionalities are properly engineered, a proper cost estimation can be made. Next to this, the estimates of the cost price are rather high compared to the cost prices of existing VanRaam seats, this is likely due to inaccurate estimations, but also because of added functionality. In a follow up study the added value of each functionality has to be weighed to the added cost for the consumer in order to examine what the consumer actually needs. In this thesis, the focus is on emphasizing the functionalities that the seat needs to have from emphasizing with the target user

What does the cost estimation tell at this stage of the development? The estimates of the cost of production and manufacturing are 3 to 6 times higher than the cost price of the ER3 or Fun2Go seat. This has to do with the addition of the additional functionalities. In order to provide some guidance for the further development op this seat, a decision matrix has been set up for each of the functionalities. This matrix includes the user importance from test results, the estimated costs, technical feasibility and impact on cycling experience.

		Euro
Matrerial and production cost:	Cheapest option (feasible) Minimal price	216
	Cheapest option (feasible) Maximal price	510
	Concept 1 Minimal	310
	Concept 1 Maximal	685
	Concept 2 Minimal	292
	Concept 2 Maximal	640
	Concept 3 Minimal	252
	Concept 3 Maximal	520
Assembly cost:	Concept 1: 8 assembly steps	24
1 assembly step is assumed to cost 3 euro	Concept 2: 6 Assembly steps	18
	Concept 3: 7 assembly steps	21
Total cost:	Concept 1:	310 -685 euro
	Concept 2:	292 - 640 euro
	Concept 3:	252 - 520 euro

Figure 86: Ballpark cost estimation overview

Functionality	User importance	Estimated costs	Technical feasibility	Impact on experience
Rotatable seat	medium	Very expensive	Difficult, close to impossible in current seat lay-out	Easier entrance, entrance is also possible now.
Adaptable ergonomics	high	Relatively inexpensive	Relatively easy to incorporate in frame or seat	Without this adaptability, the bicycle is not usable for people
Side bolsters	medium	Relatively inexpensive	Not too difficult to integrate in the seat	Adds comfort and stability, also aesthetically
(Adjustable) Lumbar support	medium	Relatively inexpensive	Not too difficult to integrate in the seat	Adds comfort and stability (least noticeable)
Stability in the materials	High	Somewhat more expensive	Not too difficult to integrate in the seat	Adds comfort and stability (most noticeable)

Figure 87: Functionality decision matrix

This decision matrix indicates that the addition of the rotatable seat will most likely be the most costly addition, adding this conclusion to section 5 findings, it raises the question whether a rotatable seat is worth the extra investment and possible redesign of the entire bicycle. Other options need to be explored for the accessibility from a cost estimation perspective. Further implication of this matrix is that the other functionalities are of medium to high importance and can therefore be worth the extra investment, especially because this investment is not always that high. Finally, the stability in the materials is paramount so first focus should be on getting this right.

To conclude this section, the final concept, concept 3, has been chosen for now based on a ballpark estimation on the cost of each functionality to come to the most cost effective concept; something that could only be done because all solutions to the functionalities are seen as equal and all fulfil the requirement specifications. In the next section the final model will be further elaborated.

4. Final model

In this section the final model will be further elaborated. The aim is to present an embodiement of a possible final design based on the outcomes of this thesis in terms of functionality and aesthetics. Athough several aspects are uncertain at this moment in time, this visual representaiton will guide the design process further into future endeavors.

The final design is an enhanced version of concept two form the previous section. What has been added are horizontal stitches to the light grey main part of fabric or mesh. The colours light grey and dark grey have been chosen to keep the colours neutral whist still adding an “active” two colour element without being too flashy in high contrast. This is done to add stability by adding width and also to limit the seize of one solid piece of fabric as this makes the seat loose its activity evocation. Furthermore, an orange brand label is added to the upholstery of the seat. This minimalistic graphic touch is commonly found on soft goods and can really add to the quality feel of the product.

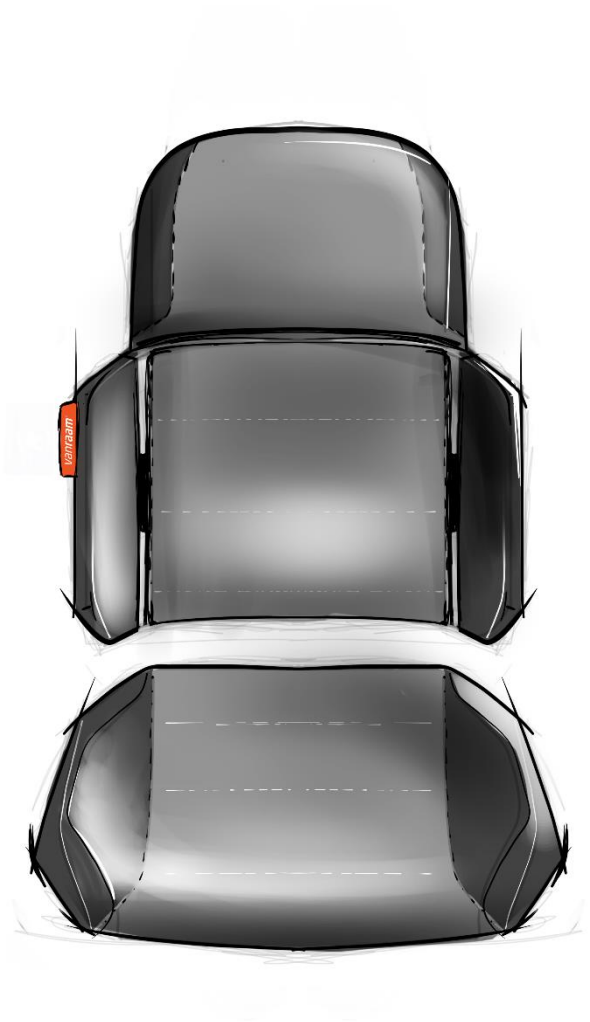
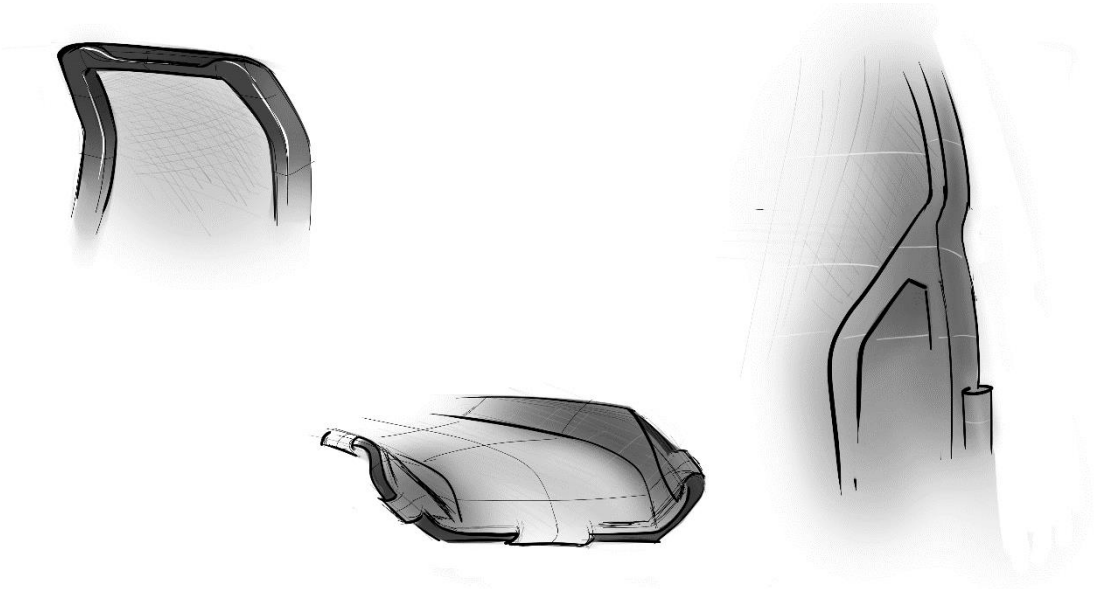


Figure 88: Front view of final concept

Figure 89: The seat on a CAD drawing of the bicycle

Figure 90: Detail view of final concept

The detailed view shows a backrest that is similar to the easyrider3 and Fun2Go in terms of design, to keep in line with the brand identity of VanRaam. The sitting area is a frame and pole structure that uses similar construction compared to the HP-Velotechnik seat, however its appearance is much more minimalistic to cater the needs and wishes of the target group better. The right image shows the aesthetic connection between the top part and the lower part of the backrest. By continuing the line diagonal line into the back of the lower part, a more coherent design is created.



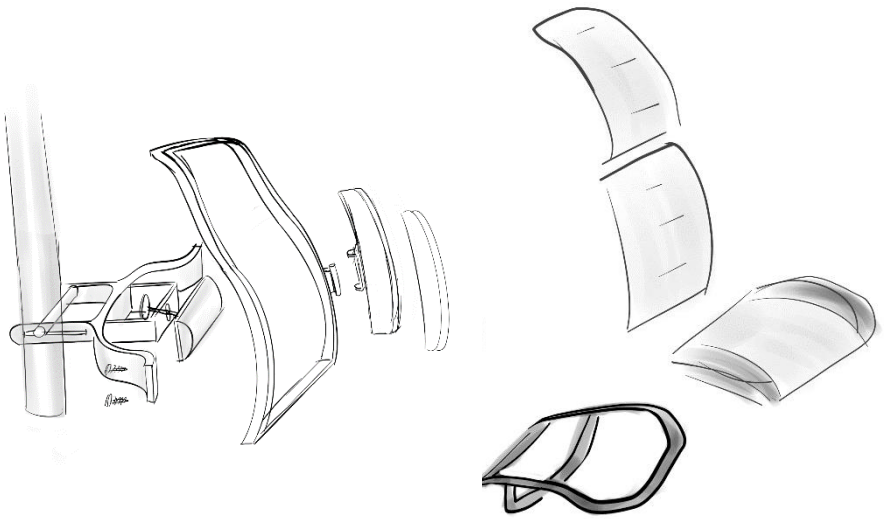


Figure 92: Exploded view of final concept

The exploded view shows a possible overview of the components included in the final design.

The simple sideview sketch shows the necessity of two mounting points to the frame; the backrest mounting point being adaptable.

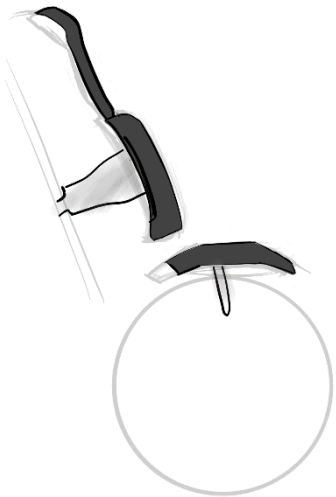


Figure 91: Side view with frame mounting points

Figure 94: Rear view of final concept

Figure 93: Velcro straps like on the HP-Velotechnik seat can also be used for a final concept

5. Discussion

This research was divided into two key components: a literature review focusing on comfort, ergonomics, aesthetics, and stability, followed by an iterative process that tested hypotheses with target users to refine the design of the seat for the Buddy tandem tricycle. This section reflects on the research process, discusses key learnings, and highlights the implications and limitations of the study.

Process Reflection and Learning

Initially, the research empathize was on perceived safety and stigmatization, rather than directly engaging users from the start. In hindsight, conducting user interviews early on would have better directed the literature review toward more relevant topics, such as stability and ergonomics. Delays in gathering relevant literature resulted in a slower prototyping phase. A more efficient approach would have been to begin with a well-defined design brief and an early focus on iterative testing, allowing for quicker refinement of concepts, rather than having to do a redefinition of the design brief. Despite these challenges, the iterative design process, guided by the Design Thinking method, proved beneficial. Regular user involvement through user tests ensured that the current prototype seat design aligned with the needs of the target group. However, the process was time-consuming, highlighting the importance of a clearly defined scope and brief from the outset. Future studies should maintain a focus on user involvement while integrating material considerations earlier to provide better cost estimates, which are critical for advancing the design into production. In terms of iteration directions, the choice after user test one has been made to focus on the development of a rotatable seat. This however did not prove to be fruitful at the moment, however in the long term it is beneficial that this is tested now. In hindsight however, bolster size, shape and some more accurate tests on measurements could have been more fruitful on the short term.

Implications of the Study

This thesis offers theoretical contributions by showcasing how the Design Thinking approach can be customized to prioritize user needs in the development of specialized cycling products. The study demonstrates that user-centred design processes result in products that more effectively meet user expectations, laying a solid foundation for progressing to higher Technology Readiness Levels (TRL). Additionally, this research bridges a gap in existing literature by connecting comfort research with the underexplored area of seated cycling ergonomics, offering new insights into enhancing comfort in such designs. The framework developed in this study, linking comfort, confidence, and aesthetics, empathizes the often-overlooked role of aesthetics in perceived stability and user satisfaction. These findings suggest that aesthetic design is integral not only to user appeal but also to the overall functionality of the product, making it a critical area for future research. The Moscow method used for criteria prioritization provided guidance throughout the process by keeping track of what must be included in the design according to the stakeholder. This proved to be a valuable criteria sorting method for this thesis.

Limitations of the Study

The study's limitations can be categorized into three areas: methodological, sample size, and material constraints. Methodologically, Moscow method for design criteria proved to provide guidance to the criteria necessary for the design of the seat, however it is still subjective in nature as it is limited to the stakeholders involved and their assessment of research and the corresponding most important features. In future research project, rating of requirements in combination of the Moscow method

might be a better alternative to this problem. The limited involvement of target users also posed challenges; participants struggled to provide detailed technical feedback, leading to a reliance on qualitative and observational data with a small sample size of five. Although trends were identified, this sample size is insufficient for definitive conclusions. For future studies, more quantitative backing of finding would ensure the enhancement of significant findings.

Furthermore, qualitative feedback was susceptible to bias from the phrasing of questions. In terms of data analysis, only basic statistical methods were applied. A more comprehensive statistical evaluation could reveal deeper insights into the relationships between different design functionalities.

The most critical limitation is the lack of a thorough material study. The comfort, stability, and aesthetics of the seat are closely tied to the materials used, and while this study provided some preliminary insights, a more detailed exploration of materials is essential in future research. This is therefore also the most logical next step. A hypotheses has been generated through this thesis through the identification of the hammock structure as being the preferred load structure and upholstery option, which materials have what influence on this phenomena could be an interesting future study.

To conclude, this thesis has shown that incorporating the Design Thinking approach, with a strong focus on user needs, leads to a more effective design process, particularly for specialized products like the Buddy tandem tricycle seat. The iterative nature of the process, despite initial inefficiencies, ultimately resulted in a prototype that includes functionalities that meets key user needs and preferences in terms of comfort, stability, and aesthetics. However, further work is needed to refine the design, particularly in the areas of material selection and detailed ergonomic analysis and eventual validation.

6. Recommendations

This section provides an overview of the necessary steps that will need to be taken in the next development phase of the seat that was the subject of this thesis. In order to do so firstly, an overview of the current state with regard to the TRL level in which the development of the seat is currently in. The project initiated at TRL level one where Basic assumptions on the design of the seat had to be set up based on previously gained knowledge. This thesis has presented a design process that finalises at TRL level three where all functionalities and some measurable requirements are presented and a low-fidelity prototype based on the existing HP Velotechnik is fitted to the bicycles for further development testing. In figure 95, an overview of the TRL levels for the development of the seat is presented.

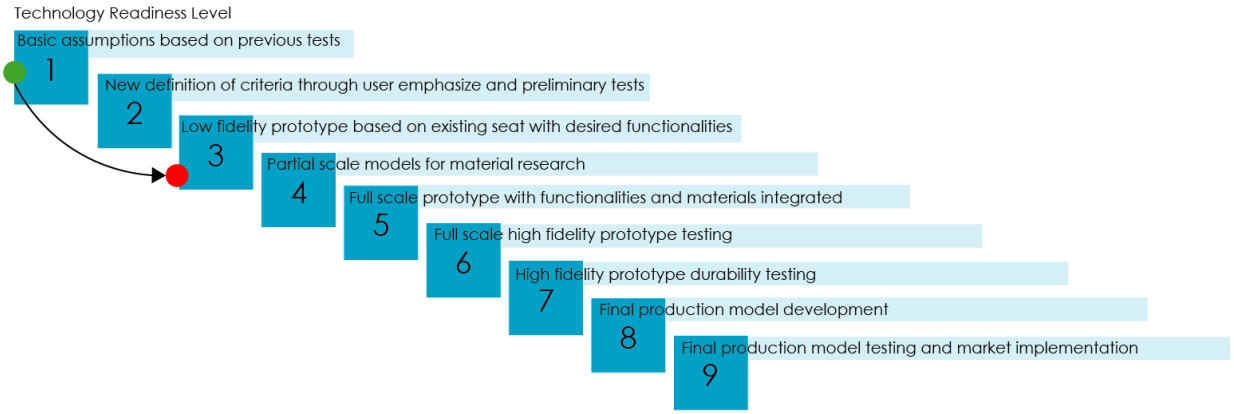


Figure 95: NASA TRL levels for the development of the seat for the Buddy bicycle, Green indicates the starting point, red is the current point of development.

This figure aids the recommendations for further development of the seat, which can be divided into several main themes, elaborated below.

Access of the bicycle

This thesis has provided insights into the key functionalities that need to be included into the design, however form the final user test, it became apparent that the rotatable seat currently fitted to the bicycle does not work as intended. Thus further research needs to be done into whether the frame of the Buddy can be altered in such a way that a properly functional rotatable seat can be integrated as this is still something the target users mentioned that is desirable.

Business case

As established in the design brief, comfort is not only based on measurable comfort, also on other models, prioritising aesthetics and blending in (conformity model) and also the connection between materials, aesthetics and price (Aesthetic-Economic model). This has not been covered extensively in this thesis, however, the ballpark estimate from chapter six can be used to explore in detail what all functionalities will cost. The next step is to explore what the target group is willing to pay for these extra functionalities.

Material Research

This study has highlighted the key functionalities and non-tangible aspects that should be incorporated into the final seat design. However, as previously mentioned, the thesis does not provide a comprehensive analysis of the potential materials for the seat. Chapter six outlines three possible material directions that can be pursued. The final material selection must align with the comfort, confidence, and aesthetic requirements identified in this thesis, while also considering the cost-effectiveness of components made from these materials. A logical starting point for this material research is to evaluate the mechanical properties of the mesh and frame, or hammock, structure, such as mesh tension and elasticity and their influence on sitting area pressure with different materials, airflow and heat/moisture absorption, cushioning effect, and pressure distribution. Understanding these measurable requirements will provide a foundation for determining the most suitable materials.

Once these requirements are defined, the ideation process for integrating these materials into the design can begin, leading to the development of different material concepts. Ideally, these concepts should be tested and directly compared by the target users to ensure they meet their needs. A similar approach can be applied to the foam used for the side bolsters, exploring options such as PU, TPU, EVA, and other foams. For upholstery, Skai is a widely used material and could serve as a good starting point for comfort testing with the target users.

Long-Term Comfort Testing

Comfort is a key factor in product success, especially for prolonged use. A long-term comfort test is essential to assess how the chosen materials and design hold up over extended periods. This can be done through implementation of long-term user trials and gather data on how the seat performs over weeks or months. Look for research papers or industry reports that cover comfort testing methodologies. These trials should measure not only immediate comfort but also factors like pressure distribution, material wear, and resilience over time.

Finally, this raises the question: what could have been accomplished with a few more months on this project? The first step would have been developing a proper business case, which would provide a clear understanding of the market potential, cost implications, and revenue forecasts. This foundation would guide the project's direction and priorities, ensuring that resources are allocated efficiently. Following this, I would have conducted thorough material research as described above. This would ensure that the chosen materials not only meet the design and ergonomic criteria but also align with cost-effectiveness and sustainability goals, ultimately enhancing the product's market viability.

7. Main Conclusions

To conclude this thesis, it is imperative to go back to the design brief established in the corresponding section. This thesis has attempted to answer the following question: “What is the ideal cycling experience regarding the seat for the target audience sitting in the front seat of the “Buddy” tandem tricycle?”

For this, the target group has been defined at 65+ people with changing medical conditions, whilst not excluding other possible target users. After user empathizing it became apparent that stigma and safety are not the main issue for the design of the front seat, comfort and confidence appeared to be the issue. Added to this are the core principles of a bicycle that provides autonomy and activity to the target user. Thus a redefinition of the design brief has been done: “What are the desired features for the prototype of the front seat of the “Buddy” tandem tricycle to give the passenger maximal comfort and confidence whilst also addressing appearance?”

In order to answer these questions, firstly, comfort and confidence needed to be defined. Comfort can be obtained by looking at what comfort is and how it can be measured. A look into existing comfort models presented a framework of three categories. The health model covers no discomfort and can thus be linked to the correct ergonomics as obtained from literature research. The community model can be linked to non-stigmatising design that is perceived as such by the general public. Finally, the aesthetic-economical model includes correct support, good stability and a not too expensive design. Confidence is defined trough the user interviews as stability whilst cycling.

This design brief has been answered iteratively through the use of the design thinking model where the initial step was to answer sub question one: Are the ideal static ergonomics found in literature found to be correct, thus perceived as comfortable, when testing with target users in a dynamic setting? In order to test these, the HP Velotechnik seat has been used; as its ergonomics do not differ significantly from what is found in literature and it was easier on resources. During testing it came forward that Distance to crank is paramount. In terms of functional seating angle it remains highly personal; however, 123 degrees is a good default setting. Also the lumbar support and the side bolsters added a feeling of comfort to the target user. The material of the sitting area needs to minimise contact pressure, the hammock structure from the HP Velotechnik seat is very suitable for this. Thus not all ergonomic measurements in literature have been tested, however, the most important functionalities and measurements have been transferred from literature into practice with success. A rotatable seat might add to the comfort of the passenger, as it provides less discomfort according to the health model, however in order to achieve this, the rotatable seat needs to able to rotate 90 degrees. If this cannot be obtained, the frame of the bicycle needs to be re-evaluated, this is a direction for further research.

A maximal sense of stability is twofold. Firstly, it comes from the feeling of stability which is hard to pinpoint. Some aesthetic elements can contribute to a sense of stability. However, it is mainly obtained through the use of this same functional seating angle, the use of a lumbar support, side bolsters and the material of the load structure.

Then the aesthetics of the seat should also incorporate comfort and confidence into the design together with activeness that was found to match the characteristics of the Buddy bicycle. Because of the specific impairment of the target group, the design of the seat needs to be kept simple with straight continuous lines. In order to keep the design in line with the VanRaam brand, the design should be approachable, contemporary and high quality. A visual representation of such a design is provided in this thesis.

Looking ahead, the focus should be on material selection to enhance comfort and stability. The proposed final conceptual design incorporates necessary functionalities while making use of VanRaam's existing knowledge to achieve cost-effectiveness without compromising aesthetics. To validate this design, a comprehensive business case should be developed. Additionally, long-duration comfort tests are recommended to gather further insights.

Summary of key points

- The target group are people of 65+ age with changing medical conditions losing their autonomy in traffic
- After empathizing with users, the design brief was refined to focus on maximizing comfort and confidence while addressing appearance.
- Comfort was linked to ergonomics, non-stigmatizing design, and cost-effective support, adaptability and stability.
- Confidence was primarily associated with the stability of the seating experience.
- Key ergonomic features like seating angle (123 degrees as a good default), lumbar support, side bolsters, and material for the sitting area were qualitatively validated through user testing with the enhanced HP Velotechnik seat.
- The potential for a rotatable seat to enhance comfort was identified as an area for future research.
- Stability was understood as both a physical and psychological sense, influenced by seating ergonomics and aesthetic elements.
- The seat design should be simple, align with the VanRaam brand's values, and incorporate comfort, confidence, and activeness.
- The next steps include selecting materials that enhance comfort and stability, developing a business case for the design, and conducting long-duration comfort tests for further validation.

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Appendices

Appendix A: Parkinsons stages

Hoehn & Yahr Staging of Parkinson's Disease

In 1967, Hoehn & Yahr introduced a five-stage scale to classify Parkinson's disease (PD) based on the severity of motor symptoms and clinical disability. This scale is widely used to track disease progression, categorizing early (stages 1 and 2), mid (stages 2 and 3), and advanced stages (stages 4 and 5) of PD.

Stage One:
In this initial stage, symptoms are mild and localized to one side of the body. Movement issues like tremors, posture changes, and altered facial expressions may appear, but daily activities remain largely unaffected.

Stage Two:
Symptoms worsen, affecting both sides of the body or the midline. Walking difficulties and poor posture become more noticeable. Although the person can still live independently, daily tasks take more time and effort.

Stage Three:
Marked by balance problems, especially when turning or being pushed, this mid-stage sees an increased risk of falls. Although motor symptoms worsen and independence becomes more limited, the person can still manage basic daily activities with mild to moderate disability.

Stage Four:
Symptoms become severely disabling. While the person can walk, they may need assistive devices like a cane or walker. Help is required for most daily activities, and independent living is no longer feasible.

Stage Five:
The most advanced stage, characterized by severe mobility issues. The person is typically bedridden or wheelchair-bound and requires around-the-clock care for all activities due to extreme stiffness and disability.

Appendix B: All design criteria

Underneath, an overview of the design criteria is given:

Must have:

1. The seat must cater to the needs and wishes of elderly with changing medical conditions
2. The seat design must prioritize stability, as this is directly linked to user confidence and safety.
3. Ergonomics must be adaptable to suit a range of user preferences and needs.
4. The seat must accommodate the target group's anatomical measurements (P5 to P95 range).
5. The seat design must support a sense of autonomy, allowing the passenger to sit in front of the supervisor and have some control over the ride, enhancing the feeling of independence.
6. The seat must have an adjustable Functional seating angle, with 123 degrees being a key reference point.
7. The seat must include adjustable lumbar support to cater to different user preferences and enhance comfort and stability.
8. The seat must be designed to prevent slipperiness and be ergonomic, taking inspiration from a hammock-like structure to improve comfort.
9. The seat must have side bolsters that enhance stability without significantly impeding core rotation or the ability to move.
10. The design must allow for adjustable pedal distance to ensure stability and comfort for different users.
11. The bicycle must have a simple design to avoid distractions, especially for users with Parkinson's disease.
12. The design must communicate an active lifestyle to appeal to users who value activity and engagement.
13. : The design must incorporate continuous lines to ensure a cohesive and visually appealing appearance.

Should have:

1. Seating position should facilitate a minimal hip angle that does not exceeds 95 degrees
2. The seat should incorporate Gestalt theory principles, focusing on stability, comfort, activeness, and visual balance.
3. The design should follow the MAYA (Most Advanced Yet Acceptable) principle to ensure aesthetic appeal and user acceptance.
4. The seat should be designed with a sporty and active aesthetic to align with user expectations for the Buddy bicycle and to reduce stigma.
5. The bottom bracket and seat design should be considered together to ensure optimal positioning and comfort.
6. The side bolsters should be adjustable to cater to various user preferences and ensure they do not overly restrict movement..
7. The seat materials should prioritize comfort by addressing heat transfer, water vapor, support, and freedom of movement, regardless of the chosen material route (conventional, ER3/Fun2Go, or 3D printed options).

8. The design should maintain functionality comparable to other VanRaam models like the OPair and Fun2Go, balancing features such as ease of entry, comfort, and storage.
9. The seat should be designed in a way that disguises, redirects attention from, or transforms stigmatizing features, addressing cultural and user-related stigma.
10. The top layer must be selected to minimize tensile stress, and load structure must reduce reaction forces effectively, possibly using a spring mechanism.
11. The seat should be rotatable to facilitate easier access for people with Parkinson's disease..
12. design should include elements that enhance user confidence and the perception of safety.
13. The design should incorporate side bolsters to enhance perceived comfort, ensuring users feel secure and supported.
14. The design should avoid a clinical look to make the bicycle more inviting and user-friendly.

Could have:

1. The seat could rotate to make accessing the bicycle more convenient
2. The seat could include a headrest to enhance the perception of safety for users who prefer it.
3. The design could incorporate clever ergonomic adjustments, inspired by recumbent bicycle designs, to cater to varying user needs.
4. The seat could include features that enhance the appearance of stability, such as a wider base or visible support elements, since stability is a key aspect that influences user confidence.
5. The design could incorporate elements that visually communicate activeness and autonomy, differentiating the Buddy from other models and competitors.
6. The design could include subtle elements that hint at adventure, without overwhelming the user with an adventurous aesthetic.

Won't have:

1. The design of the front seat won't exclude people with down syndrome and people recovering from surgery
2. Seat won't cause unpleasant pressure points around the shoulder/scapula region
3. Seat won't have seatbelts fitted as standard
4. The design will not exaggerate the recumbent position, as this can introduce stigma and reduce user comfort.
5. The design will not solely focus on shelter for safety, as stability is more crucial for the target users.
6. The design will not rely solely on the handlebar movement as a means for entry and exit without considering additional support mechanisms or ergonomic adjustments.
7. The design will not prioritize features that are better suited for bicycles targeting users with lower levels of autonomy or activity, as this contradicts the active, engaging nature of the Buddy.

8. The seat won’t have a fixed lumbar support, as adjustability is crucial for comfort and compatibility.
9. The seat won’t have rigid or non-adjustable bolsters, as they may impede movement and reduce comfort.
10. The bicycle won’t have a complex design that could distract or overwhelm users with Parkinson's disease.
11. The seat won’t have a fixed seating angle, as adaptability is necessary to meet the needs of a diverse user base.

Appendix C: Personas

Andy Alzheimer

"I want to exercize and feel autonomous"

Positive Trends
- He wants to exercize
- His wife is his caregiver
- He understands that he is not able to go through traffic alone anylonger

Opportunities
- A bike that helps him maintain his autonomy
- A bike that does not provoke his back pains
- A bike in which he does not need to use much force
- A bike that cycles smoothly and promotes Longer distance rides

Hopes
- Cycling autonomously without pains and panics or getting lost

Bio
Andy lives together with his wife Eva. Before he got ill they used to cycle long distances together. Due to Andy's illness this is no longer possible.

Age	67
Occupation	Retired
Status	Married
Location	The Netherlands

Active Chronic illness Stubborn

Negative Trends
- Loses cogntive function
- Forgets things
- Declining overall fitness
- Loved ones do not trust him alone in traffic

Frustrations
- Gets lost
- Panics when he gets lost
- Is more afraid to cycle
- Has a bad back and worn joints
- Has Parkinsons disease

Fears
- Trouble managing traffic
- Unexpected situations
- Declining strength

Carol Challenged

"I want tocycle and feel normal"

Positive Trends
- She wants to exercize
- Her parents are her caregiver
- She wants to take part in society
- She lives in a supervised appartment

Opportunities
- A bike that gives her a sense of autonomy
- A bike that can handle her spasms
- A bike in which she does not need to use much force
- A bike that gives her a sense of being "normal"

Hopes
- Participating in traffic like a "normal" human being

Bio
Carol has Down syndrome. She realises that she is not "normal". However she wants to be perceived as normal and do things also normal people do like cycling thorugh traffic

Age	23
Occupation	Voluntary work
Status	Single (lives together)
Location	The Netherlands

Active Chronic illness Lonely

Negative Trends
- Cannot "read" traffic
- Limited mobility
- Slow to react to situations
- Spasms

Frustrations
- Not able to express herself properly
- Is not autonomous
- Sees that she is "different"
- Position of body parts not "normal"

Fears
- Dealing with traffic
- Not being able to cycle
- Being left alone

Harry Hip

"I want to recover and regain confidence"

Positive Trends

- He wants to exercize
- His wife is his caregiver
- Has a lot of cycling experience

Opportunities

- A bike that helps him maintain his autonomy
- A bike that does not provoke his back pains
- A bike in which he does not need to use much force

Hopes

- Recovering fully and being able to cycle independently again

Bio

Harry had a hip prosthesis half a year ago. His biggest wish is to regain his mobility and being able to cycle again. However, he is a little afraid to participate in traffic alone.

Age	72
Occupation	Retired
Status	Married
Location	The Netherlands

Active Recovering Dependent

Negative Trends

- Needs to recover from a hip transplant
- Is getting older

Frustrations

- Is more afraid of falling now
- Recovery takes a lot of time
- Is used to being very fit
- Finds recovery bikes stigmatising

Fears

- Not able to cycle anymore in his life
- Getting pains again

Sally Supervisor

"I want to enjoy cycling with someone I care about"

Positive Trends

- Want to cycle together with challenged person
- Wants to try new technology
- Feels responsible for husband

Opportunities

- A bike that looks normal
- A bike with not much extra resistance
- A bike that evokes confidence
- A bike on which she can see her husband

Hopes

- Cycling with her husband for as long as possible
- Having a bike that can facilite her as well

Bio

Sally is the wife of someone challenged. She loves to cycle outdoors and being together with her husband. She finds his condition difficult but still wants to do things together.

Age	66
Occupation	Retired/Volunteer
Status	Married
Location	The Netherlands

Empathic Social Concerned

Negative Trends

- Is quickly concerned with her husband
- Cannot leave her husband alone
- Is getting older herself

Frustrations

- Cannot do the activities like before
- when a bike has too much resistance, cycling is not fun anymore

Fears

- Not knowing where her husband is
- Crashing with her husband
- Leeting the challenge take over her marriage

Appendix E: S-Curve

Then, there is the matter of the S-Curve; each body is unique and has its own S-Curve. This means unique lumbar support is necessary. For starters, men and women have different S-curve measurements. However, both genders need the lumbar support mainly at the height of the L3-Vertebrae (Nadine M. Dunk Jack P. Callaghan, 2005).

This being said, according to Zemp, a functional seating position of 127 degrees has a lower lumbar seating angle compared to a functional seating angle of 90 degrees. (Zemp et. Al, 2013) Therefore, one could argue that a large lumbar S-curve support is of lesser importance for the comfort of the rider in a relaxed position of the Buddy tandem bicycle. However, it will be taken into account in this research.

Finally, there is also a significant difference in S-curve between elderly >50 years of age and adolescents (20-29 years of age); elderly have a much smaller S-curve compared to adolescents. This is something to take into account.

All in all, it is important that the S-curve support fits the measurements of everyone included in the target group in order make the seat as ergonomic as possible (Dreischarf et al., 2014). The way to do this is by incorporating adaptable S-Curve support in the seat of the Buddy bicycle in order to let the target user choose their own support.

Appendix F: User interviews round 1

User interviews 19-22-01

General outcomes

- Stigma does not appear to be a problem with the target group
- Not everyone spoken to fits the target group
- Safety does not come from shelter, rather from stability
- Stability gives confidence
- Trike takes getting used to
- It does not matter what the bicycle looks like as long as it fits function. However, when taking it too far by exaggerating the position of the passenger, stigma does become a problem.
- There is a difference in active and sporty cycling and many people want the buddy bike to be active and to cycle as a normal bicycle.
- The buddy would appear more normal if it looked more like a sporty bike
- There is no consensus over sitting upright or laying down position, this has to be tested with two different concept directions
- The buddy is seen as more active and sporty than the fun2go and the twinny thus deserves to be a model in the range of VanRaam
- Generally, the Buddy is one of the most liked bikes in the group of four different bikes

Who fits target group?

1. José and Piet
2. Fam Hudepohl
3. Gerda Schuddeboom
4. Fam. Boomkamp → Because of the mother also able to cycle, but 3 wheels not necessary

Fam Hulleman does not fit target group because to them cycling is more a social activity.

What are the main opportunities for design?

- Gestalt (Appearance, look and feel and what it communicates) of the seat
- Sitting upright vs. Laying down
- Ergonomics of pedalling in both positions
- Feeling of safety through stability
- Ergonomics of different bodies

José & Piet

- Ervaring
    - Tandem gehuurd
        - Angst om te vallen door instabiliteit
    - Fun2Go gehuurd
        - Ong. 20 km
        - Fijne ervaring
        - Opletten op paaltjes
        - Niet geneigd tot kopen
    - Easyrider was beter dan verwacht
        - Stabiel en gemakkelijk
    - Ligfiets gehad
        - Meneer fietst graag hard
- Zijn opzoek naar een fijne mobiliteitsoplossing
- Tworby was minder stabiel

- Angst om te vallen geeft gevoel van onzekerheid en onveiligheid
- Piet fietst het liefst alleen zonder angst
- Het gevoel minder afhankelijk te zijn is voor Piet erg prettig
- Een rollende eettafelstoel is voor piet niet echt een optie want geeft ook een gevoel van onzekerheid

Assocaties

Fun2Go	Hase Pino	Twinny Plus	Buddy
- Stabiel want zit naast elkaar, voelt veilig → geen gevoel dat je gaat vallen - Gezellig → lekker kletsen → Maakt contact makkelijker - Lager volume dus beter verstaan van Piet - Doet denken aan een spoorlijn fiets - Makkelijk afstanden afleggen op de fiets door ondersteuning - Lekker zitten door goeie ondersteuning, geen zadel - Piet gleed een beetje naar onder, onprettig maar geen gevoel van onveiligheid	- Sportief - Is heel laag vergeleken met de vorige fiets - Wel stabiel omdat de voeten goed bij de grond kunnen - Niet door een diepe plas rijden ivm bagagerek - Fiets voor lange tochten - Veel snelheid ontwikkelen met deze fiets - Fiets in zn geheel niet stabiel - Zitje voelt stabiel - Lengte is korter - Kan niet per se makkelijk op de fietsendrager → karretje huren - Als degene voorop groot/zwaar is dan is ie minder stabiel dan de driewieler	- Ziet eruit als gewone tandem door zadel - Stuk meer weerstand, stuk minder aero - Lage instap - Stoeltje is comfortabeler → stabieler - Tandem is piet bang om te vallen door het gewone zadel - Gevoel van “hellen” is niet fijn/onnatuurlijk - Piet ziet zichzelf er niet op fietsen → het gewone zadel als voornaamste reden - Liever lager zitten zodat hij harder kan fietsen -	- Stuur oogt alsof het aan de zijkant is → is ook zo - Leuk samen fietsen - Mooie mogelijkheid om lange tocht te maken - Fijn om een langere tocht te maken - Geeft niet per se een sportievere look, ziet er meer uit als een rolstoelfiets - Liever buddy dan fun2go want is veel sportiever. - Beide fietsen hebben gevoel van stabiliteit

Op welke fiets het liefst gezien worden?

- Minst graag op de Twinny Plus
- Hase Pino het liefst op gezien worden → meest sportieve uitstraling

- Buddy op 2 want ziet er minder sportief uit
- Hase Pino ziet er meer uit alsof er iemand op zit met een beperking

Windscherm oid prettig?

- Hoeft niet per se
- Optie zou wel fijn zijn
- Maar je word toch wel nat van fietsen
- Vespa scherm miss
- Voor voeten?
    - Niet op gelet dus niet per se een probleem
- Vrij zicht is fijn en dat geeft het plezier

Conclusie:

Piet en José zijn in de markt voor de buddy omdat ze zelf vroeger veel gefietst hebben en de buddy Piet het meeste het gevoel van hard fietsen van vroeger teruggeeft. Het liefst zou Piet alleen op een driewieler fietsen maar dit is niet echt meer een optie dus dan is dit de beste optie. Op het gebied van zittingen moet het gewoon stabiel zijn voor piet want daar komt zijn vertrouwen en veiligheidsgevoel vandaan. Extra beschutting heeft piet niet per se nodig en ook qua stigma vinden zowel Piet als José het niet erg hoe de fiets er uit ziet, als ie maar functioneel is. Maar het badkuip idee ging dan weer te ver.

Fam. Hudepohl

Fun2Go	Twinny Plus	Hase Pino	Buddy
- Heel mooi maar niet handig op smallere paden - Herman vind het gezellig - Geen optie want te breed, tov van fiets en bospad - Rolstoelfiets makkelijker - Moeilijk op te bergen - Ziet er relaxed uit, mooi rechtop - Bij herman doet nooit iets zeer - Hoe veilig is een fiets? - Niet onveiliger als een gewone fiets - Veilig in de bochten want vrij laag in de grond, geeft	- Mooi ding maar minder ideaal voor herman want kan niet in de gaten gehouden worden. - Herman kijkt tegen een rug aan - Herman vind vooruit kijken mooier - Deze fiets is minder stabiel omdat de mensen er zo hoog opzitten - Inschatten van de breedte is ook lastig want 2 wielen achter - Ziet er wankelig uit, zadel is sws	- Mooie fiets voor het circus - Kaal en onveilig, te weinig bescherming → Herman zou er zo afvallen - Mensen met een goed koppie en een goeie motoriek - Herman heeft aan de kant iets bescherming nodig en ondersteuning van het hoofd. - Gevoelsmatig stuurt de fiets zwaar vanwege het gewicht op de voorkant - Vooriemand die blind is en verder helemaal goed - Houvat is handig maar voor herman niet	- Ideale fiets voor Herman - Meetrappen maar hoeft niet - Sturen want dan heeft ie eigen waarde - En hij zit wat actiever - Hij vind de vrijheid van het fietsen mooi - Zitting is goed want is als een stoel - Als hij moe is hoeft hij niet te trappen maar het kan wel - Fiets zou overal voor gebruikt kunnen worden - Het prettige gevoel zit m voor herman in de veiligheid en dat ie ergens komt - Achterop zitten

meer stabiliteit	geen optie. - Moet altijd zadel met rugleuning en gordel hebben - Geen zicht op passagier is voor begeleider niet prettig, daar zit het gevoel van control hem in - Ziet eruit als een driewieler	nodig - Is dit misschien een wedstrijdfiets (Alpe D'Huez)	vindt hij minder veilig en komt ie in spasme - Toch liever voor zitten want dan kan ie in de gaten gehouden worden - Added value is dat hij zelf actiever kan zijn - Voor het trappen is een liggende houding prettiger voor hem

Op welke fiets het liefst gezien worden?

- Geen fiets waar herman achter moet zitten
- Wat beschermder zitten is prettiger
    - De zitting is prettiger als stoel dan als zadel
- Het boeit niet, gaat meer om functionaliteit
- Gaat om de persoon die vervoerd word
- Buddy het liefst op gezien worden
- Ervaring is voor Herman belangrijk

Op welke fiets fietst u het liefst?

- Buddy

Voeten vooruit bescherming

- Herman heeft geen last van het beschreven probleem
- Meer de zijdelinkse ondersteuning zorgt voor het veiligheidsgevoel
- Een bak om de stoel liever niet want dan is het uiterlijk gewoon heel raar, want dan val je te veel op. Zit hem puur in de vorm van de kuip
- Misschien een windscherm wel een optie, maar snelheid aanpassen is beste en windscherm houd het gevoel van natuur wat meer op afstand

Conclusie:

Voor Herman en zijn vader is de Buddy de perfecte fiets waar ze mee kunnen gaan en staan waar ze willen. Voor herman is het zelf meesturen en voelen dat hij iets moet doen echt een aanwinst. Voor de ouders is het fijn dat ze herman in de gaten kunnen houden. Voor Herman geldt ook dat hij het gevoel van veiligheid haalt uit het feit dat de fiets niet geks doet en stabiel op de weg ligt. Stigma is voor hen ook geen probleem als de fiets maar functioneel is. De buddy is wel echt een unieke fiets omdat hij actief, sportief, autonoom en stabiel is. Herman heeft niet per se bechutting nodig, maar armsteunen en hoofdsteunen misschien wel. Een liggende houding is voor Herman heel comfortabel

Petra Boomkamp

- Met de buddy meer mogelijkheden dan met de Fun2Go

    - Want sportiever
- Hebben nu zelf een Twinny met passagier voorop
    - Betekend dat naar een driewieler switchen wel een leercurve is
    - Maar evenwicht houden gaat goed
        - Met Ties erop is wel spannender
    - De Twinny heeft een rugsteun waar een band op bevestigd kan worden maar die zat er nu niet op
- Tie heeft Dyspraktie en is 17 jaar
- Man gebruikt fiets veel meer, in de zomer dagelijks bijna)
    - Niek (Man) geniet het meest van de fiets als de fiets net zo snel kan als de gewone fiets
- Ties vindt het zelf sturen heel leuk
    - Hij leert door te doen
- HUKA was te wiebelig
- Zelf vindt ze vooral de bochten spannend want je hebt een verantwoordelijkheidsgevoel over degen voorop
- Zitting ziet er wel comfortabel uit
- De veiligheid zit het voor haar vooral in het gevoel van fietsen

Fun2Go	Twinny Plus	Hase Pino	Buddy
- Gezellig - Mooi naast elkaar fietsen - Ziet er stevig uit - En ook breed - Handig met mandje er voorop - Te breed - Niet snel genoeg voor man en moet overal heen kunnen waar normale fiets ook heen kan - Fun2Go gaat meer om gezelligheid dan om fietsen, lekker hard fietsen overal waar je zou willen - Opbergen is echt een groot probleem net deze fiets want past	- 2 wielen achter ook geprobeerd - Bochten zijn te spannend en daar moet je aan wennen… leercurve. Weerhoud iemand van de fiets - Ties kan niet vooruit kijken en dat vind hij misschien vervelend maar dat weet ze niet zeker - Ties kan wel prima op een zadel zitten - Ties kan goed evenwicht houden - Voor Niek is deze fiets	- Sportief stoer - 2 wielen voelt als echte fiets - Positie van handen misschien een probleem - Niek zou het fantastisch vinden - Petra zou het spannend vinden - Ziet er niet zo stabiel uit - Associatie met “normale” kinderen - Gave fiets maar eng - Als ties er niet af kan vallen zou het goed zijn - Ziet er niet uit als een fiets voor mensen met een handicap - Vast houden	- 2 wielen voor zorgen voor gevoel van veiligheid maar ook minder flexibel dus voelt minder als een echte fiets - Meer gevoel van weeerstand - Sportief is meer zoals gewoon fietsen - Eerste indruk is wel een beetje een gehandicapte fiets - Zeker vergeleken met de Hase Pino - Ze vind het niet erg dat

niet door de poort - Zelf zou ze wel op deze fiets fietsen met Ties	ook niet snel genoeg - Deze fiets geeft het gevoel van fiets-fiets - Sneller van a naar b dan de fun2go - Ziet er redelijk normaal uit	als je snel door de bocht gaat is misschien wel eenvoudig	omstanders het zien als een fiets voor mensen met een beperking, het gaat vooral om de fietssnelheid

Waar zouden jullie het liefst op gezien worden?

- Hase Pino het liefst want ziet er uit als een normale fiets
- Fun2Go wat leuk dat het kan maar bij tandem heeft ze dat gevoel een stuk minder

Op welke fiets zou je het liefst fietsen?

- Hase Pino, zou goed kunnen met de beperking van Ties
- Buddy zit er tussenin en de Twinny het minst graag

Gevoel veiligheid met drempels

- Niks van gemerkt in de testrit
- Bak of windscherm lijk op een badkuip en daar willen mensen niet in gezien worden
- De fiets in z'n geheel is niet per se heel veilig
- Maar hierdoor word het niet per se gevaarlijker

Conclusie

Voor vooral Niek en Ties zou een fiets met een sportieve uitstraling die soepel en gemakkelijk fietst de best uitkomst zijn. Omdat evenwicht niet per se een probleem is voor Ties zou hij ook een tweewieler kunnen hebben. Ook is stigma weer niet het probleem, het gaat er vooral om dat de fiets z'n functie vervult. Een windscherm is niet nodig. Ties vind sturen wel heel leuk dus dat is wel het overwegen waard. Veiligheid komt vooral van stabiliteit weer en dat Ties zich goed kan vasthouden tijdens het fietsen. De buddy is een optie als ie er sportiever uitziet en minder weerstand bied.

Gerda Schuddeboom

- Heeft zelf een tandem in bezit maar is te hoog groot en zwaar voor de heuvels in haar omgeving.
- Op de tandem zit ze achterop
- Gerda heeft veel fietservaring
    - Vanaf haar 11^{e} jaar en altijd op zadels
    - Gerda is al haar hele leven blind
    - Ze heeft met veel mensen samen gefietst
    - Ze heeft altijd op 2 wiel tandems gefietst
- Zo vond het ontzettend leuk om voorop te zitten op de tandem fiets
- Liggen vind ze helemaal niks want het voelt onwennig en heeft liever recht op maar ze verwacht dat ze er wel aan zou kunnen wennen. Het liggen voelt voor haar minder actief omdat ze zelf niet haar evenwicht hoeft te houden.
    - Het wennen zit haar vooral in de afweging dat ze het zelf sturen leuker vind. Idealiter wil ze rechtop zitten
- Op een duofiets heeft ze zelf veel minder het idee dat ze iets toevoegd en dat vindt ze minder prettig

- Maar een driewieler voelt wel lekker stabiel, echter is evenwicht voor haar nietecht een probleem
- De buddy voelt ook heel stabiel en dat geeft haar een veilig idee
- Het is een andere ervaring dan de duofiets want iets doen vind ze echt leuk
- Ze was tijdens de testritten geen problemen tegengekomen

Twinny Plus	Hase Pino	Fun2Go	Buddy
- Wel stabiel met 2e wiel achter, is iets positiefs - Onafhankelijk van elkaar trappen want niet duidelijk wat de voorrijder doet, specifiek voor blinde mensen - Je moet weten wanneer je iets moet doen	- Niet fijn - Geen fijne balans - Geen idee hebben dat je wat doet maar rare houding om in te liggen - Vooral ook vanwege de plek van het stuur en het evenwicht maakt het minder veilig - Met liggen minder het gevoel dat je goed kracht kan zetten	- Voelt stabiel door 3wielen - Ze weet niet of je verschil voelt tussen 3 of 4 wielen - Beter om te kletsen dus kan zich voorstellen dat het gezellig fietst - Veilige gevoel komt van de twee wielen achter	- Liggen wat minder, liever op een stoel recht op - Zware mensen meer last van hobbels

Fietst het liefst zelf op?

- Duofiets of buddy maar buddy met zitstoel is beter

Veiligheid van voeten

- Nog niet over nagedacht
- Misschien is het wel zo
- Zelf niet ervaren tijdens het fietsen

Conclusie

Voor Gerda is het voornaamste probleem van de buddy de lighouding. Voor haar is het echt zo'n meerwaarde echter om voorop te zitten en zelf te kunnen sturen dat het opweeg tegen dat nadeel. Voor Gerda is stabiliteit ook het belangrijkste gevoel van veiligheid. Iets van beschutting wil ze liever niet maar ze had nog niet nagedacht over of iets voor haar benen voor extra veiligheid kan zorgen, is dus niet echt een probleem. Een Fun2Go is voor haar te zwaar dus dat is geen optie.

Koos Hulleman en partner

- Zitting op de buddy was niet zo fijn, liever iets rechter op
- Fun2Go voelt fijner omdat je dan naast iemand anders zit
- Kleiner stuur op de buddy is minder prettig
- Ook de open kettingkast is niet fijn
- Met recht op zitten kan je alles beter overzien, net zoals op een normale fiets
- De duofiets is op hoge snelheid niet zo stabiel
- Ze vinden gezellig fietsen belangrijker dan actief en hard fietsen
- Er zijn geen ergonomische klachten voor deze mensen van de buddy stoel

- Meneer vraagt zich af waarom er geen normaal zadel op zit want een zitting heeft automatisch een Stigma, Maar een zitting is gewoon fijner qua ondersteuning voor mevrouw
- Voor meneer is een zitting meer ziekenvervoer dan een conventionele fiets
- Vriendinnen van mevrouw zijn bang voor de tandem

Fun2Go	Hase Pino	Twinny plus	Buddy
- Zitje is niet goed voor de billen met trapbewegin g, vooral met kracht zetten - Meer gewicht voorop voor meer stabiliteit - Vinden hem heel mooi, net een Princess en voelen zich heel veilig op deze fiets - Veilig vanwege goede communicati e - Lekker kletsen - Altijd een zitje om te rusten - Mooie fiets - Chique afgewerkte fiets - Blijft goed stabiel op elk terrein	- Vind ze helemaal niks - Voelt zich echt invalide, maar weet niet waarom - Technisch mooie fiets - Bestuurder kan er mooi overheen kijken - Veiligheid is bij elke fiets hetzelfde want het zijn fietsen - Misschien dat je als je voorop zit niet meebeweegt is een beetje vreemd - Bestuurder is heel verantwoordeli jk voor de veiligheid van de ander.	- Voelde zich niet veilig - Ze willen naar links en kijken naar rechts en dat werkt niet in de praktijk - Voorwielmotor ziet er ouderwets uit	- Grote zitting, springt in het oog - Driehoek bij stuurinrichtin g is ook te opvallend - Eerste indruk matig dus - Fietst makkelijk

Op welke fiets zou u het liefst gezien worden?

- Maakt niet zo veel uit
- Ook geen fiets waar ie liever niet op gezien wil worden

Welke fiets zou u het liefst fietsen?

- Puur technisch de hase pino
- Maar de fun2go is het beste voor hun situatie

Tijdens het fietsen

- Fietst makkelijker dan de duofiets
- Fiets trekt naar rechts
- Maar over t algemeen fietst de fiets niet verkeerd

- Hij moet meer zijdelinkse steun hebben voor in de bochten

Conclusie

Meneer en mevrouw Hulleman zijn erg tevreden met hun Fun2Go. Meneer zou voor zichzelf liever een tweewieler of een iets vlottere fiets zoals de buddy willen hebben maar past zich aan voor mevrouw die echt verliefd is op de Fun2Go, ik zie ze dan ook niet switchen naar de buddy. Voor mevrouw komt veiligheid vooral voort uit een frame wat er netjes uit ziet en het gevoel van stabiliteit. Voor mevrouw is ook gezelligheid enorm belangrijk. Voor beiden is ook stigma geen probleem als de fiets maar functioneel is. Wat betreft de zitting vind mevrouw het prettiger om rechtop te zitten omdat ze dan meer overzicht heeft. Iets om de voeten te beschermen ziet meneer niet per se als iets noodzakelijks.

Interview-Specific Insights:

1. José & Piet

Experiences:

- Positive experiences with Fun2Go (20 km trip) and Easyrider (stable, easy).
- Less positive experience with Tworby (unstable).
- Safety concerns stem from instability and the fear of falling.

Design Preferences:

- Prefer bikes that allow independence and hard cycling (e.g., Easyrider, Buddy).
- Stability and function outweigh aesthetics, but dislike designs resembling a bathtub.

Associations with Models:

- Prefer Hase Pino (sporty, stable) and Buddy (less sporty than Pino).
- Prefer the Buddy's stability and sportiness over Fun2Go's social aspect.

Conclusion:

- Buddy is a good fit due to its sporty feel and stability, aligned with their past cycling experiences.

2. Fam. Hudepohl

Experiences:

- Prefer bikes that enable control over the passenger (important for safety).
- Herman appreciates an active role (steering, pedaling) while maintaining safety.

Design Preferences:

- Favor Buddy for its stability, active engagement, and ability to be involved.
- Stigma is not a concern; function is prioritized.

Associations with Models:

- Prefer Buddy (active, stable) over Fun2Go (too wide, focused on social interaction).

Conclusion:

- Buddy is ideal due to the combination of control, stability, and sportiness.

3. Petra Boomkamp

Experiences:

- Ties (17 years, dyspraxia) enjoys steering and learning through doing.
- Twinny (currently used) is functional but requires careful balance.

Design Preferences:

- Prefer a sportier design, but concerned about safety in tight turns.
- Stigma is not a major concern; speed and sportiness are priorities.

Associations with Models:

- Hase Pino is favored for its normal, sporty look.
- Buddy seen as a compromise between sportiness and safety.

Conclusion:

- Sporty design with stability and less resistance would be ideal for Ties and Niek.

4. Gerda Schuddeboom

Experiences:

- Blind from childhood, highly experienced cyclist.
- Prefers upright seating, struggles with reclining positions.

Design Preferences:

- Values active participation (steering, balancing).
- Stability is key for safety; reclining positions feel less active.

Associations with Models:

- Prefers Buddy for its combination of stability and active engagement.
- Fun2Go is too heavy and doesn't align with her needs.

Conclusion:

- Buddy fits her need for an active, stable, and engaging cycling experience.

5. Koos Hulleman and Partner

Experiences:

- Prefer social over active cycling.
- Feel more comfortable sitting upright for better visibility and stability.

Design Preferences:

- Prefer Fun2Go's social and stable riding experience.
- Stigma is not an issue, but dislike open chain designs and less conventional seat structures.

Associations with Models:

- Fun2Go preferred for its social nature, Buddy for more active solo riding.

Conclusion:

- Buddy is not a primary choice due to their preference for social cycling.

Appendix G: Preliminary tests

Questionnaire test 1 + 2: Lumbar support + Backrest

Person 1

Demographic Information:

- Age: 24
- Gender: m
- Height: 184
- Occupation: industrial design engineer

Seating position 1 (straight without):

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

Stoel support vanaf zijkant, kan je sowieso ergens aan vasthoudendus geen angst om om te vallen, geen krukje met vlakke ondergrond. Rand zorgt dat je tegen word gehouden bij zitting. Je zit ingeklemd.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

7

Why?

Comfortabel maar... zit oke maar rit voor langere tijd lastig zonder steun in rug. Lumbaal support maakt het echt beter. Gevoel dat je ergens tegenaan tikt met je benen is vervelend maar niet irritant. Nu naar vveld fietsen is geen probleem dus niet extreem oncomfortabel. Verbetering mogelijk.

Seating position 2 (straight with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Steun in onderrug precies op de plek waar je het nodig hebt, lekker zacht kussentje. Vormt naar je rug. Verder in je stoel gedrukt minder last van contact met zitvlak hamstrings. Zat gewoon beter dan zonder. Afknellend gevoel benen

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Nog minder het gevoel dat je eruit kan vallen dus nog gemakkelijker en nog stabieler. Nog zelfverzekerder in je stoel zit. Beter zit, minder irritatie aan de stoel .

Seating position 3 (laying down with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

9

Why?

Enige vershil dat bij 2 iets meer gevoel was dat t afknelde, dat bepaald het verschil. Drukpunten schouders iets beter bij 3 dan bij 2

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8,5

Why?

Nog lekkerder in de stoel ligt, comfortabeler, msis minder stabiel maar de stoel sluit nog beter aan op jouw persoonlijke zithouding. Net eff wat meer stabiliteit. Bij geen stoel het gevoel dat je eruit zou kunnen kiepen

Seating position 4 (laying down without):

How stable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

Stoel support vanaf zijkant, kan je sowieso ergens aan vasthoudendus geen angst om om te vallen, geen krukje met vlakke ondergrond. Rand zorgt dat je tegen word gehouden bij zitting. Je zit ingeklemd. Niet veel verschil met pos. 1. Psychologisch gevoel omdat je lager zit dat je een stabieler gevoel hebt. Niet het gevoel dat je op een andere stoel zit. Pos 1, degelijker, actiever. Pos 2 passiever, relaxter, als hangmat. Stabiliteit maakte weinig uit.

How comfortable do you feel at a seating position 2? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

7,5

Why?

Minder afknellen van hamstrings, betere doorbloeding. Maar je schuift wel wat makkelijker naar voren, of iig het gevoel. Maar als je eenmaal stabiel zit, dan zit je gewoon goed.

Additional Comments:

Is there anything else you would like to add regarding your seating preferences, comfort, or stability?

Veel beter dan 1. Minder contact hamstring maar wel afgekneld gevoel van de benen. Met steuntje significant beter dan zonder

Positie 2 vs 3 het liefst pos 3, omdat daar minder een afknellend gevoel was, ontspannen gevoel. Verschil is niet heel groot, 3 wel iets meer gestrekte armen wat onprettig is. Rechtop zitten geeft wel meer overzicht en een actiever gevoel.

Positie 3 is de prettigste, zie hierboven.

Person 2

Demographic Information:

- Age: 22
- Gender: m
- Height: 188
- Occupation: student

Seating position 1 (laying down without):

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Vrij tevreden zeker in het vergelijk met rechtop zitten is achterover liggen vrij stabiel. Misschien nog heel iets stabielr als je verder naar achter gaat en meer een kuipstoel idee.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

6,5

Why?

Onderrug snel last, voor 5/10 min is prima maar daarna heb je het wel gezien (lange onderrug) gevoelig voor verkeerde steun in onderrug.

Seating position 2 (laying with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

9

Why?

Je zat veel stabieler, door steun in onderrug, waarom geen 10? Had verder naar achter gekund, geeft natuurlijkere houding en zijsteunen zou ook een goede toevoeging zijn

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Positie vergeleken met de rest was top en zorg qua stabiliteit door naar achter leunen dat je wat meer in je stoel word gedrukt. Als je recht in je bureaustoel zit ben je vrij maar als je achterover leunt merk je dat je = prettig. schouders naar achter worden gedrukt. Door kussen ook meer stab. Beter in stoel gezet word.

Seating position 3 (upright with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

6

Why?

Kussentje was comfortable maar rechtop zitten past niet bij mij, voelt onnatuurlijk zowel met trappen als zonder trappen. Je zit dicht met je knieen tegen je borst en als stijf persoon zit dat niet lekker. VCeel spanning op je rug, heel snel een bolle rug. Trappers zitten te dicht bij, als ze meer onder mij hadden gezeten was het natuurlijker geweest. Ook iets te hoog. Positie klopt gewoon niet.

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

7

Why?

Aanzienlijk slechter als achterover maar kussen nog enigszins op de plek, voor de rest was het redelijk. Bewegen was makkelijk, zat niet vast. Veel movement van links naar rechts, als je je niet bewust in de stoel drukt, zeker als stuur verder weg zit.

Seating position 4 (sitting without):

How stable do you find seating position 4? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

5,5

Why?

Minst fijne positie, je bent heel vrij wat fijn is maar voor langere duur meer stab en vaster in het stoeltje wordend gedrukt en niet zo vrij kunnen bewegen. Omdat je zo rechtop zit heb je niks wat je vast houd want het is een vrij vlak stoeltje.

How comfortable do you feel at a seating position 4? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

4,5

Why?

Slechtste van alle 4, vanwege de spanning die direct opbouwde in de onderrug en dat voelde niet heel chill, zou nog liever gaan lopen. Gewoon geen natuurlijke houding voor mij rug, misschien omdat ik stijf ben maar was gewoon niet chill.

Additional Comments:

Is there anything else you would like to add regarding your seating preferences, comfort, or stability?

Test was leuk rondje fietsen, extra ondersteuning zijwaards en nog iets verder naar achter zou prettiger zijn.

Pos 1 of 2 → 2

Pos 3 of 4 → 3

Liggend is beste en positie 2 is de absolute winnaar.

Person 3

Demographic Information:

- Age: 24
- Gender: m
- Height: 186
- Occupation: student

Seating position 1 (upright without):

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Niet het gevoel dat je er vanaf valt of dat ik me onveilig voel. Op momenten dat je een stoepje afgaat kan je met je voeten wegzakken. Je raakt immers bijna de grond met je voeten want geen wiel.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8

Why?

Voelde gewoon lekker zitten als stoel. De vormgeving van de stoel e nde kussentjes die erin zaten waren fijn. Was wel sportief, dat is goed bij een fiets.

Seating position 2 (upright with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

5

Why?

De steun hoort niet op een fiets, gevoel dat er iets in mn rug zit te porren, gevoel op kantoor te zitten, omdat kantoorstoelen vaak zo geleverd worden.

How stable do you feel at a seating position 2? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8

Why?

Niet het gevoel dat je er vanaf valt of dat ik me onveilig voel. Op momenten dat je een stoepje afgaat kan je met je voeten wegzakken. Je raakt immers bijna de grond met je voeten want geen wiel.

Seating position 3 (laying down with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

6

Why?

Naar achter zitten geeft je meer kracht en dat is wat fijner. Voelde meer als fietsen voor mij, maar geen fan van de steun

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Doordat je verder achterover zit, zit je dieper in de stoel en dit geeft mij meer stabiliteit.

Seating position 4 (laying down without):

How comfortable do you find seating position 4? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

9

Why?

Zelfde als bij andere zonder kussen, maar omdat je wat meer naar achter zit, kan je meer kracht geven tijdens trappen en heb je meer het gevoel dat je aan het fietsen bent. (Misschien door ketting)

How stable do you feel at a seating position 4? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Kan nooit perfect zijn maar was wel erg fijn. Drempel is nogsteeds lasting maar dat komt doordat je een wiel mist.

Additional Comments:

Is there anything else you would like to add regarding your seating preferences, comfort, or stability?

Manier van testen is goed ook tijdens het fietsen? Meer diversiteit in je sample size.

Pos 1 of 2 → 1

Pos 3 of 4 → 4

Liggend is beste en positie 4 is de absolute winnaar.

Person 4

Demographic Information:

- Age: 71
- Gender: f
- Height: 177
- Occupation: Voluntary

Seating position 1 (sitting up without):

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

2 wielen achter je voelen stevig en qua frame ook; geen gevoel dat je er af kan vallen. Dit komt doordat de stoel het idee van een kuipje geeft, dit is prettig en geeft het idee niet te kunnen vallen.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

7

Why?

Mist iets van support in de rug. Met kussen fietste makkelijker. Als je rechtop fietst meer druk op achterste dit is onprettig want voelt als kunststof.

Seating position 2 (sitting up with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Meer vastigheid a.k.a. ondersteuning in de rug, zit beter. Een beetje als een goede bank, zit gewoon lekker

How stable do you feel at a seating position 2? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8,5

Why?

Stoel maakt weinig verschil, gewoon goed. De fiets is bepalender voor stabiliteit.

Seating position 3 (laying down with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

9

Why?

Liggend meer overzicht dan rechtop zittend. De huidige stoel geeft een gat in de rug wat het kussen goed opvult. Kussen geeft vastigheid.

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

10

Why?

Het kussen en het liggen is echt prettiger. Ze zou er wel mee kunnen fietsen dat was bij de vorige 2 niet het geval. Het achteroverliggen geeft haar rust waardoor ze meer denkruimte vrij heeft voor het fietsen. Ook als de fiets een actievere leefstijl moet uitstralen is het positief die rust.

Seating position 4 (Laying down without):

How comfortable do you find seating position 4? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

Idee van een kunstofstoeltje door de buizen in het zitvlak. Zeker als je langer dan 25km zou fietsen. Ook was er in deze stoel meer ruimte om van links naar rechts te schuiven. Ze denkt dat meer steun in de stoel voor mensen over het algemeen comfortabeler is.

How stable do you feel at a seating position 4? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Stabiliteit gewoon goed, het enige wat mist is het kussen in de rug, hierdoor een punt minder

Additional Comments:

Is there anything else you would like to add regarding your seating preferences, comfort, or stability?

Stang aan de voorkant vervelend. Miss ER3 beter (lag naast persoon). Gaat minder om rug meer om zitvlak.

Liggend vs rechtop → liggend

Wel/geen kussen → wel (meest stab. Meest comf.)

Pos3 favo. Fijnste, comfortable.

Person 5

Demographic Information:

- Age: 22
- Gender: f
- Height: 166
- Occupation: student

Seating position 1 (laying down without):

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

6

Why?

Voldoende, geen angst om te vallen maar zelf veel doen qua core aanspannen, rekken benen om goed te kunnen zitten en te kunnen fietsen. Voelde voermoeiend en zwaar, niet zomaar een stuk mee gaan fietsen. Dan word het zwaar. Te veel compenseren in buiksperen. Pstuur te liggend, te plat, niet genoeg ondersteuning in de stoel o er coomf in te liggen. Miss stuur te ver weg, Neiging om rechtop te zitten want meer zien. Pos 1 minste dat gevoel.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

6

Why?

Niet zo lekke liggend, vooral personnlijk voorkeur. Niet het gevoel dat er ergens ietsmiste, willicht hoofdsteun.

Seating position 2 (laying down with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

4

Why?

Niet comf, idee dat he kussentje vanwege de liggende houding rechtop werd geforceerd daardoor niet genoeg steun zitvlak, naar voren geduwd, stompere heuphoek dus dan glijd je van de stoel. Tegendruk op de pedalen word als niet fijn ervaren geen gevoel van stevigheid. Minst favoriete.

How stable do you feel at a seating position 2? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

5

Why?

Niet heel stabile, gevoel er af te glijden. Stabiliteit links rechts was goed, alleen naar beneden afglijden was vervelend.

Seating position 3 (upright with):

How comfortable do you find seating position 2? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Heel fijn om rechtop te zitten, overzicht op de weg. In geen enkel opzicht moeite te doen om goedin de stoel te zitten. Wrs omdat je rechtop zit en dus makkelijker wat dieper in de stoel kon zitten.

How stable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Van alle posiities het meest het idee dat je door te zitten stevig zit, stuur en tappers niet nodig voor stabiliteit. Altijd ruimte voor verbetering dus geen 10, stalen buis onder zitting is niet prettig.

Seating position 4 (Upright without):

How comfortable do you find seating position 4? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

7

Why?

Beduidend fijner dan pos 1 & 2, lager dan pos 3, dieper in de stoel maar bij 4 zit je veel meer met je stang tegen die bovenbenen aan en bij 3 was dat goevle minder. Fijn de ondersteuning aan de zijkant maar lendenensteun geeft meer stabiliteit door soort foam, bij 4 kon je meer links rechts bewegen.

How stable do you feel at a seating position 4? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8

Why?

Fijne stab housing, goed in de stoel kunnen zitten. Kussenen l-r waren fijn maar te veel beweegmarge dan met lumb. Steun dus minderf stabiel gevoel. Grotere zijde ondersteuning kan miss ookal goed zijn.

Additional Comments:

Is there anything else you would like to add regarding your seating preferences, comfort, or stability?

Stang aan de voorkant vervelend. Miss ER3 beter (lag naast persoon). Gaat minder om rug meer om zitvlak.

Liggend vs rechtop → rwechtop

Wel/geen kussen → wel (meest stab. Meest comf.)

Pos3 favo. Fijnste, comfortable.

Questionnaire test 3

Subject 1

Demographic Information:

- Age: 71
- Gender: f
- Height: 177
- Occupation: Voluntary

EasyRider 3 seating area

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Feels stable, noting much to add. However, old seat felt nicer.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

7

Why?

Sitting area feels too short for subject. Also the material feels slippery. Can also be because of clothing. Without lumbar support, really the feeling that something was missing. No feeling of insecurity because of someone present behind you. Subject would not buy this seat. Seat with "bucket" as sitting area is preferred.

General remarks:

Seat was a little too far from the pedals.

Subject 2

Demographic Information:

- Age: 22
- Gender: f
- Height: 166
- Occupation: student

EasyRider 3 seating area

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Zat stabile niet het idee zelf veel te hoeven doen om stabiel te zitten, ging vrij moeiteloos. Geen 10 want zitvlakje moet ietsje verder naar voren.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Was wel comfortable. Comfortalbvel als stabile zit, geen last van iets. Vorige keer stang in been en dat had ik nu niet. Harde zitting is fijner want mesh kan heel erg doorzakken. Meer speling door doorzakken en hierdoor gaat stabiliteit verloren.

General remarks:

Zat fijn, rugleuning ook fijn. Zitting prettig – iets te veel naar beneden. Naar voren gekanteld, Niet storen maar meer horizontaal is stevig. → ronde 2 met goede zitvlak. Fijn zitten → Stevig en comfortable. Niet het idee dat ik eraf gleed. Zitvlak meer horizontaal → andere kant op. Fijn dat je niet meer tegen stang aan komt. Verderf niet veel. Rugleuning was fijn achterover.

Kiest voor harde zitting: harde is fijner. Fijner is comfortabeler. Comfortabeler is stabieler.

Subject 3

Demographic Information:

- Age: 24
- Gender: m
- Height: 186
- Occupation: student

EasyRider 3 sitting area

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

4

Why?

Material is too slippery and the sitting are is too short. This makes for an unstable feeling. Also there was a feeling of not being able to exert pressure on the pedals, which makes cycling feel very uncomfortable.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

5

Why?

Material is too slippery and the sitting are is too short. This makes for an unstable feeling. Also there was a feeling of not being able to exert pressure on the pedals, which makes cycling feel very uncomfortable.

General remarks:

The pervious version was significantly better also with the 123 degree back angle.

Subject 4

Demographic Information:

- Age: 22
- Gender: m
- Height: 188
- Occupation: student

EasyRider 3 sitting area

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

7

Why?

Prima, rugleuning prima, andere stoel wat gladder daardoor glijd je er makkelijker vanaf. Voelt meer als bureaustoel door bolling in zitvlak ipv holling. Glijd ook makkelijker van links naar rechts. Daarom moet je je goed vast houden aan het stuur, of iig dat gevoel heb ik. M.a.w. erg het gevoel dat het stuur nodig is om stabiel te blijven.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

6,5

Why?

Prima, maar niet top. Ook niet extreem slecht. Vorm kan ook beter. Misschien als het stoeltje minder vlask afgesteld word dat ie comfortabeler en stabieler is.

General remarks:

n.v.t.

Subject 5

Demographic Information:

- Age: 21
- Gender: m
- Height: 185
- Occupation: student

EasyRider 3 sitting area

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

7,5

Why?

Zit gewoon goed en blijft goed zitten, niet hele tijd corrigeren om achterin de stoel te zitten of in de goede houding te zitten. Goed is gewenste positie hoe jij wilt trappen, positie schuift niet. Linke boel maar niet gewend om op zon fiets te fietsen (snellere bocht) misschien zadel nog stroever. Wel een stabiel gevoel, constante houding. Goed in de stoel zitten zoals je wilt zitten. Zit wel vrij que je kan makkelijk bewegen, niet heel vast in de stoel. Als je wil verplaatsen kan het heel makkelijk. Geen 10 omdat geen referentiewaarde heb. Kort hard zitje miss qua stabiliteit bestgoed omdat je een vastgedeelte hebt want netje kan veren wat als onstabiel ervaren kan worden. Stabilieit als je meer vast in de stoel zat miss beter.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

8

Why?

Zit best prima maar moest been te ver strekken. Tijdens trappen bovenbeen tikt met hamstring tegen stoel, klein drukpunt niet per se hinderlijk. Want je kan er best mee fietsen maar idealiter wil je het niet. Afstelling is belangrijk. Had idealer gekund maar kon prima mee gefietst worden. Wat mis je: iets meerf veerkracht van de zitting, dat je er iets meer in zit ipv erop zitten. Kuipje misschien beter.

General remarks:

Verder niks.

Questionnaire test 4

Subject 1

Demographic Information:

- Age: 24
- Gender: m
- Height: 184
- Occupation: industrial design engineer

Bucket seat

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9.5

Why?

"Not the feeling that you can move anywhere, sits super stable. Not a 10 because there can always be one better. Maybe a lumbar support would be more comfortable. A negative point is that there is no torso rotation possible anymore, which greatly complicates looking back, the question is whether this is necessary."

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

"Fits nicely snug, wobbles less, can't move around. Provides a nice support in your back. Like a hug in the chair. Not a straight back. So, a slightly curved back. Back is a bit more in a bowl shape. Might be uncomfortable after a while."

General remarks:

No remarks

Subject 2

Demographic Information:

- Age: 22
- Gender: f
- Height: 166
- Occupation: student communication sciences

Bucket seat

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

10

Why?

Very stable, never felt the need to correct myself to stay balanced. Chair holds well in place. Didn't feel like the pedals were too far away, didn't have to engage core muscles.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

9,5

Why?

Found sitting very comfortable: felt very stable and pleasant. Pleasant is comfortable. Comfortable sitting is pleasant. A headrest would make it a 10.

General remarks:

No remarks

Subject 3

Demographic Information:

- **Age: 21**
- **Gender: m**
- **Height: 185**
- **Occupation: student**

Bucket seat

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Sitting in a bucket seat feels snugger, deeper in the chair, can't really move from side to side. Resistance against body movement. Damping is better horizontally too because it's softer. Not a 10 because there's no specific reason. There's always room for improvement.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

In terms of comfort, the seat is softer so it feels nicer. The hard seat used to pinch, but not anymore. No discomfort while pedalling. The upper seat is more comfortable because it's like a bucket seat. Don't feel like I could easily fall out.

General remarks:

I felt safer than on the hard seat

Subject 4

Demographic Information:

- Age: 24
- Gender: m
- Height: 186
- Occupation: student

Bucket seat

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

In my opinion, it's 0.5 better than everything from before. Always adding 0.5. Why? You're really nestled, like in a bowl, and you stay stable. You don't sway left or right in a turn.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8,5

Why?

Compared to others, it feels more like sitting in a chair: sporty. Leaning back and pedaling. Maybe too comfortable: just feels nice. Why not a 10? --> Perhaps because while it's comfortable for your back, the seat itself is just not quite there. Seat area is quite small. Would I prefer it differently? Not really, for a bike it's just fine.

General remarks:

No remarks

Subject 5

Demographic Information:

- Age: 77
- Gender: m
- Height: 173
- Occupation: voluntary

Bucket seat

How stable do you find seating position 1? (On a scale from 1 to 10, with 1 being extremely unstable and 10 being extremely stable)

9

Why?

Don't have the feeling, maybe a bit due to that dip, but otherwise no feeling of falling out. Not a 10 because of the potential to slump down.

How comfortable do you feel at a seating position 1? (On a scale from 1 to 10, with 1 being extremely uncomfortable and 10 being extremely comfortable)

8

Why?

Feels good, feels safe. Distance to the pedals is an issue. Distance between pedals and seat needs improvement. Good in the sense that it's comfortable, like sitting in a comfortable chair at home. But not for sleeping, need to see everything. Feels safe. Don't feel like I'll fall out left or right. But do feel like I might slump down because pedals aren't positioned well.

General remarks:

No remarks

Appendix H: Design criteria for first user test

Must have:

1. The seat must cater to the needs and wishes of elderly with changing medical conditions
2. The seat design must prioritize stability, as this is directly linked to user confidence and safety.
3. Ergonomics must be adaptable to suit a range of user preferences and needs.
4. The seat must accommodate the target group's anatomical measurements (P5 to P95 range).
5. The seat design must support a sense of autonomy, allowing the passenger to sit in front of the supervisor and have some control over the ride, enhancing the feeling of independence.
6. The seat must have an adjustable Functional seating angle, with 123 degrees being a key reference point.
7. The seat must include adjustable lumbar support to cater to different user preferences and enhance comfort and stability.
8. The seat must be designed to prevent slipperiness and be ergonomic, taking inspiration from a hammock-like structure to improve comfort.
9. The seat must have side bolsters that enhance stability without significantly impeding core rotation or the ability to move.

Should have:

15. Seating position should facilitate a minimal hip angle that does not exceeds 95 degrees
16. The seat should incorporate Gestalt theory principles, focusing on stability, comfort, activeness, and visual balance.
17. The design should follow the MAYA (Most Advanced Yet Acceptable) principle to ensure aesthetic appeal and user acceptance.
18. The seat should be designed with a sporty and active aesthetic to align with user expectations for the Buddy bicycle and to reduce stigma.
19. The bottom bracket and seat design should be considered together to ensure optimal positioning and comfort.
20. The side bolsters should be adjustable to cater to various user preferences and ensure they do not overly restrict movement..
21. The seat materials should prioritize comfort by addressing heat transfer, water vapor, support, and freedom of movement, regardless of the chosen material route (conventional, ER3/Fun2Go, or 3D printed options).
22. The design should maintain functionality comparable to other VanRaam models like the OPair and Fun2Go, balancing features such as ease of entry, comfort, and storage.
23. The seat should be designed in a way that disguises, redirects attention from, or transforms stigmatizing features, addressing cultural and user-related stigma.
24. The top layer must be selected to minimize tensile stress, and load structure must reduce reaction forces effectively, possibly using a spring mechanism.

Could have:

7. The seat could rotate to make accessing the bicycle more convenient
8. The seat could include a headrest to enhance the perception of safety for users who prefer it.
9. The design could incorporate clever ergonomic adjustments, inspired by recumbent bicycle designs, to cater to varying user needs.
10. The seat could include features that enhance the appearance of stability, such as a wider base or visible support elements, since stability is a key aspect that influences user confidence.
11. The design could incorporate elements that visually communicate activeness and autonomy, differentiating the Buddy from other models and competitors.

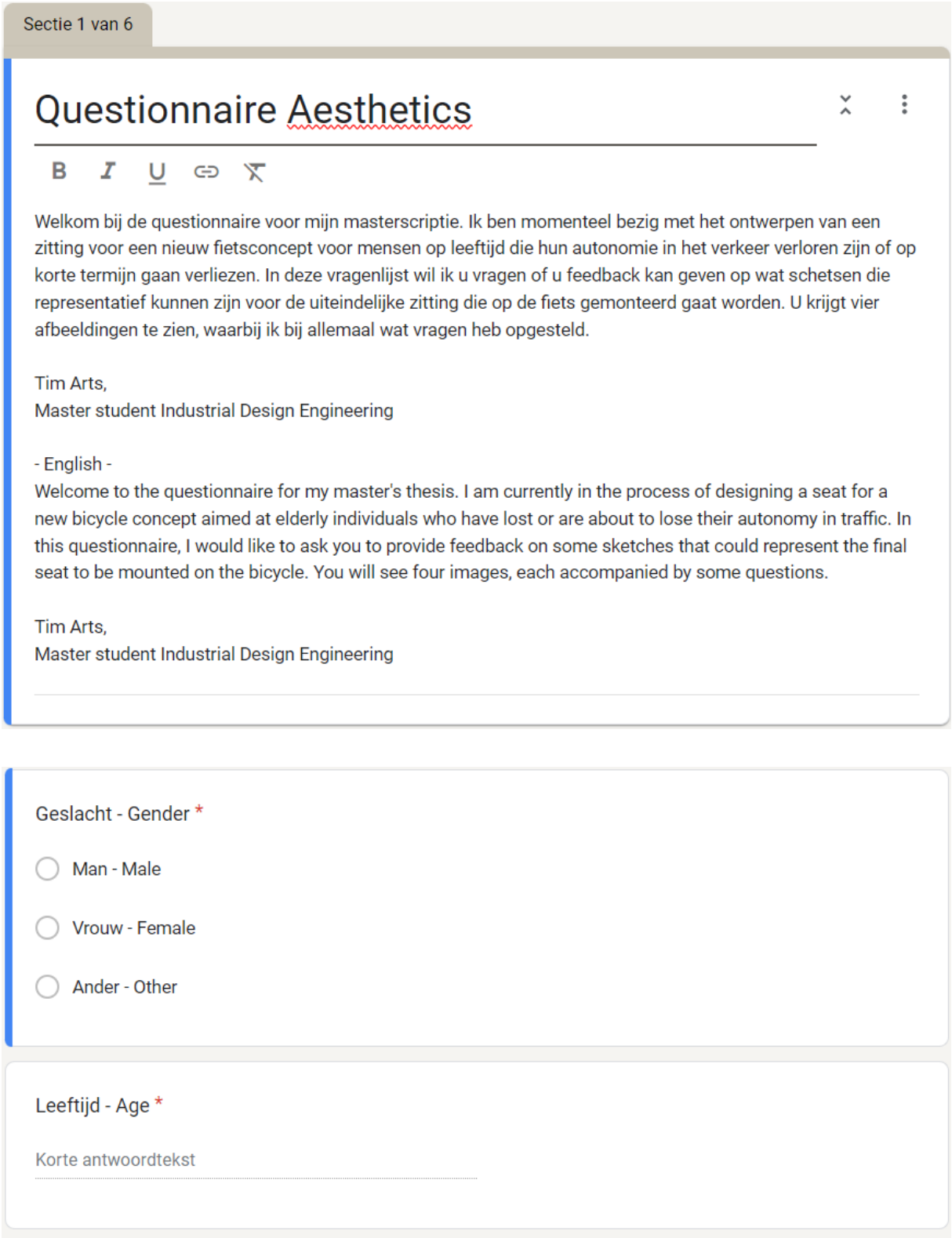
Won't have:

12. The design of the front seat won't exclude people with down syndrome and people recovering from surgery
13. Seat won't cause unpleasant pressure points around the shoulder/scapula region
14. Seat won't have seatbelts fitted as standard
15. The design will not exaggerate the recumbent position, as this can introduce stigma and reduce user comfort.
16. The design will not solely focus on shelter for safety, as stability is more crucial for the target users.
17. The design will not rely solely on the handlebar movement as a means for entry and exit without considering additional support mechanisms or ergonomic adjustments.
18. The design will not prioritize features that are better suited for bicycles targeting users with lower levels of autonomy or activity, as this contradicts the active, engaging nature of the Buddy.
19. Non-Adjustable Lumbar Support: The seat won't have a fixed lumbar support, as adjustability is crucial for comfort and compatibility.
20. Rigid Bolsters: The seat won't have rigid or non-adjustable bolsters, as they may impede movement and reduce comfort.

Appendix I: Measurements from literature

	What?	Current	Ideal
1	Functional seating angle	116 deg	123 deg
2	Sitting angle	12 deg	> 4 deg
3	Back angle	104 deg	118 deg
4	Sitting length	250 mm	< 250 mm
5	Lumbar support radius	R = 1710 mm	R = 475 mm
6	X distance to crank	936 mm	t.b.d.
7	Y distance to crank	160 mm	t.b.d.
8	Lumbar support height	190 mm	200-250 mm
9	Hip angle (smallest)	87,25 degrees	95 degrees
10	Lumbar support effective height	310 mm	253 mm
11	Crank length	160 mm	t.b.d.
12	Sitting area to T8 height	330 mm	447,4 mm
13	Width seat	410 mm	440-480 mm
14	Length L2 – T12 support	Not applicable	163,80 mm
15	Radius backrest from top	Not applicable	R= 300 mm

Appendix J: Questionnaire Aesthetics



Sectie 1 van 6

Questionnaire Aesthetics

Welkom bij de questionnaire voor mijn masterscriptie. Ik ben momenteel bezig met het ontwerpen van een zitting voor een nieuw fietsconcept voor mensen op leeftijd die hun autonomie in het verkeer verloren zijn of op korte termijn gaan verliezen. In deze vragenlijst wil ik u vragen of u feedback kan geven op wat schetsen die representatief kunnen zijn voor de uiteindelijke zitting die op de fiets gemonteerd gaat worden. U krijgt vier afbeeldingen te zien, waarbij ik bij allemaal wat vragen heb opgesteld.

Tim Arts,
Master student Industrial Design Engineering

- English -
Welcome to the questionnaire for my master's thesis. I am currently in the process of designing a seat for a new bicycle concept aimed at elderly individuals who have lost or are about to lose their autonomy in traffic. In this questionnaire, I would like to ask you to provide feedback on some sketches that could represent the final seat to be mounted on the bicycle. You will see four images, each accompanied by some questions.

Tim Arts,
Master student Industrial Design Engineering

Geslacht - Gender *

- Man - Male
- Vrouw - Female
- Ander - Other

Leeftijd - Age *

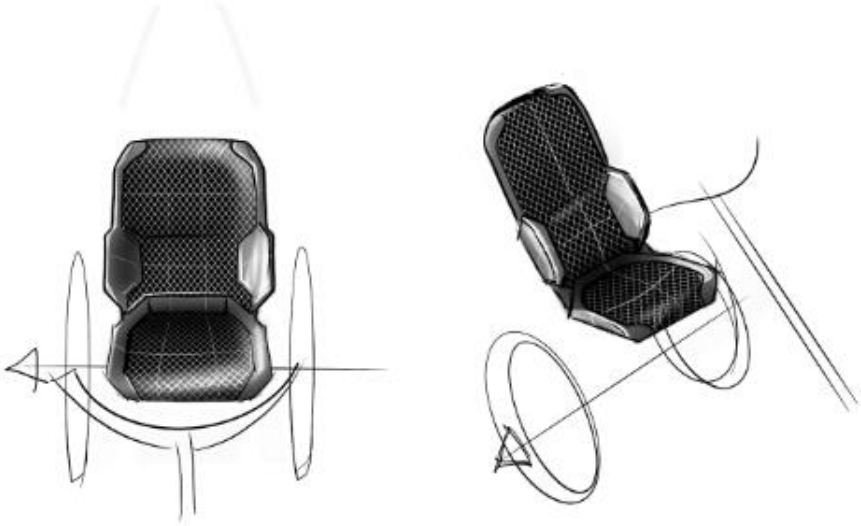
Korte antwoordtekst

Sectie 2 van 6

Concept 1 of 4

Beschrijving (optioneel)

Concept 1



Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit? *

bijv: elegant, duur, luxueus etc.
e.g.: elegant, expensive, luxurious etc.

Korte antwoordtekst

Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear? *

	1	2	3	4	5	
Oncomfortabel - Uncomfortable	○	○	○	○	○	Comfortabel - Comfortable

Hoe stabiel ziet de zitting er uit? - How stable does the seat appear? *

	1	2	3	4	5	
Instabiel - Unstable	○	○	○	○	○	Stabiel - Stable

Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly? *

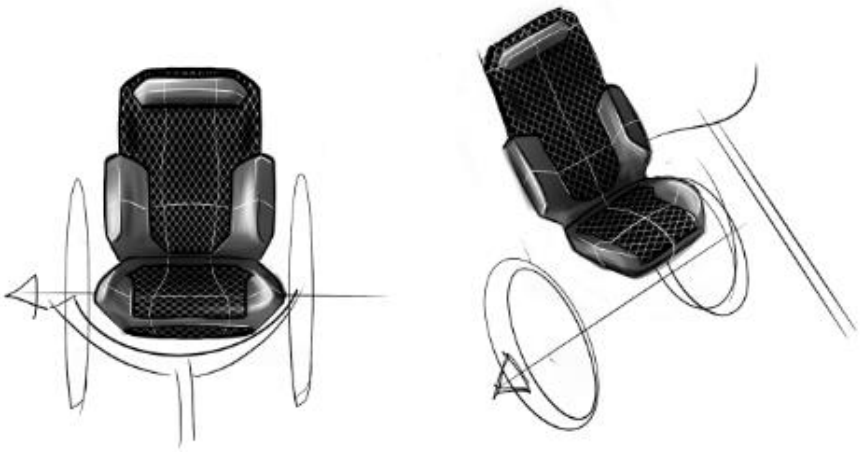
- ○ Sportief - Sporty
- ○ Actief - Active
- ○ Ontspannen - Relaxed
- ○ Klinisch - Clinical

Sectie 3 van 6

Concept 2

Beschrijving (optioneel)

Concept 2



Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit? *

Korte antwoordtekst

Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear? *

	1	2	3	4	5	
Oncomfortabel - Uncomfortable	○	○	○	○	○	Comfortabel - Comfortable

Hoe stabiel ziet de zitting er uit? - How stable does the seat appear? *

	1	2	3	4	5	
Instabiel - Unstable	○	○	○	○	○	Stabiel - Stable

Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly? *

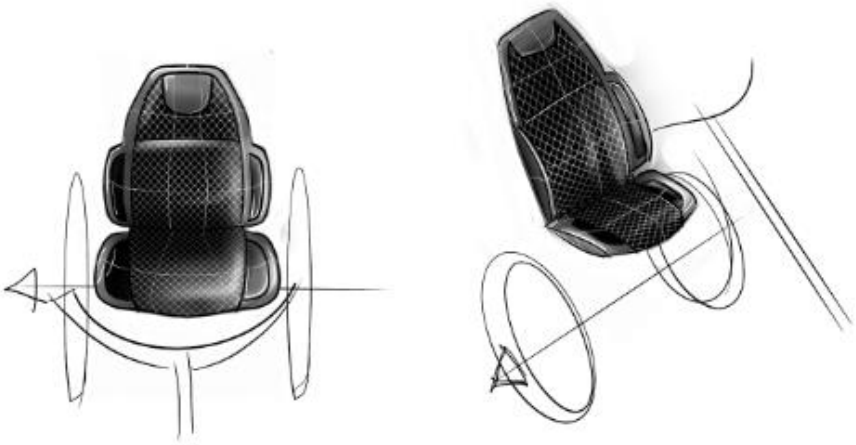
- ○ Sportief - Sporty
- ○ Actief - Active
- ○ Ontspannen - Relaxed
- ○ Klinisch - Clinical

Sectie 4 van 6

Concept 3

Beschrijving (optioneel)

Concept 3



Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit? *

Korte antwoordtekst

Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear? *

	1	2	3	4	5	
Oncomfortabel - Uncomfortable	○	○	○	○	○	Comfortabel - Comfortable

Hoe stabiel ziet de zitting er uit? - How stable does the seat appear? *

	1	2	3	4	5	
Instabiel - Unstable	○	○	○	○	○	Stabiel - Stable

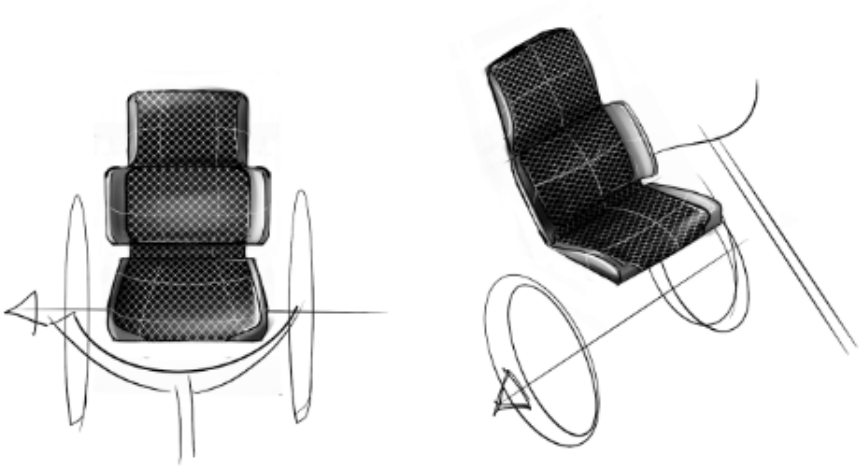
Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly? *

- ○ Sportief - Sporty
- ○ Actief - Active
- ○ Ontspannen - Relaxed
- ○ Klinisch - Clinical

Concept 4

Beschrijving (optioneel)

Concept 4



Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit? *

Korte antwoordtekst

Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear? *

	1	2	3	4	5	
Oncomfortabel - Uncomfortable	○	○	○	○	○	Comfortabel - Comfortable

Hoe stabiel ziet de zitting er uit? - How stable does the seat appear? *

	1	2	3	4	5	
Instabiel - Unstable	○	○	○	○	○	Stabiel - Stable

Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly? *

- ○ Sportief - Sporty
- ○ Actief - Active
- ○ Ontspannen - Relaxed
- ○ Klinisch - Clinical

Sectie 6 van 6

Laatste vraag - Final Question

Beschrijving (optioneel)

Welke van de zittingen spreekt u het meeste aan en waarom? - Which of the seats appears to you most and why? *

- Concept 1

- Concept 2

- Concept 3

- Concept 4

Appendix K: Ballpark cost-estimation

		Version 1	Costs 1	Disclaimer	Source	Version 2	Costs 2	Marge 2	Source	Version 3	Costs 3	Marge 1	Source
1	Material Backrest	3d printed TPU on ABS baseplate and mesh top layer	100-200 euro	According to salesman Shapemakers: a simple cusion will cost 200 euro	Shapemakers	Similar to ER3: Glass reinforced nylon injection moulded frame with mesh upholstery	30-70 euro	1/3 to 2/3 of the cost price for the Fun2Go seat	VanRaam employee	Aluminium frame with mesh and spacer fabric upholstery	Aluminium frame: 50-100 euro, Upholstery: 50-100 euro, total: 100-200 euro	Based on a retail price of 300 dollar of the HP frame only. Divided by 2. Upholstery also based on van elburg upholstery	https://nl.ostelshoppe.com/products/hp-velotechnik-gekko-gef-gel-main-seat-frame?srsltid=AfmBOop2GEJap1-Yi26SF9OoNHVz3TaOMEInFER-jUe-
2	Material sitting area	3d printed TPU on ABS baseplate and mesh top layer	100-200 euro	According to salesman Shapemakers: a simple cusion will cost 200 euro	Shapemakers	Aluminium frame with mesh and spacer fabric upholstery	Aluminium frame: 50-100 euro, Upholstery: 50-100 euro, total: 100-200 euro	Based on a retail price of 300 dollar of the HP frame only. Divided by 2. Upholstery also based on van elburg upholstery	elshoppe.com/products/hp-velotechnik-gekko-gef-gel-main-seat-frame?srsltid=AfmBOopZGEJap1-Yi26SF9OoNHVz3TaOMEInFER-jUe-niqv-9P2PUmT https://www.stoffen-hemmers.nl/3d-mesh-stof-met-geweven-achterkant-grijs?gad_source=1&gclid=CjwKCAjwoJa2BhBPEiwiA0I0ImO11				
3	Backrest angle adaptability	Central pivot point integrated in Alu frame	10-90 euro	and screws integrated into the welded frame will presumably be cheaper.	https://nl.aliexpr	Slots and bolts mechanism	10-20 euro	Ballpark estimation	https://www.rvspaleis.nl/moeren				
4	Backrest length adaptability	Extendable pole with quick release clamp	1-10 euro	ballpark estimate	alibaba.com "quick release clamp"	Slots and bolts mechanism	10-20 euro	Ballpark estimation	https://www.rvspaleis.nl/moeren				
5	Lumbar Support	Inflatable with pump	5-50 euro	ballpark estimate	Alibaba.com "inflatable lumbar support	Foam (Polyurethane)	20-50 euro		google.com "Foam lumbar support"	Automotive mechanism with some fasteners	20-50 euro	Ballpark	.aliexpress.com/item/4000553357558.html?src=google&src=google&albch=shopping&acnt=494-037-6276&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&gclsrc=aw.d
6	Lumbar Support Adaptabilit	Inflatable with pump. Heigth adaptability through slots and bolts mechanism	10-20 euro	Assumption on easy height adaptability mechanism		Slots and bolts mechanism	10-20 euro	Ballpark estimation	https://www.rvspaleis.nl/moeren	Automotive mechanism with some fasteners	1-10 euro	assumption on fasteners	https://www.rvspaleis.nl/moeren

7	Side Bolsters	Frame + Spacer fabric frame is calculated in aluminium frame	20-50 euro	Assumption based on size of entire frame	https://hostelshoppe.com/products/hp-velotechnik-gekko-gef-gel-main-seat-frame?srsltid=AfmBOopZGEJap1-Yi26SF9OoNHVz3TaDlMEInFER-jLle-niqv-9P2PUmT	3d printed TPU on ABS baseplate and mesh top layer	50 euro	Assumption based on shape and size of entire cushion	Shapemakers employee	PU foam on ABS plate with Skai toplayer	foam: 5-15 euro, abs plate: 2-5 euro, Skai: 3-10 euro. Assembly:30 euro: Total: 40-60 euro	lots of different foams and skai available; no research done yet	https://www.big-in-fabric.nl/product/koudschuim-op-maat/?gad_source=1&gclid=CjwKCAjwoJa2BhBPEiwA0I0ImChVD1ssHmKRVqOjij-eg6faJXz_fcPgHk4LL0W1b9CV_30NJUWJxsBoCFYcQAvD_BwE
8	Side Bolsters Adaptability	Phone Holder Mechanism	10-50 euro	dependent on mold cost. But for this mechanism , rougly 5 parts will be used. These parts will assembled. Each assembly step will be	https://www.custompartnet.com/estimate/injection-molding/?units=1	Hinge for connecting two surfaces	10-20 euro	Ballpark estimation		Current clamp for surface and cylindrical shapes with fasteners	1-10 euro	Ballpark estimation	https://www.custompartnet.com/estimate/injection-molding/?units=1
9	Rotation Mechanism	Plates with rotation bearing plates are ABS	25 euro	Only rotation mechanism	https://www.hobbyticgear.nl/bootaccessoires/comfort-aan-boord/draaiplateau-bootstoel/draaiplateau-met-of-zonder-lock.html?gad_source=1&gclid=CjwKCAjwoJa2BhBPEiwA0I0ImADLqiLwejwGaBgkxtCF8Q8bR4H1DYqMKzDyWPSrtxgRorBupVckZRoCIBwQAvD_B	current construction (aluminium part + rotation bearing + steel part + fasteners	50-100 euro	Cost of peoduction and material with also the rotation part					

			Euro
	Matrerial and production cos	Cheapest option (feasible) Minimal price	217
		Cheapest option (feasible) Maximal price	520
		Concept 1 Minimal	320
		Concept 1 Maximal	705
		Concept 2 Minimal	302
		Concept 2 Maximal	660
		Concept 3 Minimal	262
		Concept 3 Maximal	540
	Assembly cost:	Concept 1: 8 assembly	24
	1 assembly step is assumed to cost 3 euro	Concept 2: 6 Assembly steps	18
		Concept 3: 7 assembly	21
	Total cost:	Concept 1:	344-729 euro
		Concept 2:	320-678 euro
		Concept 3:	283-561 euro

Appendix L: Statistical Analysis of questionnaire & answers

Aswers:

Comfort

Descriptive statistics of your k=4 independent treatments:

Treatment →	A	B	C	D	Pooled Total
observations N	53	53	53	53	212
sum $\sum x_i$	192.0000	206.0000	199.0000	178.0000	775.0000
mean $\bar{x}$	3.6226	3.8868	3.7547	3.3585	3.6557
sum of squares $\sum x_i^2$	752.0000	854.0000	793.0000	662.0000	3,061.0000
sample variance s^2	1.0856	1.0254	0.8810	1.2344	1.0799
sample std. dev. s	1.0419	1.0126	0.9386	1.1110	1.0392
std. dev. of mean $SE_{\bar{x}}$	0.1431	0.1391	0.1289	0.1526	0.0714

One-way ANOVA of your k=4 independent treatments:

source	sum of squares SS	degrees of freedom ν	mean square MS	F statistic	p-value
treatment	8.0896	3	2.6965	2.5521	0.0566
error	219.7736	208	1.0566		
total	227.8632	211			

Conclusion from Anova:

The p-value corresponing to the F-statistic of one-way ANOVA is higher than 0.05, suggesting that the treatments are not significantly different for that level of significance. The Tukey HSD test, as well as other multiple comparison tests like Scheffe or Bonferroni, might not narrow down which of the pairs of treatments are significantly different. Even though your data does not suggest the presence of significaty different treatment pairs in one-way ANOVA, we proceed witht he multiple conparison tests. In some instances, a Bonferroni test of a small set of pairs might show significance, even though 1-way ANOVA suggests that there is too much noise and randomness in your data.

Tukey HSD results

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.8708	0.5437133	insignificant
A vs C	0.9354	0.8999947	insignificant
A vs D	1.8708	0.5437133	insignificant
B vs C	0.9354	0.8999947	insignificant
B vs D	3.7417	0.0432306	* p<0.05
C vs D	2.8062	0.1972495	insignificant

Tijdstempel	Geslacht - Gender	Leeftijd - Age	Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit? bijv: elegant, duur, luxueus etc. e.g.: elegant, expensive, luxurious etc.	Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear?	Hoe stabiel ziet de zitting er uit? - How stable does the seat appear?	Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly?	Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit?	Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear?	Hoe stabiel ziet de zitting er uit? - How stable does the seat appear?	Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly?	Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit?	Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear?	Hoe stabiel ziet de zitting er uit? - How stable does the seat appear?	Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly?	Kunt u de eerste impressie van deze zitting met 1 woord beschrijven, zo ja, welk woord? - Can you describe the first impression of this seat with one word, which word would fit?	Hoe comfortabel ziet de zitting er uit? - How comfortable does the seat appear?	Hoe stabiel ziet de zitting er uit? - How stable does the seat appear?	Welke term is het meest van toepassing op de uitstraling van deze zitting? - Which word describes the appearance of this seat mostly?	Welke van de zittingen spreekt u het meeste aan en waarom? - Which of the seats appears to you most and why?	Waarom? - Why?
11-6-2024 15:29:12	Vrouw - Female	23	strak	4	5	Sportief - Sporty	comfy	5	4	Ontspannen - Relaxed	short	3	3	Actief - Active	standardized	2	4	Klinisch - Clinical	Concept 1	strak, mooi, stevig, goed, maar zonder teveel gekkigheid
11-6-2024 15:30:48	Man - Male	21	Elegant	2	3	Ontspannen - Relaxed	Gaming	4	4	Actief - Active	Baby chair	2	5	Ontspannen - Relaxed	Business	5	3	Klinisch - Clinical	Concept 2	I like the desin of the low part of the seat. It looks comfor

																				table, the other ones look flat
11-6-2024 15:45:03	Man - Male	24	futuristisch	4	4	Sportief - Sporty	luxe	5	5	Ontspannen - Relaxed	dynamisch	3	3	Sportief - Sporty	klassiek	4	5	Klinisch - Clinical	Concept 2	comfortabele look
12-6-2024 11:01:49	Man - Male	27	Sportief	4	4	Sportief - Sporty	Luxueus	5	4	Ontspannen - Relaxed	Basic	3	3	Klinisch - Clinical	Functioneel	4	4	Klinisch - Clinical	Concept 2	Lijkt me het meest comfortabel en ziet eruit als de fijnst zittende en mooiste stoel
12-6-2024 11:08:05	Man - Male	26	Basis	3	3	Actief - Active	Lekkah	3	3	Actief - Active	Breed	4	4	Ontspannen - Relaxed	Geil	3	3	Ontspannen - Relaxed	Concept 3	Lekker breed
12-6-2024 11:09:49	Vrouw - Female	21	comfortabel	4	3	Actief - Active	relaxed	4	4	Actief - Active	elegant	3	3	Klinisch - Clinical	hoekig	2	4	Klinisch - Clinical	Concept 2	Lijkt mee te vormen naar de vormen van het lichaam (andere zijn wat statischer) -> meest comfortabel.
12-6-2024 11:10:59	Man - Male	26	Simpel	3	3	Sportief - Sporty	Luxe	4	4	Ontspannen - Relaxed	Sportief	3	3	Sportief - Sporty	Luxe	5	5	Ontspannen - Relaxed	Concept 4	Meest ruim, comfortabel en veilig
12-6-2024 11:18:27	Man - Male	26	Maxicosi	2	4	Sportief - Sporty	Maxicosi	2	4	Sportief - Sporty	Maxicosi	3	4	Ontspannen - Relaxed	Maxicosi	2	4	Klinisch - Clinical	Concept 3	Ik zie weinig verschil in de concepten en weet niet goed waar de differentiatie zit die je wilt

																				testen? Het ziet er allemaal een beetje uit tussen een kruising van een maxicosi en een race/gaming stoel.
12-6-2024 11:19:43	Man - Male	30	Relaxt	4	4	Ontspannen - Relaxed	Small	3	4	Klinisch - Clinical	Dik	3	4	Klinisch - Clinical	Easy	4	4	Ontspannen - Relaxed	Concept 1	Vormgeving
12-6-2024 11:24:45	Man - Male	26	Comfortabel	5	4	Ontspannen - Relaxed	Luxueus	4	4	Klinisch - Clinical	Elegant	3	3	Actief - Active	Gaaf	4	4	Sportief - Sporty	Concept 4	Ziet er het meest geschikt uit
12-6-2024 11:26:47	Man - Male	24	Futuristisch	3	4	Actief - Active	Stevig	3	4	Actief - Active	Comfortabel	5	4	Ontspannen - Relaxed	Simplistisch	2	3	Klinisch - Clinical	Concept 3	Concept 3 ziet er simpelweg het meest comfortabel uit
12-6-2024 11:44:01	Man - Male	24	Sportief	2	4	Sportief - Sporty	Sportief	2	4	Sportief - Sporty	Bulky	4	4	Ontspannen - Relaxed	Boring	2	5	Sportief - Sporty	Concept 2	Dikke comfortabele steunen, voelt veilig.
12-6-2024 11:49:01	Vrouw - Female	23	Stabiel	4	5	Klinisch - Clinical	Kinderzitje	5	4	Ontspannen - Relaxed	Cool	4	4	Sportief - Sporty	Modern	3	4	Klinisch - Clinical	Concept 3	Concept 3 ziet er in mijn mening het meest sportief uit en heeft voor mij de minste associaties met een kinderzitje voor in de auto
12-6-	Man -	24	Premium	3	4	Sportief	Secure	4	5	Sportief	Playful	4	2	Ontspa	Formal	2	2	Klinisch	Conc	Seems te

2024 12:10:17	Male					- Sporty				- Sporty				nnen - Relaxed				- Clinical	ept 2	most secure
12-6-2024 12:37:14	Man - Male	24	Fast	4	4	Sportief - Sporty	Speels	4	5	Actief - Active	Klein	3	3	Actief - Active	Strak	3	5	Ontspannen - Relaxed	Concept 2	Meest sportief, max van den stap zou deze ook kiezen
12-6-2024 12:51:57	Man - Male	26	Elegant	4	4	Actief - Active	Stabiel	3	5	Klinisch - Clinical	Relaxed	4	3	Ontspannen - Relaxed	Breed	4	4	Ontspannen - Relaxed	Concept 1	Lijkt mij het fijnst om in te zitten
12-6-2024 16:59:15	Vrouw - Female	39	Strak	4	5	Sportief - Sporty	Compact	3	3	Sportief - Sporty	Ruim	4	3	Ontspannen - Relaxed	Open/ uitnodigend	4	4	Actief - Active	Concept 1	Juiste (optische) balans tussen uitnodigend voor beweging maar wel ondersteunend
13-6-2024 10:30:52	Vrouw - Female	23	hoekig	2	5	Klinisch - Clinical	robuust	4	4	Sportief - Sporty	bol	1	2	Actief - Active	rechthoekig	3	4	Ontspannen - Relaxed	Concept 2	Ziet eruit alsof het de meest stevige stoel is. Ziet eruit alsof je lekker "in" de stoel kan zitten en dan niet heen en weer gaat schuiven
13-6-2024 12:18:33	Man - Male	29	Comfortabel	4	3	Sportief - Sporty	Relatief gelijk aan voorbeeld 1	4	3	Sportief - Sporty	Breed	4	4	Ontspannen - Relaxed	Houterig	2	3	Klinisch - Clinical	Concept 2	Meest sportieve look
13-6-2024 12:25:	Man - Male	56	Chique	4	4	Actief - Active	Pompeus	3	4	Sportief - Sporty	Ergonomisch	4	3	Klinisch - Clinical	Basic	2	2	Klinisch - Clinical	Concept 1	Geeft meer zijdelingse steun dan 3

04																				en 4 en is niet te gevormd zoals no. 2.
13-6-2024 12:26:54	Man-Male	53	Comfortable	5	4	Ontspannen-Relaxed	Luxere	5	5	Sportief-Sporty	Soft	5	4	Ontspannen-Relaxed	Strak	3	3	Sportief-Sporty	Concept 2	Lijkt meest confortabel
13-6-2024 12:37:53	Vrouw-Female	54	Elegant	5	5	Ontspannen-Relaxed	Comfortabel	5	5	Ontspannen-Relaxed	Sportief	4	5	Sportief-Sporty	Functioneel	4	5	Klinisch-Clinical	Concept 3	Ruim, stevig en comfortabel
13-6-2024 13:16:22	Vrouw-Female	54	Voor Gehandicapten, lomp, functioneel	3	4	Klinisch-Clinical	Voor Gehandicapten, lomp, functioneel	3	4	Klinisch-Clinical	Functioneel	4	3	Ontspannen-Relaxed	Functioneel	3	4	Ontspannen-Relaxed	Concept 3	Belijning
13-6-2024 16:53:14	Man-Male	57	Compact.	4	3	Sportief-Sporty	Supportive	4	4	Sportief-Sporty	Wide	4	4	Sportief-Sporty	Wider	4	4	Sportief-Sporty	Concept 1	Zitting 1 maakt de meest compacte indruk. En dat hoort voor m'n gevoel het meest bij een fiets.
13-6-2024 16:57:34	Man-Male	31	Sterk	3	5	Sportief-Sporty	Raceachtig	3	3	Sportief-Sporty	Comfortabel	4	3	Actief-Active	Te breed	2	2	Actief-Active	Concept 1	Verhouding
13-6-2024 17:15:38	Man-Male	48	Elegant	5	4	Actief-Active	Luxe	5	5	Ontspannen-Relaxed	Rond	3	3	Klinisch-Clinical	Comfy	5	5	Ontspannen-Relaxed	Concept 2	Goede zijdelingse steun in rugdeel en zitting.
13-6-2024 19:40:05	Man-Male	56	Sportief	4	5	Sportief-Sporty	Stevig	4	5	Ontspannen-Relaxed	Comfortabel	5	5	Ontspannen-Relaxed	Groot	5	5	Ontspannen-Relaxed	Concept 2	Goede zijdelingse steun
13-6-2024 23:	Man-Male	68	netjes	4	3	Sportief-Sporty	netjes	3	3	Sportief-Sporty	goed	4	4	Ontspannen-Rel	goed	4	4	Ontspannen-Rel	Concept 4	Lijkt mij een fijne stoel om op

10:56														axed				axed		te zitten
14-6-2024 9:30:58	Man - Male	24	Sportief	4	3	Sportief - Sporty	Sportief	3	4	Sportief - Sporty	Sportief	4	3	Sportief - Sporty	Sportief	3	3	Sportief - Sporty	Concept 2	Vorm en
14-6-2024 19:50:51	Vrouw - Female	46	Comfortabel	5	4	Ontspannen - Relaxed	Stevig	4	4	Klinisch - Clinical	Breed	3	3	Klinisch - Clinical	Breed	3	3	Klinisch - Clinical	Concept 1	Hij lijkt te ondersteunen met toch nog bewegingsvrijheid
15-6-2024 9:59:10	Man - Male	58	Sportief	5	5	Sportief - Sporty	Comfy	5	5	Actief - Active	Normaal	3	5	Klinisch - Clinical	Modern	5	5	Ontspannen - Relaxed	Concept 1	Meest sportief
15-6-2024 10:16:57	Man - Male	73	Strak	1	2	Actief - Active	Comfortabel	4	3	Ontspannen - Relaxed	Comfortabel	4	4	Ontspannen - Relaxed	Ouderwets	3	2	Actief - Active	Concept 3	Zal lekker zitten
15-6-2024 10:18:19	Man - Male	75	Elegant	1	1	Actief - Active	Comfortabel	1	1	Actief - Active	Luie stoel	5	5	Ontspannen - Relaxed	Luie stoel	5	5	Ontspannen - Relaxed	Concept 2	Sportief
15-6-2024 11:04:17	Vrouw - Female	43	Sportief	4	4	Sportief - Sporty	Luxe	5	5	Ontspannen - Relaxed	Simpel	3	3	Klinisch - Clinical	Strak	2	2	Klinisch - Clinical	Concept 2	Deze oogt luxe en comfortabel. Er lijkt veel steun in de rug en ik denk dat je er stabiel in zit.
15-6-2024 13:03:21	Man - Male	60	rechten oncomfortabel	2	4	Klinisch - Clinical	ondersteunend en hard	3	5	Sportief - Sporty	steun met bewegingsvrijheid	4	3	Sportief - Sporty	ouwemensenstoel	2	2	Klinisch - Clinical	Concept 3	Lijkt op een goede steun in de rug (onderrug, lende) en tegelijk voldoende bewegingsvrijheid, je zit niet

																				ingesnoerd
15-6-2024 13:05:47	Man-Male	70	Comfort	5	5	Ontspannen-Relaxed	Mooi	5	5	Ontspannen-Relaxed	Top	5	5	Ontspannen-Relaxed	Goed	4	4	Ontspannen-Relaxed	Concept3	Ook uitstraling
15-6-2024 17:09:37	Man-Male	57	Degelijk	3	4	Ontspannen-Relaxed	Degelijk	4	4	Actief-Active	Modern	4	4	Sportief-Sporty	Ergonomisch	3	4	Sportief-Sporty	Concept3	Deze geeft denk ik de meeste zijwaartse steun en oogt modern en sportief
15-6-2024 22:15:39	Vrouw-Female	52	Riant	5	5	Ontspannen-Relaxed	Strak	5	5	Actief-Active	Compact	5	5	Sportief-Sporty	Grof	5	5	Klinisch-Clinical	Concept2	Sportief, elegant
17-6-2024 11:48:44	Vrouw-Female	45	Praktisch	3	3	Ontspannen-Relaxed	Mooi	2	3	Sportief-Sporty	Prachtig	2	3	Ontspannen-Relaxed	Mooi	2	3	Ontspannen-Relaxed	Concept2	Ziet er beste uit..
17-6-2024 19:26:43	Man-Male	58	comfortabel	4	4	Ontspannen-Relaxed	comfortable	4	4	Ontspannen-Relaxed	comfortabel	4	4	Sportief-Sporty	comfortabel	4	3	Klinisch-Clinical	Concept3	voorzien van zijsteunen en hoofdsteun; comfortabel en het meest sportieve ontwerp
20-6-2024 14:38:01	Vrouw-Female	13	lekker zittend	4	5	Ontspannen-Relaxed	stevig	3	5	Actief-Active	stabiel	4	5	Sportief-Sporty	chill	3	4	Ontspannen-Relaxed	Concept1	deze ziet er mooi uit en lijkt mij het fijnste zitten
20-6-2024 14:56:15	Vrouw-Female	69	Elegant	4	4	Ontspannen-Relaxed	Robust	5	5	Sportief-Sporty	Onelegant	2	3	Klinisch-Clinical	Stevig	3	3	Actief-Active	Concept2	Deze lijkt mij het meest stabiel
20-6-2024 14:57:25	Man-Male	71	Sportief	4	4	Sportief-Sporty	Comfortabel	5	5	Actief-Active	Comfortabel	5	5	Ontspannen-Relaxed	Comfortabel	5	5	Klinisch-Clinical	Concept4	Goede steun zijdelings en op zitvlak

20-6-2024 16:12:38	Man - Male	41	Stadionstoeltje	2	4	Klinisch - Clinical	Autostoel	4	4	Sportief - Sporty	Fauteuil	5	3	Ontspannen - Relaxed	Budget	2	5	Klinisch - Clinical	Concept 2	Als ik een ouwe lul zou zijn, dan lekker comfortabel luxueus en sportief
20-6-2024 16:25:00	Vrouw - Female	24	Angular, minimal, sporty	3	3	Actief - Active	Bold, luxurious, sport car vibes, but still angular	4	4	Sportief - Sporty	Car seat, familiar design, angular	4	3	Actief - Active	Minimal, budget	2	3	Actief - Active	Concept 2	I like the cushions of concept two, looks comfortable, and like they are stable within the chair. I also like the sporty vibe of it, it gives it a cooler vibe. However I do like the headrest of concept 3! Combining might be an option?
20-6-2024 16:25:15	Man - Male	26	Sporty, Stiff shape, sturdy design	3	4	Actief - Active	Softer than the previous one, luxurious, sturdy	4	4	Sportief - Sporty	Car seat, soft material on the back,	3	2	Actief - Active	budget option, very wide, non-aerodynamic.	3	3	Klinisch - Clinical	Concept 2	The cushions near the waist area looks very comfortable. The thickness makes it look more sturdy. The shape is aerodynamic just the

																				headrest could be tapered on the left and right side, like concept 3.
20-6-2024 19:17:18	Man - Male	35	Sportief	3	5	Sportief - Sporty	Veilig	2	5	Sportief - Sporty	Comfortabel	5	3	Ontspannen - Relaxed	Groot	5	4	Ontspannen - Relaxed	Concept 1	Comfortabel maar ook stevig
20-6-2024 19:56:37	Vrouw - Female	39	Luxe	4	5	Sportief - Sporty	Comfortabel	5	5	Ontspannen - Relaxed	Oudbollig	4	4	Klinisch - Clinical	Stijf	3	4	Actief - Active	Concept 2	Lijkt me het meest comfortabel
20-6-2024 21:16:50	Vrouw - Female	28	Luxueus	4	5	Sportief - Sporty	Comfortable	5	5	Ontspannen - Relaxed	Strak	3	3	Klinisch - Clinical	Stevig	4	5	Actief - Active	Concept 2	Lijkt mij het meest comfortabel
21-6-2024 10:08:25	Vrouw - Female	25	Sportief	3	4	Sportief - Sporty	Ondersteunend	4	5	Actief - Active	Autostoel	5	5	Ontspannen - Relaxed	Minimalistisch	3	4	Actief - Active	Concept 4	Niet zo bulky als model 2 en 3, maar meer ondersteuning in de rug (ergonomisch) dan 1.
21-6-2024 15:31:33	Vrouw - Female	39	Ondersteunend	5	5	Klinisch - Clinical	Doordat er 2 wielen aan de zijkant getekend zijn, lijkt het een driewieler en is de associatie met een anders.	5	5	Klinisch - Clinical	Is deze zitting breder?	5	5	Klinisch - Clinical	Ik zie weder om weinig verschil, sorry	5	5	Klinisch - Clinical	Concept 3	Ziet er sportiever uit

							Maar dit geldt ook voor vraag 1. In eerste oogopslag lijkt de zitting hetzelfde													
22-6-2024 10:37:32	Man-Male	69	Goed	5	5	Ontspannen-Relaxed	Goed	5	5	Ontspannen-Relaxed	Goed	5	5	Ontspannen-Relaxed	Goed	5	5	Ontspannen-Relaxed	Concept 4	Ik heb eigenlijk geen verschillen kunnen ontdekken. Die er mogelijk wel zijn. Vooraf in woorden aangeven waarna gekeken zou moeten worden was misschien een idee geweest. Succes met je afstuderen!
23-6-2024 19:42:23	Man-Male	55	Sportief	4	4	Sportief-Sporty	Robust	4	4	Ontspannen-Relaxed	Praktisch	3	3	Klinisch-Clinical	Algemeen	2	2	Klinisch-Clinical	Concept 2	Pasvorm
25-6-2024 14:27:21	Vrouw-Female	60	Elegant	4	4	Actief-Active	Ondersteunend	3	5	Sportief-Sporty	Ruim	4	4	Ontspannen-Relaxed	Comfortabel	5	4	Ontspannen-Relaxed	Concept 3	Zowel comfortabel als ondersteunend voor het hoofd
		40,7169		3,62264	4,01886			3,88679	4,22641			3,75471	3,66037			3,35849	3,7924			

		8113		1509	7925			2453	5094			6981	7358			0566	5283			
		13		4	4			4	4			4	3			3	4			

Stability

Descriptive statistics of your k=4 independent treatments:

Treatment →	A	B	C	D	Pooled Total
observations N	53	53	53	53	212
sum $\sum x_i$	213.0000	224.0000	194.0000	201.0000	832.0000
mean $\bar{x}$	4.0189	4.2264	3.6604	3.7925	3.9245
sum of squares $\sum x_i^2$	895.0000	982.0000	752.0000	815.0000	3,444.0000
sample variance s^2	0.7496	0.6785	0.8055	1.0138	0.8474
sample std. dev. s	0.8658	0.8237	0.8975	1.0069	0.9205
std. dev. of mean $SE_{\bar{x}}$	0.1189	0.1131	0.1233	0.1383	0.0632

One-way ANOVA of your k=4 independent treatments:

source	sum of squares SS	degrees of freedom ν	mean square MS	F statistic	p-value
treatment	9.9245	3	3.3082	4.0748	0.0077
error	168.8679	208	0.8119		
total	178.7925	211			

Conclusion from Anova:

The p-value corresponing to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test, Scheffé, Bonferroni and Holm multiple comparison tests follow. These post-hoc tests would likely identify which of the pairs of treatments are significantly differerent from each other.

Tukey HSD results

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.6769	0.6204703	insignificant
A vs C	2.8965	0.1741077	insignificant
A vs D	1.8294	0.5601273	insignificant
B vs C	4.5734	0.0076977	** p<0.01
B vs D	3.5063	0.0662564	insignificant
C vs D	1.0671	0.8618527	insignificant

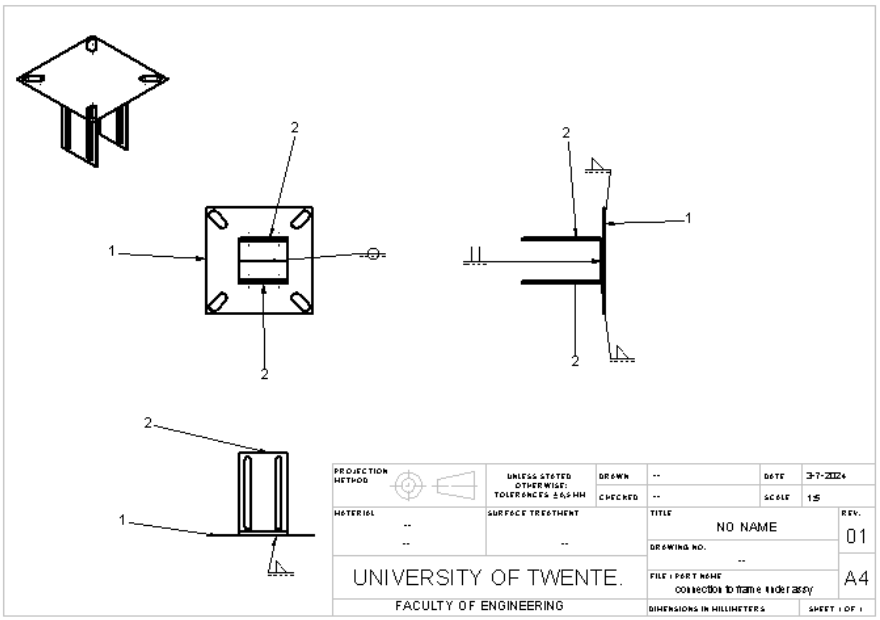
Why perform this?

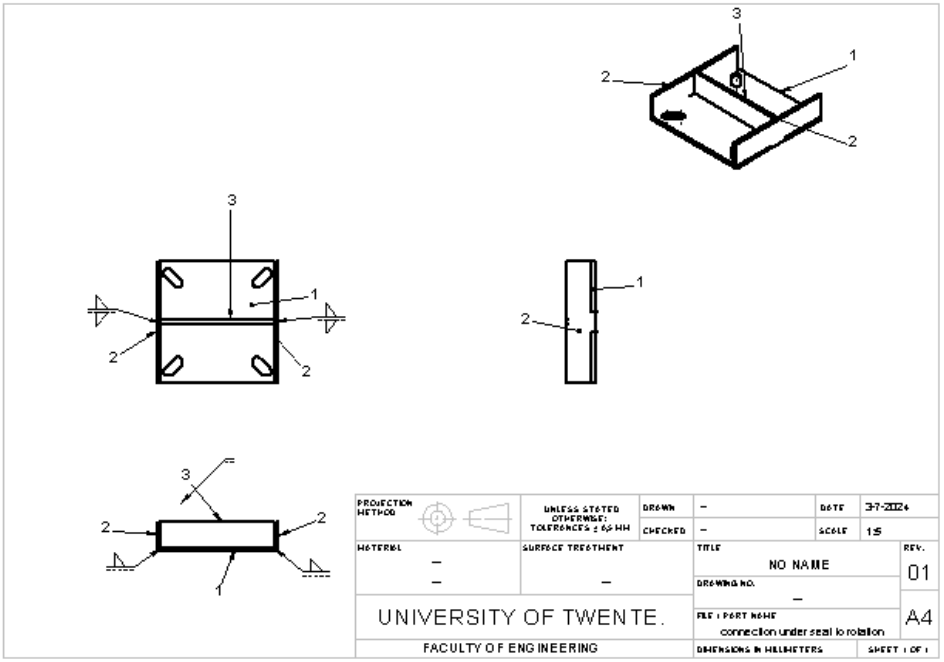
ANOVA is used to compare groups to see whether or not there are significant differences in means of the comfort and statistics ranges within the four different concepts. Tukeys HSD is then used to see which concept scores significantly better than an other concept.

An online calculator tool has been used to perform this ANOVA analysis and Tukeys HSD.

https://astatsa.com/OneWay_Anova_with_TukeyHSD/_result/

Appendix M: Solidworks drawing for assembly





Appendix N: User test 1

Questionnaire test plan Buddy test with end users

Tim Arts, Master thesis intern @ Ideeënfabriek Ulft VanRaam

Introduction

For the development of the seat for the passenger of the Buddy bicycle, it is imperative to emphasize with the target user. With this test, the finding in the literature research and early design phase testing can be checked and tested if the assumptions made and conclusions drawn are also applicable for the target group.

Aim

The aim of this user test is to gather insight into the preferences in terms of comfort and stability of the seat for the target user (65+ with changing medical condition) and whether the requirements set after preliminary tests are also correct for the target user. Next to this, also some insight in to the aesthetic wishes of the target user will be explored.

Subjects

The subjects will all be people within the target group. For this they should be at least 65+ of age and suffering for some sort of (changing) medical condition that makes them not able to navigate through traffic independently.

Ideally, 5 subjects will be used, this makes all the ratings not very statistically significant, however according to Norman & Nielsen, 5 subjects are sufficient in order to tackle 75% of the usability problems and different feedback points. (Nielsen & Landauer, 1993)

Ethical approval

Bring an informed consent form for every volunteer, which has to be signed by researcher and subject. All data will be stored carefully and securely, without mentioning of names.

Assumptions and Dependencies

- The ideal functional seating angle is 123 degrees with a back angle of 118 degrees and a corresponding sitting angle of >4 degrees
- A lumbar support might improve passenger comfort and stability
- Lateral Bolsters are desired for optimal lateral stability for the passenger when cycling.
- The ideal seating position is highly dependent on a correct distance to the bottom bracket
- A “bucket” seat sitting area is preferred for longitudinal stability for the target user
- The perception of comfort is decided by the absence of discomfort, annoyance, potential dangers, inclusive design, no stigma in design, customization, comfortable and the seat not being too expensive.

Logistical preparations

1. Find target users
2. Set a date with target users
3. Make a planning
4. Prepare bicycle, plan and questionnaire
5. Find colleague to join
6. Book a van at VanRaam
7. Make sure the battery of the bicycle is fully charged
8. Test the test with someone at VanRaam beforehand

Preparations on the day itself

1. Load the Buddy in to the van
2. Check if all materials are present
3. Check if colleague is present
4. Check if phone is charged

Preparation at Target User

1. Check if Buddy is working and the seat is fitted correctly

Test Plan (Protocol)

- Introduce everyone
- Tell what the plan is
- Ride for 10 minutes in both positions
    - First new position then old position
    - In between the two positions, the seat needs to be positioned back to the old setting. This will take 10 minutes. In this time, one of the two colleagues can ask questions to the end user.
    - Before leaving make sure everyone is fitted properly to the bicycle
    - During the ride, let the passenger steer and brake while researcher/supervisor gives directions
- Afterwards a questionnaire with user feedback
    - See next section for questionnaire

Questionnaire

Demographic information:

Age	
Gender	
Height	
Current Bicycle	
Impairment	

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Waarom?

Comfort Algehele fietservaring

Oncomfortabel Comfortabel

Comfort Lumbaalsteun

Oncomfortabel Comfortabel

Comfort Zitvlak

Oncomfortabel Comfortabel

Comfort Zijsteunen

Oncomfortabel Comfortabel

Comfort Materialen

Oncomfortabel Comfortabel

Comfort hoek rugleuning

Oncomfortabel Comfortabel

Waarom?

Stabiliteit Algehele fietservaring

Instabiel 0 — Stabiel 10

Stabiliteit Lumbaalsteun

Instabiel 0 — Stabiel 10

Stabiliteit Zitvlak

Instabiel 0 — Stabiel 10

Stabiliteit Zijsteunen

Instabiel 0 — Stabiel 10

Stabiliteit Materialen

Instabiel 0 — Stabiel 10

Stabiliteit hoek rugleuning

Instabiel 0 — Stabiel 10

Waarom?

Uitstraling Zitting

Oncomfortabel Comfortabel

Uistraling Zitting

Stigmatiserend Inclusief

Uitstraling Zitting

Goedkoop Duur

Bewegingsvrijheid tijdens het fietsen

Gevangen Vrij

Algemene opmerkingen

Then, four moodboards will be shown to see which style is most attractive for the end user. They will have to say which style is their preferred style.

After the moodboards have been shown, four sketches that correspond with the moodboard will be shown to see which sketch is preferred by the end user. The most important question is why. Thus these are qualitative questions.

Test Cases

Subject 1

Demographic information:

Age	72
Gender	Female
Height	153
Current Bicycle	Sometimes a tandem
Impairment	Blind

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Remarks:

- when sitting more upright, more the feeling of actually doing something
- The new position is more relaxed, more suitable for watching TV
- Lumbar support is of lesser importance than sitting upright
- When in the new position, lower back becomes hollow
- The sitting area in the old position is shorter and more the feeling of something hitting the hamstring, no real discomfort though. It does not feel like you are trapped in both positions. Slight preference towards new position
- Old position feels safer than new because of upright position, the new position allows for more core rotation
- Material is good, however there was no comparison available. Feeling of material was nice and soft
- Sitting upright makes the angle for pedalling better
- Stability was better in old position because of upright position
- A bucket seat was also found to be less comfortable for this subject
- There was no feeling of unsafety or worry of falling out of the seat in both positions
- In terms of material, the most important thing is not to get dirty because of the chain
- Touch is very important for visually impaired person, especially when moving the handlebar.
- Touch is calibration for the blind person when entering the bike, so if the handlebars move after first touch, it is confusing.

- All questions were a 4 in rating
- Important to have no sharp edges on any interface
- It could be a comfortable addition to add some nice bulky handles

Subject 2




Demographic information:

Age	46

Gender	Male
Height	170
Current Bicycle	VanRaam Opair
Impairment	Tethered cord syndrome

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Then, four mood boards will be shown to see which style is most attractive for the end user. They will have to say which style is their preferred style.

After the mood boards have been shown, four sketches that correspond with the mood board will be shown to see which sketch is preferred by the end user. The most important question is why. Thus these are qualitative questions.

Remarks:

- Both positions make subject happy; he is just happy to ride with his father
- Subject chooses safe position to ride that is why he is steering to the left; to keep clear of vehicles
- Subject does not feel pain or tired legs
- Confidence is everything for subject; riding with his father and communication gives him confidence
- The fact that the subject did not complain on a specific road with much speed bumps tell the parents that the subject did not experience discomfort
- When subject condition becomes worse, maybe a rotatable seat is required for getting in and out of the seat.
- The handlebar moving away when getting in and out feels comfortable for the parents
- Subject however needs something firm to hold when getting in and out of the seat

- Subject did not have a preference in seating position, parents found new position appear to be more comfortable, secure and sporty because of the side bolsters.
- When showing the mood boards, the sporty and active mood board were preferred; the clinical was highly disliked because of negative associations.
- When showing the sketches, the “active” seat was preferred because of its rugged look. The “Comfortable” seat was least preferred.

Subject 3

Demographic information:

Age	74
Gender	Male
Height	170
Current Bicycle	VanRaam Easyrider3
Impairment	Parkinson

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Then, four mood boards will be shown to see which style is most attractive for the end user. They will have to say which style is their preferred style.

After the mood boards have been shown, four sketches that correspond with the mood board will be shown to see which sketch is preferred by the end user. The most important question is why. Thus these are qualitative questions.

Remarks:

- For this subject, mainly the steering was too heavy and felt unnatural to have to correct all the time, also when the steering is influenced by the supervisor, this feels very unpleasant for the subject. This mainly has to do with prior experiences of flipping an ER3 bicycle on its side.
- The difference between the two sitting positions was hardly noticeable for subject as he was mainly focused on the task of cycling (positive).
- In the new position the subject mentioned that he slipped a little bit out of the seat which he feels is down to the material. I feel it is more the distance towards the pedals.
- He feels a little unsafe when turning left or right and also going down from the pavement to the street or riding over a speedbump is found to be unpleasant, fear of falling out.
- Asks for difference between ladies and gentlemen theme when seeing the mood boards
- For aesthetics, subject wants to keep it as simple as possible; should not cause any stress. Preference for clinical/sporty looks. Active had too many distractions. Comfort also
- The "Comfort chair" is the preferred chair because of the continuous lines instead of the squared of lines
- He wants to be the boss of the bicycle not the other way around, that is how he feels
- Support in the corners was sufficient for subject
- Seat and bicycle as it is now is too complicated for the subject, design should be more simple and minimalistic.

Subject 4+5+6+7





Demographic information:

Age	72
Gender	Female
Height	154
Current Bicycle	EasyRider
Impairment	Parkinson

Age	74
Gender	Male
Height	176
Current Bicycle	Easyrider/Fun2Go
Impairment	Parkinson

Age	74
Gender	Male
Height	186
Current Bicycle	Fun2Go
Impairment	Parkinson

Age	75
Gender	Male
Height	178
Current Bicycle	Fun2Go/Easyrider
Impairment	Parkinson

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Then, four mood boards will be shown to see which style is most attractive for the end user. They will have to say which style is their preferred style.

After the mood boards have been shown, four sketches that correspond with the mood board will be shown to see which sketch is preferred by the end user. The most important question is why. Thus these are qualitative questions.

Remarks:

- Feet support for every size
- Rotateable seat for easy access
- Bel is too low
- Rearview mirrors are lacking
- Handlebar should go a little higher when getting in and out of the bicycle. More space inbetween handlebar and seat
- No pain whilst cycling
- Seat, new position was very comfortable.
- Used to instability over bumps, not really a problem
- Feels more stable than Easyrider, stable on the road
- Chain protector is necessary
- Comfort is good, did not even notice drain covers
- Fun2Go more the feeling of falling over
- Bicycle gives a lot of confidence
- Putting the bicycle away is a problem → needs a container
- Bike feels stable, one subject finds it too long, for practicality
- Grades comfort:
    - 4 → rides nicely, always room for improvement
    - 4,5 → Material is good however frame should be aluminium
    - 5 → very nice experience, seat should be rotatable
    - New seat: 4,75 → Side bolsters make it more comfortable
    - Old seat: 4,5
- Handlebar movement: Nice to do it themselves without help → adds to autonomy, According to some it is not that important; rotatable seat is more important
- Basket for groceries is also important or to bring a stroller on the bicycle

Subject 8

Demographic information:

Age	
Gender	Male
Height	
Current Bicycle	Normal bicycle
Impairment	Parkinsons

What was the first impression when riding the Buddy bike today and why

Likert scale questions:

For the questionnaire, Likert scale scorings will be used. These can later be used in order to say something about the statistical significance of the scores of both seats in several areas. The Likert scale uses Emoji's instead of numbers as this is more convenient for the target users according to the caregivers.

Then, four mood boards will be shown to see which style is most attractive for the end user. They will have to say which style is their preferred style.

After the mood boards have been shown, four sketches that correspond with the mood board will be shown to see which sketch is preferred by the end user. The most important question is why. Thus these are qualitative questions.

Remarks:

- General comfort for the new position was better as cycling felt nicer and easier.
- General comfort not much difference
- General stability not much difference; the side bolsters did provide stability; cornering speed is very relevant for general perception of stability. Stability is mainly of importance in the corners according to person
- In terms of aesthetics, the stable one is preferred because of the large side bolsters that look comfortable. Sitting area appearance is also of importance. Al lot of sketches gave person the impression that he/she could slide out forwards.
- Also in terms of aesthetics, the active lifestyle is preferred, however not too much unnecessary features.
- When looking at sketches, there were concerns about freedom of movement with the side bolsters, afterwards, there was no issue.
- A handle for easy entering and exiting of the bicycle will be a good addition.

- In the end, Both the person and persons supervisor would prefer the seat to have adaptability to personalize it.
- In terms of moving the handlebar away from the person, Person would like to do it themselves, however, when supervisor does it, also fine.
- A button or something would be ideal, also rotatable seats would make everything much more comfortable for subject.

Materials and Environment

- Buddy Bicycle
- Charged Battery
- Inflated tires
- 2 side bolsters
- Audio recorder
- Video recorder
- Notepad
- Questionnaire
- Pen
- Red stickers
- Measuring device
- Allen keys
- Spanners
- Monkey wrench
- Sketches of Aesthetics
- Black marker
- Blue Marker

Data processing

In order to process the data, some hypotheses need to be established that can then be statistically tested when processing the data. The hypotheses will be based on the assumptions previously mentioned. The aim of this is to obtain a statistically significant result from the responses of the target users.

Hypotheses:

1. **General**
    a. **Null Hypothesis (H0):** There is no significant difference in comfort or stability between the two positions. X1 = X2
    b. **Alternative Hypothesis (H1):** There is a significant difference in comfort and stability between the two positions, with the first position being preferred over the second position. X1 > X2
2. **Seating angle**
    a. **Null Hypothesis (H0):** There is no significant difference in comfort or stability between the two positions. X1 = X2
    b. **Alternative Hypothesis (H1):** There is a significant difference in comfort and stability between the two positions, with the first position being preferred over the second position. X1 > X2
3. **Lumbar support**

a. **Null Hypothesis (H0):** There is no significant difference in comfort or stability between the seat with lumbar support and without lumbar support. X1 = X2
b. **Alternative Hypothesis (H1):** There is a significant difference in comfort and stability between the two positions, with the first position being preferred over the second position. X1 > X2

4. **Lateral Bolsters**
    a. **Null Hypothesis (H0):** The support does not significantly affect the comfort of the seat.
    b. **Alternative Hypothesis (H1):** The support significantly affects the comfort and stability of the seat.

For all the other questions, the score will be evaluated; however the qualitative feedback is there more important, and the scores con be used to compare to the scores of the eventual prototype.

Statistical evaluation

rating on comfort and stability in the position of 123 degrees with 5 degrees sitting area angle and 118 degrees backrest angle with the current seat and with the current position. This gives a continuous outcome variable then you can use a T-Test to check is the null hypothesis can be rejected. Based on the test results, determine whether to reject or fail to reject the null hypothesis. If the p-value is less than your chosen significance level, you reject the null hypothesis in favour of the alternative hypothesis. If the p-value is greater than the significance level, you fail to reject the null hypothesis. Then, the main conclusion will be drawn based on the remarks of the participants. The statistic test will still be performed, however this will not be a reliable outcome, so the final conclusion will be done based on argumentation.

Material checklist

Check?	What	Quantity
	Buddy bike	1
	Charged battery	1
	Inflated tires	3
	Side Bolsters	2
	Spare clamp	2
	Lumbar support	1
	Mobile phone charged	2
	Notepad	1
	Printed questionnaire	10
	Pen	2
	Red label stickers	1
	Tape measure	1
	Allen keys	Set
	Spanners	Set
	Monkey Wrench	1
	Printed sketches of aesthetics	1
	Black marker	1
	Blue marker	1

Appendix O: Final User test

Questionnaire test plan Buddy final test with end users

Tim Arts, Master thesis intern @ Ideeënfabriek Ulft VanRaam

Introduction

For the development of the seat for the passenger of the Buddy bicycle, it is imperative to emphasize with the target user. With this test, the finding in the literature research and early design phase testing can be checked and tested if the assumptions made and conclusions drawn are also applicable for the target group.

Aim

The aim for this final user test is to check whether the rotatable seat is an imperative functionality for the general comfort and autonomy of the cycling experience of the Buddy bicycle. Furthermore, final sketches of the aesthetics for the seat will be shown and an opinions on this will be asked. This is all to check if the chosen design direction fulfils the needs and wishes of the target group.

Subjects

The subjects will all be people within the target group. For this they should be at least 65+ of age and suffering for some sort of (changing) medical condition that makes them not able to navigate through traffic independently.

Ideally, 5 subjects will be used, this makes all the ratings not very statistically significant, however according to Norman & Nielsen, 5 subjects are sufficient in order to tackle 75% of the usability problems and different feedback points. (Nielsen & Landauer, 1993)

Ethical approval

Bring an informed consent form for every volunteer, which has to be signed by researcher and subject. All data will be stored carefully and securely, without mentioning of names.

Assumptions and Dependencies

- The rotatable seat is a necessity for getting in and out of the bicycle and thus adds comfort and confidence to the target user.
- The stability is still sufficient with the rotatable seat
- The 45 degree rotation might not be sufficient for the target user
- The aesthetics evoke a feeling of comfort, stability and activity to the target user
- Placing the sitting area forward leads to more discomfort for the target user.

Logistical preparations

9. Find target users
10. Set a date with target users
11. Make a planning
12. Prepare bicycle, plan and questionnaire
13. Find colleague to join
14. Book a van at VanRaam
15. Make sure the battery of the bicycle is fully charged
16. Test the test with someone at VanRaam beforehand

Preparations on the day itself

5. Load the Buddy in to the van
6. Check if all materials are present
7. Check if colleague is present
8. Check if phone is charged

Preparation at Target User

2. Check if Buddy is working and the seat is fitted correctly

Test Plan (Protocol)

- Introduce everyone
- Tell what the plan is
- Ride for 10 minutes on the bicycle
    - Focus is observing the getting in and out of the bicycle
    - Before leaving make sure everyone is fitted properly to the bicycle
    - During the ride, let the passenger steer and brake while researcher/supervisor gives directions
- Afterwards a questionnaire with user feedback
    - See next section for questionnaire
    - Also on aesthetics
    - Can be done in small groups

Questionnaire

Demographic information:

Subject 1:

Age	72
Gender	Female
Height	154

Current Bicycle	EasyRider
Impairment	Parkinson

Subject 2:

Age	74
Gender	Male
Height	186
Current Bicycle	Fun2Go
Impairment	Parkinson

Subject 3:

Age	74
Gender	Male
Height	176
Current Bicycle	Easyrider/Fun2Go
Impairment	Parkinson

Subject semi-structured interview + Observations:

Subject 1:

- Not every corner was very stable
- Sitting in the seat is easy
- The sitting area is too high for this subject to comfortably get in and out of the seat
- Wheel is in the way of the ankles of the subject
- Used to enter the bicycle through sitting upright
- More comfort because of rest in this seat
- Sitting goes automatically because of bicycle at home
- Straight seat is sufficient for getting in and out
- Good working rotatable seat would be better
- Seating sometimes does not feel stable in the corners because of the wobbly seat
- On own bicycle this is less however it is not a nuisance, during cycling this is no problem.

Observations:

- Needs bolsters to lean against bolsters to keep stable
- Pedals are still too far away
- Sits relaxed in the seat
- Subject was moving around a lot due to medical condition, the side bolsters limited this

Subject 2:

- Steering in front is difficult
- Free chain feels difficult
- Seat feels comfortable because it is not too hard
- Especially the sitting area
- Speed bumps can be nerving
- Cycling was a fun experience
- The support in the back was sufficient and good
- Rotatable seat did not work so it is not very useful
- Rotating mechanism has too much friction

Observations:

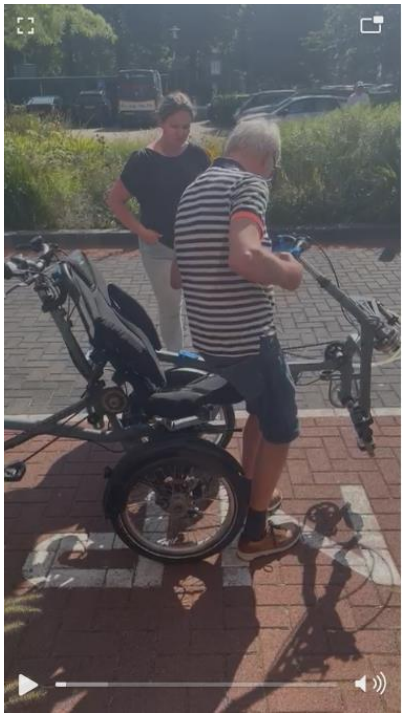
- Sits comfortably in the chair
- Getting in and out takes time, rotatable seat did not help

Subject 3:

- Seat was very stable
- Managed to go over bumps very well and still felt comfortable and safe
- Backrest fits perfectly to the user
- Rotatable seat did not work because the wheel was in the way of the subject trying to enter the bicycle
- In the corners, the subject experienced proper support as well
- Steering the bicycle gives the passenger more stimulus, could lead to stress
- Bike needs rear view mirror
- The sitting area feels nicer than the fun2go because that one is too hard.
- Sometimes, subject fears to get off the road because of previous experiences.

Observations:

- Passenger was sitting relaxed in the seat and enjoyed the ride
- Steering looked confident in de corners
- Steering was too heavy for the subject
- Getting in and out of the seat took time but eventually managed very well to do this
- Rotatable seat did not help in doing this.
- Subject was moving around a lot due to medical condition, the side bolsters limited this



Polar questionnaire:

The questionnaire will consist of polar questions (yes or no) in order to gather insight into the hypotheses as mentioned before. Further remarks will be examined and asked as well. The following polar questions will be asked:

1. Does the rotatable seat add comfort to the cycling experience?
2. Does the rotatable seat give you confidence in your own capabilities with the bicycle?
3. Is the stability of the bike still sufficient with the rotatable seat?
4. Is the rotation of the seat far enough the way it is now?
5. Do de aesthetics evoke a feeling of comfort for you?
6. Do de aesthetics evoke a feeling of stability for you?
7. Do de aesthetics evoke a feeling of activity for you?
8. Does the sitting area provide any discomfort for you?

For every question, the “why “ question is also of importance

Outcomes of questionnaire:

Question	**Yes**	**No**
1.	**0**	**3**
2.	**0**	**3**
3.	**3**	**0**
5.	**3**	**0**
6.	**3**	**0**
7.	**2**	**1**

Note: Question four was skipped because it was obvious from the observations.

Importance of functionalities:

1. Include adaptable backrest?
2. Include adaptable lumbar support?
3. Include adaptable side bolsters?
4. Include rotatable seat?
5. Include adaptable bottom bracket?
6. Include similar materials?

Materials and Environment

- Buddy Bicycle
- Charged Battery
- Inflated tires
- 2 side bolsters
- Audio recorder
- Video recorder
- Notepad
- Questionnaire
- Pen
- Red stickers
- Measuring device
- Allen keys
- Spanners
- Monkey wrench
- Sketches of Aesthetics
- Black marker
- Blue Marker

Data summary

For the qualitative feedback, a limited number of n=3 has been used due to time constraints. From these three subjects however, the following trends and observations could be determined.

Results

The results of the polar questions are visualised in a table:

Question	Yes	No
1.	**0**	**3**
2.	**0**	**3**
3.	**3**	**0**
5.	**3**	**0**
6.	**3**	**0**
7.	**2**	**1**

Conclusions

Based on these polar questions, the conclusion can be drawn that:

8. The rotatable seat mechanism as was used in this test does not work as intended
9. The stability of the seat is still good, despite the new sitting area construction
10. The aesthetics of the seat do evoke a feeling of comfort and stability to the user.

Based on the interviews after the test drives, the following conclusions can be drawn.

7. **Rotatable seat mechanism:** The rotatable seat mechanism did not work as expected, however, a rotatable seat is still desired to make entering and exiting the bicycle easier.
8. **General Comfort:** Across all subjects, the seat was generally found to be comfortable, particularly due to its softness and back support. This suggests that the seating design is largely effective in providing comfort during use.
9. **Positive Experience:** Despite the aforementioned challenges, the overall riding experience was described as fun and enjoyable by the users. This suggests that, with some adjustments, the bicycle could be very well-received.
10. **Effective Bolsters:** Side bolsters were effective in keeping users stable, especially those with medical conditions that cause them to move around more. This underscores the importance of such supportive features in maintaining user stability and comfort.

Discussion and Limitation

General note on all the answers is that this target group is limited in the ability to express themselves, this is due to their medical condition and thus sometimes, gathering feedback from this group proves to be challenging.

Material checklist

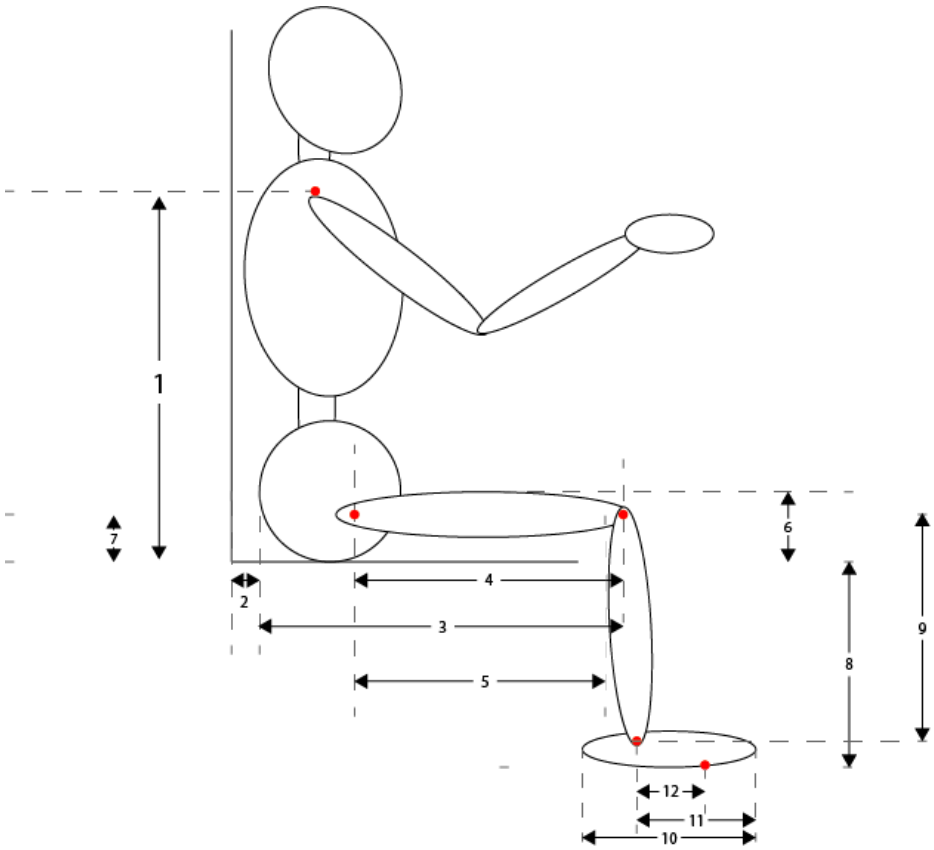
Check?	What	Quantity
	Buddy bike	1
	Charged battery	1
	Inflated tires	3
	Side Bolsters	2

	Spare clamp	2
	Lumbar support	1
	Mobile phone charged	2
	Notepad	1
	Printed questionnaire	10
	Pen	2
	Red label stickers	1
	Tape measure	1
	Allen keys	Set
	Spanners	Set
	Monkey Wrench	1
	Printed sketches of aesthetics	1
	Black marker	1
	Blue marker	1

Appendix P: Human dimensions whilst seated

This information will be combined with body measurement data for the target group from sources like DINED and Molenbroek (1987), as detailed in the table below. (Molenbroek, 1987)

Number	Ergonomic consideration	Smallest p5 (mm)	P5 (mm)	P50 (mm)	P95 (mm)	Largest p95 (mm)
1	Cervical height	513	517	591	660	693
2	Back plane to sacrum	10	10	26	71	74
3	Buttock-knee depth, sitting	561	568	617	666	671
4	Effective thigh length	481	487	540	595	598
5	Buttock popliteal depth	401	406	463	524	525
6	Thigh Clearance	114	114	137	160	162
7	Height hip joint	57	57	68,5	80	81
8	Popliteal height, sitting	384	392	450	508	519
9	Effective height knee ankle	346	354	423,5	493	505
10	Foot length	223	226	254	282	288
11	Position ankle w.r.t. foot	167	169,5	190,5	211,5	216
12	Position pedal w.r.t. ankle and foot	80	80	85	100	100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10

Appendix Q: Comparison to other seats

To assess the viability of the newly developed seat concept for VanRaam bicycles, it is essential to compare its performance and features against existing seats currently used in similar applications. This comparison will focus on key criteria, including functionality, cost-effectiveness, user experience, and technical feasibility.

"The comparison will be based on five primary criteria:

1. **Functionality**: Evaluating the ability to meet ergonomic and adaptability requirements.
2. **Cost**: Analysing the estimated production and manufacturing costs relative to existing models.
3. **User Experience**: Considering user feedback, comfort, and usability.
4. **Technical Feasibility**: Assessing the practicality of implementation and reliability.

The ER3 and Fun2Go seats represent the current standard in the market, offering simplicity in design, cost-efficiency, and basic ergonomic support. However, these models lack advanced adaptability features, such as customizable lumbar support or side bolsters, that are increasingly demanded by users with specific ergonomic needs.

Criterion	New Concept	ER3 Seat	Fun2Go Seat	HP Velotechnik seat
Functionality	Advanced adaptability, adjustable lumbar support,	Basic ergonomic needs	Basic ergonomic needs	Good functionality, stability could be better, no lumbar support
Cost	Cost price with all functionalities is 3-6 times higher than ER3 and fun2go	135 euro cost price	96 euro cost price	Asummed cost price of:
User experience	High comfort and stability, customizable	Too little support for use case, sitting area too hard	Too little support for use case, sitting area too hard	Sufficient comfort and stability, can be better
Technical feasibility	Technically feasible but requires further refinement	Proven design, simple to produce	Proven design, simple to produce	Proven design, needs some VanRaam development

Appendix R: Midterm focus group

What?

A group of elderly voluntary caregivers stopped by at Civon for an event. They were asked about their first impressions when looking at the "Buddy" bicycle whilst stationary. Some even sat down on the front seat and one male and one female rode a lap together on the DRU industrial estate.

The questions asked were mainly about the first impressions of the bicycle and the seat, also some questions were asked about some associations that the people had with the bike. Finally, some general feedback was given on the bicycle.

This event was to get some feedback from the "supervisors" that have experience with taking care and cycling together with impaired people. No major conclusions can be drawn from this event, it does however provide some feedback and insight for the design process of the seat and the "Buddy" in general.

The people were male and female in ages 68 until 77 years. Some had experience with riding on a bike as a supervisor, others hadn't

First impressions:

1. Sitting comfortably
2. Gives good support in back
    - More focus on task of cycling
3. Bike seems agile
4. Nice overview whilst cycling
5. Relaxed seating position
    - Feels comfortable and safe
6. A Lumbar support that can be pumped up would be ideal
7. Bike looks nice
8. Support to enter and exit the bicycle is needed
9. A rotatable seat is preferred for people in a wheelchair.
10. Sitting next to each other is more fun
11. Armrests are needed especially with (partly) paralyzed people
12. Sits comfortable
13. Side bolsters give a safe feeling
14. Bike position is more comfortable than initially thought
15. Generally, the lack of width compared to a Fun2Go is named as the most important advantage of the Buddy
16. Bike gives stable and tough impressions because of two wheels
17. Little bit of a bucket seat is better than a fully bucket seat
    - Softer seating is nicer, watch out with vulnerable skin
18. Sitting in front as passenger is very nice
19. Getting in and out much easier than on a tandem
    - Impressions after cycling:
20. Sidewalks can be quite scary because of the length of the bicycle
    - For the person on the saddle in the back

- The person sitting in the seat did not feel this inconvenience as such

21. Maybe make the steering for the person in front a little bit less influential
    - Feels not nice
22. Pedalling for the passenger is a nice addition
23. People worry about the weight of the passenger

Associations

24. Recumbent bicycle
    - Because of length
25. Nice for the people to be able to ride outdoors
26. Good communication with each other possible on the bike

Conclusion

The Buddy bicycle was generally perceived as a nice new bicycle concepts. People said the bike looked, stable tough and more practical than the Fun2Go. The caregivers wanted a lot is support and possibility to secure the passengers in place. Generally, they thought the bicycle is meant for impaired people in a wheelchair, thus they want a rotatable seat. The seat feels comfortable, lumbar support can be added the bolsters do not need to be too big but have to offer some support.