“The next generation of sheet steel formed e-bikes for the daily commute”

GRADUATION REPORT

APPENDICES

MARK VAN HASSELT
FEBRUARI 2020

MASTER THESIS INTEGRATED PRODUCT DESIGN
DELT UNIVERSITY OF TECHNOLOGY
### APPENDIX A: COST PRICE

#### Kostprijs staffel

<table>
<thead>
<tr>
<th>Modellen en opties</th>
<th>Dam Alloy 8-sp</th>
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<th>Dam City single speed</th>
<th>Dam Electric</th>
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#### Productiekosten frame

| 50 stuks | € 312,20 | € 312,20 | € 312,20 | € 312,20 | € 179,00 |

#### Nabewerking

- Poedercoat/enlaken: € 77,50
- Assemblage: € 32,00

| Totaal nabewerking | € 105,50 | € 105,50 | € 105,50 | € 105,50 | € 102,50 |

#### Onderdelen

- Frame: € -
- Voordynamo 5P: € -
- Voordynamo Son: € 105,00
- Verblijflicht: € 59,75
- RYDE velgen: € 16,00
- Brooks zadel: € 26,00
- Handwatten: € 4,00
- Gates CDX Belt: € 39,97
- Gates CDX 55T: € -
- Gates Crank + tandwiel: € -
- Gates CDX achter tandwiel 22T: € 42,88
- Gates CDX voor tandwiel 46T: € 45,03
- FSA ACR Lagers: € -
- Superstar headset: € 15,00
- Superstar zadelkern: € 7,00
- Tune headset: € -
- Schwalbe: € 15,00
- binnenband: € 3,46
- Magura MT4 voorremset: € -
- Magura MT4 achterremset: € -
- Shimano remset voor-achter: € 44,97
- Shimano affine crank: € 49,99
- Shimano Nexus Inter SE: € -
- E-bike parts: € -
- Tracify GPS unit: € -
- Shimano 8/11-speed: € 110,36
- Shimano 8/11-speed shifter: € 14,71
- Shimano Cap Nut: € 7,99
- Rohloff 14-speed hub: € -
- Spatborden: € 31,26
- Lightskin Zadelpen: € -
- Sator I zadelpen: € 8,11
- Sator stuur: € 5,63
- Sator stuurpen: € 11,00
- FSA ACR Stuurpen: € -
- Excentrische trapas: € 8,15
- HT pedalenset: € 20,00
- EVO voorvork: € 40,69

| Totaal Onderdelen | € 731,95 | € 852,21 | € 402,88 | € 862,96 | € 1.121,87 |
### Frame productiekosten stafel

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<th>Aantal stuks</th>
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<th>50 (staal) e-bike</th>
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APPENDIX B: MARKET FIGURES

Most people dislike bicycling for more than 30 minutes for their commute, but most people live a longer distance from their work than these 30 minutes. With the help of an electrically aided bicycle, a commute of 1 hour or more suddenly is no issue for the rider. Because you will not arrive all sweaty at work, like with a conventional bicycle. An extra effect on the consumer is that they already had some relaxed exercise before they arrive for their day at work, which will lead them to be more energized than when this time had been spent in a traffic jam.

The figures

Amount of new bicycles sold each year

Total net worth of newly bought bicycles
New e-bikes sold in comparison to regular bicycles

Market share e-bikes of total sold bicycles

Average costs of a new bicycle
As seen from the figures before, it becomes clear that the e-bike is indeed on a rise since the last few years. Another interesting finding from these figures is that bicycles are getting more expensive, but customers are still willing to buy these expensive bicycles, especially when it comes to e-bikes. Seeing that even in 2016 there was already a 29 percent market share of e-bikes as a part of regular bicycles, which includes road cycling, mountain biking and children’s bicycles as well, is very impressive. From these different areas we can surely say that the e-bike is indeed on the rise, and the e-bike is here to stay.

Reference:
APPENDIX C: COMPETITIVE PRODUCTS

To gain insight in this competition, the main competitors are analysed. From this, requirements can be found to which the Mokumono e-bike must comply. Moreover, opportunities in the market for Mokumono to exploit can be identified. In this analysis, only bicycles with integrated battery systems are included.

**Qwic urban series**

Retail price from €1.699  
Smartphone connection possible  
Action radius: up to 180 km.  
Removeable battery  
Weight: 23.3 kg  
Front wheel motor

**Cowboy**

Integrated light  
Retail price from €1.990  
Smartphone connection possible  
Action radius: up to 70 km.  
Removeable battery  
Weight: 16.1 kg  
Rear wheel motor

**Van Moof Electrified S2**

Integrated light and display  
Retail price from €2.798  
Smartphone connection possible  
Action radius: up to 150 km.  
Removeable battery  
Weight: 19 kg  
Front wheel motor

**Watt**

Display on the bicycle  
Retail price from €1.350  
Action radius: up to 60 km.  
Battery integrated in frame, non removeable  
Weight: 17 kg  
Rear wheel motor
**APPENDIX D: ALTERNATIVE E-BIKE MOTORS**

**Bosch**
Bosch is a key player in the e-bike world. They provide many different types of e-bike systems, fitted for different groups. They have competitive, high speed units. But they also sell strong, high torque units for cargo bicycles. Many e-bikes are fitted with Bosch motors.

**Performance line**
- Dynamic acceleration
- Minimal pedalling resistance
- Quiet
- Compact and lightweight
- Enough power for longer distances
- Weight: 3.2 kg

**Active line**
- Compact design
- Compatible with derailleur and rear hub gearing systems
- Gearing identification makes sure of less wear in the system.
- High compatibility
- Weight: 2.9 kg

**Bafang**
While Bafang might be lesser known than Bosch or Shimano, they still are used in many e-bikes today. They gained a foothold in the market with their front wheel motors, they produce some of the strongest front wheel motors available. Nowadays, Bafang designs great middle motors as well. The motors of Bafang have a lot of power, but because of this, the system makes more noise than their counterparts by other companies.

**M420 system**
- Weight: 3.6 kg
- Low drag, the motor disengaged when a speed of 25 km/h is reached.
- Pairable application
- 240 W
- 80 Nm

**M400 series**
- Light, powerful and durable
- 250 W
- 3.9 kg
- 80Nm torque
**Shimano Steps**

Weigh: 2.88 kg  
Small Q factor for a traditional bicycling experience.  
Small integrated design  
Automatic gearing

![Figure 5: Shimano Steps](image)

**TQ e-mobility systems**

TQ is a German company that holds on strongly to a few aspects of electric motors. Their motors have a high torque, are compact and are very efficient. TQ motors are already used in e-mountainbiking.

**TQ HPR 120S**

These motors are high-performance motors  
There is an integrated sensor system  
250 W  
120 Nm torque  
3.9 Kg  
146 mm shaft length

![Figure 6: TQ HPR 120S](image)

**Fazua**

Fazua is a company that creates modular drivesystems for hybrid e-bikes.

The Fazua Evation system is a fully integrated e-bike system. The motor, engine, sensors and battery are all integrated into one product.

Above 25km/h a freewheel disengages the motor from bottom bracket, thus giving no resistance.

**Fazua Evation**

Light  
Compact  
Integrated  
Total weight 4.6 kg  
Fazua rider app

![Figure 7: Fazua Evation](image)
IDE Master Graduation
Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student’s IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student’s registration and study progress.
- IDE’s Board of Examiners confirms if the student is allowed to start the Graduation Project.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format “IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy”.
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1!

family name
van Hasselt

initials
M

given name
Mark

student number
4215028

street & no.
Nunspeetlaan 171

zipcode & city
2573GA Den Haag

country
The Netherlands

phone
0611753331

e-mail
markvanhasselt@gmail.com

Your master programme (only select the options that apply to you):

IDE master(s):

2nd non-IDE master:

individual programme:

honours programme:

specialisation / annotation:

IPD

DFI

SPD

01 - 09 - 2016 (give date of approval)

Honours Programme Master

Medisign

Tech. in Sustainable Design

Entrepreneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right!

** chair
Erik Thomassen
deppt. / section: Design Engineering/PA

** mentor
Olaf Wit
deppt. / section: Design Engineering/PA

2nd mentor
Bob Schiller
organisation: Mokum Mono B.V.
city: Amsterdam
country: The Netherlands

comments (optional)
I want to combine the production knowledge of Erik Thomassen with the cycling knowledge of Olaf Wit.

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v.

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.
Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Erik Thomassen date signature

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

Master electives no. of EC accumulated in total: 30 EC
Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC
List of electives obtained before the third semester without approval of the BoE

name date signature

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks?
- Does the composition of the supervisory team comply with the regulations and fit the assignment?

Content: APPROVED NOT APPROVED
Procedure: APPROVED NOT APPROVED

name date signature

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30
Initials & Name M van Hasselt Student number 4215028
Title of Project The next generation of sheet steel formed e-bike frames
The next generation of sheet steel formed e-bike frames

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

**start date** | **end date**
--- | ---
29 - 04 - 2019 | 01 - 11 - 2019

**INTRODUCTION**
Please describe the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology,...).

The bicycle is a Dutch landmark on its own. The bicycle has been a truly loyal companion of the Dutch for many years now. During those years, the shape of the bicycle has not changed all that much. However, the way that bicycles are produced has changed drastically over time. Nowadays, bicycle frames are not produced in the Netherlands anymore. Almost all of the bicycle frames are produced in the Far East, because of the economically beneficial aspects. Using new production methods, the frames could potentially be produced locally again. This will reduce the costs of the bicycles by cutting out transportation around the world. In the research of this project, the choice of this production method and the benefits will be further analysed. from the research I will see if this is actually the most beneficial way of production for Mokumono.

Mokumono designed a new type of bicycle frame back in 2016. This new bicycle frame is much more tailored to be manufactured locally, which is something valued by the company. Mokumono focuses on designing and producing properly made bicycles with premium materials and components. There is no need to make the bicycles ‘smart’, just well made and thought through. It is important that the outcome of this project will hold on to the values that Mokumono believes in.

By using rubber pressing, two sheet metal shells are made. These two shells are welded together by a laser welding robot. Because of this very easily automated process, prices can be set competitively with those of the bicycle frames produced in the Far East.

With the upcoming trend of more and more e-bikes, it is a logical step for Mokumono to get in on this market. Since the bicycle frame designed by Mokumono has a lot of extra potential free volume in the frame, there is an opportunity to completely hide all of the electronics inside the frame. Also, you would want to have a removable battery inside of the bicycle, so the customer can recharge the battery inside of their home and the battery will be less exposed to weather conditions.

The goal of this project is to fully exploit the production method, while still having a functionally sound and reasonably priced e-bike frame which fits the target group and the brand image of Mokumono.
image / figure 1:  Mokumono bicycle

image / figure 2:  One out of two formed sheet metal parts
PROBLEM DEFINITION **
Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full-time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Production
If these bicycles were to be mass produced, some changes need to be made. The production currently includes a few expensive steps that might become unnecessary with a new product geometry. The possibilities of the given production methods will be researched and fully utilized in the following design. (Rubber pressing, two-mold pressing, hydropressing). The geometry of the frame will lead to increased stiffness where it is needed, while the frame still can be optimally produced.

Material and weight.
Since this bicycle is going to be an e-bike, weight is less of an issue than it is with regular bicycles or road cycling bicycles. However, the frame will still need to be optimized for as less weight as possible, since all of the electronic components will add extra weight as well. The choice has already been made that the frame will be made of steel instead of aluminum. The possibilities within this material will be researched and the frame geometry will be designed fittingly.

Integration
The electronics that make this bicycle an e-bike will probably be placed inside of the frame. This is because of the space available inside of the frame with this production method. A good integration in the shape of the frame is necessary. Also a design challenge will be the battery. The battery will need to be removable from the frame for charging, this means that there will be a hole in the frame somewhere, compromising the overall strength of the frame.

Aesthetics
With the upcoming trend of e-bikes, it is important to look into a good target group for Mokumono’s e-bike. It is important that the bicycle’s new aesthetics fit the target group and Mokumono’s brand image well.

ASSIGNMENT **
State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in “problem definition”. Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... . In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

"Designing a new sheet steel formed utility e-bike frame with integrated electronics to fit a desired target group and express the values of Mokumono."

For this assignment, a few variables are already given. First of all, it is certain that the bicycle frame designed is going to be an electrically aided bicycle. A target group will be defined according to the trends within this segment of the bicycle market, a new aesthetic language will be developed to fit this new group, while still holding on to the strong brand image of Mokumono.

The electronics needed for the bicycle will need to be fully integrated in the frame of the bicycle. This will present some extra design challenges for the geometry of the frame itself.

The material of choice is going to be some kind of steel. Which type of steel this is is still to be determined. There will be research into different (upcoming) steel types and their benefits towards the frame and the production method involved.

The bicycle frame that will be designed will be aimed at exploiting the positives of the chosen production method, while still holding on the the visions and values Mokumono believes in.
PLANNING AND APPROACH

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

Week 1-4 | Analysis
In this period research will be done on the production method. Parallel to this, research will be done on the current and near-future trends in the e-bike and regular bicycle industry. From this research a lot more insight will be gained on the production method and on sheet metal forming in general. Also an overview will be made of the electronics needed for this particular e-bike. During this research a clear target group will be defined.

Week 3 - 6 | Ideation
Directly after, and a bit during this phase, the ideation phase will be initiated. The ideation method will overlap with the research phase. During the ideation phase the most relevant ideas will already be further developed into more detailed concepts.

Week 7 | Concepts
There will be one week for further creation and selection of concepts, as well as documenting the ideation process.

Week 8 - 24 | Embodiment
From here on there is a 10 week window for the embodiment of the design. This may sound like it is a bit much, but in this period a lot of prototyping will be done. This period also has extra space for eventual additionally required research. During the embodiment phase, an iterative process will be followed, so there will be space at all time to take a step back in the design and rethink.

The last 3 weeks of the embodiment period will be focused on validation of functionality, production and aesthetics and final prototyping.

Week 17-20 | Presentation / Documentation
The final 4 weeks of the project will be focused on documentation and presentation making, as well as some possible extra work on the final prototype.
MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed.

Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge on a specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... . Stick to no more than five ambitions.

There are a few particular aspects of this project that are most appealing to me. I have done a few cycling-related projects in the past and this field really interests me. However, these projects were always more aimed at road-cycling instead of the utility e-bike market. The world of road cycling is primarily aimed at peak performance, and not so much on user ergonomics and aesthetics. I am very excited to work on a bicycle frame itself, as my previous design projects were mostly aimed at peripheral products for the bicycle.

One of the main reasons for my enthusiasm is the new aesthetic language that will be explored for the new e-bike frame. I have always liked exploring aesthetics and find it very interesting how important aesthetics are to appeal to consumers. Another challenge is that the form language of the design will be derived from the research on the production method, this means that production is always minded while designing the geometry of the frame. Also it is going to be a big challenge to give a less dull image to e-bikes.

Moreover, working with sheet metal is going to be very interesting for me. I have worked a lot with metals in the past, but never with sheet metal forming like this. I did some work for a company which used bending to make sheet metal products, but sheet metal forming is going to give a whole array of extra possibilities in comparison with regular bending.

A big challenge for me during this project is going to be to keep prototyping. What I see happening a lot on designers who work on a new aesthetic for a product, is that they are stuck in pretty renderings and sketches. What I want to do differently is to always keep a link to the physical world by making a lot of prototypes. These will range from little quick models to more elaborate physical prototypes. By doing this I hope to keep a link with the actual outcome of the project, while still being able to create an aesthetically pleasing design that fits the style and brand image of Mokumono, as well as to connect the design with the chosen target group.

An important learning goal for myself will be the planning and overview of the whole project, including updating Mokumono regularly and keeping the project transparent for all the participants. Also a good time planning will be essential for this project, due to only having 20 weeks to complete it. This means that the more time efficient I can work, the more will be done in the end. In my bachelor this has always helped me out a lot.

The most important learning goals of my graduation project will be:
- Realistic planning and sticking to this planning.
- Time management
- Clear communication with all involved parties.
- Ongoing prototyping
- Aesthetic validation

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.