Marginal gains for major improvements:

A user-centered cycling shoe to increase performance for elite short-course triathletes

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Executive summary

Introduction
The domain of triathlon seems promising for Cadomotus, a company specialising in helmets, bags, and shoes. Right now, they are known for high-end ice-skating equipment, but the triathlon market seems a great fit and they want to expand further there. A new triathlon specific product would solidify Cadomotus in the market as truly understanding triathletes' desires and demands.

Method
A user-centered design process was used, meaning that athletes were involved in every crucial step. A double diamond design process was used. The results of the discovery phase were synthesised into a user-journey with 23 different design opportunities. Together with the company and users these were narrowed down to one design brief.

A creative session started the developing phase. Here four different concepts were generated, prototyped and evaluated. One of them was chosen for further development in the delivery phase. The delivery phase consisted of an iterative process going from paper to high-fidelity prototypes. This concept was put through a final usage evaluation, and its insights led to the Talaria. A new triathlon specific cycling shoe.

The reaction of users to the design was mostly positive. *"I dare to say that I have almost mastered this element of transitioning and then directly getting into cycling, but this would work even quicker" - Sem*.

Results
The Talaria (see the next page) addresses two concrete needs: getting in and out quicker and stop the shoe from spinning during the second transition. The quicker athletes can get in or out of shoes, the better they can perform during their race. Especially in elite short-course racing this is vital. The spinning shoes are a phenomenon where the shoe hits the ground and starts spinning, which in turn can cause the bike to ‘jump’, creating stress and a potentially unsafe situation.

Definitions

Triathlon: Swimming – Cycling - Running

Drafting: Cycling behind one another

T1: Transition one, from swimming to cycling

T2: Transition two, from cycling to running

Taper: the last period before a race in which an athlete tries to get fresh and ready for the race

Super League: organisation that organises elite short course races and are unique for their prize money and revolutionary race formats.

Nike Vaporfly: A running shoe that came out in 2017 revolutionised the running market by their superior performance. For a while, I observed that every single athlete was wearing them.

Elastic bands: currently used to hang the cycling shoes (while clicked in) on the frame in T1, in such a way that they are level and ready to jump in quickly after running out of transition and jumping on the bike.

PVA: Performance Value Added

XVA: Experience Value Added

The Talaria

Envelop tongue
An envelop shaped tongue makes sure that toes can not get stuck, or that fabric bends in the wrong direction

LED
A LED to show whether the brake in the pedal is active or not

Brake
A build-in brake in the pedal keeps the shoe horizontal when there are no feet present

Heel
An opening heel creates a bigger opening, making it easier to slip into the shoe

Dial winding button
Allowing the athlete to set how tight the shoes should be before the race start. Offering adjustability during the race as well

Handle
A handle allows the shoe to be tightened quickly and strongly. Only one simple movement is necessary before optimal power transfer is achieved

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1. Introduction

This chapter presents the preconditions of the conducted project. It starts with introducing the wide context and issuing company. This chapter thereafter introduces possible opportunity areas that have been identified at the start of the project. The last part of this introduction explains the project's goals and chosen scope; to what do I narrow my focus and what approach to use.

1.1 Context of this project

1.1.1 Triathlon: the phenomenon it all starts with

Triathlon is one of the quickest growing sports in the Netherlands (BNR, 2020). It consists of swimming, cycling, and running in direct succession, while the aim is to cross the finish line quickest. It was invented and gained traction in the 1980's. In general, it can be considered to be divided in short distance (races up to approximately 2 hours) and long distance (races up to 8 hours for the elite athletes). It is an endurance sport characterized by many training hours, that often comes down to which athlete is freshest the longest. Triathlon is an Olympic sport, at the Olympic games there is a mixed team relay (2 women and 2 men execute a short triathlon before tagging the next person in a relay format) as well as

Figure 1: Responses when athletes were asked to describe triathlon in three words (size corresponds with frequency)

an individual event: the Olympic Distance (OD, 1.5km swim, 40km bike, 10 km run).

In elite short distance racing there is also the element of drafting, which means cycling behind someone else is allowed, leading to larger groups of athletes cycling together. During the cycling leg of a triathlon, the small gaps that have been formed during the swim and transition are often amplified. Meaning that missing the front pack after the first transition can be disastrous for a good result. With an ever more levelling playing field, transitions between the different legs become vital for staying in the mix. Athletes that lose time in transition often struggle coming back, whereas a small gap in the swim can sometimes be closed by having a quick transition to the bike.

The fact that short distance athletes need to put such a heavy emphasis on their transitions has led to transitions being coined the fourth discipline. The focus of this thesis is therefore on the short course racing experience, as they are expected to have higher demands from their products during time-pressured actions in the race. Transitions are less important for long distance or non-drafting races. Their experience before and after the race is similar to those that of non-drafting racing, so by focusing on this use-case one can expect a trickle-down effect to the other disciplines.

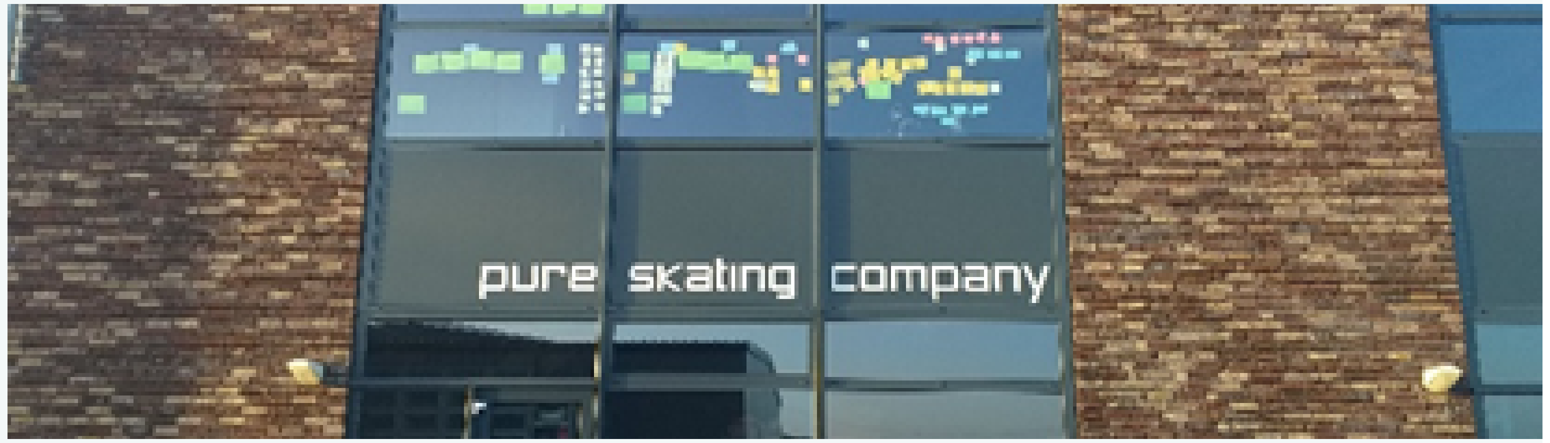


Image 2: Cadomotus' offices with post-its from this project

1.1.2 Cadomotus: the company this project was conducted for
This is a master thesis for the Industrial Design Engineering Master Design for Interaction and performed for Cadomotus. This project is conducted by me, Daan Gehlen, both designer and triathlete myself. Which is why this project is extremely interesting to me, but also presents some challenges in the user research phase to avoid bias as much as possible (see chapter 2.4).

Cadomotus is a company that at present produces helmets, bags, and shoes for (ice-)skating. Their focus is on the higher end segment of the market, trying to make their products functional, of high quality and having good performance (read: aerodynamic or stiff). The combination of a growing and innovative triathlon market offers an interesting opportunity for Cadomotus. Another factor making the triathlon market interesting for them is that the average triathlete is willing to invest a substantial amount of money for high-end products that give them marginal gains in their performance.

Even though Cadomotus has already been entering the triathlon domain, the company feels there is still a lot to learn and gain. Cadomotus' aim of this thesis is therefore two-folded. Research into the triathlon context documented in this thesis can help Cadomotus to further understand what drives the triathlete in the form of overall and in-depth views on all pains and gains. As such it can provide a solid fundament for future product innovation and development, so they can cater to the needs of triathletes and improve their race day experience. The design phase of this thesis aims to develop a triathlon-specific product to emphasise Cadomotus' interest in, and understanding of, the sport. Doing this by catering to a triathlon specific need, means giving triathletes the possibility of having a more pleasant race day experience!

1.2 Expected design opportunities

This sub-chapter starts narrowing down the large context domain of triathlon into smaller areas that could be interesting to investigate further. Weich (2015) and Millet & Vleck (2000) show that there has been quite extensive research into the biomechanical part of these transitions between different sports. What is the effect on your body and performance? Research into the interactions and tools used seems to be less present. The rest of this sub-chapter is therefore based on my expertise and experience of being a part of the sport for the last 8 years.

This thesis addresses those interactions, as this would offer opportunities to improve the triathlon experience for athletes using design. These race-day events often require athletes to have trained consistently for extensive periods of time, with usually only a few windows to execute what they have been training for. Improving their (mental) well-being using design interventions on this important race day can be a powerful enhancer of self-confidence and generate satisfaction and proudness over their own achievements.

Furthermore, triathlon is a relatively new sport, and at regular intervals still trying to reinvent both the format and the equipment. An example of changing formats is “Superleague” triathlon, which offers shorter distances, shuffles the order of the different legs, or even takes triathlon indoors. The rules for triathlon bikes are also more flexible compared to those of the cycling federation. The frame for example does not have to consist of the traditional 2 triangles (see image 3). The missing seat tube allows the bike to be even more aerodynamic. There still seems to be room for innovation, as several things appear even in the present to be quite amateurish (see image 4).

Image 3: A triathlonbike without traditional frame design

Image 4: Elastic bands to keep the shoe horizontal

The following three promising **opportunity areas** were identified:

Transitions
The transitions seem to be a promising area to look at. These are often stressful with several different yet necessary steps and interactions in a short time. It would be valuable to make these interactions either simpler or faster.

Performance
The target group for this thesis is competitive athletes, therefore performance increase during each of the individual legs of the triathlon is a second promising area of interest. Performance improvers are likely to either make the athlete measurably faster, decrease their cognitive and/or motoric load or keep them fresh for longer.

The build-up
A third moment of interest is the build-up towards the race as stress and problems might not only be encountered during, but also before the race. Lowering these stress levels would most likely also help to improve performance during the race itself. Further research should indicate which other desires, hopes, dreams and fears athletes encounter during a race, that new designs could also take care of.

1.3 The project approach

1.3.1 Scoping: what and who am I focusing on?

As Cadomotus has a long history with performance equipment focusing on races, the race-day experience of athletes was chosen as the scope. More specifically it was decided to start the moment they come home from their last taper training, usually the day before the race. This is the moment where there is a switch from training to racing, and the last build-up to the race starts.

The end of the race day was chosen as the moment they are back home in the evening and unpack their stuff. This turned out to be happening mostly the day after, or even longer after the race, depending on how organised each athlete was.
The main users focused on in this thesis are elite short distance athletes, as Cadomotus has noticed that there is usually a trickle-down effect in which amateur athletes tend to rather want something the pros are using than something that is designed specifically for them.

As a result of this scope there are several **stakeholders** that have a stake in the race day experience of elite athletes:

Athletes
They want to perform the best they can on race day.

Cadomotus
They want to develop a triathlon specific product to show they understand the athletes' needs.

Race organisations
They are facilitators of said race day. Their ambition is to create a nice race day experience without incidents, whereas many people as possible get to experience triathlon. This is because most money is made in registration fees.

Dutch, European and World Triathlon Federation, as well as coaches of the individual athletes
These might not have such a direct effect, yet they generate the rules (federations) or heavily influence their athletes' decisions. National federations and coaches are often hard to see as different entities within triathlon, as athletes often are trained by coaches of their national federation. They want their athletes to perform as the best in the world. Often with a high focus on the Olympics since they are partly funded by the Olympic committee. At least in the Netherlands this is the case.

Product manufacturers
In triathlon athletes use different tools and materials in their race, and their manufacturers could arise as potential stakeholders in the future as well. For example, if one would create a new pedal for the bike, cycling shoe and bicycle manufacturers are something to consider as well. They could function as potential partners to Cadomotus. Their ambition is trying to generate value for their costumers and thereby sell products.

1.3.2 Goals and approach: what are we hoping to achieve and how

The goal of this graduation project is to thoroughly understand the competitive athletes experience during a race and design a fitting new solution for them. The intended result is a physical concept, as this is where the company is strongest and would help Cadomotus to extend its innovative portfolio. However, there is the possibility for other forms of deliverables if they can strongly and clearly be argued for. The intended result optimises performance in some way, whether that is by improving the actual interactions or easing up cognitive load.

The approach followed in this project is that of user-centered design. Mao, Vredenburg, Smith & Carey (2005) define it as: "*User-Centered Design (UCD) is a multidisciplinary design approach based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation. It is widely considered the key to product usefulness and usability*". In practice this means that during the project users will be involved and consulted at every crucial step along the way.

Elite short-course athlete will be the user group and stakeholder that I focus most on. Their experiences and needs are to be front and centre. The first investigative period therefore constitutes of observations, participatory research, and in-depth interviews. The design phase will constitute of a workshop and iterative prototyping cycles were athletes are asked for feedback.

1.3.3 Design process and reading guide

The process follows a traditional double diamond approach (UK Design Council). First field research leads to several possible design opportunities mapped out on a user-journey, These are then converged into a design brief that is used for developing a concept in the second half of the project. During the design phase there is first a divergence to 4 different concepts, after which several iteration cycles lead to the final design, the Talaria. A visualisation of this process, which also functions as a reading guide, can be seen in figure 5 below.

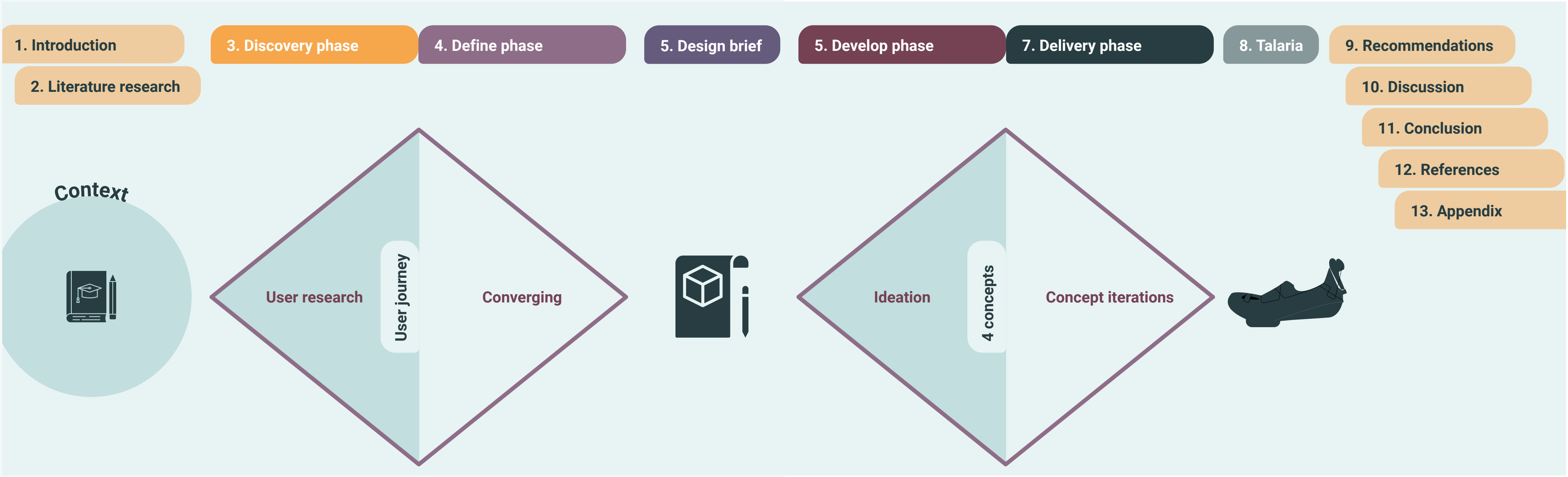


Figure 5: Visualisation of the followed design process

2. Literature research

theoretical basis of this project

2.1 Introduction

To find answers within the scope decided on in the previous chapter, I mapped out the most prominent research questions (see figure 6). Some information should be collected by doing field research later in the project, while other aspects have already been investigated by others before. This already present knowledge is presented in the following sub-chapters as it impacted the design process but wasn't generated by me. One can see it as three different lenses that I have applied during the design process. For example when deciding on which concepts to move forward with or how to improve them.

This literature research started with the following three questions, which each have their sub-chapters:

1. *How is innovation in sports usually achieved, how do others look at it? (Chapter 2.2)*
2. *How do other organisations try to optimise performance processes, and can we learn something from them? (Chapter 2.3)*
3. *I am part of a specific target group, which can both be advantageous and pose some problems, how can I optimally use this? (Chapter 2.4)*

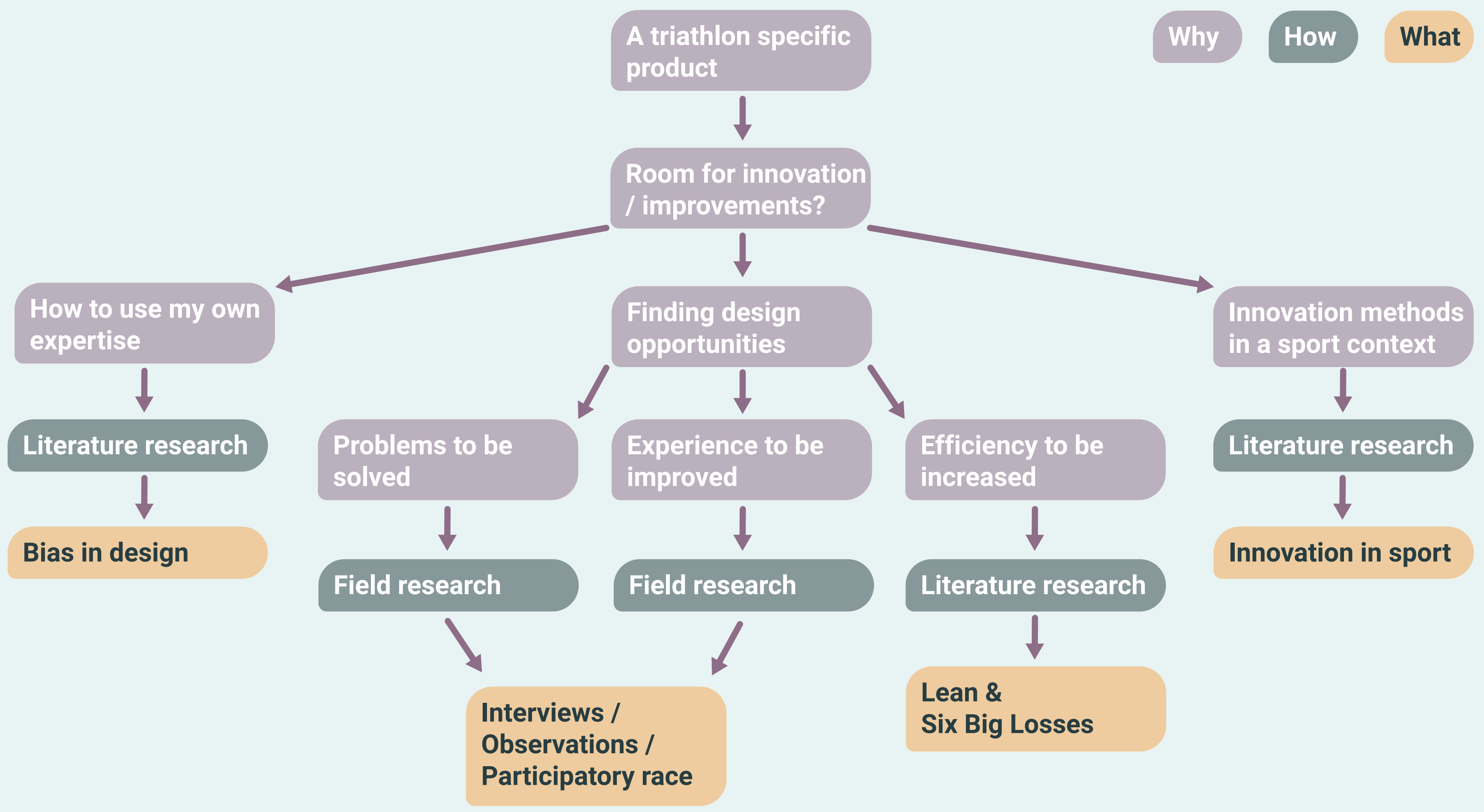


Figure 6: Research questions tree

2.2 Innovation in sport: marginal gains matter

When talking about improvements in sports, and especially endurance sports the theory of the aggregation of marginal gains comes up often. Dave Brailsford, British Cycling Performance Director & sports director of Team Sky has at one point described the theory as follows: "The whole principle came from the idea that if you broke down everything you could think of that goes into riding a bike, and then improved it by 1%, you will get a significant increase when you put them all together" (BBC Sport Olympics). In three years, he managed to win the tour the France and won six more times during the next seven years.

Hall, James, & Marsden (2012) point out that this approach has also been present in other sports in the past. From my personal experience in endurance circles, it is known that this theory gained traction as a winning philosophy. Meaning that if we can just improve something by one percent, it might be of real value, because all innovations together are bigger than the sum of their respective parts.

However, this theory also had some critique (Lewis, 2019). At some point, when are you just throwing money at a problem, and is there a point where you cross the lines of clean sport? In a complicated sport like triathlon, marginal gains have been well established at this point though. There are many different things to be improved at any one point in the race.

What to take away from this is that even seemingly marginal improvements can have a big effect over time. It is therefore valuable to not only focus on seemingly big steps, but that even small inconveniences can make someone perform better, if they just find enough places to apply them.

2.3 Effectiveness: how to save time or effort

When we are talking about performance increases in a time-based sport like triathlon, the quickest to the finish line wins, effectiveness becomes a big factor. Effectiveness is hereby a combination of being efficient and doing the right thing.

For better effectiveness, an athlete can either save time, energy or prevent failures, and doing so sets them up for a better position to take the win. Apart from sport, manufacturing has been a domain that for many years has tried to achieve just that. An expert with a long track record of 20+ years managing company processes was asked for advice on relevant methodologies.

Because manufacturing processes have this same aim of optimising a time-based performance, yet come from a domain other than design, it is interesting to look at what their approach could add to the created user journey. Two separate methods were recommended and will be presented: Lean Manufacturing and The Six Big Losses.

2.3.1 Lean manufacturing

Lean manufacturing (The lean six sigma company, 2021) comes from Toyota and focusses on one thing: value creation. For each step in the manufacturing process, one should ask whether this step is creating value for the consumer. This should be mapped out in a value stream. Processes must be designed to create flow; where are there unnecessary waiting times? Where is waste; when is the company not delivering value? Afterwards the goal is to optimise the value stream. In manufacturing there is also a pull factor in which the aim is to respond to customer demands rather than to produce for the sake of producing.

When applying lean manufacturing to triathlon, creating customer value is still in the focus. In the generated user-journey there is already a form of value stream, all actions that a triathlete is doing can be found there. The next step is to determine whether they add value or can be classified as waste. Anything that does not help getting to the finish line quicker or happier could be considered waste.

Within lean there are two types of values. Customer Value Added (CVA) and Business Value Added (BVA). For application to the user journey one can argue that a step either is Experience Value Added (XVA) or Performance Value Added (PVA). For example, oiling your bike might not be fun (no XVA) but it will help perform better the day after because an oiled chain has less friction and therefore better power transfer (PVA). However, cleaning the bike's frame is necessary for longevity of use, but is not adding any concrete value and can therefore be classified as waste. According to lean this step should therefore be minimised or eliminated. In the user journey, each of the presented actions will subsequently be judged against whether they are XVA, PVA or waste.

2.3.2 Six Big Losses

The Six Big Losses (OEE, n.d.) is another method from the manufacturing world, which is used to classify losses. It is meant to identify consistently within a chain of manufacturing processes where there might be potential losses in availability, performance, or quality, specifically in this order. Breaking this down in manufacturing processes handles around machines breaking down, planned stops such as maintenance, minor fixes or adjustments, a loss or speed, faulty product produced while running stable and faulty product produced from start-up until stable production.

In the case of this user journey and the triathlon context, these Six traditional losses need to be rewritten before they can be applicable. For this thesis Availability is rewritten as Moving forward. If not moving forward, this can either be an equipment failure, such as a flat tire, or a planned stop. Performance is rewritten to Speed. Are you moving forward yet less efficiently, for example when your feet are sitting on top of your shoes, or because you are readjusting things? Quality is re-specified as Failing. These are all other things that are going wrong, but not because of malfunctioning material, as this is already covered in Moving. Examples of this can contain a disqualification or making extra meters due to poor navigation.

2.3.3 The Triathlon Performance Indication Model

Figure 7 gives a visual overview of this newly developed Triathlon Performance Indication Model, as described in the previous two sub-chapters. The model translates the Lean and Six Big Losses methodology to the triathlon specific context.

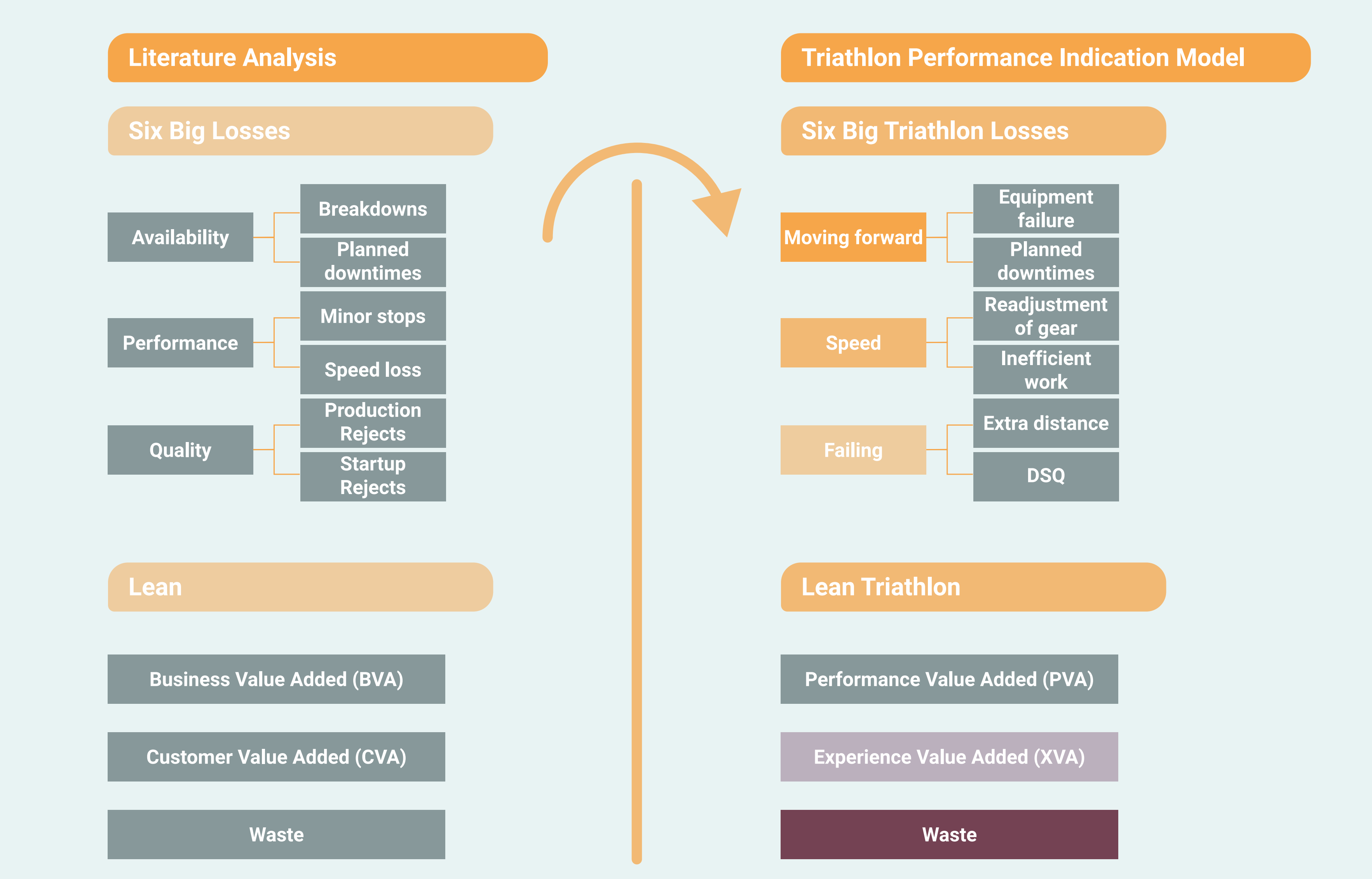


Figure 7: Visualisation of the Triathlon Performance Indication Model

The main takeaway here is that all actions within the timespan of start to finish will be thoroughly examined for whether they create value for the athlete, and if not what sort of loss it is. To this end I will zoom in on all the interactions during the race in more detail after having made the overall user journey.

Image 8: Me competing in the Dutch triathlon league

2.4 Bias in design: Me, Daan, Designer and Athlete

One of the ost challenging, yet interesting parts of this thesis is the fact that I am also part of the target group (see image 8). Seven seasons of racing triathlons have given me a unique perspective and familiarity with the domain, that can certainly help during the design process. On the other hand, it can also create certain blind spots. I probably have some form of confirmation bias in which there is a risk in which I am only designing for myself, or designing things that I experience, while there might be other relevant things to discover.

Sanders and Stappers (2012) propose to start each design process with a preconception mind map of the domain. This should help to start fresh as it helps reducing the risk that I, the researcher, project my own preconceptions on the participants. In my case I did a race, which I documented in a video and afterwards used to make a personal version of the user journey deliverable. In this way I had done a rough first draft completely based on my own assumptions, experiences, and preconceptions. This allowed me to feel way more open in the actual interviews. All my own opinions were already explicitly down on paper, so I did not need to find these anymore. Instead I could just observe. Furthermore, it created clarity and awareness on my personal bias.

What Is Systems Design? How to Surface Opportunities for Change (n.d.) elaborates on this assumption mind map in the beginning of the design process. At IDEO they ask themselves three distinct questions to be answered with associations. My assumption map can be seen in figure 9. The purpose of this exercise is not to verify whether these assumptions are valid, but rather to free up space in my head for curiosity.

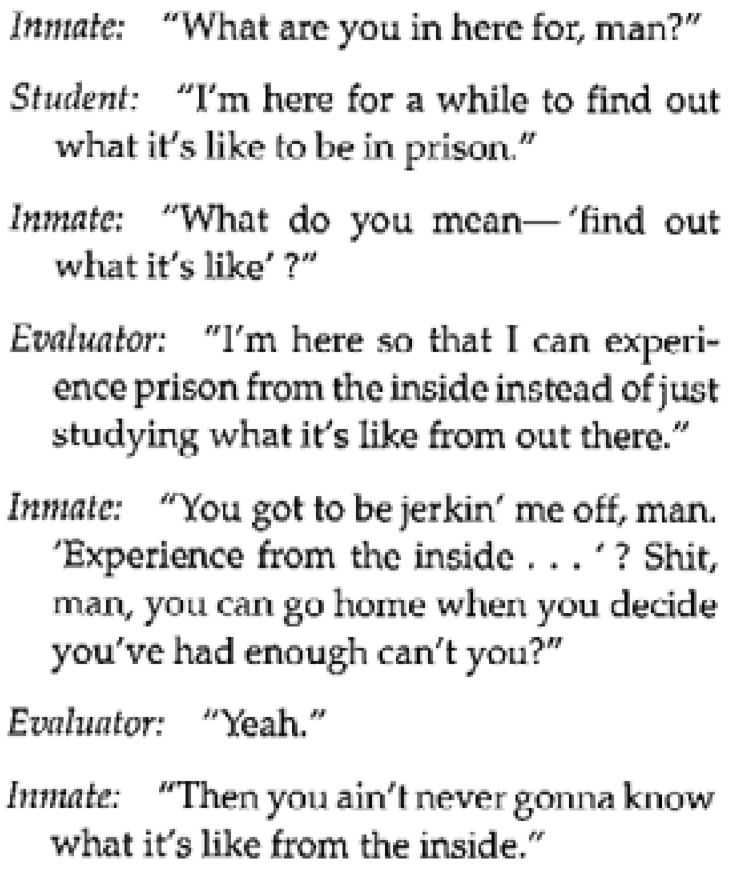
- What comes to mind when you think about this particular context or working with this community?
- Who comes to mind as groups, individuals, or images of folx in this community?
- What are some feelings that come up for you as we head into this work?

Figure 9: Preconception map of the assumptions in the beginning of the project

Sanders and Stappers (2012) also recommend making a clear distinction between raw data and interpretations. In this way it is clear for all the stakeholders in the process where certain information is coming from. In my case all the raw data that is coming from participants will be clearly labelled with their aliases. Therefore, if there is not a tag stating who said something, it is an interpretation, or leap. Transcribing parts of the data instead of notetaking was a method which allowed me to use raw data further along in the process, which is desirable since raw data leaves less room for interpretation.

In *Interviewing the Investigator: Strategies for Addressing Instrumentation and Researcher Bias Concerns in Qualitative Research* (Chenail, 2011) Chanail states that in qualitative research the instrument used is the researcher conducting the interview, hereafter referred to as investigator. To make the study repeatable it was interesting to run a pilot in which another researcher interviews the investigator, in other words: me. This improves the questions, promotes objectivity and the results can be juxtaposed with the real results to see where the differences lay.

However, being part of the target group is not necessarily something that makes interviewing difficult. Patton (2002) argues that it is almost impossible to do participatory research and become fully part of the user group, see image 10. Yet since I have been and am part of the target group, it is in fact possible for me to truly know what the experience is like. Furthermore, I am already aware of a great deal of the issues, experiences, jargon and have already a trusted relationship with the athletes, which takes those traditional interview barriers away.


Inmate: "What are you in here for, man?"

Student: "I'm here for a while to find out what it's like to be in prison."

Inmate: "What do you mean—'find out what it's like'?"

Evaluator: "I'm here so that I can experience prison from the inside instead of just studying what it's like from out there."

Inmate: "You got to be jerkin' me off, man. 'Experience from the inside . . . '? Shit, man, you can go home when you decide you've had enough can't you?"

Evaluator: "Yeah."

Inmate: "Then you ain't never gonna know what it's like from the inside."

Image 10: Excerpt from Patton on participatory observation

After the research phase, it can be argued that further extreme bias prevention is no longer necessary. Normally every researcher will be an expert in the investigated domain and have their own "darlings to kill". It means that I will still have a preference towards issues or solutions, but this is not that different from a "normal" design process. The common design practices of prototyping, testing and evaluation are already in place to try and work with or against those same confirmation biases.

2.5 Conclusion

- *Seemingly small improvements, when put together can have a strong impact on performance and optimising these little things is a way to innovate to success.*
- *It is possible to look at triathlon from a Lean & Six Big Losses approach and analyse the effectiveness of all the different steps, and what value they add.*
- *Putting this together means that if one can design a product that improves even one small element to make the triathlon step more effective, this is something worthwhile to dive deeper into and actualise.*
- *Several steps and techniques have been presented to use before and during the design process, to try and prevent too much confirmation bias due to the fact that I am an athlete myself.*

3. Discovery phase

finding design opportunities in triathlon

3.1 Introduction

In the previous chapter there was a glimpse of what is already known; how innovation could be achieved and the possible pitfalls and advantages of being a triathlete myself. As can be seen in figure 11 there were unanswered questions regarding the identification of design opportunities; where experience could be improved or problems could be solved. To this end a participatory observation, regular observations, and in-depth interviews were conducted; their methods and analysis can be seen in the first part of this chapter. The second half presents the results, where it first describes the race day experience and afterwards gathers all the identified steps and design opportunities in a user journey. This phase was the first diverging step in the double diamon process (figure 12)

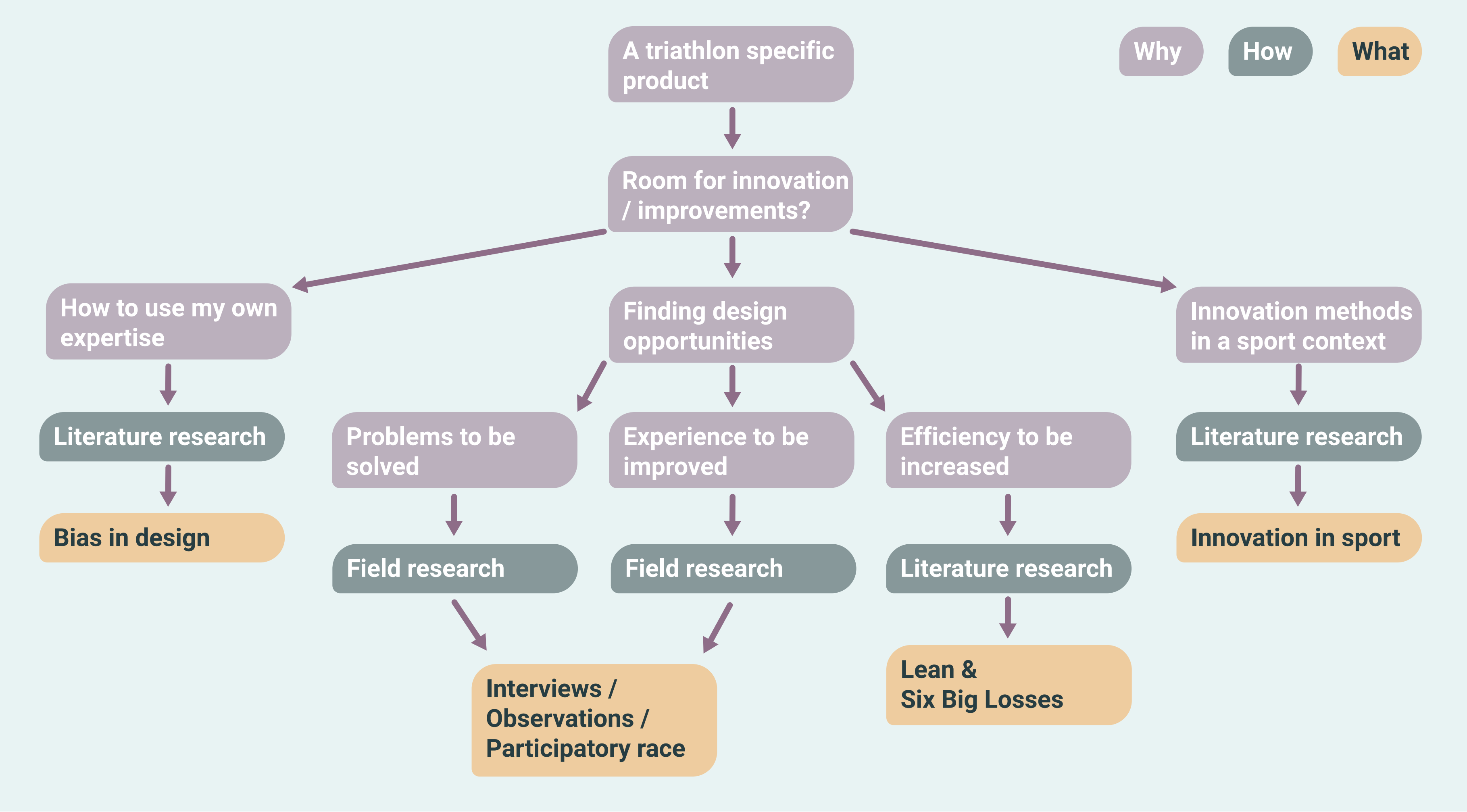


Figure 11: Research questions tree

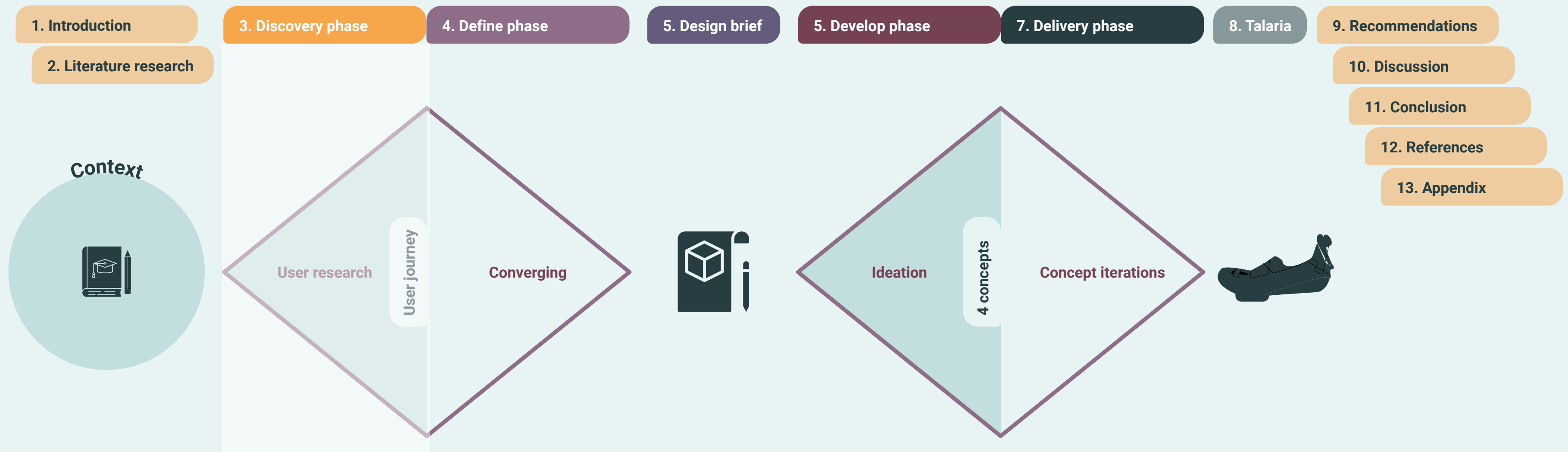


Figure 12: visualisation of the followed design process

3.2 Methods

This chapter serves to present how the results in the next subchapter were attained. These results are the combination of three different methods of data gathering, as can be seen in figure 13. These three different methods will be explained in further detail here, to give a more thorough understanding of their validity and origins.

Figure 13: Visualisation of data gathering methods to deliverables

3.2.1 Participatory observation during a race

The first step in this thesis was to participate in a triathlon event with a user-research mindset (see image 14 and 15). Patton (2002) states that there is always a degree of involvement from a researcher into a context. By consciously participating first, I have had the high involvement and aware look around to what was happening so that I could later take some distance in interviews and observations. This participatory observation was placed first in the process both because of time constraints, the season was nearing its end, but also because it functioned as a way to write down first assumptions, ideas and problems and put them on hold during the latter stages. This helped going into the interviews with a more open mindset. This first draft of a user journey can be seen on the next page.

The participatory race made it possible to do first observations,

Image 14: Impression of the participatory race

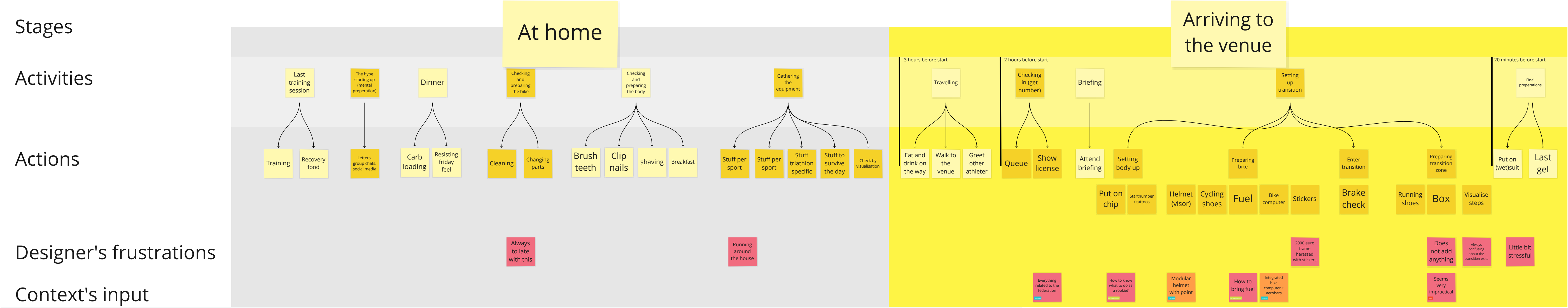
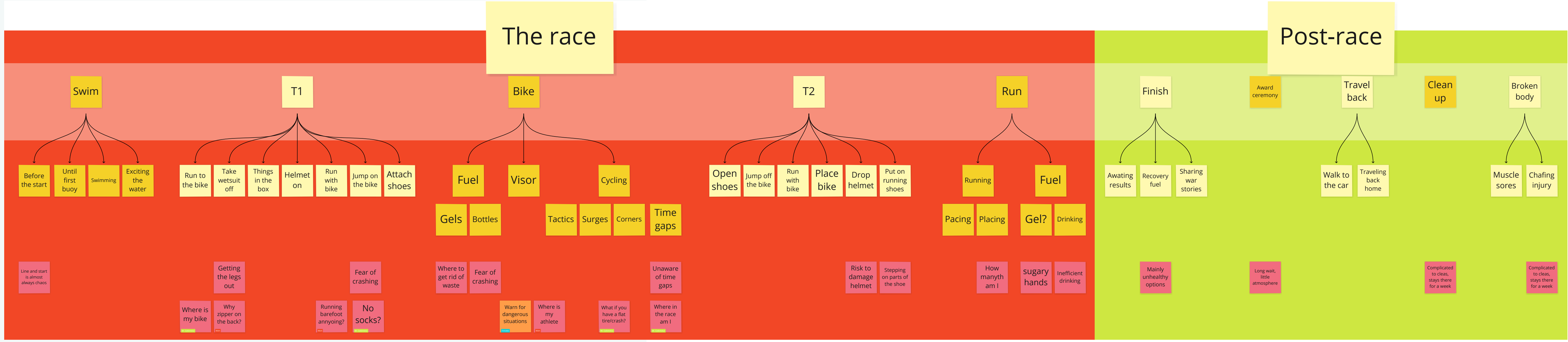


Figure 16: draft of a user-journey based on my own experiences



discover first problems and come up with ideas for improvements. The event was filmed*, which purpose was twofold: on the one hand it served to share the triathlon race day experience with the stakeholders in the project team. On the other hand, narrowing all the footage down into one comprehensible seven and a halve minute video forced me to make preliminary decisions on which steps in the experience were most relevant. I had to ask myself every single time again whether a certain shot was more important than the previous one. This creates a natural hierarchy of importance within the footage. This helped drafting up a first version of a user journey, to which my problems, as well as suggestions coming from my social context were added.

As said before these results were put to the side, in order to have a fresh perspective while adopting a more regular user-research approach in the in-depth interviews. It is impossible to truly make sure there is no interference, but this methodology served as a tool to prevent me from projecting my own preconceptions on participants and confirm my own bias, those were now already written down. It also presented an opportunity to at the end of the discovery phase check that there were new findings by comparing this initial user journey to the final results presented in chapter 3.3. This is done in the discussion part of this chapter.

Image 15: Impression 2 of the participatory race

**(https://www.youtube.com/watch?v=xCPabvt9WLE&ab_channel=DaanG)*

3.2.2 Interviews

There were several things that needed to be known about triathletes, and for which interviews were needed. These things were the elements in race day that were impossible for me to observe or experience myself.

- What are athletes' dreams and hopes in and with triathlon
- Things athletes have changed or learnt over time since they started
- What does the user journey for athletes look like on race day
    - Where are the high and low points on a race day?
    - What concerns or struggles do athletes experience during race day
    - What material specific problems do athletes encounter during race day
    - What do athletes wish for during race day

The interviews were conducted with nine participants (see image 17). An overview of their characteristics can be found in table 1. The first six participants were selected to be competing on a national level or higher. The interviews were conducted in Dutch since all participants had this as their native language and it would enable them to express themselves more nuanced and freely. Before the interviews a pilot was run in which a designer from outside the thesis and triathlon context "interviewed the investigator" (Chenail, 2011). This allowed for a fresh outside look to optimize questions, flow and probing sub-questions. Furthermore, it exposed unclear questions and uncomfortable elements in the interview flow.

After 5 participants the interview script was slightly altered to focus even more on the materials used during the race. This decision was made after a meeting with the project team where we discussed how we could steer the interviews even more towards the products athletes were using. For this image 18 was added, displaying all the materials I take with me to races. This allowed for a deeper exploration of materials used, and the visual cue was used to make it easier to talk about what products they experience problems with.

Furthermore, the script was slightly adjusted for interviews with beginner triathletes. The criteria for these beginner athletes were that they had recently started doing triathlon, but with a reasonably high level of ambition. It was hypothesised that the more experienced athletes might have been getting used to the peculiarities of the sport. Novice athletes, coming from other sports could provide a fresh perspective on the elemental difficulties of triathlon that the more experienced athletes have turned a blind eye to.

Name*	Gender	Age	Years as a triathlete	Races/year?	Highest level raced	Originating sport
Julia	Female	23	18	11 to 15	World Triathlon Cup Series	Swimming
Sem	Male	22	8	15+	World cup	Cycling and Waterpolo
Emma	Female	20	6	15+	World cup	Gymnastics and Soccer
Lucas	Male	22	12	11 to 15	European cup	Cycling
Luuk	Male	20	7	6 to 10	European cup	Soccer, Ice skating, Cycling
Levi	Male	29	8	6 to 10	Premier League	Waterpolo
Liam	Male	28	4, one year seriously	1 to 5	3rd division	Running
Finn	Male	25	1	6 to 10	Regular races	Cycling
Noah	Male	22	1	1 to 5	Regular races	Running

Table 1: Interviewees ranked from elite to beginner. **Names are altered for privacy purposes*

To give an indication, several of the asked questions are presented on this page, for the full topic guide and interview script consult appendix 14.2.

> *Imagine I know nothing about triathlon, and we meet at school. How would you describe what you do?*
>
> *What are the highlights on race day for you?*
>
> *What are the most stressful moments?*
>
> *If I were to follow you around for a race day, what would that look like?*
>
> *Do you ever feel let down by your equipment? If so, when?*
>
> *What do you think triathlon will look like in 20 years?*
>
> *Which equipment do you think the triathlon world champion has in 40 years from now?*

A selection of athletes was shown transitions of their own race thereby the interviews contained elements of observation. The next chapter elaborates further on the observation part of the user research phase.

Image 18: All the materials I take with me to races

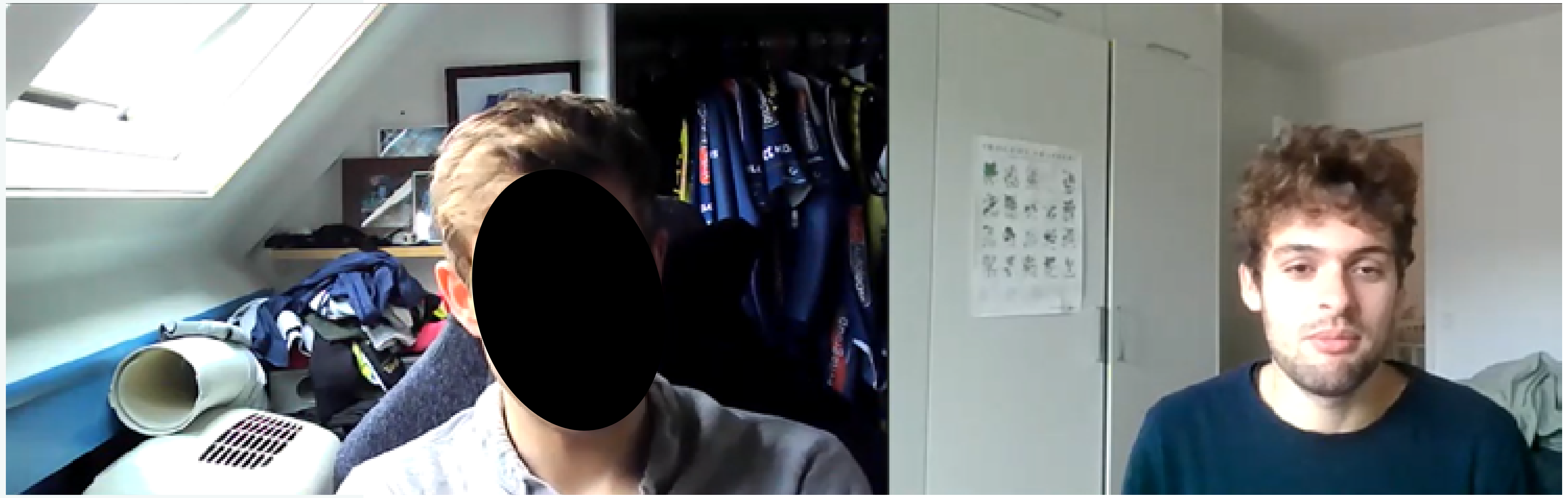


Image 17: Impression of an interview

3.2.3 Observation

After the participatory race and the interviews, I looked at what can be observed during a race as an onlooker. Are there things happening that the athletes themselves are not aware of? Or can I confirm that the problems they brought up during the interviews can be observed as well? I collected data in three different ways.

- Before and after the participatory race I observed **the actions of other athletes including the designs of their transition zones**. In another race I observed how athletes were executing their race (image 19). This was done in different spots around transition, as the individual legs are far away and therefore inaccessible (the cycling racecourse was almost 10 km).

- **Transition footage** from a race in the Dutch triathlon premier league was shown to the athletes during the interview and questions were asked regarding their actions and thoughts, as well as how they would judge their own performances in said transitions.

- **Desk research on pro-level triathlon races** on YouTube by watching World Triathlon's (triathlons governing body) 6 most popular videos. I analysed Global triathlon's channel, which came forward in the interviews, and kept a designer's eye out for insights on Instagram. Furthermore, I watched Super League Triathlon Mallorca: Sprint Enduro (both men's and women's), as this included an overview through a well-recorded race of world-class athletes who did two succeeding short triathlons.

Image 19: Observed transition footage

3.2.4 Data Analysis

3.2.4.1 Clustering
All the generated data was collected, and a division was made between two things that I wanted to know: the steps people take during a race day, and what problems, dreams & wishes they have during said race day. The self reported user journeys of the athletes were combined, and all their actions were grouped to distill the main phases of the user journey.

To find the problems, insights coming from the participatory race and context, the interviews and the observations were joined together and clustered or grouped to find patterns (see figure 20). A cluster was interpreted here as a group of insights that tell one specific story. Yet in the research, a substantial amount of information was gathered on trisuits or wetsuits, and instead of placing all these in separate clusters, sometimes they were grouped together so that in a possible redesign it would be clear what should be changed.

These clusters were divided into those that presented pain points, and those that were more descriptive in nature. The descriptive ones formed a starting point for the narrative in chapter 3.3.1, whereas the pain points were combined into design opportunities, in which a design opportunity is defined here as *a possible point of intervention based on one or more pains.*

3.2.4.2 Filtering
Before moving these design opportunities onto the user journey, a filter was applied for:

- Things only concerning elite or long-distance athletes (doping control and overnight bike stays)
- Problems that were already solved but not commonplace yet (Cadomotus already offering a magnetic click system in their helmets)
- Problems almost impossible to solve using solely products (preventing injuries)

3.2.4.3 Application of the Triathlon Performance Indication Model
When looking at the user-journey, it presents a lot of different steps. I put these different steps behind each other to make the whole process clearer, as well as making it possible to apply the Triathlon Performance Indication Model. To decide for each individual step is it added value or had a risk to be a loss.

Figure 20: Impression and process picture of the data analysis

3.3 Results

3.3.1 Triathlon and Triathletes - a deeper understanding

The goal of this sub-chapter is to give an impression of what a race is like for most athletes, as well as what that target group is like themselves. This background information is necessary to be able to make informed decisions during the design process. Solving certain problems can have more impact on the athlete’s experience than others.

3.3.1.1 What the race is like

The swim is incredibly fast, chaotic and a real fight (see image 21). Yet you must join this ‘washing machine’, as it is usually a deciding moment in a race. You can not win the race there, but you can lose it. Usually, beginners struggle the most with this discipline as they feel their legs are sinking due to poor technique.

> *“In the water it's just complete chaos all the time, I think that's a good summary of the swimming part.” - Luuk*

> *“To the swim start [I am] very nervous because it can be quite chaotic. Also because it can be decisive for the race.” - Levi*

Image 21: Chaos during the swim (image taken from ZDF broadcasting the German championships)

Then comes the transition, as distances are getting shorter and more explosive, transitions are gaining importance rapidly. They are sometimes referred to as the 4th discipline, and athletes need to practice this. In the interviews I performed, the athletes said they practiced this mostly when they were younger but a considerable amount of them freshen up on it the week before the race. When talking with athletes about improving equipment, this is as triathlon specific as it gets, they feel that transitions are the places where there should be triathlon specific innovation opportunities. The first transition is tough as you change from a horizontal to a vertical position, and the change in muscle groups is quite large. Yet you have to sprint here (see image 22), as right after the swim groups are formed on the bike, and if you miss the big ones your race is more or less over.

> *"Running as hard as possible to the transition […] that is quite difficult […] in the past always really tough […] mentally something that you have to push" - Emma*

Image 22: sprinting to transition to make it to the right group

Image 23: All out cycling to make it to the bigger groups, while at the same time trying to drop competitors (image retrieved from Teamcompetities Triathlon)

Forming these groups (see image 23) means that the first part of the bike leg is usually intense, and after a few laps it becomes clear whether groups will melt together or gain time on each other. Interesting to note is that sometimes motoric skills get tricky when it is going fast. Athletes often wear sunglasses, because of flies or the sun in their eyes. Co-operation can be a source of frustration when half the people in a group try to save energy for the run and the other half wants to try to race as hard as possible. When these "savers" take inefficient turns at the front and halter the groups flow this is found to be frustrating. However, this is also part of the game.

After this there is a switch to the run, here it is usually a big group that runs together and one by one people drop off or accelerate off the front. When it is warm, or people have long hair, headbands and caps are sometimes worn. Sunglasses are often kept on after the cycling.

After the race people are done. Drained. See image 24. There is nothing more they want to do or invest energy in, except for perhaps getting a nice comfort food dinner.

Six out of the nine participants preferred T2 (from cycling to running) over T1 (from swimming to cycling). They often reported that the first transition gave them stress and that a lot could go wrong. One person was undecided, as the first transition gave the possibility to break the pack up, but the second one meant they were almost done. The two people that preferred T1 either liked the challenge it posed or were just happy the swim was over.

> *"The first transition is the most fun, the most stressful, but I also enjoy it when it goes well." - Noah*

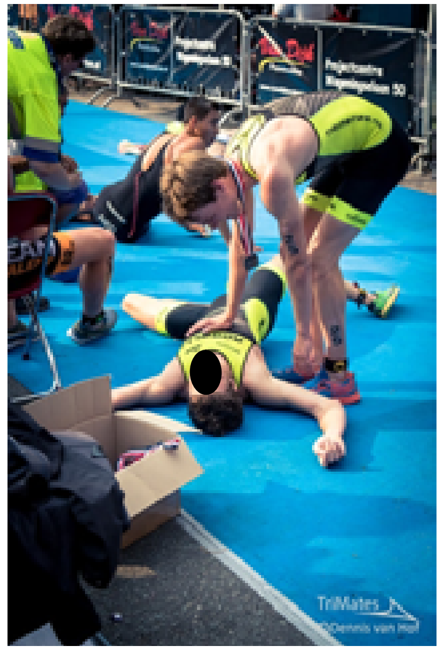
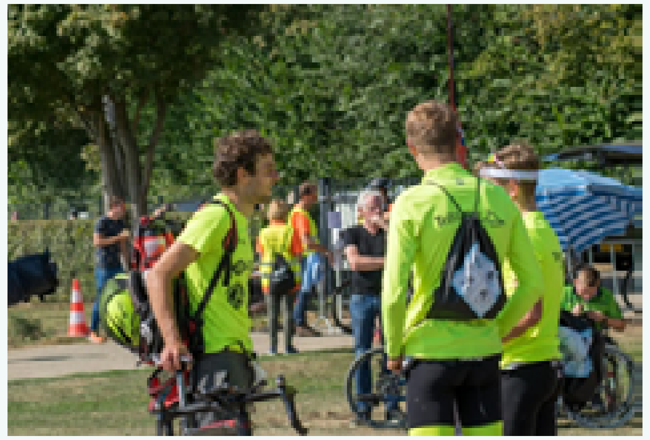


Image 24: Immediately post-race situation

Highlights of the triathlon day as reported by athletes were the build-up to the start with the race tension, arriving at the race venue and seeing friendly and familiar faces for a chat. The finish was another highly appreciated highlight, and afterwards there is again room for having fun with the people of the team or supporters. This social component is highly valued. Overall, it seemed like the highlight was not a specific point during the race per se, but the whole experience and flow around it (see image 25 to 27).



Images 25 to 27: Pre- and post-race catchups

3.3.1.2 What triathletes are like

The reason participants did triathlon was that it allows them to train in a variety of ways, that it was a combination between tactics, endurance, and power and that there were fewer crashes than in cycling. This variety also helps to always keep on learning something new and improving. It was also appreciated that it allowed them to be outside a lot.

> *"It gives peace and it makes me happy. Perhaps because you are really focussed on something that is otherwise totally useless." - Levi*

The athletes want to use the best gear. Sponsorships are hard to get in a small sport such as triathlon, and athletes sometimes feel they are not getting back enough from some of their sponsors, especially if they feel like they are not getting the right equipment. For example, when Nike created the carbon sole in their Vaporfly shoe that made everyone run faster, athletes do not like being bound to inferior shoe brands. They want the best material, even if it might not be triathlon specific, it just needs to be the best on the market. For example, several athletes reported that the Vaporfly was inefficient for triathlon, as the tongue did not help to get into the shoes. See image 28.

> *"Good competition shoes, for example I have Vaporflys and they are just worth the money because they have a good carbon plate and they just make you run faster. The shoes have been well thought out, very light and water is drained a bit in the rain." - Emma*

Part of the reason for this might be that they are also looking at what the pros are doing and wearing. As one athlete said that the Asics shoe is nowadays probably the quickest, as all the pros at the Olympics were wearing that shoe.
These pros might also be trendsetters that have more influence than it seems at first glance. To an outsider the tight suits might perhaps look a bit odd, and the sport might not scream coolness per se. There are nevertheless clear lines within the sport of what is cool and what is not. Athletes will have this as a clear criterion when choosing for example between a cap or a sweatband.

> *"Do you know that one with the squares. I really am not going to go walk around with that, it also needs to look a little bit cool." – Finn*

Image 28: Nike Vaporfly shoe, when closed, the tongue falls inside and the shoe is hard to get on. To get the tongue out, the laces need to be loosened.

3.3.1.3 What the future of triathlon might be like

Consensus amongst interview participants was that there is a strong trend towards shorter, more explosive, and spectacular formats. Which exact formats is not necessarily clear yet, but the rise of super league and the success of the mixed relay (which had its debut on the Tokyo 2020 Olympics), combined with the fact that the most popular videos were also sprint finishes, indicates that that is a direction the sport might be going. One participant even thought that the Olympic Distance might be disappearing from the Olympics in the upcoming years. The development of media coverage might play a big part I this.

> *"Equipment will have more and more influence on who will win as the level gets higher and closer together. So in the end I think the material is at some point going to make the differences somewhere." - Julia*

On the future of long-distance people were divided. Its popularity might decrease a bit with the popularity of short course, but on the other side, the long distance is one of the most legendary endurance events, and might remain popular.

As for the future equipment, participants often discussed developments in respective sports rather than triathlon specific ones. Many expected there to be faster and more integrated bikes and quicker running shoes for example. One shoe for all disciplines was only mentioned twice. Development is nice but *"a bike should also stay a bike" – Finn*. This could be interpreted as that participants want it to stay swim-bike-run rather than one fluid event.

3.3.2 Common problems

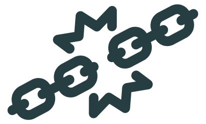
The data from the user-research was also crosschecked for the quantitative presence of issues; meaning which problem clusters came forward most often during the research. The six issues that stood out most, starting from the most common:

Wetsuit problems
Wetsuits are great for swimming, and their benefit in speed is enormous. However, taking them off proofs quite difficult for athletes, and there are many different spots where this interaction crashes. Moreover, some athletes reported that it was hard to run in them, yet that is something that is quite often required.

Tricky to put running shoes on
Running shoes are often not designed triathlon specific, and athletes therefore struggle putting them on quickly. The heel gets stuck, or they still need some form of tightening.

Many different, chaotic steps make it stressful when they go wrong
There are many things that need to be done from the moment an athlete arrives at the race venue. When one of these things takes a little bit longer, for example a long line at check-in, this creates stress to get everything done before the start.

Problems dropping last minute things
In the final moments before the race the athletes often have some stuff left, for example a towel, asthma pump, a gel or something to eat or drink. In the last minutes of the race it can be tricky to know where to leave these things, if the bag is checked in in transition for example. Often coaches or parents take care of this, but what if the athlete is alone.

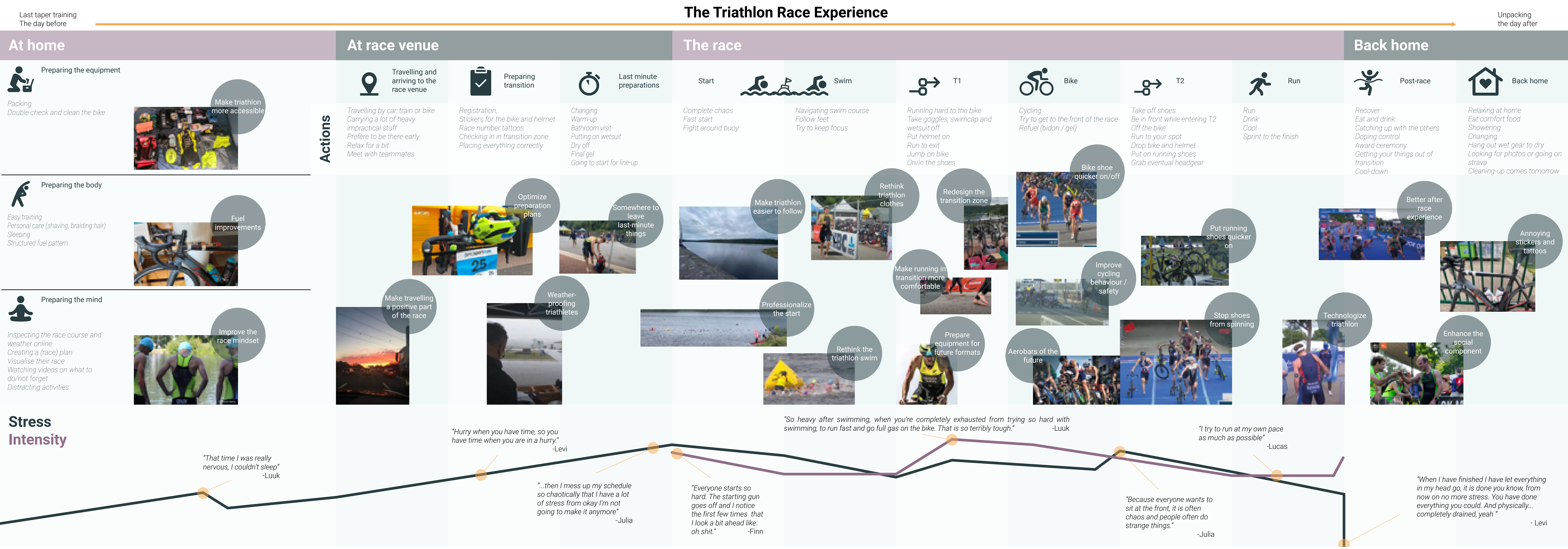


Depending on complicated gear that can break
When asked if their material ever let them down, the first thought almost always goes to the bicycle: athletes are essentially dependent on that. A flat tire or problems with shifting and your race can be over. It is therefore, that athletes often spend extensive effort checking their gear, but of course not all issues can be prevented.

Difficult open water swim skills are necessary
Navigation and manoeuvring through the pack, playing it tactical and holding focus during the swim are important, yet quite difficult, especially for those without a swimmer's background.

3.3.3 Race day user journey

The resulting user journey can be found on the next page. Each of the green circles contains one of the design opportunities identified in the field research, which will be presented more in-depth thereafter.


The Triathlon Race Experience
Last taper training
The day before
Unpacking
the day after
At home
At race venue
The race
Back home
Preparing the equipment
Packing
Double check and clean the bike
Make triathlon more accessible
Preparing the body
Easy training
Personal care (shaving, braiding hair)
Sleeping
Structured fuel pattern.
Fuel improvements
Preparing the mind
Inspecting the race course and weather online
Creating a (race) plan
Visualise their race
Watching videos on what to do/not forget
Distracting activities
Improve the race mindset
Actions
Travelling and arriving to the race venue
Travelling by car, train or bike
Carrying a lot of heavy impractical stuff
Prefere to be there early
Relax for a bit
Meet with teammates
Preparing transition
Registration,
Stickers for the bike and helmet
Race number tattoos
Checking in in transition zone
Placing everything correctly
Last minute preparations
Changing
Warm-up
Bathroom visit
Putting on wetsuit
Dry off
Final gel
Going to start for line-up
Start
Complete chaos
Fast start
Fight around buoy
Swim
Navigating swim course
Follow feet
Try to keep focus
T1
Running hard to the bike
Take goggles, swimcap and wetsuit off
Put helmet on
Run to exit
Jump on bike
On/in the shoes
Bike
Cycling
Try to get to the front of the race
Refuel (bidon / gel)
T2
Take off shoes
Be in front while entering T2
Off the bike
Run to your spot
Drop bike and helmet
Put on running shoes
Grab eventual headgear
Run
Run
Drink
Cool
Sprint to the finish
Post-race
Recover
Eat and drink
Catching up with the others
Doping control
Award ceremony
Getting your things out of transition
Cool-down
Back home
Relaxing at home
Eat comfort food
Showering
Changing
Hang out wet gear to dry
Looking for photos or going on strava
Cleaning-up comes tomorrow
Optimize preparation plans
Somewhere to leave last-minute things
Make travelling a positive part of the race
Weather-proofing triathletes
Make triathlon easier to follow
Professionalize the start
Rethink the triathlon swim
Rethink triathlon clothes
Redesign the transition zone
Make running in transition more comfortable
Prepare equipment for future formats
Bike shoe quicker on/off
Improve cycling behaviour / safety
Aerobars of the future
Put running shoes quicker on
Stop shoes from spinning
Technologize triathlon
Better after race experience
Annoying stickers and tattoos
Enhance the social component
Stress
Intensity
"That time I was really nervous, I couldn't sleep" -Luuk
"Hurry when you have time, so you have time when you are in a hurry." -Levi
"...then I mess up my schedule so chaotically that I have a lot of stress from okay I'm not going to make it anymore" -Julia
"Everyone starts so hard. The starting gun goes off and I notice the first few times that I look a bit ahead like: oh shit." -Finn
"So heavy after swimming, when you're completely exhausted from trying so hard with swimming, to run fast and go full gas on the bike. That is so terribly tough." -Luuk
"Because everyone wants to sit at the front, it is often chaos and people often do strange things." -Julia
"I try to run at my own pace as much as possible" -Lucas
"When I have finished I have let everything in my head go, it is done you know, from now on no more stress. You have done everything you could. And physically... completely drained, yeah " - Levi

3.3.3.1 Design opportunities
23 different possible design opportunities were identified. These opportunities do however not exist in isolation; one product could serve several design opportunities at once. For example, using a digital solution during the swim could be a way to address both *Rethink the triathlon swim* and *Technologize triathlon*:

At home

- Make the sport more accessible: you need a lot and expensive equipment to be competitive in triathlon.
- Fuel improvements: gels taped to the frame can be lost, and fuelling on the run is difficult.
- Improve the race mindset: can a positive and adequate race mindset be reinforced during the race.

At race venue

- Make travelling a positive part of the race: it often takes quite a while of “dead” time to get to race venues.
- Weatherproofing athletes: it is often hard to stay cool or warm before and during races.
- Optimize preparation plans: there are strict schedules with many steps that triathletes must follow before the race, and nothing can go wrong.
- Somewhere to leave last-minute things: after checking in in transition, athletes usually still use something like a towel to dry off after a warm-up swim. But when alone they have nowhere safe to leave these things.

The race

- Make triathlon easier to follow: right now it is hard to know who is where in the race, both for spectators and athletes themselves.
- Professionalize the start: the start at triathlon is often only auditory, unclear, and unfair.
- Rethink the triathlon swim: a chaotic fight with tricky navigation and big buoys, can swimming be done smarter?
- Rethink triathlon clothes: right now, triathlon has a wetsuit and a tri suit, but it does not have to be that way.
- Redesigning the transition zone: a tight transition zone where people bump into each other, bikes fall out of racks and useless boxes are just standing around.
- Make running in transition more comfortable: running barefoot on asphalt hurts, and wet mats are often slippery.
- Prepare equipment for future formats: short distance races with several triathlons behind each other asks new things of the equipment, for example when using the bike for the second time, the elastic bands are gone.
- Bike shoe quicker on/off: right now, jumping into the shoes is not going well, and tightening as well as taking them off takes time and makes people loose speed.
- Improve cycling behaviour / safety: how can we stop illegal drafting and avoid crashes on the bike.
- Aerobars of the future: cheaper, customised and integrating aerobars that fit on all steering bars and provide a solution for sunglasses in transition.
- Put running shoes on quicker: athletes have often trouble getting into their running shoes.
- Stop shoes from spinning: after cycling the cycling shoes tend to start spinning, which has a risk of the bike “jumping” as well as them getting stuck to the floor and being damaged/falling off.
- Technologize triathlon: triathlon is still in its core old-school racing. No watches, maybe a power meter on the bike, but most of the decisions are made without digital technology or data.

Back home

- **Better after race experience**: even though there is a strong and appreciated social component at the finish line, there are several elements that could be improved such as more space to relax, better fitting food and less actions required before one can crash on one's couch.
- **Enhance the social component**: one of triathlons key strengths is that it is in fact quite social for being an individual sport, yet this is not seen during most of the races.
- **Annoying stickers and tattoos**: taping stickers to an expensive bicycle frame and helmet seems odd, apart from that they never sit perfectly, and that the race number tattoos on your arms and legs are hard to remove.

3.3.4 Application of the Triathlon Performance Indication Model

As discussed in chapter 2.3, triathlon can also be viewed as a production process and be analysed using the Triathlon Performance Indication Model. In figure 29 all the actions of the triathlon are mapped out and marked according to this method. Those steps containing one or several of the big losses and/or including waste present possible points of intervention.

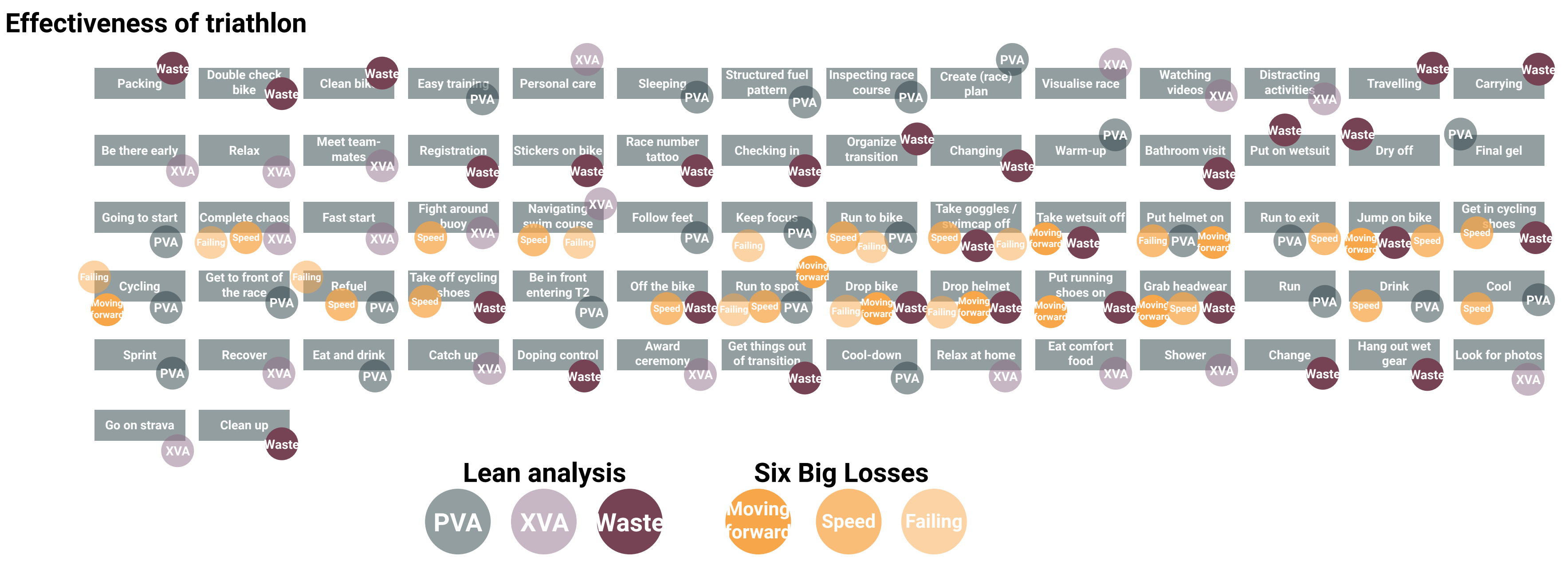


Figure 29: Application of the Triathlon Performance Indication Model

This is a visualisation of the application of an effectiveness lens in triathlon. If we take the whole value chain apart, there are many opportunities to improve and create marginal gains. Figure 29 is not directly influencing the converging phase in the next chapter, but it was instrumental in adopting a *"marginal gains/effectiveness"*-mindset that I used further on in the design phases.

3.4 Discussion

As mentioned in the previous chapters, **confirmation bias** and thereby designing for yourself is the biggest risk when I as a designer am also part of the target group. An extensive and carefully chosen design process was put in place to manage this phenomenon. To further check the validity of the results, meaning whether I learned new things during the discovery phase, it is possible to compare the initial user journey drafted by me after the participant observation (see page 22) to the final user journey after the interviews and observations (see page 34). They have a lot of significant differences. Later on, I will choose to zoom in on the problem areas of getting quickly into the bike shoes and to stop them from spinning. What is important to note here is that those were lacking on this first self-made map. Meaning that one can conclude that I am most likely not (just) designing for myself.

Interviewing novice athletes turned out to be two-folded. On the one hand it was useful, as they exposed some things of the sport that the pros are missing, for example the complexity of it all, or how many things you need and how expensive that gets. On the other hand, some of their problems will go away with time, as they are now lacking skills and experience, as well as triathlon specific equipment. It is important to be aware that these problems exist as they undeniably have a market and could be catered for. However, as explained in the introductory chapter, my focus is on elite athletes. In the end it was absolutely the right choice to also include this target group in the participant pool, as they brought interesting things up such as that running barefoot hurts. Something which the elite athletes probably also dislike but have grown accustomed to.

For the most common problems: I am aware that this is qualitative research and how often things come up is not necessarily representative. For example, maybe only one person is able to put into words something that all of them suffer from yet didn't think of nor realised. Additionally, the specific questions asked, as well as interviewer bias, might lead to some things coming forward more often. It is therefore that this quantitative approach is not a decisive factor; yet something that six out of nine people experience issues with is worthwhile taking an extra thorough look at. To that end they are explained more in-depth in the results chapter

3.5 Conclusion

The main goal of the field research was to identify what actions characterize triathlon, to get a glimpse into what triathletes are like and how they experience their races, and finally to identify possible areas for design interventions. After doing a participatory race, nine interviews and several observations a significant amount of data was gathered. When all of this field research data was combined and clustered, a user-journey with 23 possible design opportunities was generated and presented to the company. The next chapter is going to explain how I went from these 23 possibilities to one design brief.

4. Define phase

converging to the design brief

4.1 Introduction

In the previous chapter 23 different design opportunities were presented, and this chapter is going to explain the second half of the user research phase, as can be seen in figure 30. This chapter explains how the scope narrowed from 23 different design opportunities to two, synthesised into one design brief.

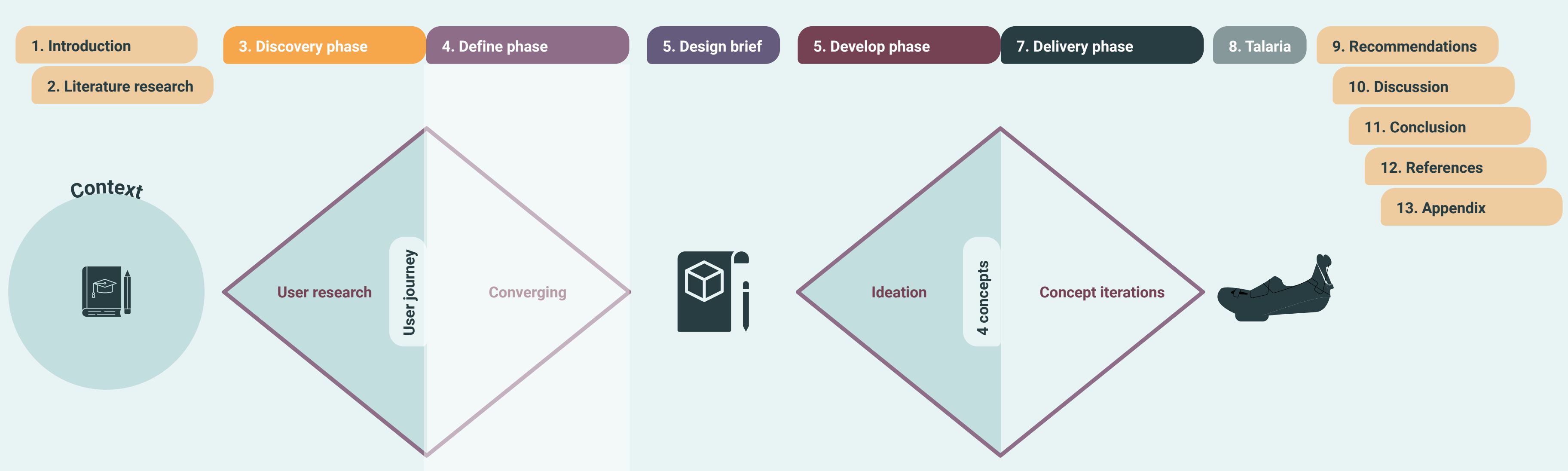


Figure 30: visualisation of the followed design process

4.2 Method

In order to create both value for the company as well as keeping a user-centric approach, both stakeholders were consulted in an attempt to narrow the 23 different design opportunities down to one. Together with Cadomotus the design opportunities were narrowed down to eight that were interesting to explore further within the scope of this project. Knock-out criteria used for narrowing the scope were:

- The design opportunity is not specifically related to triathlon
- The design area is not focussed on the athlete (too much other stakeholders such as organisations for example)
- The design opportunity does not fit Cadomotus' expertise and brand

Afterwards interviews were held with six athletes (see table 2) that hadn't been consulted before. This was to discover if the identified problems were also present outside the original participant pool. Each participant was asked their opinion on the eight identified design opportunities, as well as how recognisable they were and how important they deemed it to solve them. The full interview recruitment, script and data analysis can be found in appendix 14.3.

Name	Age	Gender	Years of triathlon experience	How many races a year	Category
Olivia	18	Female	4	6 tot 10	Elite athlete
Oliver	22	Male	6	11 tot 15	Elite athlete
William	33	Male	6	6 tot 10	Fanatic amateur
Alice	20	Female	9	11 tot 15	Elite athlete
Elias	32	Male	10	6 tot 10	Fanatic amateur
Hugo	34	Male	10	1 tot 5	Retired

Table 2: Participants in the second round of interviews ranked by experience

The results from these interviews were used as a base for Harris profiles (Van Boeijen, Daalhuizen, van der Schoor, Zijlstra, 2013) (Figure 31). The requirements used were:

1. Focus on the athlete rather than organisation
2. Desirable for the athletes (coming from the interviews)
3. Recognisable to the athletes (coming from the interviews)
4. Create value for the company (filled in by Cadomotus)
5. Help athletes to keep moving forward (Triathlon Performance Indication Model)
6. Help athletes to increase their speed (Triathlon Performance Indication Model)
7. The innovation is disruptive (different and visible)
8. Implementable in the near future (fit within the current rules and available technology)
9. Create societal impact (Improve safety or reduce waste)
10. Large potential target group size (the solution is valuable and transferable to non-elite athletes as well)

Harris profiles

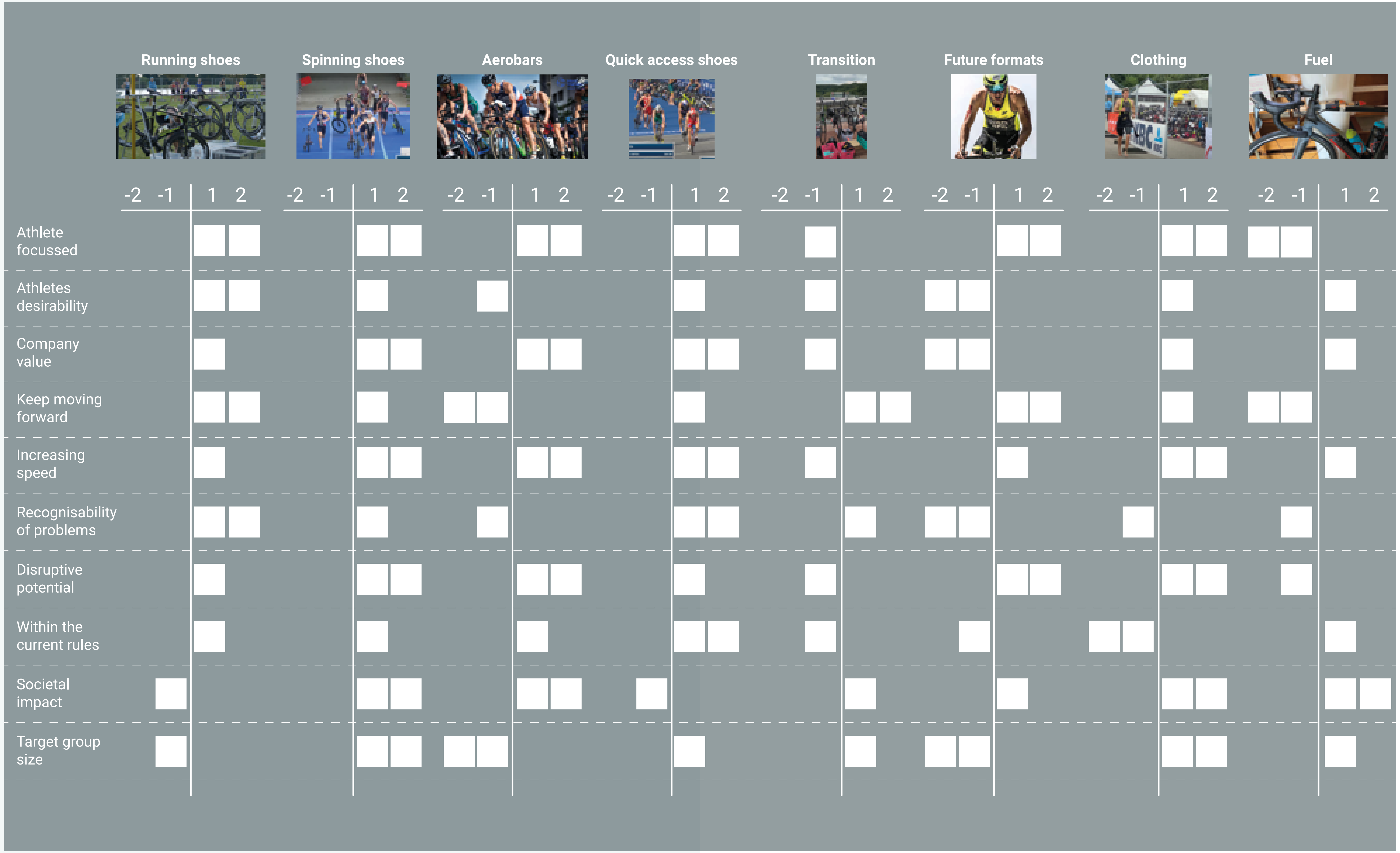


Figure 31: overview of the Harris profiles generated from the second round of interviews

4.3 Conclusion

Based on the Harris profiles and conversations with athletes and Cadomotus, I decided to focus on the cycling shoes. By doing this I could address two different design opportunities in one; the problem of "quickly getting in" and that of "the cycling shoes are spinning in T2". Furthermore, it fits with Cadomotus' future plans and expertise. By working on cycling shoes I would therefore add considerable value to both the users and the company.

- **Bike shoe quicker on/off:** *right now, jumping into the shoes is not going well, and tightening as well as taking them off takes time and makes people loose speed.*
- **Stop shoes from spinning:** *after cycling the cycling shoes have a tendency to start spinning, which has a risk of the bike "jumping" when they hit the ground as well as the shoes getting stuck to the floor and being damaged/falling off.*

The design brief introduced in the next chapter will further elaborate on these problems and their context.

5. Design Brief

This chapter introduces the design brief used in the second phase of this project. Firstly the problem is introduced in more detail, while the second part describes the how; what is the goal of our design, how should it be experienced by users and what should a user be able to do with it.

Image 32: the current regular triathlon shoe.

5.1 Problem statement

The problem, as defined in chapter 4, is that the current triathlon cycling shoe is minimally adjusted to triathlon context.

Currently there are only minor differences (a loop on the back and Velcro bands to close, see image 32) in comparison to the traditional bike shoe. They have been designed to make the shoe quicker for triathlon, yet the shoe has not been redesigned from scratch with the sole purpose of making it ideal for triathlon. There are two main problems that derive from the research, which are that the shoes need to be easier to get in/out of and that the shoes are spinning when there is no power on them.

Goals that athletes have:

Time
Athletes want to start powering their bikes as quickly as possible without hesitations

Power
Have an optimal power transfer from muscles to bike

Distance
Deliver power to the bike until the last meter

Quick transition
Losing as little time as possible releasing feet from the bike

Design challenges:
- How can you make it easier to step into a shoe?
- How can you close a shoe?
- How to lock a foot on a bike?
- How can you open a shoe?
- How to keep the shoe from spinning?

Relevant context factors include:
- Many people jumping on at once in close proximity
- Tight transition areas
- Having bare feet
- Being dizzy
- Lowered motoric skills due to the impact of intense physical exercise

What should be **avoided at all costs** is the creation of unsafe situations.

It is **admissible** to have to do an action to release the feet, as you also want them to not accidentally release.

5.2 Design Goal & Interaction Vision

This sub-chapter describes the envisioned solution to the problem described before. The Design Goal introduced first explains what it is we (company and designer) want to design, and the Interaction Vision explains how we want it to feel for athletes.

5.2.1 Design Goal

> ***We want competitive short-course athletes to focus primarily on their race by taking care of their needs for them while delivering a similar performance as the current triathlon shoes***

The **desired impact** with the design is to:

- Increase safety
- Increase athletes' confidence
- Disrupt the industry
- Take away athletes' stress
- Keep moving forward more, fail less, lose less speed
- (Increase sustainability)

Affordances that the developed concept needs to fulfil are:

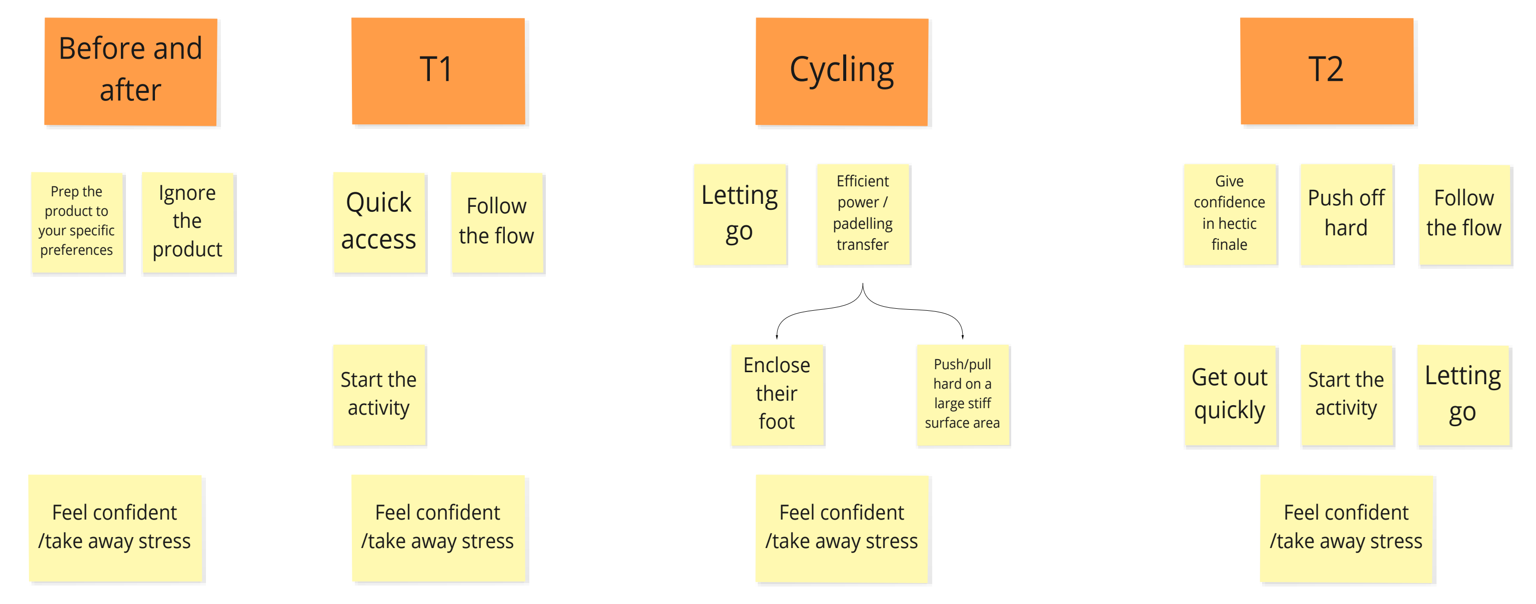


Image 33: Visualisation of the Interaction Vision

5.2.2 Interaction Vision

Going down a waterslide (jumping in on the waterslide)

You decide <u>when to go</u>. Once you jump there is a certain <u>flow</u> that you get used to. There are many turns and twists, but you have to do next to nothing, you should just go with the flow. It might be scary at first, but since it is always the same and never goes wrong, you can <u>trust</u> the system. You <u>focus</u> on a point <u>ahead</u> of time (the next corner or jumping out) instead of what is happening right now. You enjoy what is happening, there is a certain rush when going through the slide. Jumping into the chute and accelerating all the time gives <u>a big boost</u>. At the end of the slide, you are explosively <u>propelled out</u>. This goes really quickly, giving you a boost again while always occurring in the same way and at the same time. See image 33.

Desired interaction characteristics, derived from the interaction vision were:

- Exciting
- Safe
- Confident
- Speedy
- Thrilled
- Easy

Design properties observed in the interaction vision:

- High walls; unable to fall out
- Glide; you determine the speed
- Shallow corners; know where the flow goes
- Shift in material; indicate next steps
- Repeatable; each time it is exactly the same

6. Develop phase:

from Project brief to four different concepts

6.1 Introduction

This chapter explains how four different concepts were generated, based on the design brief introduced in the previous chapter. A creative session helped to broaden the range of ideas, after which a morphological chart led to four different concepts. The final part of this chapter presents the evaluation of the concepts. This led to the converging strategy which was the basis for the next phase: delivery (see figure 34).

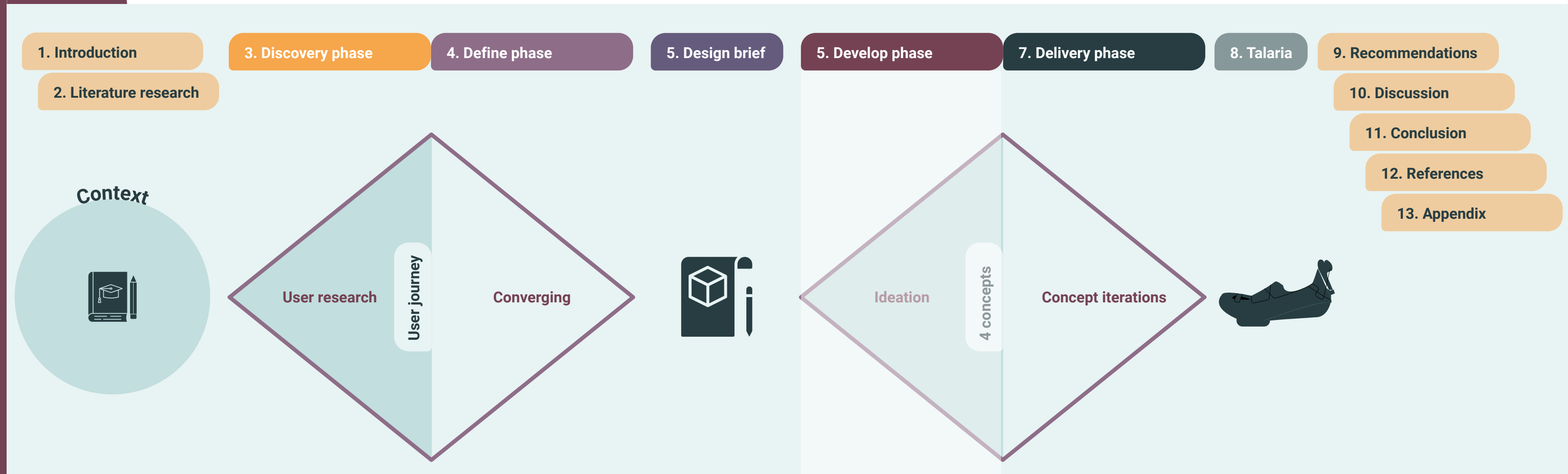


Figure 34: visualisation of the followed design process

Image 35: Impression of the creative session

6.2 Creative session

To maximise the range of possible ideas to move forward with, I held a digital creative session (image 35) with eight participants. I got outsiders to add their own unique perspective. Participants came from all the different design masters + one mechanical engineer. Two triathletes joined as well, as they could add contextual experience to the mix during the group discussions.

The session started with an introduction to the thesis project and the design opportunities identified. To further immerse in the context, participants were asked how they would like to feel when jumping on the bike during a triathlon.

Subsequently two brainstorm rounds were conducted on all the different sub-functions a good triathlon shoe had to adhere to. The first round contained more abstract “how to” questions. The second round was about the (more concrete) design challenges as presented in the design brief. After each round there was a collective discussion on promising or creative solutions. The used Miro board, including generated ideas, can be found in appendix 14.4.

6.3 Generating four concepts

From this creative session I created a morphological chart (van Boeijen et al., 2013) with four different concepts and one mechanism (see figure 36). This was done by selecting the (max seven) ideas per challenge that were most:

- Original
- New
- Clever
- Inspiring

The four concepts were generated by drawing lines between the different solutions in the morphological chart. These lines were chosen because they either:

- formed a cohesive concept
- challenged the solution space by seeming quite different

The concepts were first roughly sketched (see image 36) to become a single concept. Thereafter they were made in 3D in the form of rapid paper prototyping, to get a feel for how the whole interaction and functionality would work.

One insight during earlier research activities has been to make things as concrete as possible for this target group. Before testing, the concepts were therefore also drawn in higher fidelity. The drawings are meant to look more like shoes one can use (including GIF’s of their envisioned interactions).

Morphological chart

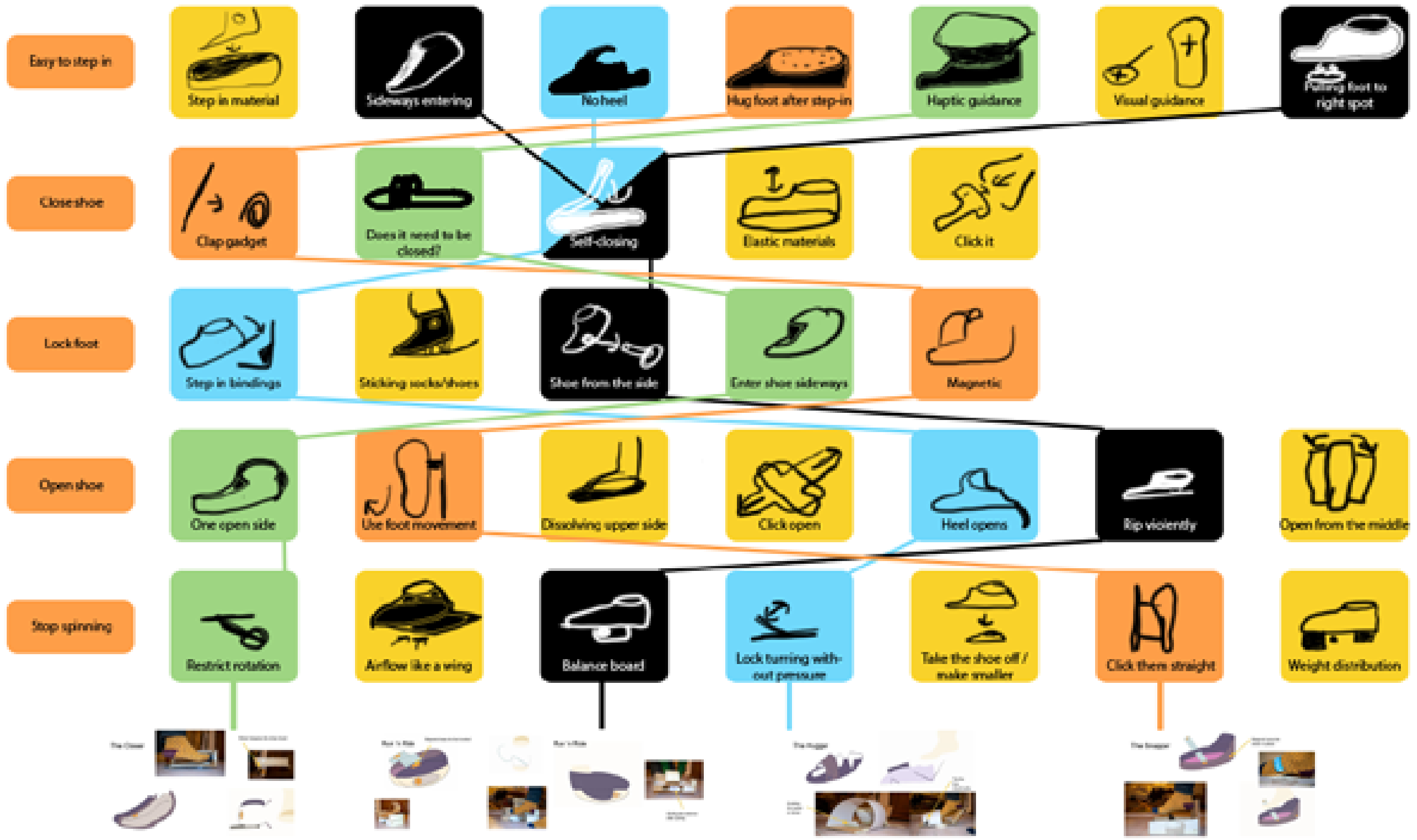


Figure 36: Morphological chart from ideas to concepts

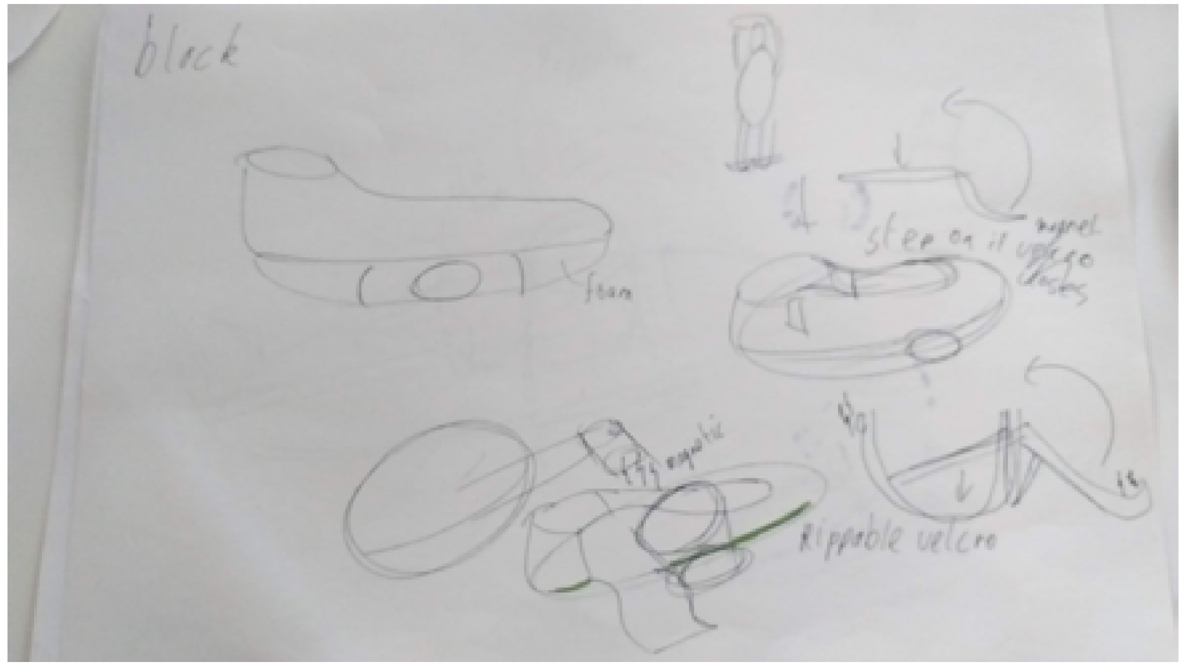


Image 36: Sketching a concept based on the elements of the morphological chart

These four concepts were evaluated with four athletes, with a mix of three elite and one ambitious amateur. One of the elite athletes (Luuk) has been interviewed before, the rest was new to the project.

6.4 Four concepts

This chapter presents the four concepts (figure 37 until 41) that were discussed with the four athletes. Each concept is accompanied with some representative quotes from the athletes and a summary of the feedback. Chapter 6.5 will afterwards explain the converging strategy used for the next phase of the project.

Figure 37: Concept Blue: The Hugger

"Cool, clever, fast" - Benjamin

"This is really sick!" - Luuk

This concept seemed easiest to envision for participants as it is close to what a shoe looks like nowadays. Furthermore the smoothness of the envisioned interaction seems promising. One participant considered whether or not it would be interesting to link the electronic tightening to external variables such as speed or power.

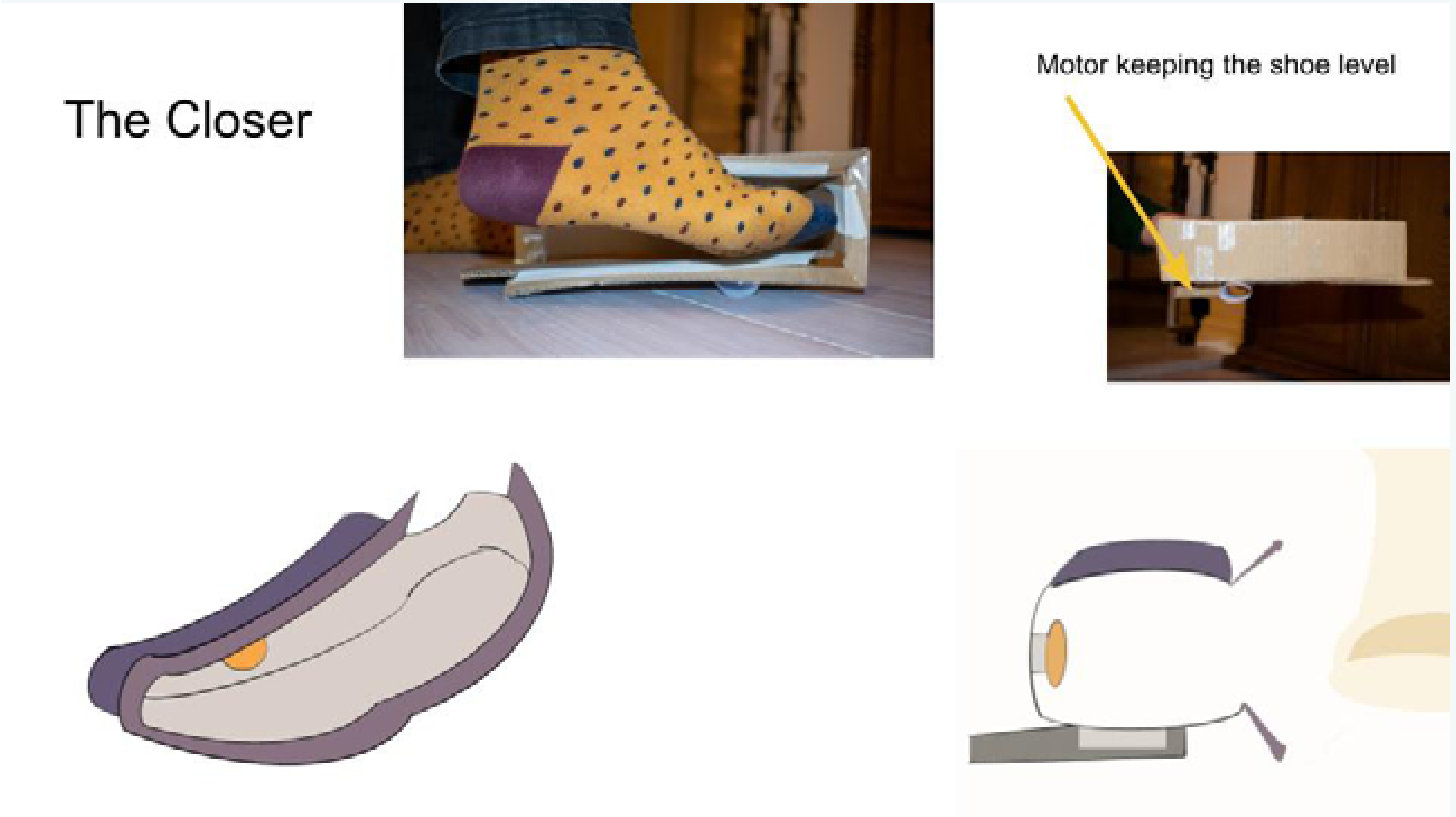


Figure 38: Concept Green: The Closer

"Parts to the side are a risk in tight transition zones" - Henry

"Motor with moving parts leans towards mechanical doping" - Henry

"How easy is it to aim: you come from above and can not see" - Michael

This concept was considered to be strong for pedalling, because it was solid in the up and down directions. This could contribute to more stiffness and therefore less powerloss. To enter from the side was however not such an easy movement. Furthermore, the flaps making the shoe wider would need to be designed in such a way that they did not stick out and could be damaged in the tight transitions zones. Having a motor to stabilise the shoe horizontally is interesting, but having a motor that controls a moving axis opens up too much towards mechanical doping to be acceptable.

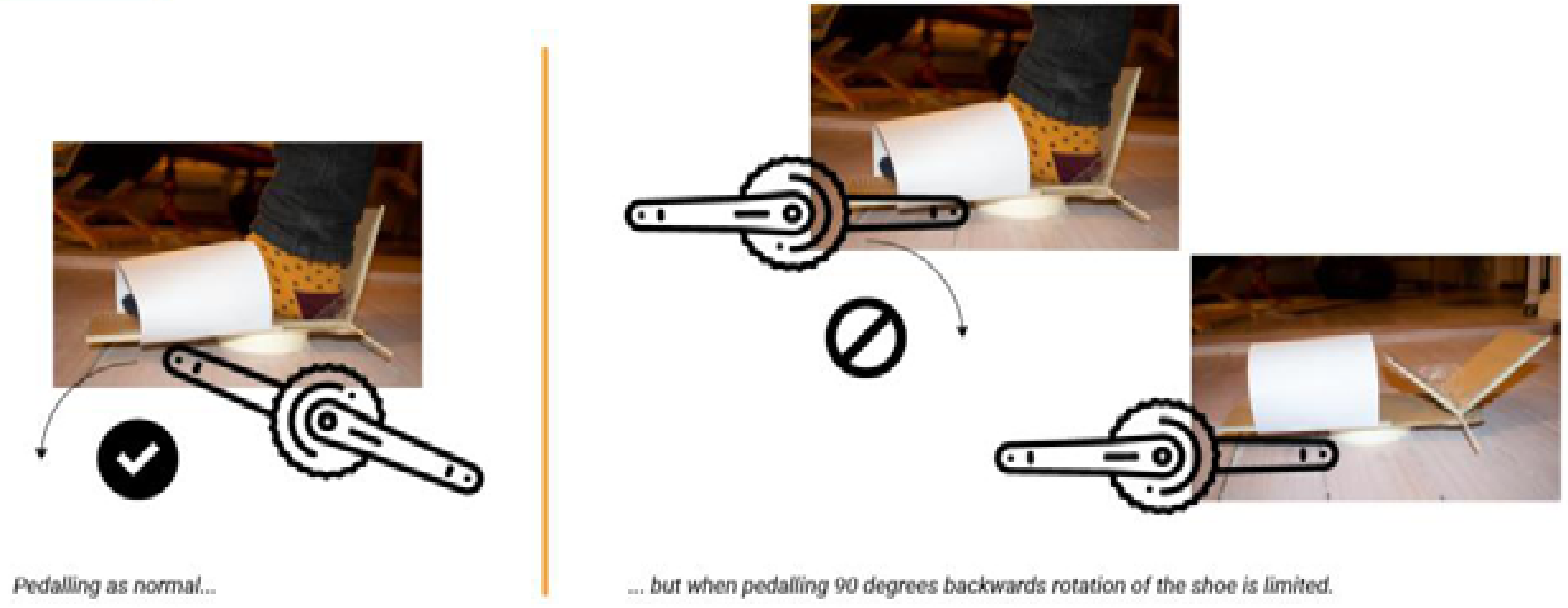


Figure 39: Coaster break mechanism

"Almost dangerous" - Benjamin

"Not relaxed to know that you don't have the option" - Luuk

The coaster break mechanism could be something that works, but athletes mentioned that it could be tricky in technical zones with a lot of corners (when taking a turn to the left, the left pedal should be high as to not scrape the ground and to create downforce with the right pedal to keep grip in the corner). When switching which feet to press down, or when spinning a bit backwards to loosen the legs in the peloton, this has the potential to create dangerous situations. This might be something that can be unlearned, but athletes indicated that they did not like the feeling that they had no choice to use it.

Figure 40: Concept Black:

"Little too complex" - Henry

"Shoe might hit the ground in the turns" - Benjamin

"Are you really quicker?" - Henry

Explaining this concept took a lot of time, as participants struggled to fully understand how all the steps worked together. This was already a first indication that this was not a desired solution. Furthermore, athletes were unsure whether this concept would help them to be quicker, and of the new pedal design would offer the stability needed.

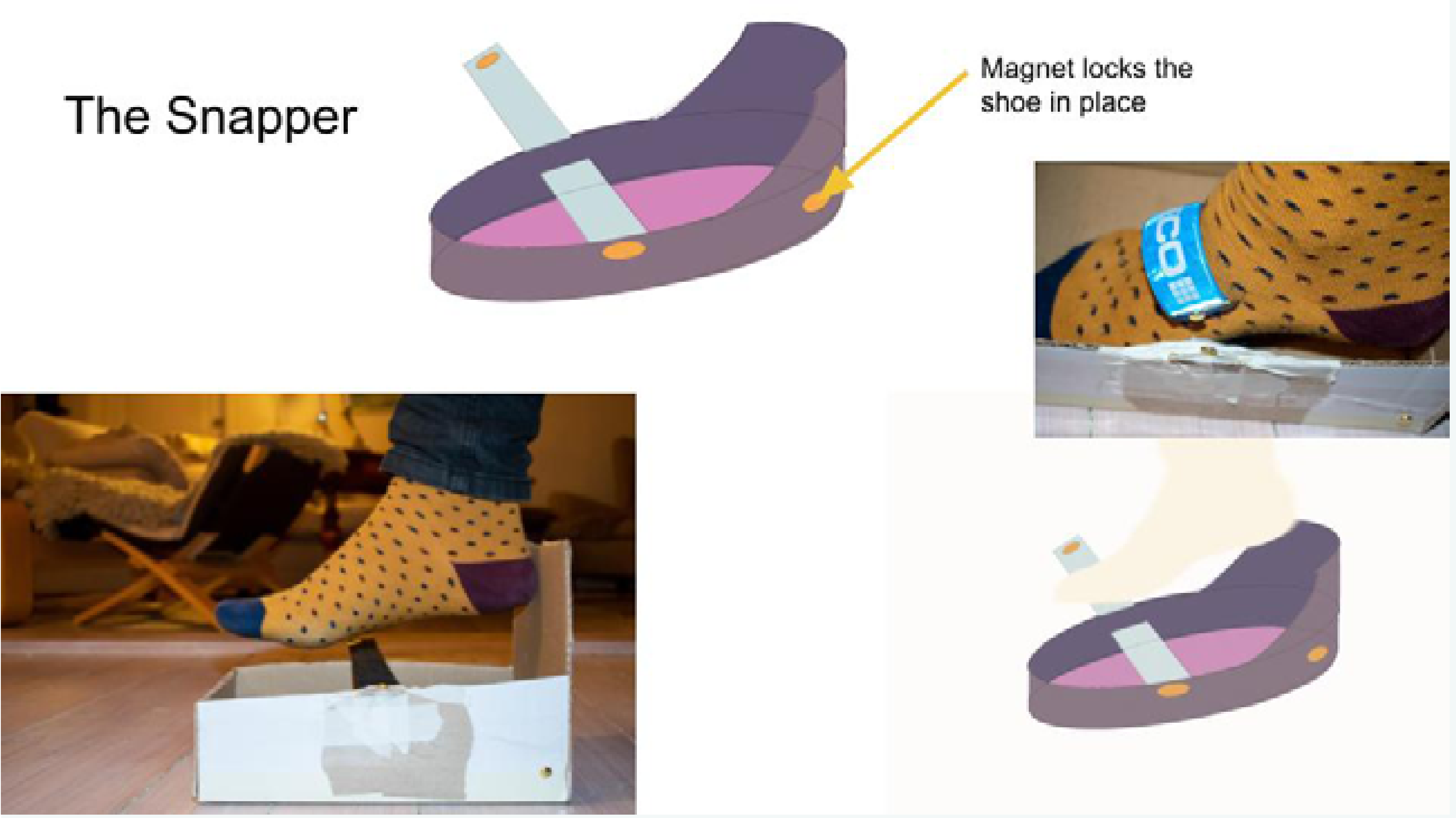


Figure 41: Concept Orange: The Snapper

"Need to be able to pull hard on band after turns" - Henry

"It needs to fit the form of your foot" - Michael

The athletes seemed to like the quick- and snappiness of this design and interaction, but serious concerns were raised regarding how well the design was able to follow the foot's form and subsequently hold it tight. The tiny band would be too loose and there is a high chance of discomfort and power loss.

6.5 Converging to one concept

Based on the insights from the interviews, I chose to use The Hugger as a starting point to move forward. Athletes also almost unanimously leaned in favour of this design. It was quick, simple and at the same time enclosing the entire foot for optimal power transfer.

This concept also fitted with the Triathlon Performance Indication Model (chapter 2.3) that I aimed to adopt in this project. The goal was to limit the amount of interactions that did not add any value. This should lead to an aggregation of marginal gains. From a lean perspective, one can argue that putting on and tightening shoes was not adding any value. Only wearing them has performance increasing value. Therefore the first explorations in the next chapter focus on a shoe design with minimal interaction. Instead it forms around the athlete's foot.

Three alterations to the concept of The Hugger were to be explored during the delivery phase:

- Several athletes were not convinced about the addition of a completely new pedal system, which is why I decided to explore the possibility of limiting all innovation to the shoe itself.
- I was not convinced about the possibility of using electronics for something as essential as tightening the shoe. What if an athlete forgets to charge them come race day, during which user-research showed that there were already many different steps to take. Or what if the system malfunctions and an athlete cannot pull their pedals during the entire cycling leg, losing performance; essentially adding instead of taking away potential losses.
    - Instead of automatically closing the shoe using electronics linked to speed for example, could it close mechanically when the foot entered. To use a mechanism inspired from The Closer, where the shoe would start closing when the foot pressed a button on the inside, as this seemed a smooth and reliable interaction.

6.6 Conclusion

A creative session based on the challenges as described in the design brief led to an assortment of different ideas from which the most promising were selected to create four different concepts. These were assessed together with members of the target group, and their results gave direction for the delivery phase. The Hugger concept was used as a base with certain elements identified as points for improvement.

7. Delivery phase

iteratively improving the design

7.1 Introduction

This was the final phase of the project as can be seen in figure 42. In several iteration cycles the concept went from a paper prototype, to a low-fidelity shoe to in the end a high-fidelity prototype which was used for a final usage evaluation. This evaluation and its results are described in the latter part of this chapter, before introducing the final design of the Talaria in chapter 8.

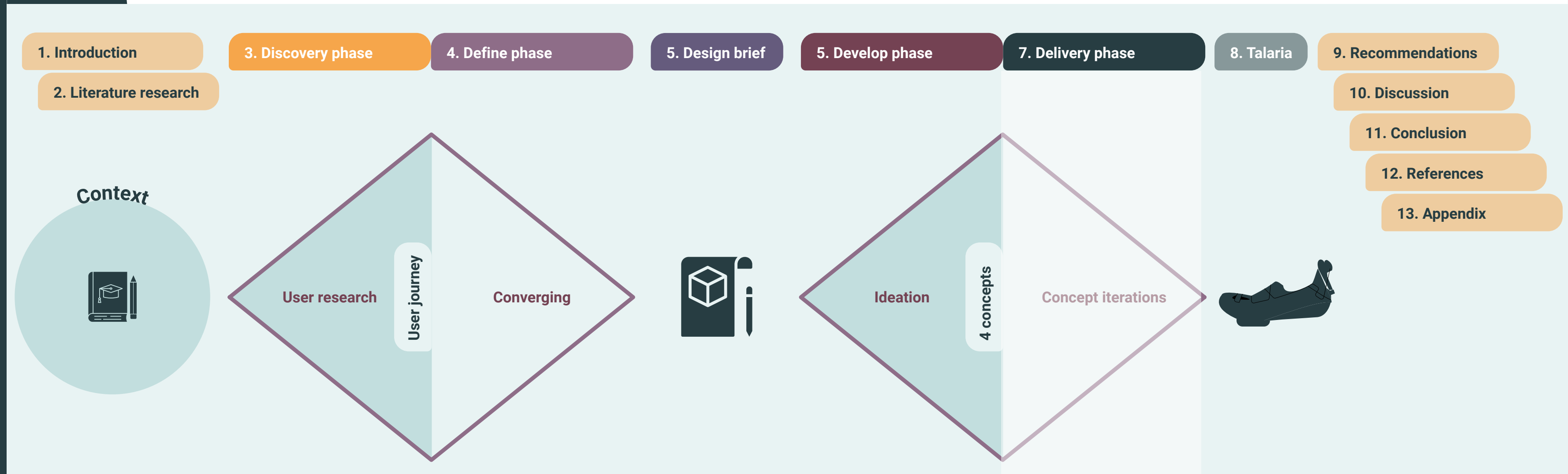


FIgure 42: visualisation of the followed design process

7.2 Paper prototyping

The goal of the paper prototyping phase was to implement the changes proposed in chapter 6.5. The main issues concerned the functionality of the mechanisms. I used carboard prototyping to define and prove how the mechanism in the shoe could work. To this end the concepts in images 43 to 47 helped to iteratively reach a proof of concept paper prototype.

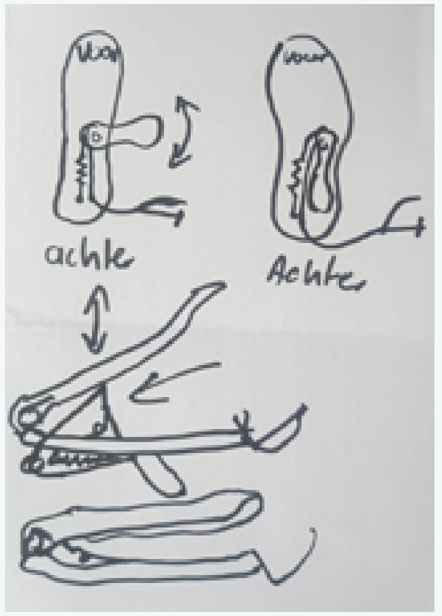


Image 43: Sketch of the technical mechanics of the concept

Image 44 and 45: First paper prototypes with elastic bands and ice cream sticks as pins to determine placement of springs on both the pins and the shoe.

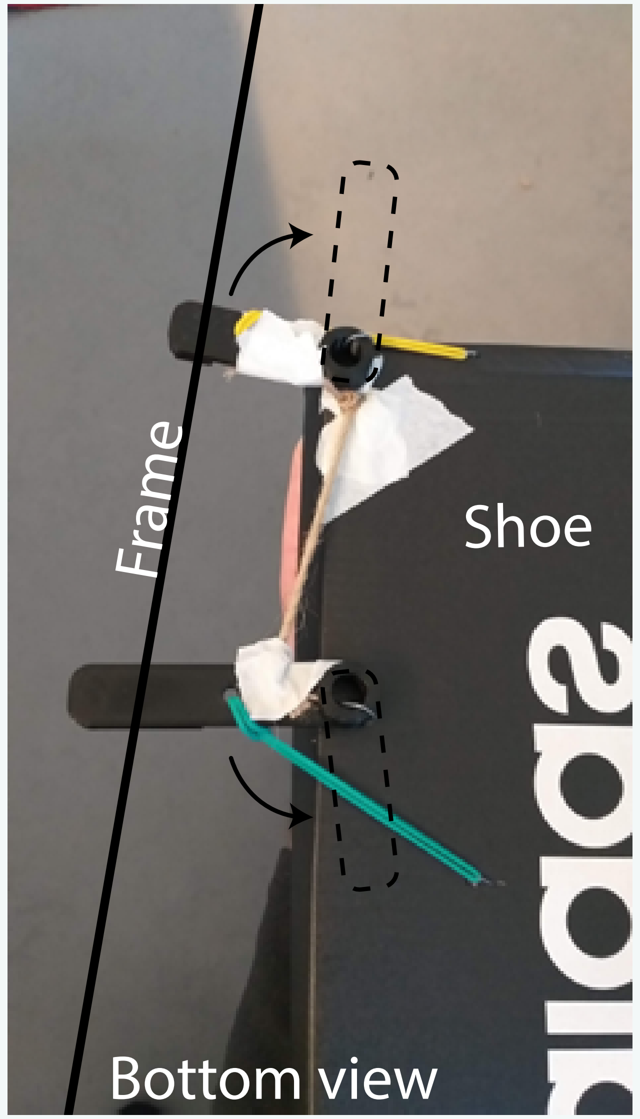


Image 46: A technically working paper prototype of the desired mechanism with custom 3D printed pins that rotated in and out of the shoe based on pressure in the sole. When out, they would rest on the frame. Thereby keeping the shoe horizontal

Image 47: A tongue that wanted to flap downwards if a pedal was not holding it up. It also included a 'hanging' heel that would move up when a foot puts pressure on the sole.

The paper prototype worked in keeping the shoe level and open until a foot were to enter. When this happens, the shoe would close and the pins on the side would retract, allowing for a pedalling motion. During this iteration cycle, focus was on placement and size of the springs and pedals, which were necessary for a working prototype.

7.3 Concept shoe V1

The previous subchapter showed that there was a proof of concept, but the paper prototype lacked nuanced dimensions. Furthermore, it was hard to determine how the interaction would look and feel like, or what comfort the shoe could offer. As mentioned earlier, it had proven most useful if athletes were shown concepts that look as concrete as possible. To answer these questions a low-fidelity prototype was built (image 48 until 56), which would allow for a more realistic assessment of the envisioned user experience, rather than the mechanics.

Image 48, 49 and 50: The process of heating the glue to take the padding away from the carbon sole. Afterwards a gluegun was used to re-apply the modified components.

Image 51 to 53: Custom designed 3D-printed pins could hold the shoe horizontal by leaning on the frame. They were glued to the carbon sole for extra strength.

Image 54 and 55: overview shots of the concept shoe V1

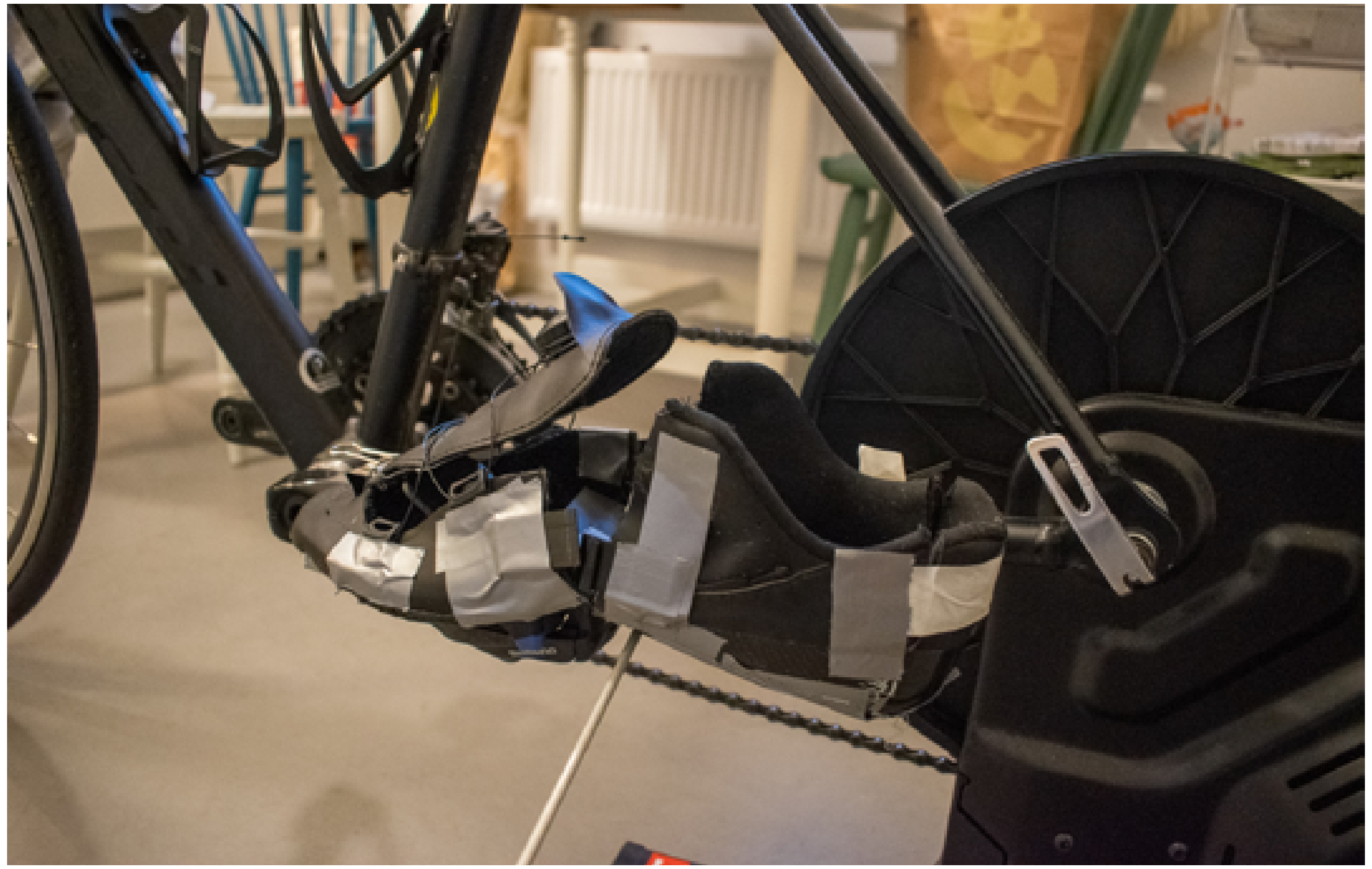


Image 56: Concept shoe V1 on a bike

This shoe was tested by two non-triathlete users, and the company was involved in the feedback round for this concept. Several minor aspects of the shoe were identified by users as needing improvement in next iterations. However, based on company feedback the major thing to be improved was the feasibility of the concept. The main concern was the stiffness of the carbon sole.

7.4 Concept shoe V2

The three exploration points, as determined in chapter 6.5 and repeated below, were altered to go from their extremes to more realistic versions. The Concept shoe V1 was for example an extremely "lean" shoe, it tried to eliminate all interactions that did not add value. Having the shoe on was the thing that added value for users, not the process of tightening it, so I tried to mechanically automate this. To create a more feasible iteration towards the final design, I worked in close collaboration with Cadomotus. We changed the requirements to:

- You should not have to touch the shoe at any point during the race
  > **One should have to touch the shoe as little as possible**

- It should all function mechanically (no battery or electronics)
  > **All vital interactions for race success should function mechanically**

- All innovation should be contained within the shoe itself, leaving the pedal out of the equation
  > **Contain as much of the design as possible to the shoe itself, but desirability and feasibility take precedence over this restriction**

We tackled the following **design challenges** to increase feasibility (figure 56 to 58):

- How to open and close the heel while minimally affecting the integrity of the carbon sole, thereby retaining stiffness and performance.
- How to close the front of the shoe with a different mechanism.
- When allowing shoe-pedal systems in the solution space: How to lock rotation of the shoe in the absence of feet.

Image 56: Exploration of how the tongue could close

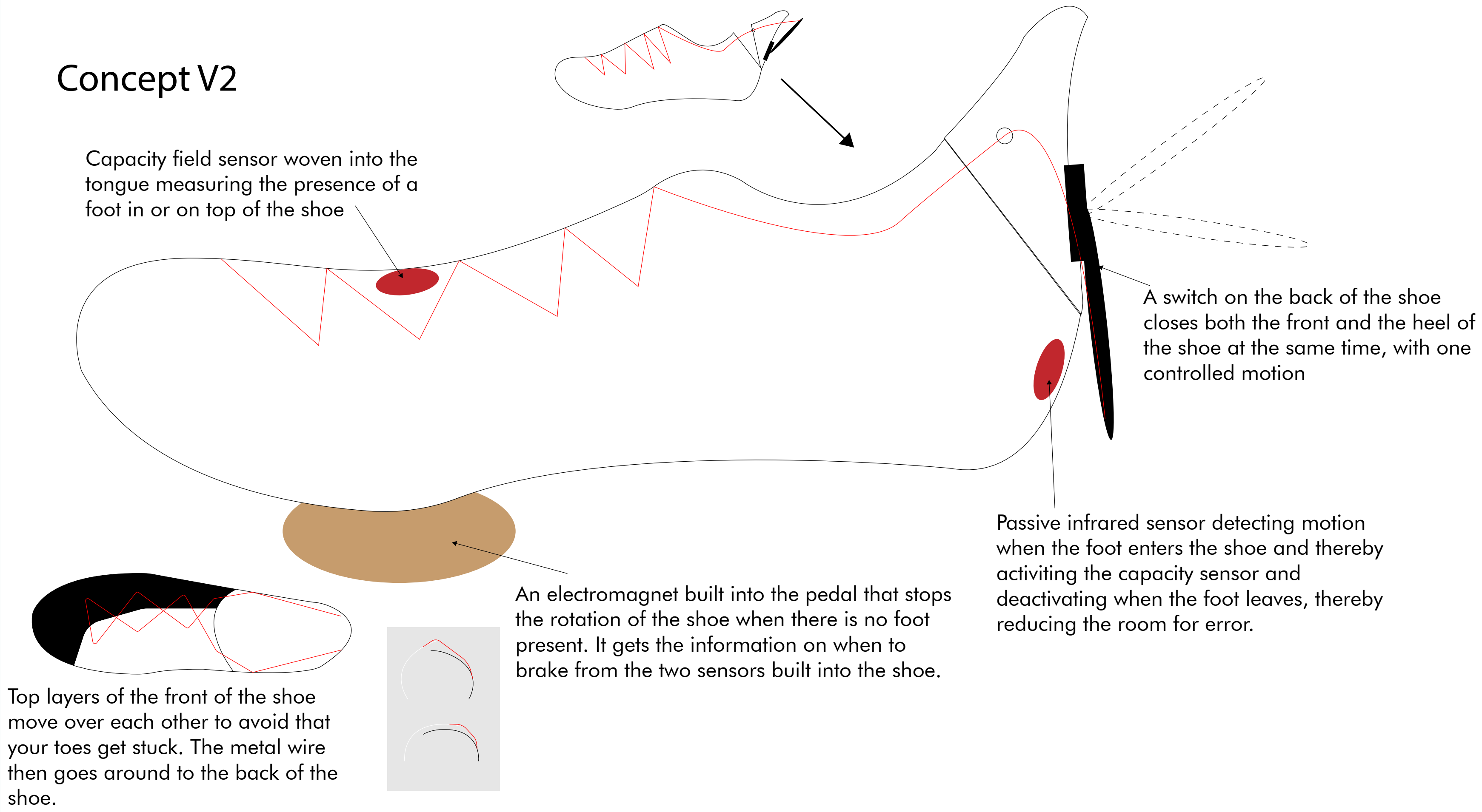


Figure 57: First schematic drawing of the Talaria

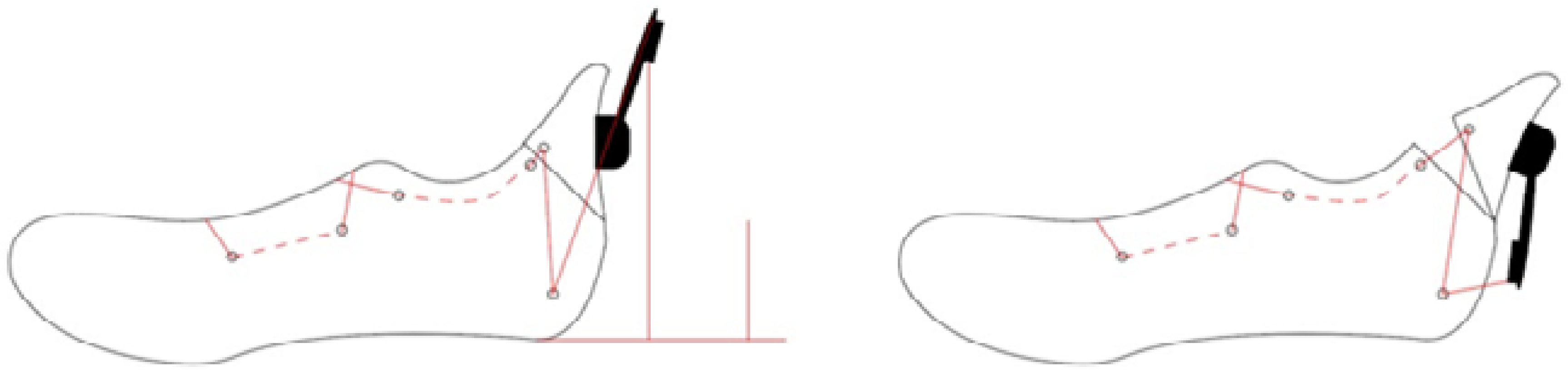


Figure 58: More finalised schematic of the closing mechanism

7.5 The Handle

After figuring out how to close both the heel and tongue of the shoe in a single movement using a handle, a secondary design challenge emerged regarding the shape of said handle.

The process of the handle went from testing different paper shapes (image 59 and 60) to several 3D printed iterations (image 61 and 62). I discovered that it was most user-friendly if it offered some form of indentation for people to feel the handle well. It was also important to afford the same two-fingered motion one uses to put on shoes (where the two fingers press the heel of the shoe backwards). A moodboard (image 63) was used to brainstorm about a design language for the handle. Based on company knowledge, it was decided that in a next iteration of the Concept Shoe it would be best to have a dial winding button (such as BOA) on the handle. This had a major influence on the final handle design (image 64 and 65).

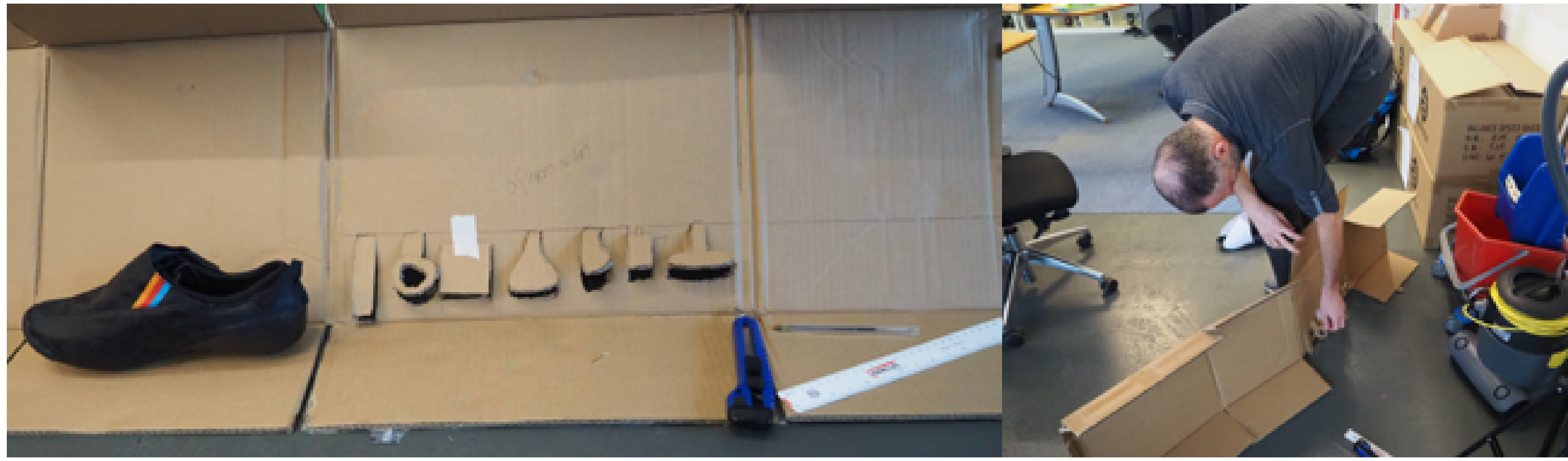


Image 59 and 60: First small ergonomics study into handle design

Image 61 and 62: First prototypes of the handle

Image 64: Handle based on the mood board

Image 63: Moodboard of sport and triathlon, used to gain inspiration to make the shoe handle more sporty

Image 65: Handle design based on company knowledge that it would be nice to have a dial winding button on it

7.6 Usage evaluation

7.6.1 Purpose

- Learning how the product is evaluated by athletes.
- Learning how the design can be optimised further.

7.6.2 Research questions:

- How do different athletes perceive the performance of the concept?
- How does the concept hold up in a (simulated) context including all different types of motoric capabilities and foot shapes?
- Where could there be improvements for the future?
- How do each of the different affordances perform in the current concept?
- How does the concept align with the interaction vision, design goal and interaction qualities?
- Would athletes buy or use the product?

7.6.3 Method

7.6.3.1 Procedure

Image 66: Photo taken during the usage evaluation

The final prototype was tested with five participants who went through the entire use case of a race, which is the most important scenario for the shoe. This use case consisted of seven tasks. During and after each step feedback was retrieved using talking out loud and probing questions. The test concluded with an interview and questionnaire around the interaction qualities and affordances specified in the design brief. The exact interview script and data analysis can be found in appendix 14.5.

The tasks:

1. Lock shoe on the bike (set-up T1)
2. Move foot in the shoe
3. Tighten the shoe
4. Cycle
5. Untighten the shoe
6. Get out of the shoe
7. Step off

The test was conducted by putting a bike on a trainer (device that allows one to cycle without moving forward)(image 66) so that all interactions with the shoe could be carefully observed and recorded.

7.6.3.2 Prototype

Based on the design as developed in chapter 7.4 and 7.5, a final prototype (image 67 and 68) was produced. Based on company suggestion, an external consultant (ProReva, image 69 and 70) helped by creating the final prototype of the shoe. This was done because of the skill and experience required to create a shoe.

When a user locks the shoe in place, it is important to get feedback that this was a successful interaction. Additionally one needs to be able to get feedback that the shoe is unlocked while cycling. To this end a LED and button were programmed using Arduino. When the user pressed and held the button (image 71), the red light would flicker three times and then stay on, meaning that the shoe was locked in place. The lights were not in any way taped on the shoe in order to maintain the freedom to move, and give the shoe a higher fidelity look and feel.

Image 69: ProReva is a prosthetics company that also creates shoes with carbon support

Image 70: Workshop at ProReva with Koen who helped creating the shoe

Image 67 and 68: final prototype used for testing

Image 71: User pressing the button during the usage evaluation

7.6.3.3 Participants

The diversity within the target group of elite short-course athletes is limited, additionally the product is not too complex. It is therefore deemed that five participants (table 3) would be enough to learn about the biggest issues. Three short course elite athletes tested the shoe, as well as one ambitious amateur and one athlete shifting to long-course racing, as that would also be an opportunity to gather insights in how the shoe would hold up in other triathlon distances. However, they all have raced at a European Cup level or higher, so they are experts on the ins-and-outs of triathlon. The hardest exclusion criteria used was that participants needed to be able to wear a shoe that was size 42, which led to exclusively male participants. I accepted shoe sizes in the range of 41 to 43.

Age is not deemed of particular importance, as elite short course athletes tend to be within a certain age limit of approximately 20 to 35, and therefore all elite athletes automatically met this criterion. The age-grouper is a bit older but still in an age where he can be competitive in the higher divisions of the Dutch team competitions.

Name	Age	Highest level raced:	How many races a year	Extra information
Mees	21	European cup	1 -5	
Luuk	21	European cup	6-10	
Milan	23	European cup	6-10	Turned long distance - pro
Elias	32	European cup	6-10	Ambitious age-grouper
Sem	22	World cup	11-15	

Table 3: Participants final usage evaluation based on experience

7.6.4 Results

Overall athletes were happy with the shoe, and would like to use it in races, provided that the mechanism worked reliably. Some of the statements from athletes that were introduced to the shoe but had too big feet to participate:

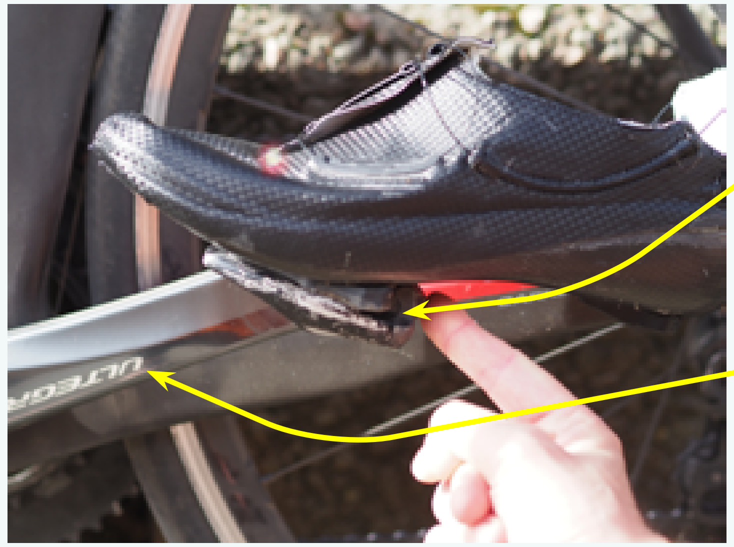
> *"Here I can see myself riding in next season" - Bart*

> *"Good idea man" - Levi*

The full data analysis method can be found in appendix 14.5.7. In the next two subchapters I will present the most important qualitative and quantitative results, before drawing a conclusion on what to tackle first in the final design.

7.6.4.1 Qualitative results

Task one: setting up transition



- It is nice without the hassle of elastic bands in T1 or spinning shoes in T2.
- There were some questions on the feasibility of the brake in terms of weight and price, with weight as the main concern.
- What if in T1 the shoes get a hit somewhere and the cranks start spinning?

> *"Would be easy, not having to mess with elastic bands anymore." - Mees*

> *"Very clear, three times [blinking of the light] and then it is locked and ready" - Elias*

Task two: getting in the shoe

- When participants pressed their foot against the tongue when gliding into the shoe, the heel started coming up too early, creating a risk of stepping on top of the heel.
- The shoe needs to open further, but right now it is acceptable according to the participants.
- In the last test the front of the tongue started bending, probably from repeated use and a lack of padding.

> *"I dare to say that I have almost mastered this element of transitioning and then directly getting into cycling, but this would work even quicker" - Sem*

Task three and four: tightening the shoe and cycling with it

- One participant suggested that putting the handle on the side could be even more of an ergonomic movement, yet another participant pointed out that the current interaction was the same movement as breaking the elastic bands, so it is something that they have already practised.

- Right now, the handle does not stay upright as it should.

"Looks like the movement of breaking the elastic bands" - Sem

- Under the ankles there was usually quite a gap from material to skin, which is both unnecessary and bad for the aerodynamics, so this could be lower.
- Two people reported too much space above the forefoot
- The shoe needs to get tighter than the prototype.

- The last participant also noticed the shoe's heel pressing against the Achilles heel. Perhaps due to material fatigue again.
- The padding now sometimes cut in the barefoot due to the way it was constructed.

Task five to seven: Untighten the shoe, get out of the shoe, step off

- Athletes glide down on their leg to put the handle down in T2.
- The string does not retract immediately when released from tension.

- Athletes still use a hand to get out of the shoe by pressing the heels backwards.

- After getting out the heel is often on top of the carbon sole, rather than in it, meaning sensor placement should be revised.

"[getting loose] is often quite easy, but this is very smooth. Very easy movement, just plop and it is loose" - Elias

Post-test questions

- In order to get used the shoe needs to be better finished; little tighter, better fit, details with padding better.
- Athletes would like to see other people race with the shoe and see its advantages proven in practice.
- Without a brake the position of the handle at the back of the shoe is vulnerable for damages in T2.
- Ventilation dilemma: You want some ventilation and wind to dry the feet a bit and facilitate a better transition to running, but at the same time it is often also valuable if a shoe offers protection in cases of cold or rain.
- Athletes indicate that they are on average willing to pay 250 to 300 euros (which is about the same as the revolutionary Nike Vaporfly running shoe). Strong focus here is on the durability of the shoe; it is okay to pay that much money if the shoe lasts several years.
- Due to the electronics this would be a race shoe only
- It is important that this is washable, as long-distance athletes sometimes pee over themselves.

Quantitative results

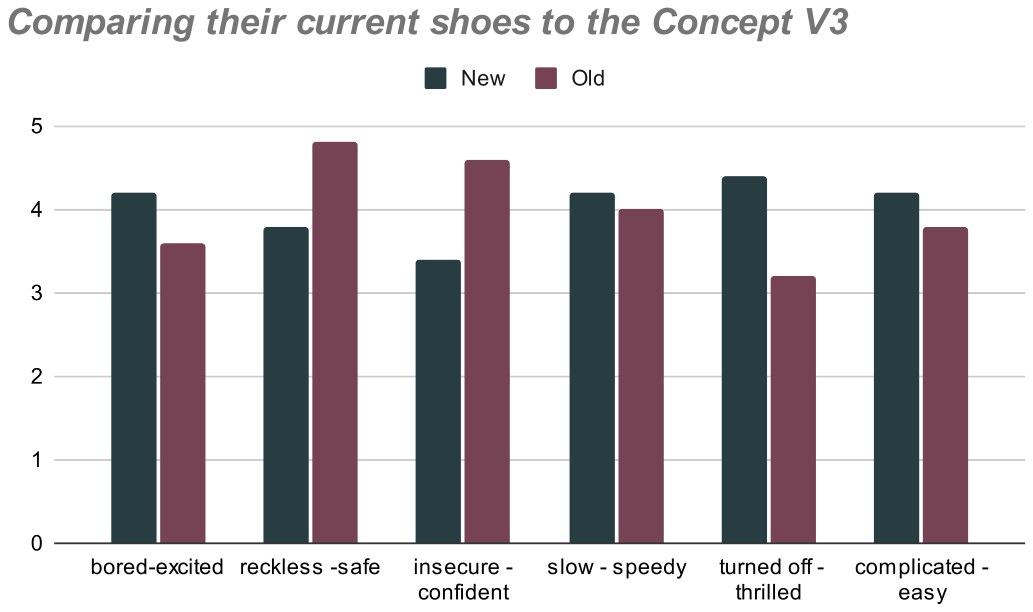


Table 4: Comparing the new shoe design against the shoe athletes are currently using.

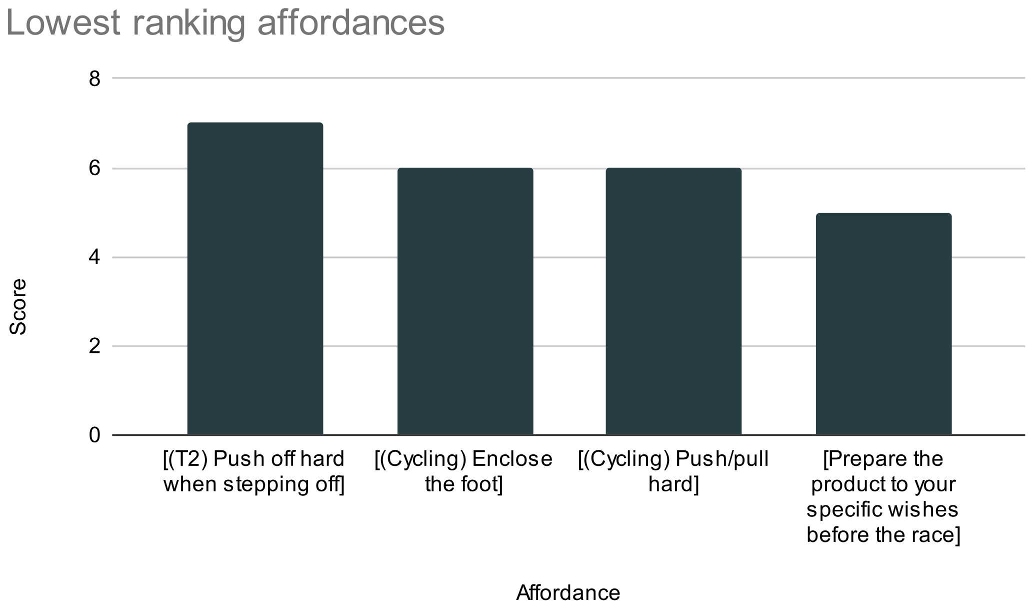


Table 5: The lowest ranking affordances (a high score is a low evaluation)

7.6.5 Discussion

Testing the shoe in a true **real-life context** of a race was impossible in February, as it was before the triathlon season had started. I believe that since all participants were extremely experienced this was not a problem, since they know exactly what such a context looks and feels like from memory and experience.

The two factors the Concept Shoe V3 scores lower on than the current triathlon shoes are ***safety*** and ***confidence*** (table 4). This can perhaps be explained due to the fact that athletes have had way less time to familiarise themselves with the new concept. They have also not raced any high pressure situations with it either. In any case it would be best to look for improvements that would increase safe and confident feelings.

I was only able to test with **one prototype**, which was the left side and size 42. This excluded a range of potential participants, most notably I did not have any women in my participant pool. I expect that this does not matter yet this assumption should be validated. The prototype was a left shoe model, which I believed to be the best version, since left is often the undominant side and if something works wel motorically with this side, it can be argued that the other side should not be a problem.

The three elite athletes are coming from the same elite training group in Utrecht. This might mean that there is a small chance for **recruitment bias** (a phenomena where results are influenced by the way the researcher recruits participants). Since they spent a significant amount of time together on a day-to-day basis, they might develop a similar attitude and behaviour towards products and in races. Copying tips and tricks off each other.

I sent my participants the **Google Form** directly after the interview via WhatsApp. A paper version would have worked better in this case since the digital version of the form did, for the first three participants, not create an incentive to fill it out immediately after the test. This in turn led to less reliable data, as well as texting back and forth about what certain affordances exactly meant.

7.6.6 Conclusion

The results, both the qualitative and quantitative, were put together in a (see table 6). How much something would ruin the race was put on the impact scale. How often a problem was likely to occur was placed on the frequency scale. This gives an indication on which next steps should be prioritised. However, if things take relatively little effort to improve, they will be tackled in the final design anyways.

Frequency/ Impact	**No impact**				**High impact**
Highly unlikely to happen		• Fabric can not cut in the bare food			• Vulnerable position on the back of the shoe if it for some reason touches the ground
				• Spinning cranks after a hit in T1	• Front foot too much space
		• Ventilation dilemma			• Needs to close tighter
		• Under ankle too much space • Washable	• Stepping off should be better	• Front folds over	• Heel closes a bit when you push the front up
Highly likely to happen				• Open further • Still need to push back heel to get out	• Feasibility brake • New sensor position necessary • Increase safety feeling • Increase confident feeling

Table 6: Overview of the main issues discovered during usage evaluation

Eight **improvements** emerged that should get highest priority:

1. Feasibility of the brake
2. New sensor position necessary on top of the carbon
3. Increase safety feeling
4. Increase confidence feeling
5. Open further in T1
6. Still need to push back heel to get out
7. Heel closes a bit when you push the front of the tongue up
8. Front of the tongue folds over

7.7 Conclusion

Three major iteration cycles were done, going from paper prototyping to a high-fidelity prototype. This design, the Concept Shoe V3, was tested with users in a usage evaluation. During this evaluation athletes simulated a race scenario and gave feedback on the concept and prototype. The concept was generally received positively. Eight further points for improvement were identified from the data. The redesigned final concept is described in the next chapter.

8. Talaria
the final design

Envelop tongue
An envelop shaped tongue makes sure that toes can not get stuck, or that fabric bends in the wrong direction

LED
A LED to show whether the brake in the pedal is active or not

Brake
A build-in brake in the pedal keeps the shoe horizontal when there are no feet present

Heel
An opening heel creates a bigger opening, making it easier to slip into the shoe

Dial winding button
Allowing the athlete to set how tight the shoes should be before the race start. Offering adjustability during the race as well

Handle
A handle allows the shoe to be tightened quickly and strongly. Only one simple movement is necessary before optimal power transfer is achieved

8.1 Introduction

This chapter introduces the final design in this project. The Talaria. A new triathlon specific cycling shoe. On the previous page the most important design parts were already presented. This chapter starts with further explaining the why of the design and showing the use scenario during a race. The second part of this chapter elaborates further on the design's effectiveness, technology and price.

8.2 Design explanation

The Talaria is a triathlon specific cycling shoe named after the Hermes' winged shoes (image 72).

Image 72: Hermes, messenger of the gods

A **handle** at the back of the shoe allows triathletes to swiftly and effectively close the shoe. It combines the quickness of Velcro and the strength of the winding dial buttons like BOA. Users can set the desired strength of the wire before the race. All they need to do during the race is flip the handle up and the shoes are tightened. This movement resembles the breaking of elastic bands that athletes are currently already doing, and fits well into the pedalling motion. The quick and easy movement of the handle allows the athletes to focus more on the road ahead, thereby increasing safety.

Image 73: Render of the handle

The handle (image 73) has an indentation so that when an athlete slides their hand down over their leg, they get confirmation that they can push down. A small and easy to release snap joint is added to the front of the handle. This snap joint makes it impossible for the handle to move upwards, but only away from the shoe. This prevents the heel from closing too early when stepping in; the joint makes sure that when the tongue is pressed forward by an athlete, the heel of the shoe does not immediately come with.

A **brake system** build in the pedal keeps the shoe horizontal when there are no feet present. This allows athletes to run with the bike through transition without the shoes hitting the ground. Before *and* after the race. When sensors detect presence of the feet, rotation of the pedal is unlocked and athletes can start racing. This increases safety, as it prevents bikes from "jumping" when a shoe smashes into the ground. Thereby also minimizing the risk that a shoe falls and has to be retrieved
The brake also allows the shoe to adopt different angles before the athlete jumps on the bike. Combined with the increased opening (tongue and heel) this takes stress away from the athletes as it is easier to get in.

8.3 Use scenario of the Talaria

Step 1: Press the shoe on the pedal

Step 2: Press and hold the button to lock rotation

Step 3: Shoe ready to race

Step 4: Run out of transition

Step 5: Slide foot in the shoe

Step 6: Lift handle to tighten the shoe

Step 7: Cycling!

Step 8: Press handle to open the shoe

Step 9: Lift foot out

Step 10: Pedal on top of the shoes

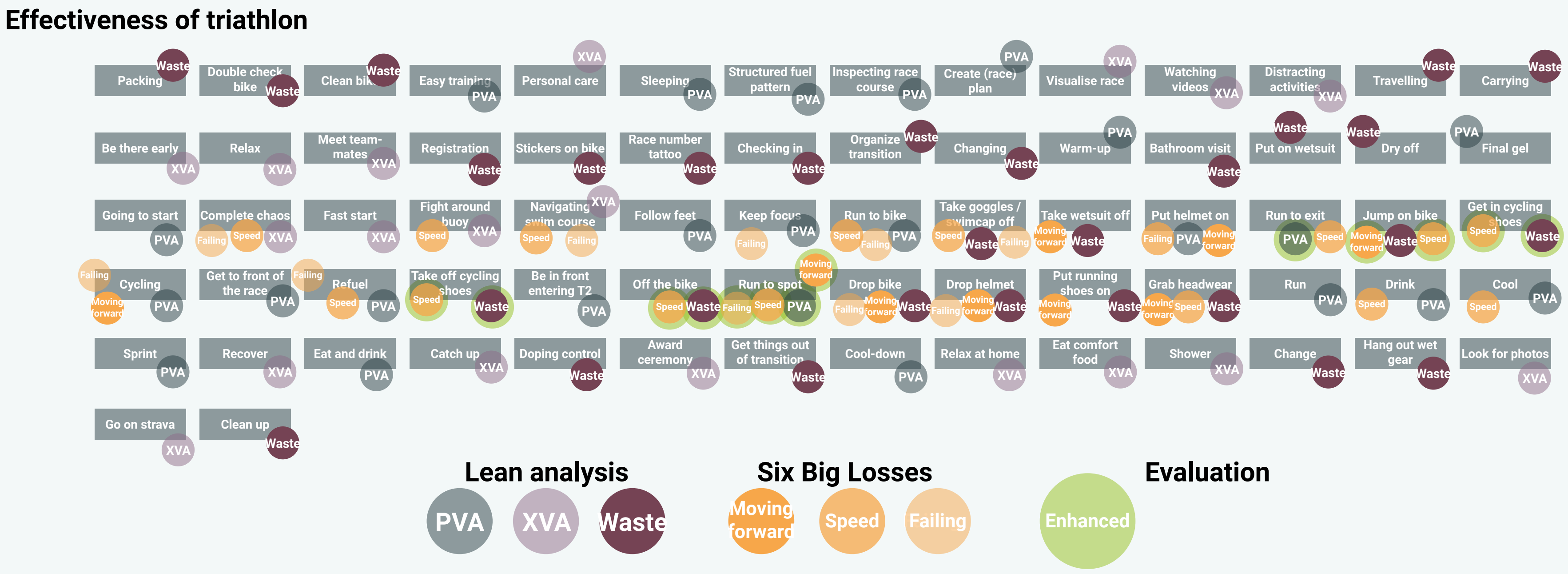
Step 11: Stepp off

Step 12: The shoe stays horizontal

8.4 Effectiveness of the Talari

In the literature section (chapter 2) it was argued that small improvements could mean big changes on an overall performance, combined with looking at all the little things where effectiveness in triathlon is compromised. Figure 74 shows what happens when putting this together with all the advantages of the Talaria. One can see that this one product does not solve everything, but that it has a little bit of impact on several steps, which is how performance optimisation in sports was theorized

Figure 74: Effectiveness in triathlon combined with all the advantages of the talaria



8.5 Technical side of the Talaria

As for the more technical side of the design, this has two critical components; the handle mechanism and the brake to keep the shoe level. This sub-chapter is here to present and argue for the technical design of both.

8.5.1 The handle

The primal mechanism of closing the shoe comes from snowboard bindings. In the bindings in image 75 for example, a lever is pulled up, tightening the backend of the binding. In the Talaria the same mechanical principle is used. Yet by pulling the handle one does not just lock the heel, but also tighten the front of the shoe.

Image 75: Snowboard bindings that function by lengthening a rope (private photo from Cadomotus)

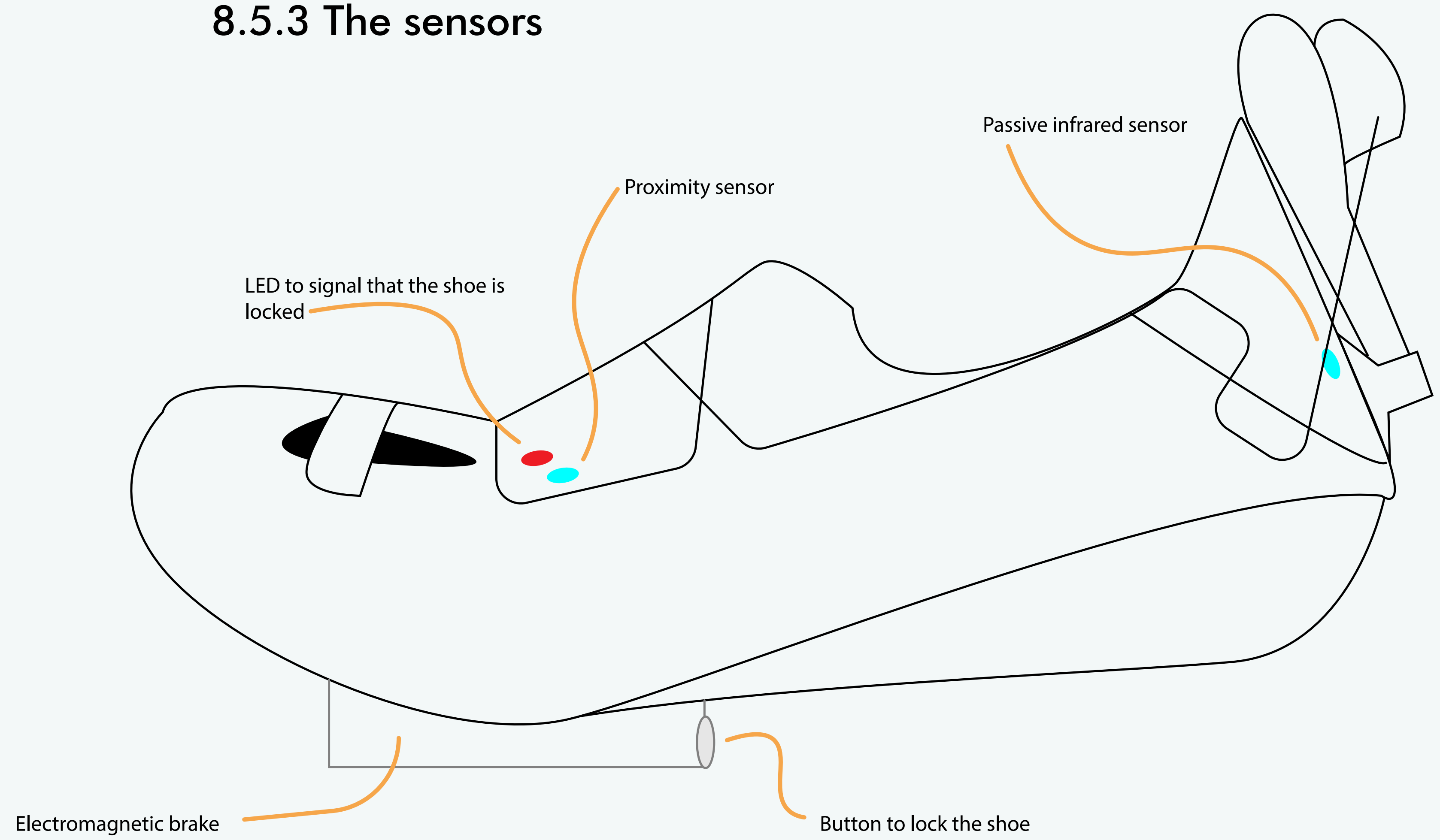
8.5.2 The brake

There are several reasons to opt for an electromagnetic brake:

- There is no wear and tear in the same way as a mechanical solution
- It can respond incredibly fast
- When the system fails and there is no more power, the brake just stops working and you can still cycle.
- It is easier to precisely regulate power.

If the power is adjusted to be perfect for holding the shoe level (even on bumps) but nothing more, it is possible to just push your pedal through the brake. If the sensors would not recognise your foot this would therefore only mean a little loss of energy for a few seconds until the system picks up that you are moving, and the failsafe releases the brakes. (An estimation of the necessary power can be found in appendix 14.6)

8.5.3 The sensors



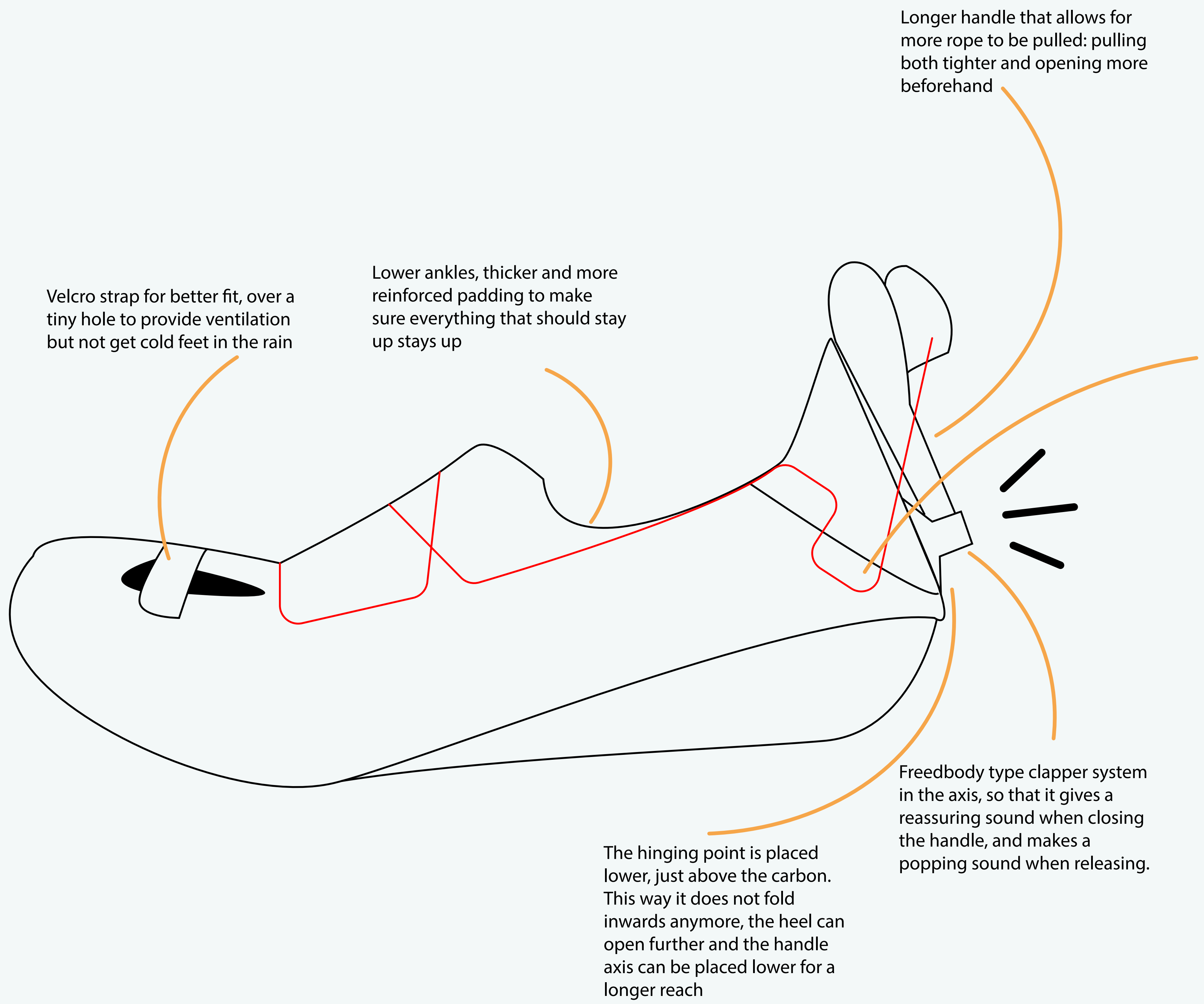
To lock the shoe in a certain position, one presses the button at the back of the pedal. With a long press the user gets confirmation that the brake is on through a LED. The argumentation for this choice is:

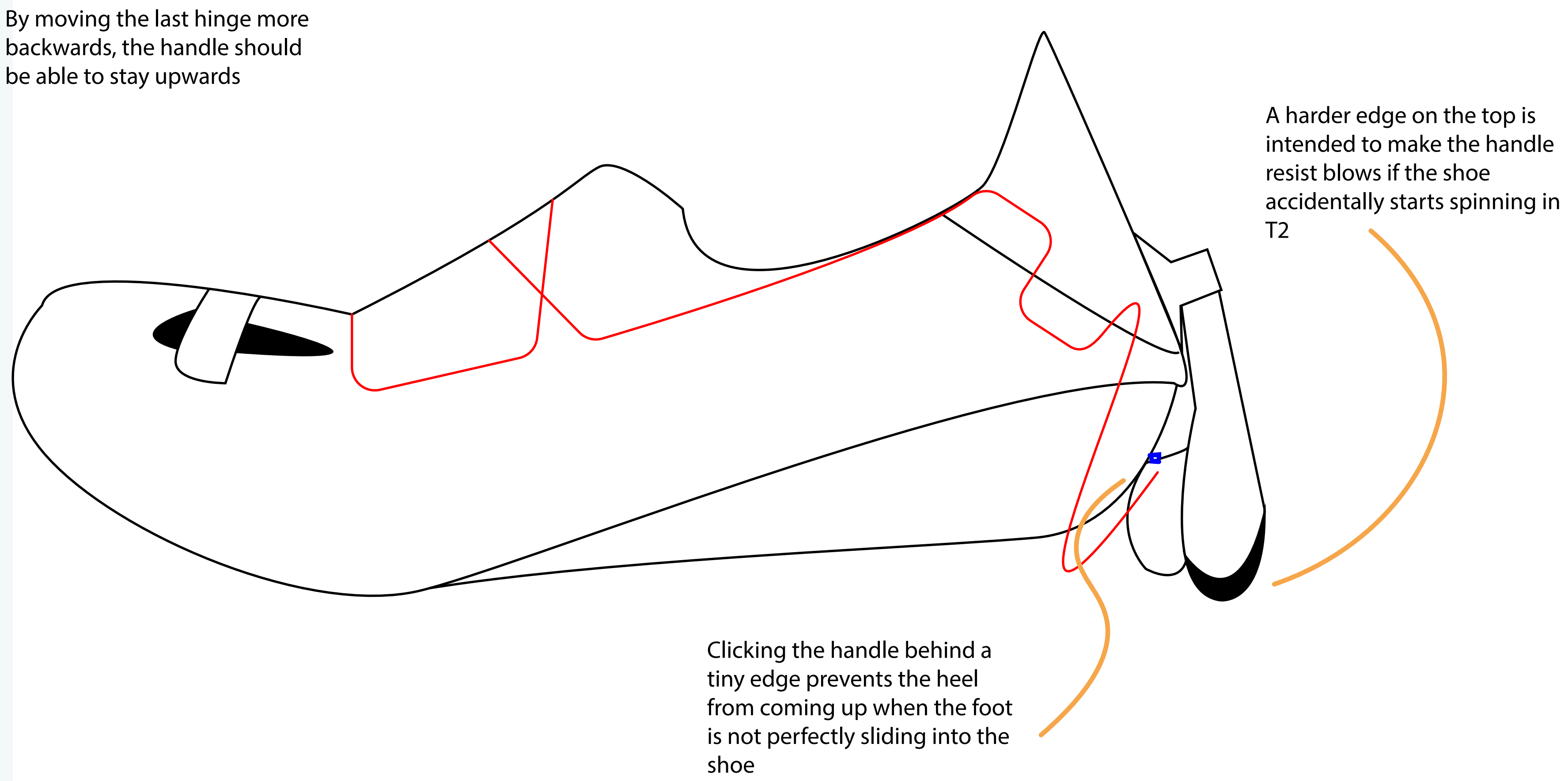
- Visible when cycling if an athlete wants to check
- Easy to see while pressing
- Vibration or sound as feedback does not work in the context
- Red has a high contrast to the black shoe
- The tongue has three layers on top of each other, allowing for easy integration in the fabric
- Button position is chosen for maximum security, it is unlikely to be accidentally pressed
- Power meter companies are already able to build a powermeter inside a pedal. It is therefore plausible that the same battery systems and circuitboards could be fitted in this concept too.

A proximity sensor is woven into the tongue's middle layer, and in the heel there is a passive infrared sensor.

- Two sensors necessary for maximum security
- Sensors need to detect a foot both in and on top of the shoe
- Proximity measures the presence of something that conducts, need confirmation that it is not just water or rain
- Infrared can detect a warm object moving in and out of vision, needs confirmation the object is still there
- Using own sensors, instead of power meters for example, decreases response time and increases reliability due to shorter communication lines.
- Sensors are placed in relatively safe areas for damage, inside the tongue or behind the handle's axis.

The next page gives one more final overview of the Talaria specifically targeting all the different design elements.


Longer handle that allows for more rope to be pulled: pulling both tighter and opening more beforehand
Velcro strap for better fit, over a tiny hole to provide ventilation but not get cold feet in the rain
Lower ankles, thicker and more reinforced padding to make sure everything that should stay up stays up
Freedbody type clapper system in the axis, so that it gives a reassuring sound when closing the handle, and makes a popping sound when releasing.
The hinging point is placed lower, just above the carbon. This way it does not fold inwards anymore, the heel can open further and the handle axis can be placed lower for a longer reach


By moving the last hinge more backwards, the handle should be able to stay upwards
A harder edge on the top is intended to make the handle resist blows if the shoe accidentally starts spinning in T2
Clicking the handle behind a tiny edge prevents the heel from coming up when the foot is not perfectly sliding into the shoe

8.6 Price

The price of the handle mechanism is estimated by Cadomotus to be somewhere around 35 to 40 euros. A full calculation of this cost can be found in appendix 14.7. The price including brake system and sensors is a bit harder to estimate, as Cadomotus does not have experience with this. But since I recommend looking for a partner (see chapter 9.1), they would be able to help with an accurate estimation up front. Since this means that people are buying both a shoe and a pedal, this also shifts the acceptable price range.

This price of 40 euros will most probably not be a problem for athletes. When combining it with a regular carbon sole it will be in the same approximate price range as its competitors and the price indicated by users during the user test (250-300 euro). Due to the handle system being stronger than Velcro and quicker than a dial winding button, it has the potential to be a decider on whether the peloton can be reached. This could have far-reaching consequences for results. The Nike Vaporfly has shown that athletes are willing to pay for this value.

With a carbon tub sole, which is Cadomotus' speciality the price of the shoe raises to around 400 euros. This is significantly higher than what athletes indicated they were willing to pay during the usage evaluation. Important to note here is the age range of the participants though: mostly students without a real income, relying for a big part on sponsoring. The regular target group of Cadomotus which consists of ambitious amateurs with a job, might be willing to pay more. A good course of action would perhaps be to target early adopters as well as sponsoring pro athletes so that the added value becomes clearly visible.

8.7 Conclusion

This chapter presented the final design of the Talaria, both in a use, technology and price perspective. The next chapter will present further recommendations to the company.

9. Design recommendations for the company

This chapter introduces the next steps in the design process, as recommendations to the company. While the previous chapter introduces the final design, there are a few things that I would recommend Cadomotus to look into. The main thing that I believe Cadomotus should focus on now, is the technological development of the shoe. Some suggestions where to look first are given in the next sub-chapters. The end of this chapter presents some future applications of the shoe that Cadomotus could consider.

9.1 The pedal

The first, short-term focus should obviously be on managing the technical challenges of the current design of the shoe. Since Cadomotus has no previous experience in pedal design and electronics, my first suggestion would be finding a partner for this. Shimano would be a perfect match, since they both have experience with pedals, electronic shifting, and a trusted reputation. Yet any other pedal-based power meter company would probably have the necessary expertise (figure 76).

Figure 76: Power meter companies

9.2 The handle

For the handle I think that there is enough in-house knowledge within Cadomotus and suppliers to make this a success. Especially since there are snowboard bindings to use as an example. During the decision-making on manufacturing processes I would strongly urge Cadomotus to think about durability of the handle design. This can be achieved by a strong design, or high repairability. One repairable solution is to just have a harder top part on the handle which can easily be unscrewed and replaced. I think this repairability is important since the carbon sole shoes in themselves are already expensive. Athletes expect their triathlon cycling shoes to last long. So when the shoes are more expensive than usual, they need to be durable. No one likes their expensive new product breaking after two races.

At this moment the handle is shaped for a positive interaction, but extra benefits can be generated by optimising it for better aerodynamics. Gibertini, Grassi, Macchi and Bortoli (2010) state that "the power request to overcome the aerodynamic action over the two shoes is approximately 8% of the power required to overcome total air resistance." Validating and improving aerodynamics present therefore a significant opportunity to influence and advance performance. Cadomotus has the experience to conduct such aerodynamics tests, and they could be important in convincing athletes.

9.3 Sensors

Theoretically the sensor system works and can be argued for. A next step is to test if the concept also holds up in practice. The following two research questions could form the start of further validation:

- Is the combination of a Passive Infrared and a proximity sensor indeed picking up a foot and not reacting to rain or dirt?
- Does the infrared still work with a small difference between body- and outside temperature

One other promising direction to explore is simplifying the system using one sensor that can truly discriminate between humans and innate material (Electronic specifier, 2012). This sensor was already documented in 2012, but since then it did not seem to be widely shared as a solution. For this reason the sensor is mentioned here in the recommendations rather than the final design chapter.

9.4 Shoe development

Next steps in shoe design would mean firstly integrating the current suggestions into another working prototype. This should be distributed to athletes and be tested in several conditions: rainy, cold, sweaty and high-pressure ones for example. They would most definitely have more things to improve, after which it would be important to start trying out the shoes during racing and observe its value. Do we see a difference between athletes using this shoe and the original one when comparing for example where they exit T2 and their position in the race 5 km later; does it increase their odds of making it to one pack further to the front? If this proves fruitful the range should be expanded to different sizes and the feedback loop should reiterate again.

Market research into pricing is also recommended, since there is a discrepancy between what users indicated they were willing to pay and the estimated cost of the shoe (see chapter 8).

9.5 Stepping off harder

At the moment, the Talaria is not better or worse than other shoes in stepping off at the end of the cycling leg. Using the brake system, I believe there to be a potential for a small marginal gain though. If the shoe can lock in the last few seconds, the athlete will have a harder surface to push of from. However, this is not as easy as it looks, since we earlier decided that adding actions for users in these last hectic meters is something to be avoided. A possible detection method could be adding a weight and position sensor in the shoe, and that it should start locking as hard as it can when the following statement is met: Weight on shoe is the same as the weight of the user and the pedal is located in the lowest position. However, this is not necessarily something that has to be designed in the first generation of shoes

9.6 Long-term development of triathlon shoes

I believe that there is potential in striving for a shoe that would meet the requirements that were let go for now:

- You should not have to touch the shoe at any point during the race
- It should all function mechanically (no battery or electronics)
- All innovation should be contained within the shoe itself, leaving the pedal out of the equation

A shoe that forms around the foot mechanically and does not require any attention at all during a race is something that I believe to be the best possible design of a transition friendly shoe. If there is a strong collaboration on pedal design with a partnering company, I think that that should be continued, but otherwise I think there is some value in trying to contain it solely to the shoe. That helps to make it more accessible to more athletes. For example, those that have power meters in their current pedals and are therefore hesitant to adopt this innovation or those athletes that are afraid to switch pedals for an unknown brand. However, at the current moment technological feasibility of the aforementioned guidelines is not adequate yet, so I think that these could serve as guidelines for the future.

I think that it could however also be interesting to combine the elements of electronics in the pedal with some of the other stakeholders/problems discovered. This is a race day specific shoe, could this specificity for example also help with improving race day experience? Making triathlon more viewable because it streams real-time location to the organisation for example? For this it could be interesting to sit down with race organisers and uncover what things they feel are necessary for improving the race day experiences they are offering.

The preceding suggestions are my recommendations to Cadomotus. They have indicated that they are interested in continuing the design process, so these are the things that I perceive to be most urgent.

10. Discussion

This chapter discusses the context this project was conducted in and how that affected the process and results. Both the limitations and the things that worked well.

What makes the **context of this project** interesting is that the process was almost completely outside the triathlon season. There were several races for user research in the beginning. But after that no more. This meant that almost all the insights during the development process were coming from athletes' memory. I believe that since all participants were more or less experts on the topic of triathlon, this was acceptable, but it creates a situation where you can not bring the product to its actual context.

Being part of the target group had its clear benefits. In times of COVID-19 it provided with a big network of friends and acquaintances willing to help during all the different stages of the design process. Even in my final evaluation there were two participants who had previously no knowledge of my work or process and could reflect completely fresh. This way of networking to users also has a downside, and that is a certain risk for recruitment bias. Many of the participants have some relation to the Dutch premier league and might share an implicit Dutch view on how triathlon works. Yet even if this is the case, it is not much of a problem as this is probably the same group that Cadomotus will target first when launching a new shoe design.

Subjectivity and bias have played a huge part in this process. As reported earlier in this thesis, the problems as specified in the design brief were different from the ones that I wrote down in my first user journey and preconceptions map, indicating that these results did indeed come from user-research. During this whole process I have tried to keep a high level of user-centred design, both as that is something I believe in, as well as that users can provide me with feedback outside of my own thinking bubble and therefore make the product more well-rounded and valuable. However, by doing this entire project on my own, the subjectivity is high. I can only make my own observations during for example the user testing, but a second set of eyes is likely to draw some slightly different conclusions and observations. This is inevitable and the result of writing a thesis on your own, even for people that are not part of the target group already. Of course, the supporting team around me helps a bit with preventing this, but it would in an ideal world be interesting to see what someone else following the exact same process would come up with.

Interviewing the investigator (see chapter 2.4) proved to be an interesting tool. It did not lead to any critical changes, but it contributed to improving the interview's flow. Things that felt as unnatural transitions for the investigator could be moved around or rephrased so they made more sense. Furthermore, it is good to see a neutral designer ask questions, see what they probe for and how they tackle certain topics. This gives the investigator the opportunity to imitate some of these, as they are most likely neutral responses and probes.

Looking at triathlon through **a production process lens** trying to optimise effectives helped in creating a whole different view on where you can improve. When using user-centered design it is easy to start designing for things that participants perceive as problems. But a critical lean lens can help to challenge the status quo; to also identify points that participants consider "it has always been this way”. I believe that something similar to the Triathlon Performance Indication Model is a method that can help designers design for linear processes where they want to optionally design steps away. For a next time I would recommend incorporating the Lean and Six Big Losses stronger in the interview round of the discovery phase, I used them now more parallel than together. The model served more as a lens than as direct guidance in design, but I can also imagine that it could be fruitful to map out all the values and wastes, and subsequently have a creative session looking on how to eliminate waste. This does however, have a strong potential of going in the service design direction, which was not in the primary interest of Cadomotus.

The delivery phase of this project consisted of three iterations with increasing fidelity. The paper prototyping phase worked well for me to envision how the 3D concept mechanically would work, as it was complicated to envision this 3D concept also moving along the different parts of the pedal stroke. The second iteration cycle, which had a little bit of a higher fidelity was necessary to explain the concept to the different stakeholders. Yet here I made it look too sketchy to envision it as a finished concept, and it lost part of it’s explanatory power. This can be attributed at least partly to the fact that it was a complicated concept with a lot of different steps and mechanisms. What it should have communicated in this case was how all these different parts were one product when put together. When this is the goal, a higher fidelity prototype would be better I believe. The final and more mature prototype had a lot of value because it was easy for the target group to understand what the concept is, yet also to feel well what it is like. When working with shoes, comfort and ergonomics also play a part and to get valuable feedback on those a high level of fidelity is necessary. For example, above the toes we (Cadomotus and I) were not entirely sure if we needed a band to tighten that specific part of the shoe. To test this we needed an almost finished shoe for athletes to give feedback on.

This chapter presented a discussion around the results of this thesis. Things that might have impacted the validity of the outcomes, as well as elements of the design process that worked well.

11. Conclusion

This chapter evaluates the outcomes of the project. How well the initial goals from the introduction have been met as well as the most important lesson from conducting this project. It also judges how the concept scores on the Industrial Design Engineering pillars of desirability, feasibility and viability.

The goal of this thesis was originally to "thoroughly understand the competitive athletes experience during a race and design a fitting new solution for them." The deliverables as described in the graduation brief have been delivered, with a user-journey and an iteratively formed physical prototype that has been evaluated with athletes in the target group. Value is generated for the company since they see potential in further development of the shoe. Furthermore, the user-journey and its insights can help Cadomotus to further understand their target group, as well as having identified possible design opportunities.

The last iterative part of the design process has proven to be educational. Here the value of taking one extra iteration step proved valuable, as it led to a nice product that all the stakeholders believe in. What I take with me is that it is important to share all steps and design decisions when presenting these iterations. Even though people might be familiar with the context, they can still be caught off guard with some features that seem to come out of nowhere otherwise. By physically being at the company and having discussions around the design process, it is possible to foster a symbiotic relationship with a constant exchange of ideas and experiences. This process delivers a product that fits into the company's skill set, portfolio, and line of thinking.

At the faculty of Industrial Design Engineering it is deemed important that a product confirms to three different pillars: those of technology, business and people. A product should be feasible (meaning it can be made), viable (meaning it is affordable) and desirable (meaning people would like to have it).

For this project, most emphasis has been placed on the **desirability**. This has been a Design for Interaction graduation project, and this master focuses mainly on the people aspect of design. By evaluating with 20 different participants during the project, and having the needs confirmed again by new athletes during the final usage evaluation, it can be stated with relative certainty that there is a need for this problem and the designed solution.

The **feasibility** should get the initial focus during the next steps in the design process. By importing a mechanical system from another domain, one can be quite certain that it should be possible to actualise the envisioned interactions with the handle. Cadomotus has indicated that they see no major problems when manufacturing such a shoe. For the brake system an external company with expertise should most probably be approached. They will then also be able to give a more concrete assessment of the concept's feasibility and pricing.

It is therefore hard to determine the **viability** beforehand. Yet Cadomotus sees no significant problems which would cause the price of the shoe, excluding the brake system, to spike up. They estimate that the price will not be significantly higher than their normal offering, while seamlessly blending into their current product portfolio. A concept in a similar price category as the rest of the portfolio while at the same time addressing the athlete's needs better, is therefore most likely also viable.

The project has been reflected on, and generally its goals have been met. All that rests now is to thank all the people that have made it possible along the way.

12. Acknowledgements

My biggest thanks go out to all the people that have helped me during this project. I could not have done this alone. (The bias would just have taken over;).

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Koen Zweekhorst of ProReva, without you I would have never been able to create such a great looking prototype. I know it was stressful, so thank you for exceeding my expectations in literally every way. It was crucial in me being able to test my concept, and learn how to improve it.

To my parents and designer friends whom I burdened with reading this report and the delightful discussions on process, results, structure and visuals: thank you for all your help and inspiration.

And last but definitely not least a thank you to the Dutch triathlon community that has made this user-centered design thesis possible even in times of Corona and a lot of distance.

Cornelis
Dennis
Giel
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Joey
Kim
Koen
Lars
Luna
Marijn
Marit
Neal
Nick
Niek
Pim
Rani
Remco
Simon
Thije
Victor

& all the others that I have talked with and forgot to mention here: it gave me great joy learning about your experiences, frustrations and hopes. So let's tighten our shoes and see each other at the races next year!

13. References

All Icons are coming from the noun project.

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Marginal gains for major improvements:

A user-centered cycling shoe to increase performance for elite short-course triathletes

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