11. Appendix

Master thesis by Romy Geitenbeek,
July 2021

Appendix A. - *Design brief*

Personal Project Brief - IDE Master Graduation

TU Delft

Embodiment design of a delivery robot

project title

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 24 - 11 - 2020 | 23 - 06 - 2021 end date

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, ...).

A delivery robot is an autonomous robot that is able to deliver goods to people's doorstep. The robot is projected to be cheaper, more energy-efficient, and more flexible than most other delivery solutions. And, particularly relevant these days, they can provide a safe alternative for those stuck in quarantine. But what should the embodiment of such a robot look like? How should the robot interact with the customer at their doorstep? And how can we make the process of someone who has a robot deliver goods to their door as smooth and clean as possible?

The AMS Institute would like to create a delivery robot. They bought a robot called Husky from Clearpath (figure 1), that can be used as platform for the rest of the design. AMS is an institute for advanced metropolitan solutions. They would like to create a delivery robot that would be able to deliver lunch to the firms on the business park, where AMS is positioned as well. Their main interest is to set up innovative projects that will benefit the municipality of Amsterdam and get parties involved.
The AMS institute is trying to get an agreement with FoodLogica. FoodLogica is working with food businesses to solve their last mile logistics challenges. The autonomous (electric) delivery robot could fit their sustainable image and could possibly ensure more brand awareness and a bigger sales market. The robot would mostly likely be stored, charged and loaded at a FoodLogica location.
The stakeholder situation of the project is a bit complicated. AMS wants to be involved with the robot, but since they are not paying me or using the robot as a profit for their company, it will not be seen as a client. Besides the company stakeholders, the customers' needs are of great importance when designing an embodiment for a delivery robot. To make this project suitable for 20 weeks, the main focus will be to design an embodiment with focus on the human-robot interaction at the doorstep (figure 2). Customers want their food fast, in a good condition, complete and at a time that suits them, the more precise the timing, the better.

An opportunity that I am currently aware of is that people are ready for an innovation like this. Due to Covid-19, contactless delivery has become more important. Due to IoT and improvements of the current delivery system, people do not want to wait at home for a long period of time just to receive their package. I would like to build some prototypes in this project. AMS currently owns a robot platform. This will give me the opportunity to create a working prototype.

Due to the Covid-19 restrictions it might be harder to prototype. I will probably not be able to go to the AMS Institute for multiple days a week. Even in case of quarantine, I also would not be able to go to PMB at the faculty. It will probably also be harder to get in touch with people. I cannot just ring a doorbell and have an interview with a potential customer or see how they will respond or interact with a prototype or idea. The situation requires more planning.

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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.

The robot platform, bought by AMS, is not able to deliver goods to customers yet. To make this project suitable for 100 working days, the main goal will be to design an embodiment with focus on the human-robot interaction at the doorstep. The general problem is that the robot platform does not have an embodiment nor a system to communicate with the customer yet, resulting in an undesired human-robot interaction at the customers doorstep. So, the challenge would be to design an embodiment that enables a desired human-robot interaction. According to *Alenljung et al. (2017), quality of human-robot interaction can be evaluated with different aspects, including acceptance, usability, learnability, safety, trust and credibility. These aspects can be divided into two groups: cognitive experience and physical experience and should be addressed in the project.

Cognitive experiences:
- Learnability; the robot should make it intuitively clear what actions are needed to retrieve the goods.
- Trust; the robot should make the customer feel comfortable to interact with. Instead of behaving determined and looking aggressive, the robot should behave inviting so the customer would feel at ease to retrieve the goods. The goods are currently available to everyone and they should only be accessible to the intended customer.
- Credibility. The robot must build credibility that it will deliver the goods on time and of good quality. The design should be aesthetically pleasing (should fit the behavior of the robot). Maybe the robot should look aggressive at tough when driving (in order to prevent vandalism and theft), but innocent/inviting at the doorstep.
- Acceptance; The delivery robot should be seen as a new easy way of having your goods delivered.

Physical experiences:
- Usability; It should be physically comfortable to retrieve the goods from the robot.
- Safety; It should be safe for the customers to grab the goods from the robot. Thereby it is important that the goods remain in good quality.

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.

Design and prototype a modular, functional, and aesthetically pleasing embodiment that enable the robot platform to deliver crates with goods to people's doorstep, while keeping the human-robot interaction at the customers' doorstep in mind.

I expect a product-service combination.
The product will be an embodiment of a delivery robot that deliver goods to the customers doorstep. The embodiment will be designed keeping the user experience at the doorstep (main focus), the functionality of transferring the goods and the aesthetics of the robot in mind. The appearance of the embodiment will fit the way how people should interact/behave around it.

Service design is needed to create a smooth process of delivery. For example, an app can be created to let the customer know where the robot is and when it will arrive. The app could also provide step-by-step information in case something goes wrong in the process. However, this will not be the main focus of the project. I am expecting to come up with an idea of a service, such as an app, but I am not expecting to design the app itself.
To enhance the process of good delivery, different product-service design ideas could be created. Maybe the goods are not only transferred by a robot-human interaction, but through a certain medium, such as a big mailbox, or a "mail door" integrated in a house, or a big mailbox for the entire street.

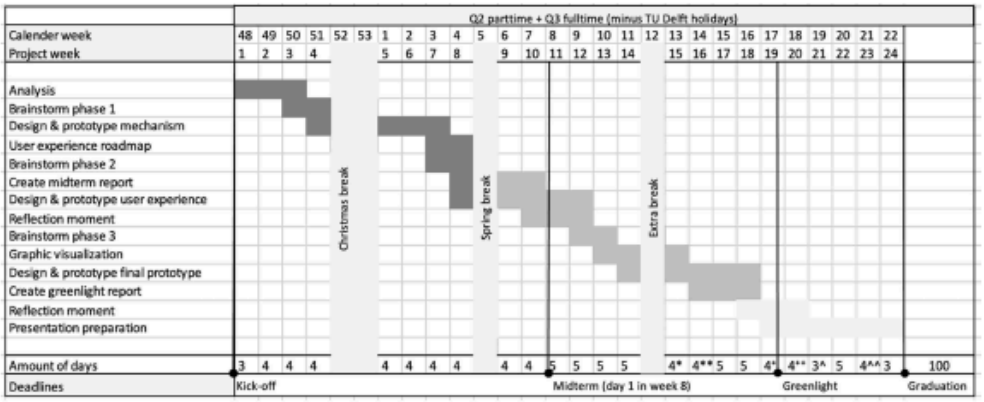
Initials & Name R.R. Geitenbeek Student number 4362160

Title of Project Embodiment design of a delivery robot

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.

start date 24 - 11 - 2020 — 23 - 6 - 2021 end date



Analysis
Stakeholders (interviews)
Current delivery situation
Trends in sectors
Current delivery robots
Human-robot interaction
Theft/vadalism (interview)

Brainstorm phase 1
How to receive goods
Mechanism good transfer
Different scenarios
Document everything

Prototype mechanism
Sketch mechanism concepts
Talk with professional
Prototype mechanisms
Test mechanisms
Improve prototype
Document mechanism

User experience roadmap
Create visual of all the interaction

Brainstorm phase 2
Placement electronics
Functions besides mechanism
Talk with municipalities
Sketches embodiment
Plan for user tests
Documentation

Prototype user experience
Sketches of prototypes
Talk with proffesionals
Create prototypes
Test prototypes
Reflect and iterate
Documentation

Brainstorm phase 3
Sustainability
How to make it in reallife
Aesthetic embodiment
Skecth of final prototype
Documentation

Graphic visualization
SolidWorks model design
Skecthes user experience
Skecthes different scenarios
Visualization revenu model

Prototype final prototype
Create prototype
Print small 3D model

Presentation preparation
Final documentation
Final reflection
Create video
Create presentation

In my planning, I scheduled to work for 4 days a week until midterm (week 7). Hopefully, the covid-19 situation will change in 2021. By stretching the timespan of the project, I hope to be able to have more interaction with AMS, the user group and other stakeholders. The Christmas break, spring break and the official TU Delft holidays are acknowledged in this planning as well. Since I am planning to make prototypes, I also scheduled an extra break. In case covid-19 restrictions will get in the way of going to PMB, I would have the possibility to shuffle with the days and use the extra break as days to work on my prototype.

The first step after the project brief will be to start with an analysis. I will analyze stakeholders, try to interview them, analyze current delivery robots and learn from their mistakes. I will do research about current trends, human-robot interaction and the reason why people vandalize or commit theft. After the analysis, I will try to come up with a functional design. The robot should be able to deliver goods, give access to the customer and being able to present goods. By making use of a brainstorm, I will try to design and prototype a mechanism of this functional design. After prototyping and testing the mechanism, I will be looking into the user experience of the robot. The robot should be easy to use and the aesthetics of the embodiment should match how the robot should make the user feel. By creating prototypes, the user experience can be tested. Once a functional design and the design experience is created, a final visualization and prototype can be made. During this project, I will be constantly documenting and reflecting every step. However, some extra days of documenting are scheduled before the midterm, greenlight and final deadline. Some extra hours of reflection are scheduled after midterm and greenlight as well. The weeks of prototyping are the weeks that needed to be scheduled with the most flexibility, due to the Covid-19 situation. To make sure I would still be able to complete the tasks described in this planning, I created a back-up planning. The days after the greenlight are mainly reserved for creating a video, perfectionating the report and finalizing the presentation.

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 a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

When setting up this project, I was aiming to find a graduation project in the robotics field with a clear assignment. I wanted to combine functional design with social design (human-robot interaction). Besides that, I wanted (and I still do) to finish my project with a tangible, visible, innovative design.

One of my ambitions is to prototype. With prototyping you gain deeper knowledge about not only the functionality of a design (does it work or not), but also about the user experience. Since I am aiming to design an embodiment that enables a desired human-robot interaction at the customers' doorstep, I believe that prototyping will give me fruitful test results that will help me come up with a final design. Every prototype will bring its own challenges and inspiration for better design. This specific graduation project also gives me an opportunity to improve my prototyping skills. I will create a robotic design and that is definitely a direction I would like to head in my future career.

Another ambition is to create a clear planning. I would love to finish my graduation project with a design I can be proud of. However, I can be a bit chaotic. I think creating a clear planning and adjusting this planning through the project, will give me a good overview of what is doable in 100 days. In this way, I should be able to get a lot done with less stress. This will definitely be a challenge for me, but I think it would be useful for my project as for my state of mind.

My last ambition, as described above, is to finish my project with a tangible, visible, innovative design. Industrial Design Engineering is all about designing for the future and I would love to design a new way of getting your goods delivered. I want to prove that I am able to design such an innovative project like this. Looking at all requirements for this project, I believe that this is a graduation project I was searching for.

FINAL COMMENTS

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

References:
*Alenljung, B., Lindblom, J., Cort, R., Ziemke, T. (2017). User Experience in Social Human-Robot Interaction. International Journal of Ambient Computing and Intelligence 8 (2), 12-31. Retrieved at 16-11-2020, from DOI: 10.4018/IJACI.2017040102

Appendix B. – *Interview FoodLogica*

Interview FoodLogica

*Nina is part of the FoodLogica direction team (HR and operations). Alberto is delivering the goods for FoodLogica with the FoodLogica vehicles. Nina and Alberto were both present at this interview.

1. How does the loading process of the FoodLogica vehicles look like?
   First, a truck of Albert Heijn arrives and delivers all the crates that has to be delivered that day. There are nametags of the companies, where FoodLogica will be delivering, on the wall. Albert Heijn will put the crates in front of the right name tag of that day. Frozen and cooled goods are placed in a big fridge. Then the FoodLogica deliverer will put the crates into the vehicle and drives towards the right addresses and deliver the goods.
2. How many people are involved with this loading process?
   There are only two people involved: the employee of the Albert Heijn delivery service and the employee of the FoodLogica delivery service.
3. Do you use the same crates, the Albert Heijn is using?
   Yes, we are reusing the crates. The companies are allowed to rent the crates as well for a small amount of money. The FoodLogica deliverer will take by the old crates, when delivering the new ones. They are also using the same coolboxes as the Albert Heijn does (also called a Tempex).
4. How do you currently cool the products?
   Well, the Marineterrein is really small, so this is actually our one exception where we do not use a vehicle with an active cooling system. Normally our vehicles are making use of an active cooling system. The temperature of inside the vehicle can be adjusted and read from outside the vehicle.
5. Do you distinguish normal, cool and freezer products in the vehicles?
   Well, we do distinguish them. We transport the normal products in crates and the cool and freeze products in a coolbox-crate. Thereby we also refrigerate those goods before transporting. The FoodLogica deliverer has to write down the temperature of the refrigerator, before taking out the products. If a product turns out to be of poor quality, we can prove that it was not our fault.
6. Did you ever had any problems with cooling the products?
   We did not have any problems with the normal and cooled products. We did have some problems with the frozen products in summer. We do not deliver frozen products that often, but we had some complains in summer that the goods were not completely frozen. Observation: the vehicle with active cooling system is not able to cool below 0°C and the refrigerator was set to a temperature of 4°C.
7. Do you need to check the food before delivering it?
   Yes, the FoodLogica deliverer needs to check the goods before loading the goods into the vehicles. The employee must check if nothing is broken, expired or dirty.
8. How do you decide what vehicle you will be using?
   Usually, I just base this decision on the volume of the goods (number of crates) and vehicles available.

9. Where do you charge the vehicles again?
   The vehicles are charged at the same location as they are stored. A big storing/loading place in Amsterdam is positioned at Houthaven.
10. What are your current customers? Mainly firms or citizens as well?
    We usually deliver goods to other companies. First, we only delivered food to restaurants and cafes, but now we often deliver lunch to companies. We also deliver food boxes to customers. FoodLogica is working with subscriptions. So, they will not just deliver groceries ones in a while, but they deliver almost the same order every week at a certain time slot. One of their focus areas is sustainability. The customers are currently also people who consider sustainability as important.
11. What are the firms on the Marine Terrain where you are currently delivering?
    Some of the are The AMS Institute, Growth Tribe and Bua.
12. What happens if an order is not complete or the customer is not satisfied?
    Since FoodLogica is more seen as the courier of the goods, people tend to complain to the company where they bought the goods. The customers do not pay FoodLogica directly.
13. Does FoodLogica only deliver food or also other goods?
    Yes, we only deliver goods, we do not deliver just normal packages.

Appendix C. – *Interview Employee Jumbo delivery service*

Interview employee supermarket food delivery service
*Vincent is a Jumbo grocery delivery employee

1. How do you know where you need to be at a certain time?
   We use a TomTom. There is a pre-programmed route that we have to follow. Sometimes, the TomTom is not up-to-date, and we need to find the location ourselves.
2. Do you work with timeslots?
   Yes, we do. Everything is timed. However, we have 3 hours extra to get all the groceries delivered. For example, the last delivery can already be delivered at 6 o'clock, but you are also allowed to deliver the groceries at 9 o'clock.
3. What do you do when you cannot be on time?
   Usually, we just give the customer a call that we are a bit later. If we are late, we can give them a compensation (food, discount). If we are late, we often still deliver, but than just later that night. The customer does not mind most of the time. If later that night is not possible anymore, the shift will be added to next day (morning) delivery.
4. Does the truck have a cooling system?
   The truck does not have one. The crates have them. There are three different kinds of crates. A normal "Jumbo" one, a cool crate and a freezer crate. The cool crate and the freezer crate are slightly bigger than the normal crate.
5. Does the average customer order just one crate or do they order often more crates at once?
   The customer must order for a minimum amount of 50 euro, so they often have more than one crate delivered. I would say the average customer has 2 or 3 crates delivered and spends around 110 euro. Every customer gets their own crates. So, the products of other customers are not allowed to be transferred in the same crates.
6. Do the crates stay are the customers? Or are you making use of plastic bags?
   The cool crate and the freeze crate are not allowed to stay at the customers. There are plastic bags in these crates and the customer is only allowed to take out these plastic bags. With the normal crates, the user is allowed to borrow the crate (deposit is 5 euro). If the customer does not want to borrow the crate, Jumbo will also make use of plastic bags. The plastic bags are 5 cent each (to stimulate the borrow-principle). In theory, the customer is allowed to unpack the plastic bags and give them back to us.
7. Are the customers often at home?
   Yes, they are. I rarely have customers who are not at home.
8. What do you do when they are not at home?
   I usually just ring their doorbell a few times. If they are still not opening the door, I will ring them on their phones. If they are still not answering, we will let the boss now and go deliver the next order. The customer can them come to the store to pick everything up or the groceries will be added to the shift of the next day.
9. Are there consequences for the customers if they are not at home?
   No, not what I am aware of.

10. Do you know what happen with the groceries if the customers are not at home?
    They hold them, so the customer can pick it up themselves or the products are placed in the store again.
11. What do you do if you have to deliver the goods in a flat?
    Park the truck and ring the door. If the customer let us in, we will use a hand truck for the crates and use the elevator to get the groceries delivered. It is not very usual that the customer will come downstairs.
12. Is there something that often goes wrong when delivering the goods?
    No, not really. Sometimes there are mistakes caused by the distribution center. One time all the products were doubled for a customer. But the customers pay at their doorstep, so I was able to remove the doubled products from the crates and from the customer's bill. Sometimes, people order products who were not available anymore. Those products cannot be delivered then, and those will be removed from the bill automatically. If a product does not survive the journey (broken), we can also manually remove the product from the customer's bill.
13. Do you get angry customers sometimes?
    Sometimes, but most of the time it is just because I parked the truck wrong. Because I do not want to lose a lot of time, I sometimes park the truck double or just not that precise.
14. Are there certain hygiene rules you should follow?
    Yes, now there are (because of Covid-19). We have to wear facemasks, clean the car steering and the truck after the shift, but before Corona we did not have to clean anything at all.

    *The customer pays at their doorstep. If the pin does not work, we will send them a payment request (Tikki or something similar).

Appendix D. – *Trend analysis*

DEPEST-method

Demographic trends

- The population is still growing, and people will live longer (due to the improving life circumstances and health care). The world should reach 8.5 billion people by 2030.
- International migration will reach record levels. It has become easier for people to move, and factors such as poverty, unemployment, conflicts and natural hazards compel people to leave their homes in search of better lives.
- Mass urbanization will be a consequence of international migration. Since there are more people in the urban areas, more houses need to be built with the result of building up (creating flats) or building down (houses underneath the ground).
  Demographic conclusion: the delivery robot should also be valuable for people who are living in a flat. Thereby, should the robot be easy to use for people from all different nationalities/languages.

Economic trends

- Due to the covid-19 pandemic, consumers across all age groups are driving a rapid acceleration of e-commerce grocery shopping.
- Cash will disappear, it will all be about paying with cards or thorough online payment.
- E-commerce is growing business. However, it is expected that after the covid-19 pandemic, the e-commerce business will decrease a bit again. However, the business will stabilize on a different level. Covid-19 improved the services/online strategies of the e-commerce businesses.
- Customer services is key. Same day delivery will become a trend in the future.
- Third-party delivery continues to grow as its usage increases across the restaurant and grocery industries. Restaurant chains are increasingly partnering with multiple third-party fleets in order to expand their delivery footprint across all their stores and at all times of day.
- It is expected that the food business will experience some changes in the future. People would like to have their food directly from the local farmer. In this way the people can support their local farmers and it is more sustainable (more environmental awareness in the future).
  Economic conclusion: More people will shop online in the future and would therefore make more use of delivery services. Delivery robots could offer a perfect outcome. However, a good customer services will get even more self-evident. The satisfaction of the service ensures that the customer will continue to use the service. The robots might not only be used for big companies, but maybe it could also be used by the local farmer/store to deliver the goods in their area.

Political trends

- Governments are defining policies for a more sustainable future. By 2030, no new addition of generating capacity will come from fossil-fuel-based technologies.

- To combat climate change, the Dutch government wants to reduce the Netherlands' greenhouse gas emissions by 49% by 2030, compared to 1990 levels, and a 95% reduction by 2050.
- Giving away free plastic bags is prohibited in many countries already and more countries will follow in the future.
- Each year, the number of states considering legislation related to autonomous vehicles has gradually increased.
  Conclusion political trends: the laws will probably make it possible for the autonomous delivery robot to operate in the streets in the future. Plastic bags should be tried to avoid in the crates, when delivering the goods. The robot should not be powered by fossil fuels but should electric instead (maybe even powered by renewable sources).

Environmental trends

- Climate change is growing problem. The world already witnessed the impact of climate change on some natural systems. People are becoming more aware that climate change is a problem and that we need to start doing something about it.
- Businesses play a major role in driving sustainability.
- Electric vehicles will replace fuel-based vehicles.
- Less people will eat meat in order to live a more sustainable life.
- Packages become part of the product. They are reusable as package or can be used as something else.
- Foods waste is and will be a problem in the future if no further actions are taken.
  Conclusion environmental trends: People are more aware of the environmental problems. The delivery robot could promote himself as the sustainable choice as a marketing strategy. Of course, the robot needs to be designed in a way so the robot will actually be sustainable. The robot could be electric, delivery less meat (or only more sustainable product) and use reusable packages, such as crates, without plastic bags. The robot itself could also be designed in a sustainable way. The robot should be easy to repair, reuse, remanufactured and easy to be recycled.

Social-cultural trends

- Equality of gender, race, disability, sex and sexual orientation gender are becoming more important.
- Due to improved technologies and competitive businesses, the customer expectation has been increased and will increase in the future.
- People care less about a specific product or service (taxi or new car) because they have so many other choices (ride share). In this environment, trust and reputation can be replaced with social recommendations and standing.
- Everything is connected and shared. The world will become more open and less private.
- First part data, privacy is getting more important. People are more and more communicating in privet groups instead of communicating with the entire internet.
- It is not important unless it is shared. Social media (for example, if something is "instagrammable") is getting more important.
  It will be harder to hold people's attention. People are also better at filtering the information that seems relevant for them.

- Millennials are becoming the biggest group; they are more demanding than the previous generation.
- A rise in food delivery subscriptions. Millennials are the first generation that would rather stay in than go out, and that often translates to dining in with a customized meal kit delivered to their door. Pre-prepared fresh meals, menu kits with raw ingredients, and other home food kits that save customers time are top draws for the 55% of millennials that prioritize convenience over even taste, according to the Food Information Council.
- Food is fun. It will not be seen as a fuel by a big percentage of the Western World in the future.
- "Meten is weten". People would like to know what is wrong with their bodies and what they can do about it. Doctors' appointments will be reduced by using official healthcare apps and other apps that will people give insight in their own body. Conclusion social-cultural trends: People will make more use of shared products in the future. However, privacy is also getting more important. The delivery robot will use a camera in order to drive autonomously. The robot should communicate in a certain way with the customer that they are not using the footage for something as then for driving and delivering the order. Since food is more seen as fun nowadays, the delivery robot could maybe add some fun to this experience. The robot could be personalized by every customer, make it instagrammable or just make it personal by delivering a completely personalized package of goods for the customer. The robot should be easy to use by all people (disabled people, by all genders etc.).

Technological trends

- Machine learning will be used and developed even more in the future.
- Tools to analyze information will be well-developed and will make some decisions-making easier. For example, it will be easier to choose products with the lowest carbon footprints, highest wages for employees and fewest toxic ingredients.
- By 2030, the share of autonomous vehicles on the road ranges from the teens to nearly 100 percent.
- Due to the internet of thing, every new device will be connected.
- Technology will manipulate us even more than what it does today. It will create new kinds of jobs, but it will also eliminate entire segments of work (taxi drivers).
- Digital self. People might be ordering their groceries by using a google home.
- Robots will downsize. Small, personalized robots will eventually "run around our houses".
- A trend could be customized food. An app could track information from the users' body and could create a specially formulated customized food composition (dinner).
- Food might be 3D printed in the future.
- Personalized advertisements
- Companies will be using chatbots as help desk or as marketing automation. Conclusion technological: The customer might use other devices in the house to order their goods. The customer might tell their shopping list to a device or the device will notice it himself (for example the fridge notice that he is out of milk and put it on a (suggested) shopping list). The food could be personalized for the customer, based on their bodies or the awareness of the ingredients by the customer.

Appendix E. – *Analysis passive and active cool boxes*

Existing active and passive cooling systems

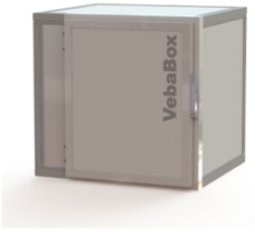
Existing active cooling systems
Vebabox
Their smallest box with an active cool/freeze system can be found below.

Model B Cool

Externe afmeting (bxhxd):
950x900x1050 mm
Volume: 450 liter

- Koelen en verwarmen tussen de 2˚C en 25˚C.
- Hoge uptime door verwisselbare koelunit.
- Direct uit voorraad leverbaar.

Model B Freeze



Externe afmeting (bxhxd):
950x900x1086 mm
Volume: 450 liter

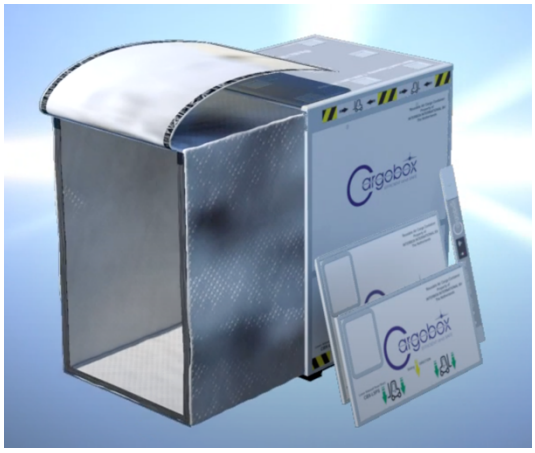
- Vriezen en koelen tussen de -20˚C en 5˚C.
- Eenvoudig vries- koel- en ongekoeld transport combineren.
- Hoge uptime door verwisselbare vriesunit.
- Direct uit voorraad leverbaar.

The coolbox weights 75kg and the freezebox 94kg. This is already too heavy for the Husky (the Husky can only carry 75kg). Placing the coolbox onto the Husky is possible, but then there is no weight left for the groceries, which will make the robot is useless.

Vebabox is making use of a removeable cool unit. This unit is the most important part of the box. The rest of the box is, I guess, just an isolated box, with a right fit for the unit. The company is also promoting a service to customize the boxes. So, the box might be adjusted for the Husky. However, I still doubt it if it will not be too heavy.

Cargobox

The Cargobox should not be seen as a box with an active cooling system. It is basically just a coolbox within another box (made from special materials) in it. The Cargobox does have a system which can accurately measure the temperature in the box. FoodLogica mentioned that they are using this box, but maybe they confused it with Vebabox?
No information is provided about the dimensions of the box. Since most of the material of the box is Styrofoam, the box will not be that heavy.



Envirotainer

Envirotainer provides active containers mainly used for cargo (flight) transport. The company uses a (1) thermostat-controlled air conditioning system with compressor cooling and (2) electrical heating and a thermostat-controlled heat exchanger, using dry ice as a coolant. With the second option, the company is using dry ice to make the temperature drop and uses the heat exchanger to get it at the right temperature.
With both methods batteries are used as energy source. The company does not provide smaller versions of these boxes. The smallest box is 2000 x 1535 x 1620 mm and weights 265kg.

Lufthansa Cargo

Lufthansa uses multiple different active cargo systems to transport goods. Some active cargo boxes are described below.

Refrigerated containers. This type of containers uses dry ice concealed in a separate dry-ice tank as a cooling energy source. Thermostats and fans help maintain the required temperature ranges and ensure proper air circulation. As this container technology does not heat the air inside the freight compartment of the unit, exposure to temperatures near or below the set temperatures should be limited.

Unicooler. The Unicooler allows the container's interior temperature to be heated or cooled using dry ice (concealed in separate dry ice bunker) with permanent air circulation as well as electrical heating provided by large rechargeable accumulators.

CSafe. The CSafe regulates the container's interior temperature, without using dry ice, by compressors for cooling or by using electrical power for heating.

All these cargo boxes described above are too big and heavy to put on top of the Husky. A size of a regular coolbox would be a better fit. Some coolboxes with an active cooling system can be found below.

DOMETIC CombiCool
The Dometic CombiCool is a portable absorption coolbox. The box can be powered by gas (remote locations) or by 12 V DC and 230 V AC. The dimensions are 508 x 500 x 441 mm with a volume of 40 liter. The weight of the box is 17kg. The coolbox will keep its contents 25°C below the ambient temperature. The price of this box is €260.

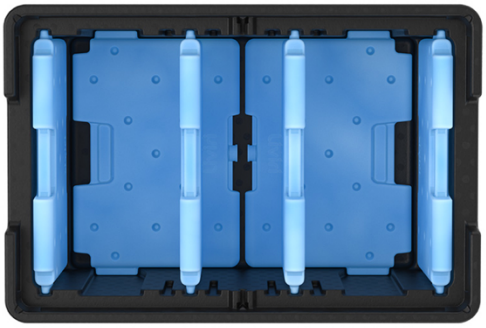
Mobicool MCF40
The Mobicool MCF40 is a compressor cooler, that is powered by 12/24V DC and 100-240V AC. The box conveniently adjusts the temperature between the +10°C and -10°C. The dimensions are 584 x 365 x 446 mm with a volume of 38 liter and has a weight of 11,5kg. The price of this coolbox is €284.

Mobicool wheeled coolbox
This Mobicool coolbox is a thermoelectric cooler & warmer with two wheels. The dimensions are 560 x 373 x 458 mm. The capacity of the coolbox is 35 liters and weights 8.8 kg. The cooling capacity is 20°C below ambient temperature (heating capacity up to 65°C). The box operates on 12V DC or 240V AC. The price is liter and has a weight of 11,5kg. The price of this coolbox is €140.

Dometic CoolFreeze CFX
The Domestic CoolFreeze CFX is a compressor cool/freeze box (A++). The dimensions are 725 x 455 x 561 mm and can carry up to 60 liters. An empty box weight 22.3kg. The box operates on 12V DC or 240V AC and adjust the temperature between the +10°C and -22°C. The price of this coolbox is €825.

Existing passive cooling systems
Passive cooling focuses on maintaining optimal operating temperatures with low or no energy consumption at all. Some examples of different kind of passive coolboxes can be found below.

Liviri



"Liviri Sprint[50] is a durable, reusable grocery box that helps grocers, specialty food companies and produce shippers with their staging and delivery. It provides more flexible options for chilled storage with high-performance insulation that keeps contents in the safe temperature zone for 12+ hours. It also reduces the need for chilled storage space or refrigerated trucks."

VebaBox
The Logibox Standard provides cooling between the 2˚C and 8˚C for a maximum of 72 hours (due to the use of cool elements). The size of the box is designed so the average crate would fit.

Nanotool
Nanotool claim that they offer a cooling system that is seven times more powerful than gels pack or ice. By activating the nanotool (pressing on the button on top) the package will become cold (between the 2˚C and 8˚C)

and will last with a choice of 2 day or 4 to 7 days duration. It looks like the nanotool cannot be used twice. It seems like a chemical reaction, but they use terms such as "activate the engine'', which are a bit confusing.

Albert Heijn crates
The Albert Heijn uses black coolboxes for their cool and freeze products. The box is made of plastic and Styrofoam. In de inside, there is extra room for a cool element. If the products need to be frozen, extra bags with ice are placed into the crates. The coolboxes are slightly bigger than the average Albert Heijn crates.

The dimensions of the Albert Heijn crates are unknown for now.

Figure X. Albert Heijn cool crate

Figure X. Albert Heijn freeze crate

Tunra 35 (Yeti)
The dimensions of the Yeti coolbox are 543 x 400 x 511 mm. The box is made from a thick layer of plastic and Styrofoam, nothing else. The box weight 9.1kg. According to Yeti, their boxes will stay cold for 2-4 days, but it has the ability to stay cold and keep ice for 7-10+ days given enough ice and the right conditions. The price of this box is €299,99.

Figure X. Tunra 35 with a thick layer of plastic

Bo-camp coolbox
The dimensions of the Bo-camp coolbox are 290 x 390 x 450 mm (32 liters). The box has a weight of 2,4kg. The coolbox is made from plastic and Styrofoam. The price of this box is €29,95.

Sunware square coolbag
The dimensions of the Sunware coolbag are 310 x 230 x 430 mm (32 liter). This coolbag is designed to fit into a crate. The bag is made of polypropylene and aluminum. The price of the bag is €13,95

Appendix F. – *Passive cool box experiment*

*One of the calculations is shown is this appendix

---

2. Coolbox (no crates, one product)

```
> restart;
```

Air variables

```
> T1 := 40;
  h1 := 25;
```

$$T1 := 40$$
$$h1 := 25$$

Thickness layers

```
> L1 := 0.005;
  L2 := 0.04;
  L3 := 0.002;
  L5 := 0.002;
```

$$L1 := 0.005$$
$$L2 := 0.04$$
$$L3 := 0.002$$
$$L5 := 0.002$$

Dimensions inside Coolbox

```
> Length := 0.51;
  Width := 0.38;
  Height := 0.265;
  LidHeight := L2 + L1;
```

$$Length := 0.51$$
$$Width := 0.38$$
$$Height := 0.265$$
$$LidHeight := 0.045$$

Dimensions carton of milk

```
> MilkCanLength := 0.10;
  MilkCanWidth := 0.10;
  MilkCanHeight := 0.20;
```

$$MilkCanLength := 0.10$$
$$MilkCanWidth := 0.10$$
$$MilkCanHeight := 0.20$$

Surfaces

```
> Afront := (Width + 2·L3 + 2·L2 + 2·L1)·(Height + LidHeight );
  Aside := (Length + 2·L3 + 2·L2 + 2·L1)·(Height + LidHeight);
  Atop := (Width + 2·L3 + 2·L2 + 2·L1)· (Length + 2·L3 + 2·L2 + 2·L1);
  A := 2·(Afront) + 2·(Aside) + Atop;
```

$$Afront := 0.146940$$
$$Aside := 0.187240$$
$$Atop := 0.286296$$
$$A := 0.954656$$

```
> A2 := 2·(Width·(Height − L3)) + 2·(Length·(Height − L3)) + Width·Length;
```

$$A2 := 0.66194$$

```
> A3 := 2·(MilkCanWidth ·MilkCanHeight) + 2·(MilkCanLength·MilkCanHeight)
  + (MilkCanWidth·MilkCanLength);
```

$$A3 := 0.0900$$

Coolbox variables

Material 1 variables

```
> Material = PE
```

$$Material = PE$$

```
> Vfront1 := (Width + 2·L3 + 2·L2 + 2·L1)·L1·Height;
  Vside1 := (Length + 2·L3 + 2·L2) ·L1·Height;
  Vfrondlid1 := (Width + 2·L3 + 2·L2 + 2·L1)·L1·(LidHeight);
  Vsidelid1 := (Length + 2·L3 + 2·L2) ·L1·(LidHeight);
  Vupperlid1 := (Width + 2·L3 + 2·L2 + 2·L1)·(Length + 2·L3 + 2·L2 + 2·L1)·L1;

  Vlid1 := 2·Vfrondlid1 + 2·Vsidelid1 + Vupperlid1;
  V1 := 2·Vfront1 + 2·Vside1 + Vlid1;
```

$$Vfront1 := 0.000628050$$
$$Vside1 := 0.000787050$$
$$Vfrondlid1 := 0.000106650$$
$$Vsidelid1 := 0.000133650$$
$$Vupperlid1 := 0.001431480$$
$$Vlid1 := 0.001912080$$
$$V1 := 0.004742280$$

```
> k1 := 0.48;
  C1 := 2300;
  ρ1 := 939;
  m1 := ρ1·V1;
  T2;
```

$$k1 := 0.48$$
$$C1 := 2300$$
$$\rho 1 := 939$$
$$m1 := 4.453000920$$
$$T2$$

Material 2 variables

```
> Material = polystyrene (EPS)
```

$$Material = polystyrene(EPS)$$

```
> Vfront2 := (Width + 2·L3 + 2·L2)·L2·Height;
  Vside2 := (Length + 2·L3)·L2·Height;
  Vlid2 := (Width + 2·L3 + 2·L2) ·(Length + 2·L3 + 2·L2)·((LidHeight − L1));
  V2 := 2·Vfront2 + 2·Vside2 + Vlid2;
```

$$Vfront2 := 0.00491840$$
$$Vside2 := 0.00544840$$
$$Vlid2 := 0.011024640$$
$$V2 := 0.031758240$$

```
> k2 := 0.033;
  C2 := 1210;
  ρ2 := 30;
  m2 := ρ2·V2;
  T3;
```

$$k2 := 0.033$$
$$C2 := 1210$$
$$\rho 2 := 30$$
$$m2 := 0.952747200$$
$$T3$$

Material 3 variables

```
> Material = PE
```

$$Material = PE$$

```
> Vfront3 := (Width + 2·L3)·L3 · Height;
  Vside3 := Length·L3·Height;
  Vlid3 := (Width + 2·L3)·(Length + 2·L3)·L3;
  V3 := 2·Vfront3 + 2·Vside3 + Vlid3;
```

$Vfront3 := 0.000203520$
$Vside3 := 0.00027030$
$Vlid3 := 0.000394752$
$V3 := 0.001342392$

```
> k3 := 0.48;
  C3 := 2300;
  ρ3 := 939;
  m3 := ρ3·V3;
  T4;
```

$k3 := 0.48$
$C3 := 2300$
$\rho 3 := 939$
$m3 := 1.260506088$
$T4$

Carton of milk variables

Material 5 variables

```
> Material = Cardboard
```

$Material = Cardboard$

```
> Vfront5 := MilkCanWidth·MilkCanHeight · L5;
  Vside5 := MilkCanLength·MilkCanHeight ·L5;
  Vlid5 := MilkCanWidth·MilkCanLength·L5;
  V5 := 2·Vfront5 + 2·Vside5 + Vlid5;
```

$Vfront5 := 0.0000400$
$Vside5 := 0.0000400$
$Vlid5 := 0.0000200$
$V5 := 0.0001800$

```
> k5 := 0.11;
  C5 := 1370;
  ρ5 := 689;
  m5 := ρ5·V5;
  T6;
```

$k5 := 0.11$
$C5 := 1370$
$\rho 5 := 689$
$m5 := 0.1240200$
$T6$

Material 6 variables

```
> Material = Milk
```

$Material = Milk$

```
> V6 := (MilkCanWidth − 2·L5)·(MilkCanLength − 2·L5)·(MilkCanHeight -2·L5);
```

$V6 := 0.001806336$

```
> k6 := 0.52;
  C6 := 3930;
  ρ6 := 1026;
  m6 := ρ6·V6;
  T7;
```

$k6 := 0.52$
$C6 := 3930$
$\rho 6 := 1026$
$m6 := 1.853300736$
$T7$

Coolbox Air variables (material 4)

```
> h2 := 25;
  C4 := 1004;
  ρ4 := 1.293;
  Vinside := (Width·Length·Height) - V5 - V6;
  m4 := ρ4·Vinside;
  T5;
```

$$h2 := 25$$
$$C4 := 1004$$
$$\rho 4 := 1.293$$
$$Vinside := 0.049370664$$
$$m4 := 0.06383626855$$
$$T5$$

Thermal resistance

$$> R1 := \frac{1}{h1 \cdot A};$$
$$R1 := 0.04189990950$$

$$> R2 := \frac{0.5 \cdot L1}{k1 \cdot A};$$
$$R2 := 0.005455717385$$

$$> R3 := \frac{0.5 \cdot L1}{k1 \cdot A};$$
$$R3 := 0.005455717385$$

$$> R4 := \frac{0.5 \cdot L2}{k2 \cdot A};$$
$$R4 := 0.6348471135$$

$$> R5 := \frac{0.5 \cdot L2}{k2 \cdot A};$$
$$R5 := 0.6348471135$$

$$> R6 := \frac{0.5 \cdot L3}{k3 \cdot A};$$
$$R6 := 0.002182286953$$

$$> R7 := \frac{0.5 \cdot L3}{k3 \cdot A};$$
$$R7 := 0.002182286953$$

$$> R8 := \frac{1}{h2 \cdot A2};$$
$$R8 := 0.06042843762$$

$$> R9 := \frac{1}{h2 \cdot A3};$$
$$R9 := 0.4444444444$$

$$> R10 := \frac{0.5 \cdot L5}{k5 \cdot A3};$$
$$R10 := 0.1010101010$$

$$> R11 := \frac{0.5 \cdot L5}{k5 \cdot A3};$$
$$R11 := 0.1010101010$$

$$> R12 := \frac{1}{k6 \cdot A3};$$
$$R12 := 21.36752137$$

Equations Coolbox

q1 - q2 - q3 = 0

```
> Eq1 := (T1 - T2(t))/(R1 + R2) - m1*C1*diff((T2(t)), t) - (T2(t) - T3(t))/(R3 + R4) = 0;
```

$$Eq1 := 844.6725900 - 22.67857577\,T2(t) - 10241.90212\,\frac{d}{dt}T2(t) + 1.561761016\,T3(t) = 0$$

q3 - q4 - q5 = 0

```
> Eq2 := (T2(t) - T3(t))/(R3 + R4) - m2*C2*diff((T3(t)), t) - (T3(t) - T4(t))/(R5 + R6) = 0;
```

$$Eq2 := 1.561761016\,T2(t) - 3.131547276\,T3(t) - 1152.824112\,\frac{d}{dt}T3(t) + 1.569786260\,T4(t) = 0$$

q5 - q6 - q7 = 0

```
> Eq3 := (T3(t) - T4(t))/(R5 + R6) - m3*C3*diff((T4(t)), t) - (T4(t) - T5(t))/(R7 + R8) = 0;
```

$$Eq3 := 1.569786260\,T3(t) - 17.54149090\,T4(t) - 2899.164002\,\frac{d}{dt}T4(t) + 15.97170464\,T5(t) = 0$$

q7 - q8 = 0

```
> Eq4 := (T4(t) - T5(t))/(R7 + R8) - m4*C4*diff((T5(t)), t) = 0;
```

$$Eq4 := 15.97170464\,T4(t) - 15.97170464\,T5(t) - 64.09161362\,\frac{d}{dt}T5(t) = 0$$

Equations Box of milk

q9 - q10 - q11 = 0

```
> Eq5 := (T5(t) - T6(t))/(R9 + R10) - m5*C5*diff((T6(t)), t) - (T6(t) - T7(t))/(R11 + R12) = 0;
```

$$Eq5 := 1.833333334\,T5(t) - 1.879913139\,T6(t) - 169.9074000\,\frac{d}{dt}T6(t) + 0.04657980456\,T7(t) = 0$$

q11 - q12 = 0

```
> Eq6 := (T6(t) - T7(t))/(R11 + R12) - m6*C6*diff((T7(t)), t) = 0;
```

$$Eq6 := 0.04657980456\,T6(t) - 0.04657980456\,T7(t) - 7283.471892\,\frac{d}{dt}T7(t) = 0$$

Implementation 2.0

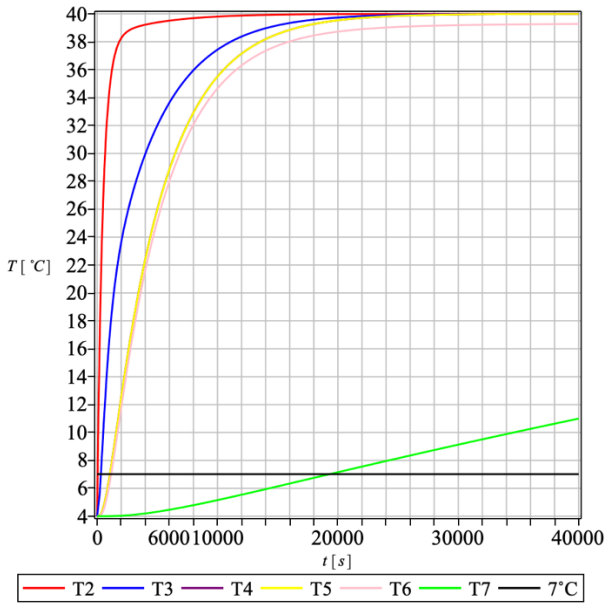
```
> Eq7 := T8(t) = 7;
```

$$Eq7 := T8(t) = 7$$

```
> ics2 := T2(0) = 4, T3(0) = 4, T4(0) = 4, T5(0) = 4, T6(0) = 4, T7(0) = 4, T8(0) = 7;
```

$$ics2 := T2(0) = 4,\ T3(0) = 4,\ T4(0) = 4,\ T5(0) = 4,\ T6(0) = 4,\ T7(0) = 4,\ T8(0) = 7$$

```
> sol2 := dsolve({Eq1, Eq2, Eq3, Eq4, Eq5, Eq6, Eq7, ics2}, {T2(t), T3(t), T4(t), T5(t), T6(t), T7(t), T8(t)}, numeric, output = listprocedure);
sol2 := [t = proc(t) ... end proc, T2(t) = proc(t) ... end proc, T3(t) = proc(t) ... end proc, T4(t) = proc(t) ... end proc, T5(t) = proc(t) ... end proc, T6(t) = proc(t) ... end proc, T7(t) = proc(t) ... end proc, T8(t) =
    proc(t)
    ...
end proc]
> T2 := rhs(sol2[2]):
> T3 := rhs(sol2[3]):
> T4 := rhs(sol2[4]):
> T5 := rhs(sol2[5]):
> T6 := rhs(sol2[6]):
> T7 := rhs(sol2[7]):
> T8 := rhs(sol2[8]):
>
> plot([T2(t), T3(t), T4(t), T5(t), T6(t), T7(t), T8(t)], t = 0..40000, axes = boxed, axis = [gridlines = [20, color = grey]], color = [red, blue, purple, yellow, pink, green, black], labels = ['t' ['s'], 'T' [°C]], legend = ["T2", "T3",
      "T4", "T5", "T6", "T7", "T7°C"]);
```




```
> m1bottom := ρ1·Vlid1;
  m2bottom := ρ2·Vlid2;
  m3bottom := ρ3·Vlid3;
  m4 := m1bottom + m2bottom + m3bottom;
```

$$m1bottom := 1.795443120$$
$$m2bottom := 0.330739200$$
$$m3bottom := 0.370672128$$
$$m4 := 2.496854448$$

```
> mCoolbox := m1 + m2 + m3 + m4;
```

$$mCoolbox := 9.163108656$$

Appendix F. – *Functionally looking, trustworthy and aesthetically pleasing user test.*

1. Associations
What are your associations with grocery shopping?
What are your associations with home delivery?
What are your associations with the mail man?
What are your associations with a delivery robot?

2. Goods suggestion
What do you think the robot is delivering? And why?

3. Rate design
Rate robot 1-8 in order of a functional looking design. Why this order? What makes the design functional looking?
Rate robot 1-8 in order of a trustworthy design. Why this order? What makes the design look trustworthy?
Rate robot 1-8 in order of an aesthetically pleasing design. Why this order? What makes the designs aesthetically pleasing?

4. Rate my design
Rate the designs based on preference. Why do you prefer one design over the other?


YAPE


FedEx


nuro


kiwi


Deutsche Post

Functionally looking design – Conclusions

Goods suggestion

1. Yape

Participant 1. Maybe it transports e-sigerates? I really don't know. The robot does not look stable, so it will probably not transfer heavy products unless they made the bottom heavy, but that would not be efficient at all.
Participant 2. I think it transports medicines, but it is hard to tell what is actually inside. It is small and close to the ground, which is a weird shape, I think.
Participant 3. I think the robot might transport diapers, since the shape of the robot is also round. The logo actually reminds me a bit of a baby. It could also be a robot for transporting medicines, since it has a small door on the side (about that size).
Participant 4. I think it maybe transport batteries or drinks? I do not know for sure. I do not have many associations with this shape.
Participant 5. I really do not know what this robot is transporting. It looks a bit like a cradle, but it could really transport anything. I really do not know.

2. FedEx

Participant 1. I think this robot is transferring packages. I know the brand already and the shape is looking quite stable, so I think it will be able to carry big, heavy packages.
Participant 2. I think this robot is transporting all sort of packages. The logo Is familiar and thereby the size of the robot could be convenient for package delivery.
Participants 3. I think the robot carries packages, just because I know the brand. The doors are visible, and I think they make it quite comfortable for the user to retrieve a package. The robot itself also looks a bit like a box.
Participant 4. I think this robot would be able to transport everything. I know the brand

already. The robot is also quite big, massive and it would probably be comfortable to retrieve any package from that height.
Participant 5. I think this robot is transporting mail and small packages. The robot looks compact. The extra front wheel gives the impression that the robot is able to drive through rough terrain.

3. Alibaba

Participant 1. I think it will transfer big packages or even humans, since the shapes is quite big. It looks like the carts in Kralingse Zoom. Those carts transport human being, so I guess that is why I think it might transfer humans.
Participant 2. I have no clue actually, it looks a bit like a suitcase, but I have no idea.
Participant 3. I think it looks a bit like a driving vending machine. The front also looks a bit like a coffee machine. Because the robot is quite big, I think he would also be able to carry big packages.
Participant 4. I get kind of limousine vibes of this robot (because of the doors, rounding's and lamps). The robot also looks a bit like a Rolls Royce design. So, I think the robot will transport something expensive, something of luxury, maybe something like clothes from the Bijenkorf.
Participant 5. I think this robot is transporting big groceries boxes. The robot is large and the camera on top gives the impression that the robot is even larger than I think it actually is.

4. Starship

Participant 1. Does this robot really transport something? It is so small. I think it might just transfer packages, and nothing else. It must be really uncomfortable to retrieve the goods from this height, so the package should not be heavy at all. If it is for food, I feel like the robot should be higher, more like a shape of a counter desk.

Participant 2. It is probably for food (after reading the text on the robot). I really like the design, but I would not know what the robot is transporting, by just looking at the design.
Participant 3. I think it carrying food, because of the text on the embodiment. It should be very small, since the robot is also small. I look a bit like a spaceship as well. However, I do not associate a starship it with food.
Participants 4. I think pizzas. I saw an ad on Instagram and those robots already operate on certain campuses in the USA. Maybe the robot can also carry a small package or something else light weighted, since the robot is pretty small.
Participant 5. The starship is a kind of thuisbezorgd I think, since the text displayed on the robot says something like “are you hungry?”. The starship also owns a flag, so I guess it will mainly drive in urban areas, so the robot is easy to spot in crowded traffic. It actually looks a bit like a small car.

5. Nuro

Participant 1. It is quite large, so I guess it transports large packages. I don’t think that it will transport humans, since it will be hard to climb through those doors. The doors probably open-up vertically.
Participant 2. I expect this robot to be really big, because of its size, the size of the wheels and the fact that a camera is needed. Therefore, I think that this robot might be transporting plants or furniture.
Participant 3. I think it will transport large packages, since the robot is large and has large doors as well. I think it is too large to be transporting food.
Participant 4. Maybe this robot transport something like buggies? You can see the line of the door and a buggy would be able to fit. However, I think it looks too fancy to carry normal groceries. So, I would expect that the robot is transporting something of value, so maybe MediaMarkt products, such as a PlayStation.
Participant 5. This robot looks a bit like an actual car. So, I think it will transport big packages or even humans. It looks a bit futuristic by the window. It already looks like an autonomous vehicle actually (with the camera as well).

6. Kiwi

Participant 1. I think it will transport kiwi's, because of the logo and the size of the robot, or maybe other small products, which can be easily taken out of the robot from this height. Or maybe it is even used to give away small products for commercial purposes, since the robot also has a small face.
Participant 2. Maybe vegetables and fruits? (because of the logo). The logo has a face, so maybe he also transports "important products", such as medicines, but I am really not sure (just based on the design).
Participant 3. I think this robot is transporting food. I think a paper big would be able to fit and food such the logo name.
Participant 4. The robot might transport fruit (logo) or mail? It is super small, so not much would be able to fit, I think.
Participant 5. The robot is very small, so I think it will carry fruit or a small plant maybe. I only have this association, because of the name of the robot. It is hard to have associations with the design of the robot. I do like the little face on the robot.

7. Post-it

Participants 1. I think this robot transport packages, maybe for a company like Amazon. It is squared, the robot is not too big, it has a nice screen, it looks stable, and I think it has a good height to retrieve a package.
Participant 2. It looks a bit like Wall-e, but also a bit like a driving cool box, so I guess food. It has actually the same lid as some cool boxes.
Participant 3. I think it transports letters, due to the bright yellow color and the size of it.
Participants 4. The robot might be transporting small boxes, since it looks like a box himself.

Participant 5. This robot reminds me a bit of Wall-E and a stroller. It probably transports food (also looks a bit like a shopping cart). The display will probably be able to show you what you ordered.

8. Deutsche post

Participant 1. I think this robot is transporting packages, just because of the yellow color and the logo of course. I feel like you can probably also sit in it.
Participant 2. I think this robot is transporting mail. You can maybe push letters through the slit. When you open the doors, you can see all the letters in a nice order maybe. The yellow color reminds me of DHL and the logo also gives it a bit away, I think.
Participant 3. The robot will probably carry packages. However, it does look a bit unstable, since the wheels are positioned close to each other. Thereby the material looks quite light weighted, so I am not sure if it would be a right fit for transporting packages.
Participant 4. I think this robot transport mail and packages (logo).
Participant 5. The robot probably transports mail and packages. I recognize the logo and I also associate the yellow color with mail. The robot also looks a bit like a suitcase.

Conclusion goods suggestion
The first thing the participants looked at was the size of the robot (**the dimensions**). This gave them an impression on how big the goods inside must be. For a weight indication of the products, they were looking at the stability of the robots. **The more stable the robot looked, the heavier the products could be. Brand familiarity** also played a big role in understanding what kind of packages the robot must be carrying. For example, FedEx is a well-known brand. Almost all participants, immediately said that the robot must be transporting packages, just because they knew that that company does deliver packages. The participants were also quite focused on the **logos.** They did not know all brands, but they were still trying to associate products with the word. For example, almost all participants thought that the Kiwi robot was transporting fruit. **The doors** in the designs were also seen as a clue for what kind of packages the robot was transporting. The size of the line would give away the size of the goods and how to retrieve it, so also how heavy it should be. The goods in a small, close to the ground robot, must be light weighted, since otherwise it would be too uncomfortable to lift. When the participants really did not have a clue apart of kind of products the robot was transporting, they tried to find an **association with the shape**. For example, according to a participant, the Post-it looks a bit like a shopping cart and therefore it probably must transport food. The Alibaba robot was associated with a limousine, by one person. It was too small to transfer human, but since he associated limousines with luxury, he thought the goods inside must have been luxury as well.

Functional looking test

Score	1	2	3	4	5	6	7	8
Participant 1	Yape	Alibaba	Starship	Nuro	FedEx	Kiwi	Deutsche post	Post-it
Participant 2	Yape	Alibaba	Kiwi	Nuro	Post-it	Starship	Deutsche post	FedEx
Participant 3	Yape	Alibaba	Starship	Nuro	Kiwi	Post-it	FedEx	Deutsche post
Participant 4	Yape	Kiwi	Post-it	FedEx	Alibaba	Nuro	Starship	Deutsche post
Participant 5	Yape	Nuro	Post-it	Kiwi	Alibaba	Starship	FedEx	Deutsche post

Aesthetically pleasing test

Score	1	2	3	4	5	6	7	8
Participant 1	FedEx	Yape	Alibaba	Nuro	Deutsche post	Starship	Kiwi	Post-it
Participant 2	FedEx	Yape	Alibaba	Kiwi	Deutsche post	Nuro	Post-it	Starship
Participant 3	FedEx	Yape	Deutsche post	Post-it	Alibaba	Kiwi	Starship	Nuro
Participant 4	Yape	FedEx	Post-it	Kiwi	Deutsche post	Starship	Nuro	Alibaba
Participant 5	Nuro	Post-it	Deutsche post	Yape	FedEx	Starship	Kiwi	Alibaba

Trustworthy test

Score	1	2	3	4	5	6	7	8
Participant 1	Yape	Starship	Deutsche post	Post-it	Kiwi	Alibaba	Nuro	FedEx
Participant 2	Yape	Kiwi	Deutsche post	Alibaba	Post-it	Starship	FedEx	Nuro
Participant 3	Yape	Deutsche post	FedEx	Post-it	Alibaba	Kiwi	Starship	Nuro
Participant 4	Yape	Post-it	Nuro	FedEx	Starship	Kiwi	Deutsche post	Alibaba
Participant 5	Yape	Kiwi	Starship	Post-it	FedEx	Deutsche post	Alibaba	Nuro

Functionally looking design

Participant 1
The round shape of the Yape looks a bit unlogical for me. It does not look stable at all. The robot is small, and it is therefore not logical that it will carry packages. I also find it a bit unlogical that the robots that transport food are designed low to the ground. It is not comfortable to lift. I like it when the design has visual doors. Then it is easier to estimate how the robot will open up and how big or what kind of packages the robot is transporting. I think brand familiarity also help a lot with understanding the function of the robot. For example, it was quite logical that the FedEx robot was carrying packages. I enjoy the little face of the Kiwi. I especially like it, since the robot is bringing meals (something you are excited about). The face creates a friendly character for the robot, but if I would retrieve for example groceries, then such a face in the design would not be necessary for me. A face might not look that professional too and I think with groceries, I would like the company to be more professional. I really like the Post-it robot. The height and dimensions seem nice, and I really like the screen.

Participant 2
The logo and the text on the robots helped to understand what the function of the robots are. The dimensions of the robots also helped me understand the function of them. Thereby if a robot is about the same size/shape of a crate, it is probably more likely that you understand that the robot delivers crates/groceries. The Nuro is also delivering crates, but the shape of the crates is not reflected in the overall shape of the robot. Therefore, I thought it was hard to understand what the robot is transporting.

Participant 3
I think the size of the robot really helped me guess what kind of products the robots are transporting. Besides that, the logo and the yellow color also helped me discover the function of the robot. Those features were hard to find in for example the Yape and Alibaba robot, and therefore I thought it was hard to discover the functions of those robots.

Participant 4.
The robots I picked as the most functionally looking are also the most stable looking ones. I feel like the robot should be able to handle the job as a delivery vehicle in order to look like they could function properly. Something looks stable if the robot is not too small or too tall and the wheels have a proper distance from each other (so not too close against each other). The Nuro and Alibaba robot actually remined me of a Picnic vehicle, which already have a delivery purpose.

Participant 5.
The Deutsche post robot was the most functionally looking one for me. I associate the color yellow with a package service and the shape looked a bit like a suitcase. The FedEx was also easy to guess, since I am already familiar with the brand. The starship also contains a logo and the shape of this robot reminded me a bit of a rice cooking machine, which I associate with food. The Post-it actually reminded me of a grocery cart. The Nuro was on the other hand maybe too futuristic, so it is harder to associate it with something.

Conclusion functionally looking
Similar things were said as described in the previous conclusion. The participants also mentioned that they associated the color yellow with delivery. Some of them mentioned that it would be nice if the shape of the good can be seen in the shape of the robot. This makes it a bit easier for them to understand what the robot is transporting. Some of them also mentioned that they do not like it when a design looks too futuristic, since it is hard to associate a function with it. The robot must be stable-looking in order to carry packages. The bigger the wheels and the more apart the wheels are positioned from each other the more stable the robot looks like.

Aesthetically pleasing design

Participant 1
I like the design that have rounding's. I think it is aesthetically pleasing, if you really feel like that a lot of thought has been put into the design. For example, the FedEx looks like a robot that came straight out of the factory (only designed to be functional). I like it when the designs are a bit tall, so you know it is probably comfortable to retrieve your goods.

Participant 2.
I really like the design of the Starship. I like the six wheels, the colors and the rounding's. It really looks like that someone has put a lot of thought in it. In the other designs, I like the rounding's as well. I should not be round (like the Yape), but it should not have sharp edges. Looking at the Deutsche post robot, I really like the design of the doors. It looks friendly, minimalistic and user friendly. I don't like the tough wheels of the Kiwi, but I do like the rest of the box (it is simplistic as well). I find something aesthetically pleasing if a product looks like a complete product, so no protruding objects. For me, I do not like it when it only looks pure functional (like the FedEx).

Participants 3.
I think the robots are aesthetically pleasing if they look a bit futuristic. I like the black and white colors and I like it when the design looks stable; not too big or too small. The Deutsche post robot and the FedEx robot look very clean, but I do not find them that aesthetically pleasing (the designs maybe look too functional).

Participant 4.
I like designs that look a bit like luxury. For example, the Alibaba robot looks a bit like a Rolls Royce design. I like the matte black and white color on the Nuro and Starship as well. I association the yellow color with delivery, but I like it better when it is one used in some small details (logo, sport on the wheels). I like a design if you can see that there have put some thoughts in it. The Yape for example does not look like he is design with any associations in mind (bit random even maybe).

Participant 5.
For me the Alibaba, Kiwi and Starship robot are very aesthetically pleasing. I like the black and white colors and the rounding's in the design. Maybe the form language does not say that much, but I still think it is pretty. I think the shape of the FedEx and Yape are interesting, that is why I also think they are somewhat aesthetically pleasing. The Deutsche post robot is

very clean which I also like. I really do not like the Post-it. It reminds me of a stroller with weird eyes. The screen is positioned on a weird place. The Nuro is maybe I bit pretty, but too futuristic for me. Maybe it is a bit too big as well.

Conclusion aesthetically pleasing
All participants thought a design was aesthetically pleasing, if they felt like there has been put a lot of thought into it. It should not look only functional. They liked a design when it showed some details, for example the lines for a door. Rounding's in the design were also very much appreciated, so no sharp edges were visible. Some participants really liked the black and white colors. Some of them mentioned they really like a design if it looks a bit futuristic/luxury, but not all participants shared the same opinion about that. A design does look aesthetically pleasing according to the participants, if the robot does not have any protruding objects, if it looks user-friendly (comfortable height), stable and maybe even a bit minimalistic.

Trustworthy design

Participant 1.
I think a design is trustworthy if it looks heavy. The robot should also not be too small, otherwise I feel like it can just be thrown into a car (theft). I also feel like the smaller robots can get stuck somewhere and then they will not be able to help themselves and continue their route without help. The bigger the wheels the more I trust the design as well. I think it is nice that the robot can still drive on the sidewalks then it will not get stuck in traffic.

Participant 2.
I really do not trust the Yape, Kiwi and the Deutsche post robot, since they look quite light weighted, and it is probably easy to kick them over. The wheels also play a big role in winning my trust. The bigger the wheels the more trustworthy the design is. I like it when I design is symmetrical (it looks more stable then). If the material seems of great quality and the design seems more thought out, I also have more trust in that design.

Participant 3.
I think a design is more trustworthy if the center of gravity looks stable. For example, the further apart the wheels are located, the more stable it looks. If the design looks aesthetically pleasing, I also tend to trust the robot more.

Participant 4.
I think the robot look trustworthy if he is not too big. When the robot is not too big, it is still able to pass everyone on the sidewalks and does not get stuck somewhere. Brand familiarity also played a big role for me. If I know it is a good brand, then I automatically trust the vehicle more.

Participant 5.
The bigger the design the more trustworthy it becomes. For example, the Nuro is quite big, but at least it will not get stolen that easily or will get stuck somewhere in the street. Big wheels also look trustworthy. The further apart the wheels are located, the better. If I see a

camera in the design, I also believe that the robot is aware of the surrounding. I did not think that the small robots look that trustworthy. It is probably easy to just flip them over.

Conclusion trustworthy design

All participants thought that the dimensions of the design were important in how trustworthy a robot look. The robot should not be too small. It would be easy to flip it over, lift it or it would get stuck somewhere and it would not have enough power to help himself. The robot should look stable. The more symmetrical the robot looks and the bigger the wheels (and the further they are positioned from each other, the more stable the robot will be perceived. The participants also tend to trust the robot more if they feel like that the design of the robot is more thought-through (also high-quality materials). The same occurred with brand familiarity, if the participants knew the brand and they were positive about it, they automatically trusted the robot a bit more. One participant also mentioned that he trusted the robot more, since he noticed a camera on a design, “so the robot must be aware of its surroundings.