An autonomous urban delivery concept for Ford

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*“There are no big problems,
there are just a lot of
little problems.”*

- Henry Ford

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Glossary

Abbreviations and jargon used in the report and their meaning in this context.

AV
Autonomous vehicle

Autonomous operation
Technology operating by itself, without human assistance

Concept
Concrete idea/invention that embodies a future plan

Delivery
Bringing a shipment (parcel) to a customer

EV
Electric vehicle

High density delivery network
A parcel shipping company serving a large amount of deliveries per unit of area (e.g. per neighbourhood)

Interface
Touchpoint where either a user and a system interact, or where two systems interact

Last-mile of delivery
The last (inner-city) part of a parcel journey

Livability
Quality of life in a particular area

Parcel
Box containing anything the customer has ordered

Pod
Small (conceptual) vehicle

Urban consolidation center
Facility in a city where all incoming parcels are collected/combined for further distribution

Introduction

First things first. In this phase, the assignment will be explained, the expected results will be covered, and the project approach will be detailed through a schematic overview.

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1. Assignment & approach

Autonomous delivery was nothing more than science fiction when the movie 'I, Robot' came out in 2004 (Figure 1.1). But today, as we approach the year 2020, this fantasy is getting more realistic than ever.

The assignment

The assignment statement is as follows:

To conceptualize an urban autonomous delivery system for European cities that is technically feasible, user-friendly and fits the Ford business.

The timeframe of implementation is between 2 and 5 years from now.

Expected results

The expected results from this graduation project will include both:

(1) Insights and requirements (supported by research) providing clear guidelines for developing an autonomous delivery system in the European context. This report takes into account human factors through user studies, as well as business-aspects and technology by integrating knowledge from Ford's proprietary developments and from other competitors/potential partners.

(2) A conceptual autonomous delivery system fitting the requirements that were found in the aforementioned stage. Apart from a vision of the whole system, this concept will include both basic vehicle designs and interfaces in the case of between-vehicle transfers of parcels. The aim is to provide Ford with a single tangible vision that has the potential to align different departments.

***Figure 1.1:** FedEx delivery robot with a parcel, from 'I, Robot' (2004)*

Contextual analysis phase

In the first phase of the project, the approach is to first analyze the context of (autonomous) parcel delivery. This process starts with the analysis of the current parcel delivery situation and the challenges that are experienced. After that, the broader context is examined by (1) analyzing macro-trends in the field, (2) studying technological developments by competing companies, and (3) investigating the developments of companies that could be a potential partner for Ford in the delivery scene. After this, Ford's in-house developments and its strengths are analyzed.

User research phase

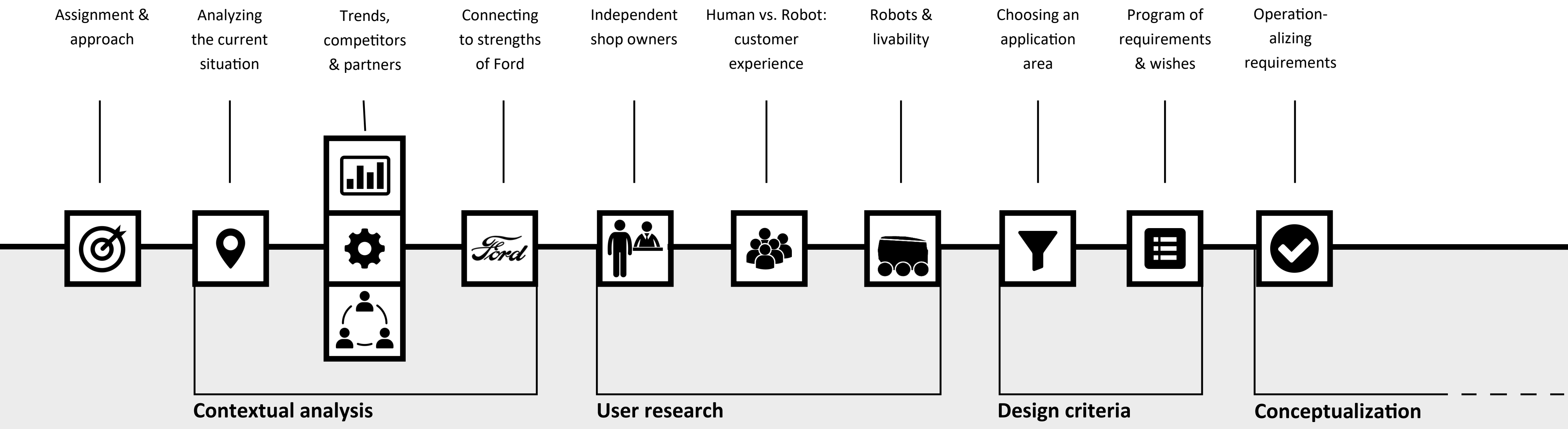
After the analysis phase, user research is performed, investigating (1) independent shop-owners that could be helped by a delivery system (2) potential future users without experience with AV's and (3) livability concerns among present-day users of a robotic delivery service in the UK. The goal is understanding user-needs and finding new requirements to be addressed by the conceptual design.

Design criteria

In this part of the project, the scope will be narrowed down using the findings from the contextual analysis and user research phase. First, an application area will be selected to design for. With this in mind, criteria will be listed. These criteria will guide the design project and align stakeholders in the process.

Conceptualization

The conceptualization phase starts with operationalizing the requirements found in the previous phase, as some of the requirements are as workable as others.



Afterwards, the ideation phase starts: finding solutions to the problems found in the aforementioned stage. Through diverging and converging techniques, multiple preliminary concept vehicles (or sets of vehicles) will be created.

Towards the final concept

In this phase, the preliminary concepts are presented to the supporting team at Ford, and to a last-mile optimization expert at DHL. Next to that, the journey of parcels before the last mile is investigated—as it is very relevant to take this into account in the final concept. Also, a further look is taken into the timing of delivery and the dimensioning of the vehicles—by setting up a basic logistical calculation model.

Final concept

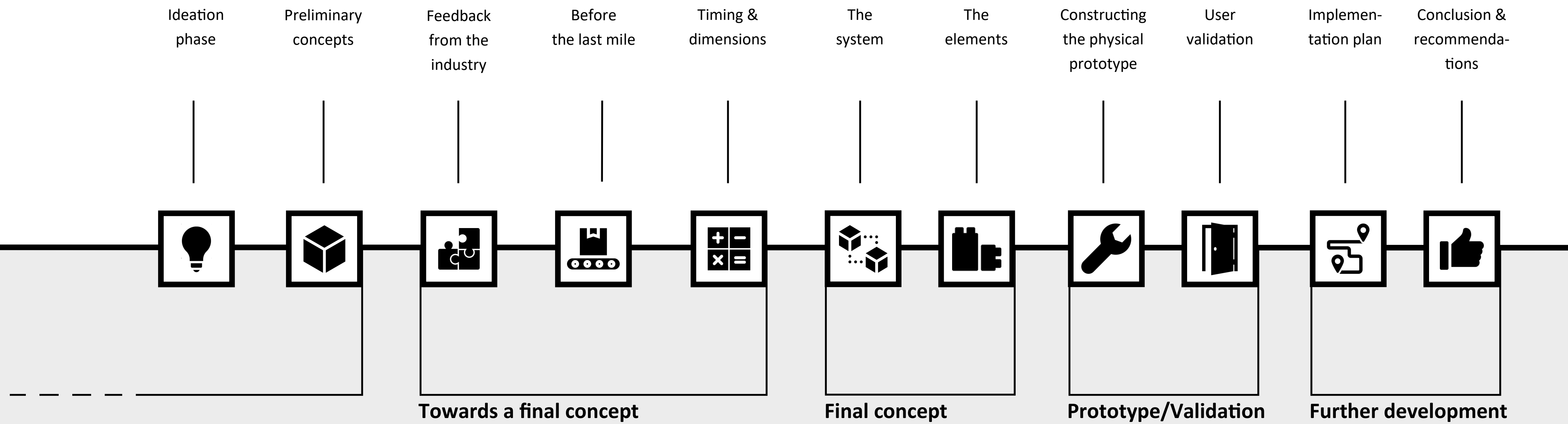
All the information that was gathered in the previous phases is used to create one final conceptual system. This system is explained in this phase, as well as the elements that it consists of.

Prototyping and validation

During this phase, the conceptual system will be validated with (future) users. In order to present these people with a tangible vision on the future of delivery, a prototype of the major user touchpoint—the pod—will be constructed.

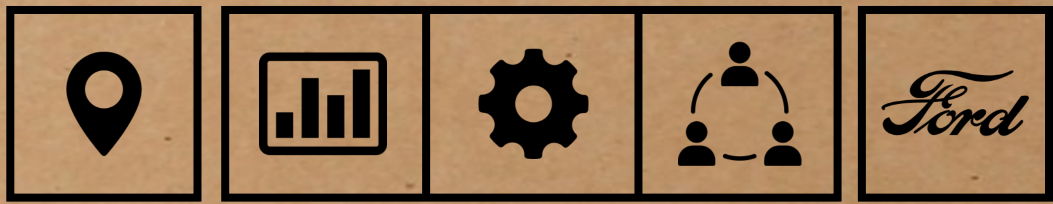
Further development

A plan for launching a robotic delivery system is detailed in this phase. After that, this report will be concluded by assessing how the eventual concept fits the original project goals, and providing recommendations for further development.



Contextual analysis

In this first phase of the project, the aim is to analyse existing information, and learn from it. Knowledge in the field of (autonomous) delivery will be gathered through desk research and interviews with experts in the field of parcel delivery. On the next page, all the insights are summarized in a visual overview. The respective insights can be found in the rest of this phase.



2. Analysis abstract: the parcel journey

Regional distribution center	Transport towards hub	Urban hub

Present day Ford

DHL

Potential partners

Regional distribution center	Transport towards hub	Urban hub
Increase in warehouse automation (6B, 6R)	No major change is expected in transport towards the city	Shipping providers will buy physical hubs in city centers (6D)
Pre-sorting into standardized units for easy deconsolidation (6A, 6B)	Municipalities will likely promote the consolidation of all incoming goods at the entrance of the city (3B, 3C)	
Food delivery and parcel delivery could be integrated into one system (4B, 6J)		Modular parcel containers can help reduce transshipment time (3F, 5A, 6A, 6S)
		Local stores and food-suppliers can act as hubs for urban deliveries (4B, 5G, 6L)
		Especially webshops with local shops can easily start using shops as a hub (6K, 6L)

Drones have the possibility to skip the slower lorry and urban 'hub' and directly fly to a landing location that has an interface for a customer

Contextual insights

Transport between hub and customer

Customers’ building

Vehicles with different strengths could work together — 5E 5I 6C 6Q

Drones only for urgent shipments, no direct contact with customer — 5F 6E 6F

Vehicles carrying more parcels can drive more energy-efficient routes — 3A 4C 6C

The public visibility of delivery vehicles could be commercialized — 6M 6O

Vehicles will be zero-emission due to new legislation — 4D 5C

The number of freight movements needs to be minimized — 3A 3B 6D

The urban area occupied by delivery vehicles per time has to be minimized — 4C 6C

Vehicles will collect data to refine the delivery service — 6H

Time slots for home-delivery will be narrowed down to minutes — 3G 3F 6H 6I

5B 6F

For physical reasons, the last meters require extra design attention for AV’s — 5D

A human delivery person will not be technically required

Locker stations, parcel-boxes, etc. offer more flexibility to customer — 3G 5H 6G

Human delivery employees could provide extra customer services — 6M 6N

Brands want to be able to customize the delivery experience — 6M 6O

3. Current urban last-mile delivery

As the field of urban delivery is relatively new for Ford, this chapter is meant to get insight of how the delivery market is currently operating, and what the challenges are on an operational level.

Benchmark

Apart from playing a small role by supplying Transit delivery vans, the actual daily practice of running a delivery service in a large city is not something Ford is currently familiar with. This chapter will first set a benchmark of how the current delivery system works. This will be done by consulting literature, internet resources and a personal interview with a professional who has experience in operating urban logistics.

Expected results

This chapter will provide insight in the current practice and present challenges in this business.

Companies

The field of parcel delivery has been dominated by national postal services historically. Today, most of these companies acquired others, which results in the current landscape of delivery providers, the biggest among which include DHL Express, UPS, FedEx and TNT Express (Seeking Alpha, 2017).

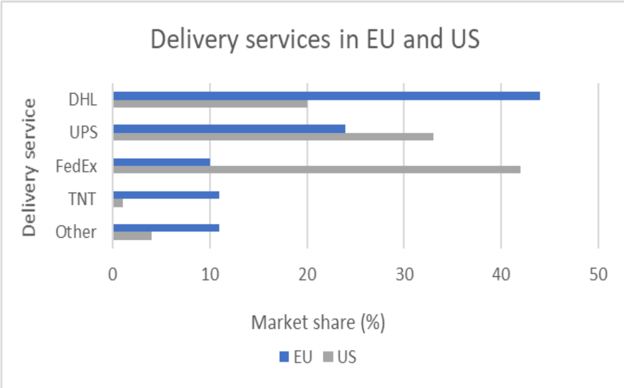


***Figure 3.1:** Delivery services in EU and US*

DHL is the market leader in Europe, while FedEx has a leading position in the United States. UPS holds a similar share in both Europe and the US (see Figure 3.1).

Way of working

This section will give insight into the operations of 'traditional' parcel companies like DHL and UPS.

Routing

Routes of traditional parcel services are typically created by software. These Dispatch Planning Systems (DPS) are algorithms that create a route that a driver has to follow (Smith, 2013). Quite some innovation has been going on in this field by companies making routes ever more efficient. Quintiq, for instance, has developed 'dynamic route planning' for DHL, incorporating real-time urban traffic data (The Logic Factory, n.d.).

- Traffic and route, depending on:
  - Type of van
  - Type of dispatch center
  - Area characteristics; speed limits
  - Real-time traffic data
- Offloading and delivery, depending on:
  - Type of parcel
  - Type of residence
  - Type of authentication required
- Timing, depending on:
  - Work hours of recipients
  - Work hours of driver

Handover of goods

The handover to the end-consumer currently happens in roughly three ways currently. Parcels are either directly handed over to a customer through door-delivery, indirectly through a service point (store), or a parcel could be retrieved from automated booths like the Packstation (Figure 3.2) that has gained popularity with 3000 stations in German cities (DHL, n.d.).

Vehicles

The vehicles that are used for parcel delivery in current urban areas are delivery vans. In The Netherlands, they are dispatched from about twenty distribution centers per transportation company. The vans are loaded with about 120 parcels each. Different delivery companies have their own networks and drive with different vans (J. Kraan, personal communication, May 4th, 2018).

> *"PostNL observes a changing world, in which the city center is increasingly problematic."*
>
> **- Jasper Kraan, Stadslogistiek (PostNL)**

Costs

The costs of current delivery, and how they relate to changes in the amount of kilometers driven and the amount of parcels that are taken, are calculated through a model supplied by NEA Transportonderoek. (De Groene Hub, n.d.). The calculation is in Appendix 1.

Figure 3.2: *DHL Packstation (DHL, n.d.)*

Challenges

The main challenges in the field of current urban delivery will be discussed in this section.

Efficiency

The municipalities are mainly concerned about the freight movements in urban areas. For parcel delivery, these freight movements are currently not an issue to municipalities, as the vans that distribute them are generally fully loaded, which means that the transport is efficient, and occupies the road with only one vehicle per 120 parcels (J. Kraan, personal communication, May 4th, 2018).. This can be seen as a generic rule of logistics: Insight 3A. For other streams of goods into and out of a city, this is usually worse. When it comes to supplying local retailers, for example, big trucks usually drive into the city center with only a few 'roll cages' (Figure 3.3).

> Vehicles that are **fully loaded with parcels** provide **more efficiency** and **fewer freight movements**

Insight 3A

Figure 3.3: *Typical roll cages used to supply local retailers*

Large shipping providers like DHL Express are currently performing over half of urban deliveries, while only accounting for 25% of urban freight movements. The rest of the freight movements in a city (75%) consist of (often proprietary) suppliers that supply a few shops for instance, accounting for 45% of the deliveries. (Rijksdienst voor Ondernemend Nederland, 2013). This leaves room for improvement (Insight 3B) by consolidating these flows at the entrance of a city. Over the last years, several municipalities have initiated tests with so-called Urban Consolidation Centers (UCCs) or hubs (Insight 3C).

> **75% of current delivery traffic** accounts for only **45% of deliveries**, which can be solved through **consolidation**

Insight 3B

> **Cities increasingly** implement **Urban Consolidation Centers while prohibiting vehicles from entering**

Insight 3C

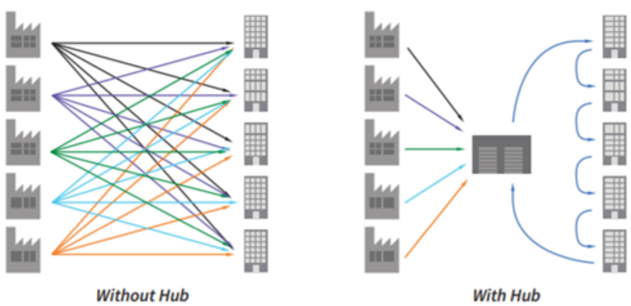


Figure 3.4: *City movements with & without a Hub/UCC*

These centers are usually positioned close to the highways, so that incoming lorries can easily drop off their goods without being a burden to inner-city traffic. For this research, an interview was conducted with Jasper Kraan, operational manager of City Logistics Delft, an initiative and Living Lab that was set up by PostNL and the municipality of Delft. The full interview transcript (Dutch) can be found in Appendix 3.

The interview covered both the advantages and the challenges of a hub-system. The advantages are obvious: freight movements are minimized and the consolidated inner-city traffic can be all electric, with smaller vehicles, like the Goupil, a French-manufactured small electric vehicle (Figure 3.5). The Goupil is a popular zero-emission vehicle because of its small dimensions, also used by grocery delivery startup Picnic (Eco-Mobiliteit, 2017).

The reason that the consolidation works for City Logistics Delft is largely because of the 'base volume' that PostNL has, being the largest parcel provider in the Netherlands with approximately 75% market share in Dutch B2C parcel delivery (Libbenga, 2015). Essentially, there has to be a certain volume in order to effectively start consolidating, that is why it is of great importance to make sure every customer and business that needs) to send/receive goods in the city center participates (Insight 3D) in the consolidation practice (J. Kraan, personal communication, May 4th, 2018).


Figure 3.5: Electric car used by City Logistics Delft

Consolidation works best if **everyone participates**, so **demands of individual parties need to be met**

Insight 3D

Another major challenge with consolidation is the costs of transshipment. Offloading goods from a big truck, into the consolidation center and into the (smaller) consolidated trucks.

Another major challenge with consolidation is the costs of transshipment. Offloading goods from a big truck, into the consolidation center and into the (smaller) trucks costs money. Currently, no parties are not willing to pay for this action if not necessary. If everyone participates, and UCCs can be automated, consolidation can lead to cost reduction, but until that moment, consolidation is likely to lead to higher costs (Insight 3E). The experimental UCC in Delft is currently sponsored by local government and PostNL, as it does not generate money on its own (J. Kraan, personal communication, May 4th, 2018). Even at those higher costs, consolidation still benefits livability of a city and the emissions can be reduced by making the last-mile electric.

Consolidation currently **involves human labour** and therefore **costs money**, and **nobody wants to pay**

Insight 3E

Figure 3.6: *Container transshipment from train to truck*

Another outcome of the Living Lab is the importance of interfaces between carriers of goods. As mentioned, goods going to shops and restaurants are usually shipped by roll cages (Figure 3.3), but the current Goupil vehicles (Figure 3.5) are not able to transport those, because they are too low and they do not have the appropriate tailgate. (J. Kraan, personal communication, May 4th, 2018). Standardization of goods-carriers can benefit the flexibility of the system and the fluency of transshipment (Insight 3F). The shipping container for instance (Figure 3.6) has been facilitating transshipment from boats to trains to lorries since the sixties (Levinson, 2016). Within our scope, DHL is developing a similar standard for inner-city transportation containers, see next chapter.

Standardization of certain elements can **decrease the transhipment costs** and **increase flexibility**

Insight 3F

Handover demands

Another challenge in current last-mile delivery is the time and place of the delivery. Consumers are often not home to receive their order at the times a delivery person is at the door. In the Netherlands, 22% (!) of parcels stay in the delivery van because the recipient is not at home. In such cases, customers find a note on their doorstep similar to the one in Figure 3.7. This percentage is expected to stay constant, but as the amount of deliveries is expected to almost double over the next five years, the problem gets worse (Twinkle, 2015). The statistic is similar in the US, with 20% parcels not being delivered at first attempt. It is expected that every failed US-delivery costs about $15 USD in extra customer service costs, fuel, working hours and van-space (Yvonye, 2016). This leads to Insight 3G.

An **increasing amount of parcels cannot be delivered at first attempt,** which is **costly for delivery companies**

Insight 3G

Figure 3.7: *Typical delivery failure notice in The Netherlands*

The solution that is often being suggested, for example by Van der Ploeg (2015), is giving maximum flexibility to customers at the moment of ordering through a webshop. The rationale behind this is that when users are enabled to make a choice whether a parcel is delivered at a service point, at a relative's house, an automated booth or at a specific timeslot, fewer failed deliveries will occur.

Larger webshops are offering more flexibility already, and it is expected that this will increase towards the future (Van der Ploeg, 2015), summarized in Insight 3H.

"We see that people want to choose when and how they are being served."

- Bas van den Berg, Coolblue

Webshops offer **an increasing amount of flexibility in time and place**, when it comes to last-mile delivery.

Insight 3H

Jasper Kraan

Operational Manager at Stadslogistiek (PostNL)

Background

Jasper has over ten years of experience in freight optimization and human resource planning for both PostNL and Transavia.

About the initiative

Stadslogistiek Delft is a 'living lab' that was initiated by PostNL in cooperation with the municipality of Delft. Within this initiative, experiments with urban freight consolidation have been running since 2014.

Why contacted them?

Jasper is an operational manager: he is close to the practical everyday work. He is planning the consolidation of freight, and the inner-city movements of freight. In the past, he has worked for the regular PostNL parcel service which means he has extensive knowledge in both fields.

Key learnings

- Increasing flexibility in time and place is required
- Urban Consolidation Centers are on the rise
- Municipalities start limiting polluting vehicles

Full interview transcript in Appendix 3.

4. Macro-context

Now that the present situation has had its deserved attention, let's move on to the future. In this chapter, the macro-developments will be analyzed, with their potential impact on the stated assignment.

Slowly progressing change

This chapter is about macro-level trends: the type of change that progresses slowly but steadily over time. While the results of this project are aimed to be implemented in about 2-5 years from now, looking further ahead can prevent Ford from investing in problems that may not be profitable or relevant in the long-term.

Expected results

In this chapter, insights on the future context of urban transportation and the city in general will be presented.

E-commerce

The large-scale development of (global) e-commerce is communicated in this section.

Increase in online shopping

Over the years, there has been a large growth in e-commerce. While the image in Figure 4.1 may look like a stock photo of exponential growth, this represents the actual (predicted) growth curve for e-commerce in Southeast Asia.

As this region may not directly be the targeted sales region of Ford, the global e-commerce is also expected to grow, albeit at a less extreme rate (Figure 4.2).

This growth indicates that exploring the market of (home)delivery could be valuable for a business (Insight 4A).

Exploring the market of home-delivery makes sense as **e-commerce shows global growth**

Insight 4A

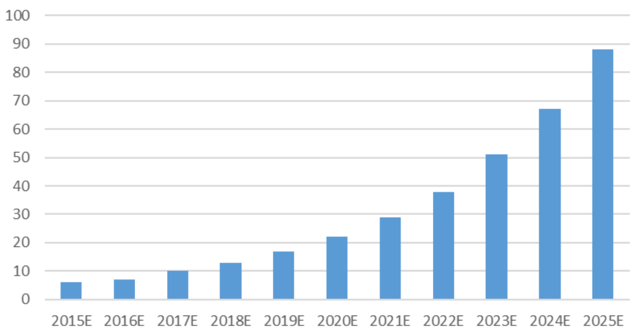


Figure 4.1: *Expected size of southeast Asia's e-commerce market in billions of US Dollars (Camhi, 2017).*

Growing categories

While every category has seen a certain growth, the increase in popularity differs per product category (Figure 4.3). Taking a closer look at those categories, a shift towards more fast-moving goods can be identified. In Europe, the largest growth over the last couple of years has been in food-delivery (Postnord, 2014-2016).

"Home delivery is interesting for all age groups, our oldest customer is 95, she orders weekly, through the app."

- Daniel Gebler, Picnic

Responsible for this growth have been supermarkets with new delivery services, but also companies like Deliv-

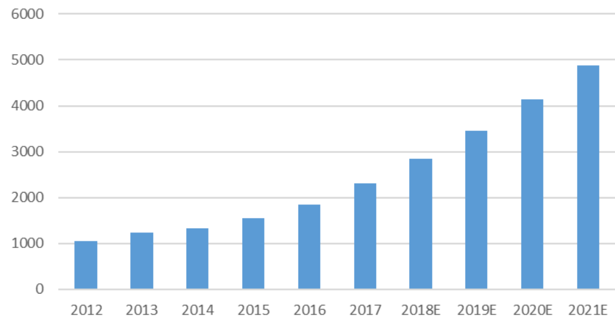


Figure 4.2: *Expected size of the global e-commerce market in billions of US Dollars (Statista, 2017).*

eroo and Uber Eats that offer delivery on behalf of local restaurants — Insight 4B. (Renard, 2018).

Food delivery is growing; new and **fast delivery intermediairs** are connecting **local food suppliers**

Insight 4B

Concerning the assignment, this means that it is worth exploring how fast-moving goods can fit into the delivery system of the future.

Urbanization

Another quite important trend in this field is urbanization. All over the world, there is an increase in inhabitants of cities. About 80% of the western world is currently living in urban areas. This amount is expected to steadily increase over the upcoming century (UN, 2007). In Figure 4.4 the growth is visualized, the bottom two lines are for the developed world (white = urban, black = rural), and the top two lines resemble the less developed regions (white = urban, black = rural). For the less developed regions the world is at a turning point

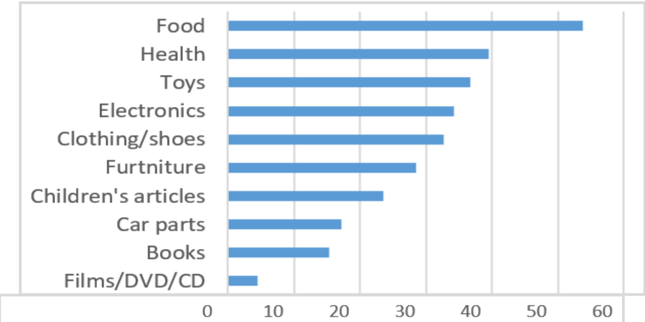


***Figure 4.3:** Percentual growth per category in e-commerce in EU, 2014-2016. (Postnord, 2014-2016).*

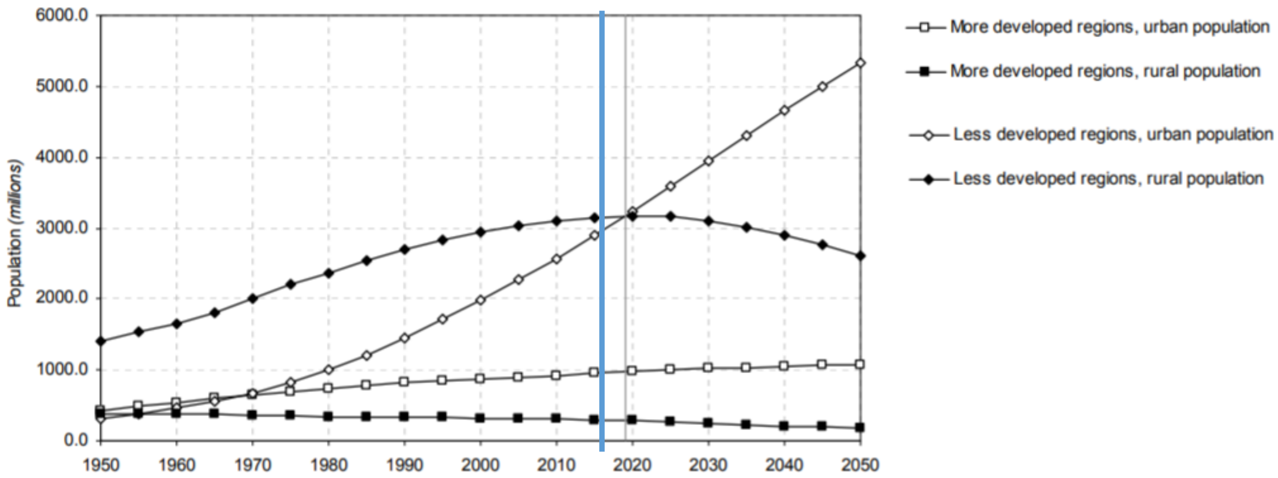


***Figure 4.4:** Urban and rural population of the world (UN, 2007).*

currently: the point where the urban population has starts outgrowing the rural population: Insight 4C. Developing countries are not Ford's target market currently, nor do these countries fit in the European scope of the assignment. However, considering Ford's focus on urban environments — serving this market could be a large long-term opportunity.

Urbanization is increasing globally, most drastically in developing countries: **more people in a smaller area**

Insight 4C

Having more people in a smaller area generally results in more pressure on delivery networks. In theory however, this is a great starting point for a new delivery solution, because more people living in a smaller area result in a potentially more efficient network.

Environment & air quality

A growing concern for people, law-makers and large corporates is the environment. On a smaller scale, this means that zero-emission vehicles are coming up. While on a larger scale this means that efficiency in operations becomes more and more important.

The European Union is creating tighter legislation on emissions that vehicles are allowed to have. By 2030, the maximum amount of CO_2 that a vehicle is allowed to emit will be decreased by 30% (Insight 4D). This is EU-wide regulation that aims to prevent the 400.000 premature European deaths that are linked to greenhouse gasses and air pollution (Morgan, 2017).

Growing environmental concerns lead to **new regulations** promoting **lowered emissions** in vehicles

Insight 4D

5. Competing technology suppliers

Proceeding in this analysis of the context of autonomous delivery, next up are the competitors. In this chapter, technologies and concepts that are developed by other companies in the field of autonomous delivery will be analyzed.

Why?

For a project in an emerging field like autonomous delivery, it is valuable to know what has been done before, what competitors are currently doing and what we can learn from their efforts. This chapter will give additional explanation on concepts that were selected because they provide a particular insight.

Expected results

The goal is to create an overview of concepts and vehicles that offer insights for this project. For all the vehicles and concepts that have been considered for this review, see Appendix 2.

Companies

There are plenty of new companies in the field trying to innovate last-mile delivery. Companies creating technologies to support last-mile delivery can roughly be divided into three categories, two of which will be covered in this chapter, the last category will be explained in the next chapter.

Automakers

A group of companies that is increasingly engaging in last-mile activities is the group of car companies. With their expertise in building vehicles, automakers — not excluding Ford — have conceptualized different last-mile solutions.

Technology-driven startups

This category comprises startups experimenting with new technologies that could facilitate last-mile delivery. Companies like Eliport, Starship Robotics, and Nuro build experimental vehicles for multiple delivery applications, with the intent of selling the technologies, selling full vehicles or licensing the patents to other businesses.

Delivery service providers

Sometimes, delivery service providers like Picnic or DHL develop new technologies in-house. These innovations will be covered in the next chapter, as these companies—being actual service providers—would classify as potential partners rather than competitors.

Relevant concepts

Relevant concepts by automakers and technology-driven startups will be discussed in this section. Relevant concepts, in this case, are concepts that fulfill parcel delivery in an innovative way. For now, while analyzing these competing concepts, the focus lies on autonomous means of transportation.

The reason for conducting this study is to set a benchmark of a future in which the new Ford concept could operate, and to be able to map the competitive strengths of different concepts at the end of this chapter.

Automakers

Let's start off with investigating propositions from other automakers.

Mercedes-Benz

The automaker that is currently investing in — and experimenting with — autonomous delivery concepts is Mercedes-Benz.

In 2016, Mercedes-Benz launched their vision on delivery of the future by launching the 'Vision Van' (Figure 5.1).

Figure 5.1: *Mercedes-Benz Vision Van (Daimler, 2016).*

There are three interesting choices that have been made in the creation of this concept.

The first choice is to make the sorting and picking system fully autonomous, but to still have a service-person that does the actual parcel handovers. As this person is not technically necessary, it is assumed that Mercedes made this choice from a service perspective.

To make an efficiency-leap, the second choice is the parcel handling system that Mercedes envisions. The system makes use of standardized units carrying parcels that can be loaded all at once (Figure 5.1), so that the vehicle is used in a more efficient way (Insight 5A). The metal framework fits in the back of the van and can autonomously select the parcel to be delivered, and hand it over to the driver to make the delivery (Daimler, 2016).

The third of these choices is implementing drones. Together with Matternet, a California-based drone manufacturer, drones can land on the roof of the vans (Etherington, 2017). The envisioned use-case for this is the fast and easy input of goods into the delivery system. Stores can send small parcels (up to 2kg) towards a delivery van, so that last-minute orders can be delivered by the delivery person (Daimler, 2016). The drones are used in this scenario to skip the first part of the logistics chain, as this part is usually slow — involving lorries and distribution centers. This is summarized in Insight 5B. Mercedes-Benz and Matternet have performed tests in Zurich integrating the drones in the logistic system (Etherington, 2017).

Reducing the time it takes **to load/unload a vehicle** makes sure the vehicle is being used **more effectively**

Insight 5A

Figure 5.2: *A batch of Goupil vehicles (Eco-Mobiliteit, 2017).*

Drones can be used **in the beginning of the logistics chain, to skip slow lorries and distribution centers**

Insight 5B

Goupil Industries

As shortly discussed in the last chapter, Goupil Industries is a French electric car manufacturer. In 2011 it was taken over by Polaris Industries. Polaris' stock has almost doubled since. In short: Goupil is successful at what they do: producing narrow zero-emission vehicles for inner-city transportation.

Because of large orders from (among others) Picnic—a Dutch online supermarket, Goupil Industries is unable to fulfill their orders timely, as they simply lack the capacity to produce the cars at such high rates. (D. Gebler, personal communication, 24-05-2018). One could argue that these cars offer little innovative value, yet they are immensely popular with companies in the field of urban delivery. This is an opportunity that traditional car manufacturers have passed on (Insight 5C).

There is a **high market demand for** narrow **battery-electric vehicles for urban transportation.**

Insight 5C

Technology-driven startups

Over the last few years, startups have come up with a variety of relevant concepts in the field of autonomous delivery.

Starship Technologies

An important company in the field building autonomous delivery robots is Starship Technologies, an Estonian company. They manufacture a 6-wheeled pedestrian-area robot, with a maximum speed of 6 kilometers per hour — avoiding restrictive regulations. The six wheels allow the robot to climb curbs as seen in Figure 5.3. This is an important characteristic, as the last meters of a delivery are full of unforeseen obstacles (Insight 5D).

Figure 5.3: *Curb climbing droid (Starship Technologies, n.d.).*

The **last meters** of delivery can be **full of obstacles like curbs**, which **a device should be able to overcome**

Insight 5D

Starship is running tests in both the US and the UK for grocery delivery, and has partnered up with Mercedes to create a concept called 'Vans and Robots.' A system featuring a mobile hub in the form of a Mercedes Sprinter van, equipped with eight Starship robots facilitating the last meters (Mercedes-Benz, n.d.). In the concept, the small robots have to be loaded manually by a driver, which makes the system quite labour intensive still (Insight 5E)

A **combination** of **a mobile hub (van) with small robots can make delivery more efficient** in certain situations

Insight 5E

Zipline

A multitude of flying concepts has emerged, perhaps most interesting of which is the company called Zipline. The business is manufacturing planes which essentially drop parcels from the sky on parachutes. The technology uses real-time data to predict the exact landing site (Petrova, 2018).

Project Wing

The Alphabet-backed company Project Wing develops a fixed-wing aircraft that can hover still (like in Figure 5.4), but can also fly faster in a wing-like orientation

This technology solves the range-issue that is usually inherent to operating drones for delivery. Another technology that sets Project Wing apart from other delivery drones is its winching system. The drone never lands at the point of delivery (Insight 5F), but instead winches the payload down (Heath, 2018).

Figure 5.4: *Project Wing hovering (Heath, 2018).*

Drones can be **a more interesting option** if they can **cover more distance**, and **don't need a place to land**

Insight 5F

Nuro

A new approach comes from the ex-Google engineers who founded Nuro. They created a narrow vehicle, comparable to the Goupil vehicles in size.

This vehicle uses Lidar to navigate, and drives on ordinary roads instead of sidewalks, and has a flexible interior to carry different payloads—from groceries to parcels and meals (Figure 5.5). The rationale behind this vehicle is the empowerment of local stores, who can compete with larger providers of autonomous delivery through buying the Nuro vehicle (Insight 5G). This is a more traditional business model, as vehicles are still sold per piece to small and medium-sized businesses (Hawkins, 2018).

Figure 5.5: *Nuro Vehicle (Hawkins, 2018).*

Apart from large businesses/logistic networks, **autonomous vehicles could also empower SME's**

Insight 5G

Eliport

A more systemic solution comes from Eliport, a Spanish startup that has pitched and prototyped both sidewalk-roaming autonomous vehicles, and connected parcel boxes (Startengine, 2018). The parcel boxes that Eliport is proposing are privately owned, similar to the current system with letterboxes (Figure 5.6).

Eliport is intending to have a standardized way of handing over goods to a stationary container. Also, the company holds a pending US patent covering the fully automated handover of a parcel into a receiving container—Insight 5H. (Startengine, 2018).

Cutting the need for **a human receiving-interaction** out of the system makes for **less waiting time** by vehicles

Insight 5H

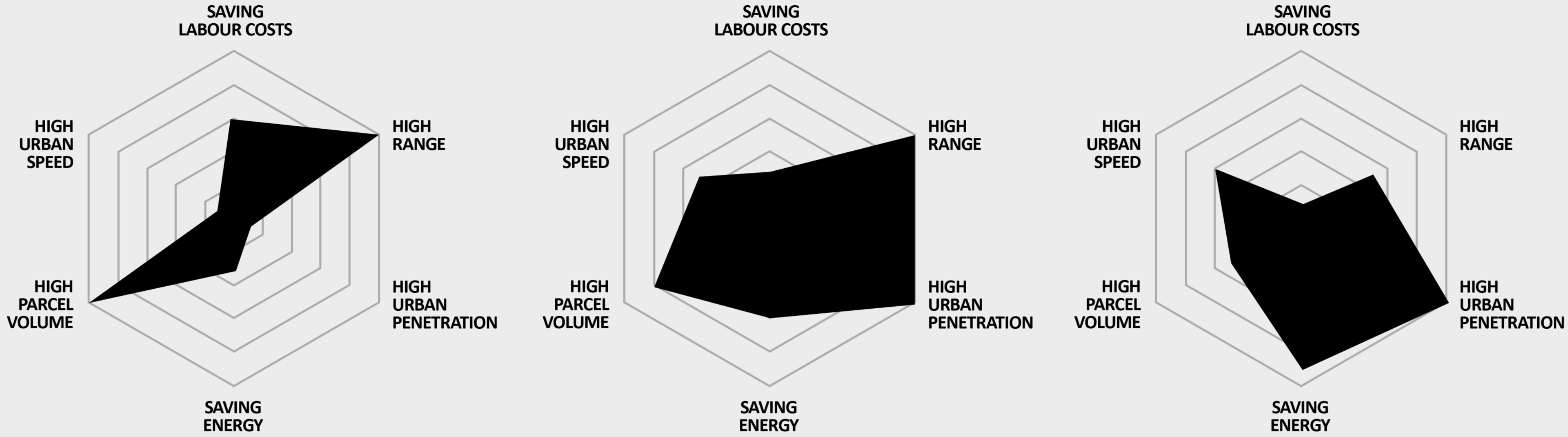
Figure 5.6: *Eliport system of lockers (Hawkins, 2018).*

History repeats?

A short story on the household mailbox

Back at the beginning of the 20th century, the mass-adoption of the mailbox caused a great efficiency boost in the United States postal industry. Experts calculated that US postal service employees would spend about 1.5 hours every day waiting for a recipient of a letter to open the door. In 1923, the Post Office Department made it mandatory for people to have either a separate mailbox or a letter slot for receiving mail (Marsh, 2006).

Fun fact: the red signaling unit was to indicate whether there were outbound letters inside the mailbox that needed to be collected by the postal employee.



Traditional Lorry

Traditional lorries have the advantage of being able to take a lot of parcels for a long drive. However, they have low penetration, high energy use and slow urban speed.

Van + human

Vans and humans combine the high range and parcel volume of a van with the high penetration of a human. Operating costs are quite expensive and emissions are high.

Bike + human

The bike and human combination performs similarly, and is increasingly being used in urban areas, because the combination is more environmentally friendly.

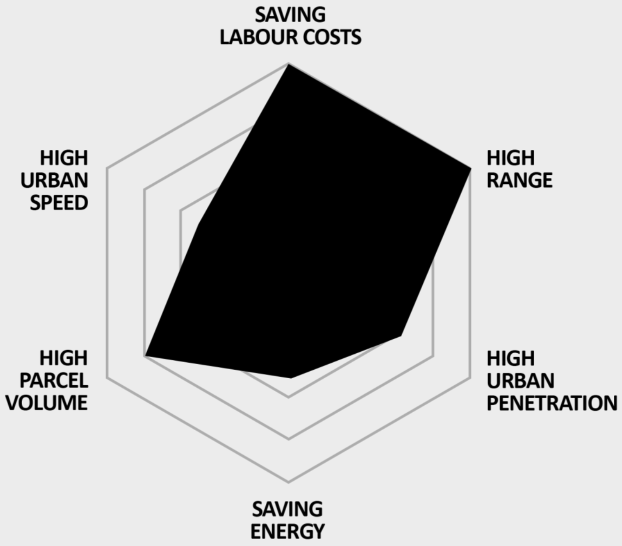
Figure 5.7: *The strengths of multiple means of transportation in a visual overview*

Comparing vehicles

Now that various types of vehicles in the field have been reviewed, that are used by companies in the field, we can compare their respective strengths and weaknesses. A qualitative rating of the current and emerging ways of last-mile transportation are shown in the graph in Figure 5.7. The figure both contains the traditional- and the emerging ways of tackling last-mile transportation.

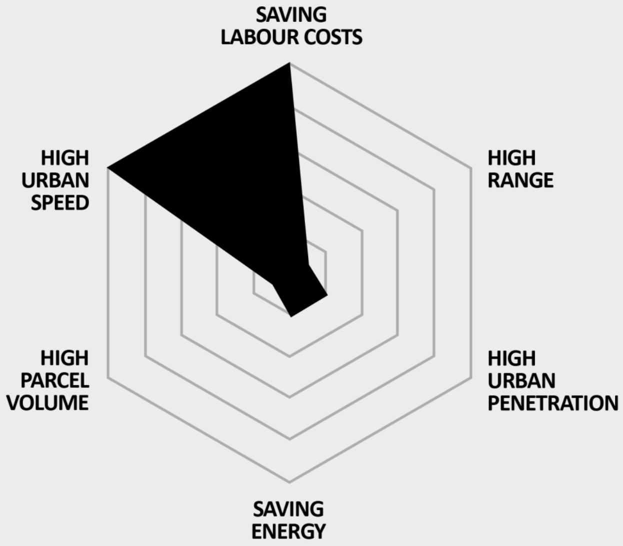
The graphs were created based on six parameters that are considered important by professionals in the delivery business, found through desk research or interviews. Parameters include labour costs, range, penetration (which is defined as the possibility to come close to all spots in a city, rated on a scale from 0 to human-like) energy use per parcel transported, parcel volume, and urban speed.

In general, traditional systems that include humans to perform the handover of a parcel, have high costs and a



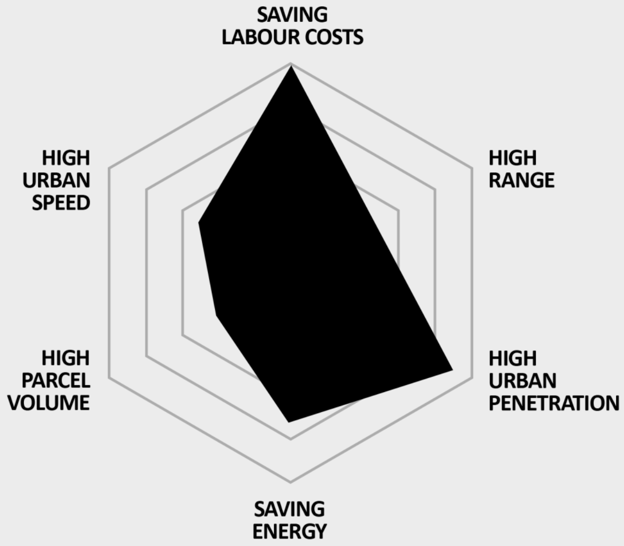
Van (AV)

When removing the human from the van, it saves labour costs, but urban penetration gets lower as vans cannot reach certain areas.



Drone (AV)

Drones have two main advantages: they have a high speed because they can skip slow moving traffic and they operate autonomously so labour costs are low.



Small driving robot (AV)

Of all autonomous vehicles in this review, urban penetration is the highest on small driving robots. They have the ability to come closer to a recepient than other vehicles do.

high penetration. Nothing currently beats the (physical) flexibility human on the last meters of a delivery. From a costs perspective, autonomous vehicles are a sensible option, but the penetration problem needs to be tackled.

Graphs are defined in such a way that a larger surface area means that the means of transportation is more capable. Making this overview visual creates an overview of which means of transportation could supplement each other (Insight 5I).

Combining means of delivery with **complementary strengths can** create **a competitive system**

Insight 5I

“Autonomous vehicles provide an enormous opportunity for making delivery more efficient and sustainable. ”

- Marijn Slabbekoorn, DHL

6. Potential partners

In the previous chapter, technology providers were investigated. Now, as Ford is also a company that is likely to supply technology, the service-side will be elaborated through research in potential partners.

Why?

As Ford is lacking experience in providing delivery services, I would not recommend the company to go and set up its own delivery network. That is why this examination of potential partners took place, investigating the categories of companies that Ford could provide its vehicles or services to, or cooperate with.

Expected results

Multiple categories of companies and their technological innovations/experiments will be explained, and insights will be formulated. Also, the vision of three professionals in different fields on autonomous technology will be detailed.

Companies

As Ford is relatively new in the last-mile industry, it makes sense to look at companies in this field that are working on innovating last-mile delivery, to potentially partner up with them. In this section, we will take a look at the companies that Ford could potentially work with—or could deliver their vehicles/services to.

Traditional shipping companies

In the field of parcel delivery, DHL is the company that openly puts the most effort into last-mile optimization. UPS and FedEx run small tests incidentally, but do not have an approach that is as systemic as DHL.

High-volume webshops

A relatively new category of companies experimenting with last-mile delivery is the category of webshops that sell a high enough volume to make it viable to skip traditional delivery service and take care of delivery themselves. Examples of these companies are Amazon in the US/Germany and Coolblue in the Netherlands.

Business-driven startups

The last on the list of companies to invest in new ways of delivery are service-oriented startups that build a proprietary last-mile infrastructure complimenting their core service. Companies in this category include online supermarket Picnic, home cooking service HelloFresh, meal delivery service Deliveroo, etcetera.

Innovations and experiments

The companies mentioned above have developed concepts in varying stages of maturity. In this chapter, the

Figure 6.1: *DHL Cubicicle Electric Parcel Bike (DHL, 2017).*

interesting concepts that Ford could learn from will be covered.

Traditional shipping companies

To support this part, an interview was conducted with Marijn Slabbekoorn, logistics engineer and project manager in last-mile solutions at DHL Express.

DHL Cubicycle

DHL has multiple initiatives for optimizing the last mile, most of which involve bikes. An example of such a vehicle is the 'Cubicycle' electric bike: a four-wheeled pedal-assisted system operated by one bicycle courier (Figure 6.1), allowing for zero emissions in the urban area. (DHL Parcel, 2017).

The beauty of this system, however, is only partly in the bike. The box on the back of the bike is a real innovative part. Te boxes, called 'Cubicontainers' or 'City Containers' are one cubic meter in volume (Insight 6A).

DHL has introduced a standard for urban shipping containers, with these **dimensions: 0.8 x 1.2 x 1.0 [m]**

Insight 6A

The system is currently operational in Alkmaar, Breda, Houten, Nijmegen, Rotterdam and Utrecht, Frankfurt (DE) and Antwerpen (BE). The containers are connected through LoRa — an IOT network operated by KPN — to share real-time location data for optimal routing and for security reasons (DHL Parcel, 2017)

The small containers are the size of a EUR-pallet, integrating well with the delivery network *before* the parcels reach the city. This integration of the small container into the network is one of the remaining challenges in the initiative. To make this process cost-effective, the automated sorting system that is currently present in the service centers must be adapted to automatically route the

Figure 6.2: *DHL Cubicontainers on trailer (DHL Parcel, 2017).*

smaller parcels for a specific neighbourhood towards the right *Cubicontainers* (Insight 6B). Bigger parcels that do not fit into these containers, are currently still delivered

Automation in **the service centers and warehouses** plays a significant role in **keeping costs low** for delivery

Insight 6B

by van. (M. Slabbekoorn, personal communication, May 25th, 2018).

The Cubicontainers can be transshipped from a mobile-hub trailer (Figure 6.2) to a bike, or to a van in a relatively easy manner. This system was tested in multiple cities. The idea is to move the 'hub-trailer' as close to the center of a city as possible, and start the bicycle delivery routes from there. This minimizes inner-city freight movements, similar to the fixed consolidation points as discussed before. The (unofficial) outcome of the test seems that the trailers - with four containers - are too small to really benefit efficiency in most cities. Carrying two more containers (six in total) would be ideal for most current cities (Insight 6C). That's why trucks/lorries are currently driven into the city to function as this mobile-hub (M. Slabbekoorn, personal communication, May 25th, 2018).

The size of a mobile hub should be **proportional to the area served** to actually make the chain more efficient

Insight 6C

Apart from creating these flexible mobile hubs, DHL is ▶

Marijn Slabbekoorn

Logistics Engineer/Last-Mile Optimization at DHL

Background

Marijn is a TU Delft graduate in Systems Engineering, Policy Analysis and Management. Since his graduation project at TNO, he has been working with DHL for four years now.

About the company

DHL is the largest shipping provider in Europe, operating a worldwide logistics network. The company has set itself an ambitious target: by 2025, 70 percent of last mile deliveries should be zero-emission. This goal has fueled innovation within DHL over the last years.

Why contacted them?

Marijn is the project lead within both the GoGreen and the Last-Mile Optimization program at DHL Express in The Netherlands. After four years of working in this field, Marijn knows the ins and outs of last mile delivery at a large shipping company like DHL.

Key learnings

- DHL is pushing to bring last-mile emissions down
- For large providers, system efficiency is currently more important than individual needs
- Innovation is focused on quick deconsolidation

Full interview transcript in Appendix 6.

investing in actual real estate inside cities. These centers will be placed at strategic points between office spaces and residential areas (Van Leeuwen, 2018)— in order to optimize efficiency and minimize emissions. From these future inner-city service centers, DHL wants to dispatch the delivery bikes and electric vans, and also offer an urban touchpoint for people to send/receive their parcels from. (Insight 6D)

Delivery companies are buying **real estate in city centers,** to **optimize freight movements and service**

Insight 6D

DHL Water Strider

Another concept at DHL is interesting for its out-of-the-box approach: the Water Strider (Figure 6.3) concept that was the result of an open innovation competition hosted by DHL in 2015.

The main rationale here, is that congestion can be avoided in some cities—like Amsterdam for example—by transporting parcels by boat. See Insight 6E.

While delivery services typically use roads, **other types of infrastructure can be beneficial** in certain use-cases.

Insight 6E

DHL ParcelCopter

While not being meant as a last-mile transportation device, the ParcelCopter is interesting because of its ability to fly. The drone carrying parcels was developed for remote areas, for instance the Swiss Alps (Figure 6.4). The ParcelCopter is three times faster than car-based transportation in this area (DHL, 2016).

The aircraft pictured here is already a second generation of the vehicle. The first generation was used to transport emergency medicine to the island of Juist (Germany).

For the second generation, DHL developed a special version of its Packstation to provide as a contact interface between the drone itself and the end-consumer collecting the parcel. As it is generally seen as unsafe for a user to directly interact with a drone. (DHL, 2016). This leads to Insight 6F.

Drones can be significantly **faster than cars** and are suitable for urgent goods, but need a safe place to land

Insight 6F

PostNL Parcel lockers

Recently, PostNL has also experimented with parcel stations, replacing old-fashioned orange letterboxes by the units seen in Figure 6.5. This replacement action makes clever use of locations that are already occupied by PostNL infrastructure.

The test is a success, as the lockers (produced in Poland) are being rolled out in more and more cities in The Netherlands. The units offer flexibility in pick-up time for customers and less failed deliveries for PostNL (PostNL, 2017). In other places in Europe – for example in Germany – they are a more common sight (Insight 6G).

Stationary locker stations are **increasingly popular** in multiple European countries

Insight 6G

Figure 6.3: *DHL Water Strider concept (DHL, 2015).*

Figure 6.4: *DHL ParcelCopter (DHL, 2015).*

Figure 6.5: *PostNL letter and parcel machine (PostNL, 2017).*

Business-driven startups

Another sector that is innovating in last-mile delivery are the ‘business-driven startups’: companies that have something other than delivery as their core business, usually fresh goods. The reason for innovating the last-mile is quite clear for these companies - services of traditional delivery businesses do not suffice. Findings in this section are supported by an interview with Daniel Gebler who is the CTO at Picnic.

Picnic Grocery Delivery

Since a few years, Picnic offering its grocery delivery services in the Netherlands. Being the first online supermarket, they do not offer traditional stores. Instead, they perform home-delivery through small electric trucks (Figure 6.6).

Figure 6.6 *Picnic vehicle (Picnic, n.d.).*

What is interesting about Picnic’s approach, is the way in which the delivery experience is tackled. While traditional shipping companies have a 20% chance of not finding the recipient at their home, for Picnic this no-show rate is 1% (Insight 6H). The main reason behind this is their timing. Picnic-customers can choose a 20-minute timeframe in which they would like to receive their groceries. Offering these narrow timeframes requires a lot of data and a good calculation of how much time every action takes. The formula for Picnic incorporates these factors (Figure 6.7).

$$C_{area} + C_{1st} + C_{product} * N + T_{\Delta}$$

Figure 6.7: *Calculating the time it takes to perform one delivery (D. Gebler, personal communication, 24-05-2018)*

Important factors in this calculation are the C_{area}: this incorporates the time it takes to find a parking spot in a certain area. The C_{1st} is an addition to the first delivery at an address, as they tend to take longer. Then, the $C_{product}$, is the time constant per product, which is multiplied by the amount of products N. The T_{Δ} factors in the time of day. In evenings it is usually harder to find a parking spot, or even to find the right door. In this way, Picnic can predict closely when they will arrive at a door, in 99% of cases, the cars arrive within the 20-minute estimated timeframe (D. Gebler, personal communication, 24-05-2018).

The app of Picnic is programmed in such a way that a car horn sounds when the delivery vehicle is 10 minutes from the customer. From that moment, the route is shown (Figure 6.8), and a timer is counting down. Now, the customer knows when to expect the groceries, which helps with planning their time. Also, this helps Picnic to be more efficient. Oftentimes, people are already waiting for the driver, standing in the opening of the door.

Using data to calculate narrow delivery timeslots can minimize the risk that a customer is not home

Insight 6H

Daniel Gebler

Chief Technology Officer at Picnic

Background
Daniel has a background in computer science. He has over five years of working experience at Fredhopper (a data-driven shelf-optimization company), completed his Ph.D. at VU Amsterdam in 2015 and has worked as the CTO for Picnic since.

About the company
Picnic is a rapidly growing online supermarket concept in the Netherlands, that operates exclusively through warehouses and home-delivery. The award-winning company now operates their supermarket service in 24 cities, with a competitive last-mile strategy.

Why contacted them?
As the CTO, Daniel is able to explain in great detail what technology is being used, and what impact it has. The reason to contact Picnic is that this company set up its own delivery network.

Key learnings

- Narrow timeframes create user satisfaction
- The human driver is Picnic’s most valuable asset
- There is an opportunity in combining goods and groceries in one delivery action

Interview notes in Appendix 5.

Figure 6.8: *Following a vehicle through app (Picnic, n.d.).*

Picnic has calculated that this saves on average 23 seconds per delivery (D. Gebler, personal communication, 24-05-2018), time that would otherwise be spent for de driver to walk up to the door, ring the bell, walk back etc. (Insight 6I).

Transparency is appreciated by users, and can even lead to **more efficiency in the delivery process**

Insight 6I

As Picnic vehicles usually drive back empty, they conducted tests with Zalando and Wehkamp to take customers' return products from their webshops (fashion items, with a notoriously high return rate). This test went well: the customers were satisfied with the integration. Since this experiment, stores have been asking Picnic to also operate their forward logistics—Insight 6J. (D. Gebler, personal communication, 24-05-2018)

Integrating food- and parcel delivery creates high **customer satisfaction,** and **businesses are interested**

Insight 6J

High-volume webshops

This section is about the webshops starting their own delivery services. The research that was performed tries to find the reasons why. The research is trying to understand what drives these (usually large) retailers in their decision to abandon traditional delivery service and start their own. The desk research was backed up by an interview with Bas van den Berg, project lead 'last-mile' at Coolblue - a popular consumer electronics retailer in the Netherlands.

Coolblue (NL)
Coolblue ships most of their volume in parcels through PostNL. Larger items such as washing machines and televisions - since the beginning - been delivered through proprietary vans and employees, as there is a large service factor involved for these products. This leads to Insight 6K.

In the bigger cities of the Netherlands, Coolblue has opened physical stores next to its web-based activities. From a few of these physical stores, the company recently started delivering the smaller items using bikes as seen

Figure 6.9: *Coolblue delivery bike (Coolblue, 2018).*

Hybrid forms of **in-house and external shipping providers** are common practice for **webshops**

Insight 6K

in Figure 6.9 (Coolblue, 2018).Here, the stores act as an urban hub: receiving goods from external warehouses and transshipping them onto smaller vehicles - in this case bikes (Insight 6L).

High volume webshops choose to **use their physical urban stores** as a hub **for city delivery**

Insight 6L

This is an interesting choice, as the network of large shipment providers like PostNL is denser and therefore more cost-effective. When asked about the rationale behind this, the answer was less complex than anticipated: it is about the customer journey.

"We have our own way of doing things, we want that to be visible in our delivery as well."

- Bas van den Berg, Coolblue

Like most companies these days, Coolblue envisions a customer journey in order to create customer experiences that lead to repeated purchases. Leaving a large part of this experience in the hands of an external parcel provider makes less sense from this perspective, summarized in Insight 6M. (B. Van den Berg, personal communication, 18-05-2018).

Webshops start their **own delivery services** in order to be able to **control the whole customer journey**

Insight 6M

In this scenario, the delivery method can almost be seen as a marketing tool, rather than a technical means of transportation. Coolblue found that during the first months of this test, customers that were served by its bicycle couriers were less likely to call customer service, as they already had the opportunity to get help from a knowledgeable person at their door (B. Van den Berg, personal communication, 18-05-2018). This, currently, is only being fulfilled by humans, Insight 6N.

Next to parcels, **knowledge and customer service** can also be provided **at the customers' house**

Insight 6N

But it is also about marketing. Between the lines, the interview with Bas is a story of authenticity. Because there is a strong identity within the company, they want to do things in their own way. The bicycle couriers are essentially driving billboards, generating visibility on the streets. The customizability of a vehicle or a service is something that brands like Coolblue would appreciate (Insight 6O).

Brands/webshops can have a need to **customize the delivery experience**, to make it fit in their story

Insight 6O

Amazon (US)

Meanwhile, online retailer Amazon is exploring the use of autonomous technologies in delivery in the United States. Their work is still very conceptual in nature, seemingly focussing mainly on securing intellectual property - of which they generate a lot.

Amazon is betting on flying drones, which - as stated before - have trouble with range and landing space. Most of the patent filings by Amazon include solutions for problems that arise from performing drone-deliveries in urban areas (Holland-Michel, 2017).

One of these solutions is displayed in Figure 6.10. It is a flying fulfilment center in the form of an airship, from which a series of smaller parcel-carrying drones take off. The strength of the airship is that it can be placed strategically/centrally, making the trips for the smaller drones shorter. Another interesting concept is the patent that was filed claiming lampposts with landing pads for drones. They have a double function as they both charge the drones, and are able to act as an interface between drone and customer, so that a customer can pick their parcels up at the nearest streetlight (Insight 6P).

Drones can be **supported by other vehicles/ infrastructure** to supplement their low range

Insight 6P

Bas van den Berg

Project Lead Last Mile Delivery at Coolblue

Background
Bas has been working in supply chain management for nine years, and has worked in stock/warehouse management for Samsung before joining Coolblue in 2014.

About the company
Coolblue is a fast growing electronics webshop in the Netherlands, with its own specific style in online retail. Over the years, they have built a brand around their authentic approach and great service.

Why contacted them?
Since last year, Bas is the project lead in last-mile delivery at Coolblue. This means that he is responsible for - and thus can provide insight in - the new bicycle delivery system that the company has launched in multiple Dutch cities in April 2018.

Key learnings

- For webshops, control over customer journey is of great importance.
- Physical stores in city centers can double as urban hubs for delivery
- Flexibility & service are key for customer satisfaction

Full interview transcript in Appendix 4.

Other concepts include beehive-like fulfilment centres, and interlocking drones able to create one mega-drone solving the problem of the potential chaos created by individual parcels flying through the air (Insight 6Q).

Individual transportation of parcels **can easily create chaos**, **AV's teaming up** can help prevent this

Insight 6Q

Apart from the customer-side of the delivery business, Amazon is famous for its impressive fleet of warehousing robots (Figure 6.11). Over 45.000 robots are roaming the warehouses, bringing shelves to order pickers, instead of the order pickers coming to the shelves. (Szal, 2017) As usual with automation, this saves time for employees and keeps costs low (Insight 6R).

Warehousing robots are an **upcoming means to optimize efficiency** early on in the logistics chain

Insight 6R

Interesting detail about the warehousing robots, is that they are flat, and do not contain any goods-storage themselves. Their only duty is to lift shelves. If every shelf

Modular goods-containers can **ensure productivity of vehicles** while **people interact with a container**

Insight 6S

would have self-driving capabilities, it would have required a lot more (unnecessary) vehicles (Insight 6S).

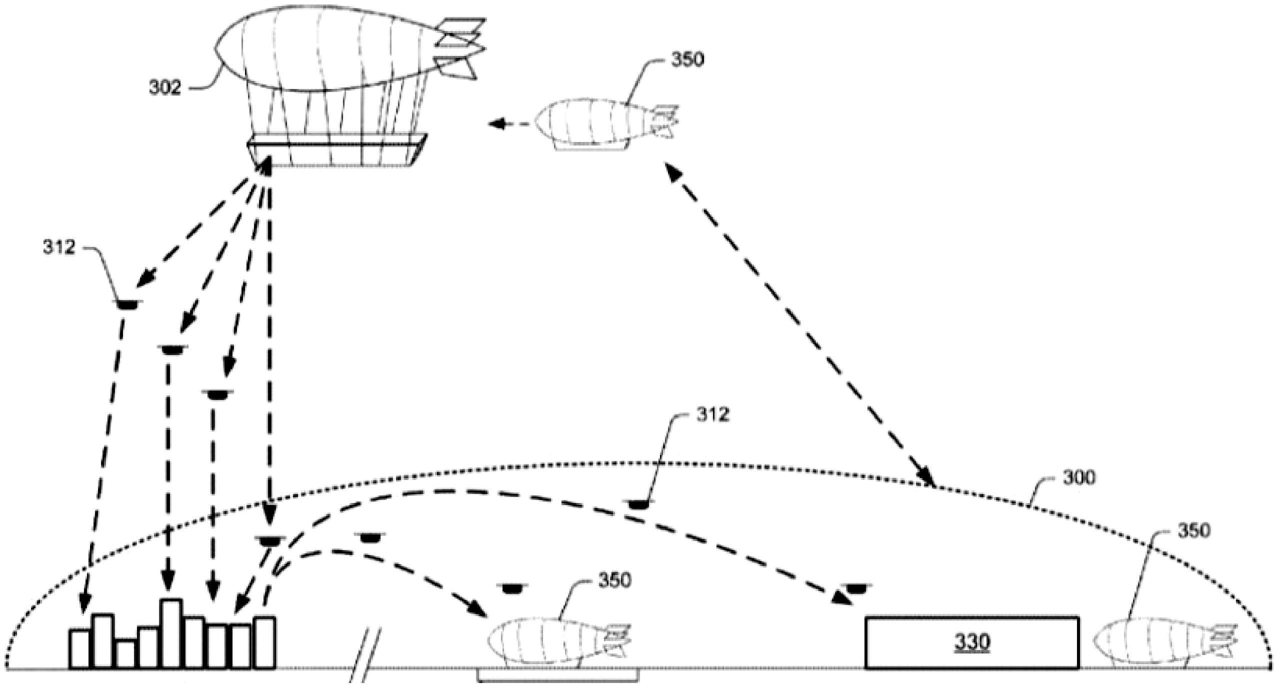


Figure 6.10: *Patent drawing of a drone fulfillment center by Amazon (Holland-Michel, 2017)*

Figure 6.11: *Amazon warehousing robots (Szal, 2017).*


1B↑
playmobil
5348
1A↑
750 lbs. BASE CAPACITY
DO NOT EXCEED LIMIT
2716
1695

7. Vision of Ford

After analyzing the future context (everything outside), now its time to take a look inside. What does the company stand for, and how does this relate to autonomous delivery?

Why?

In order for this project to be a success, it is important for the final concept to connect to Ford as a company.

Expected results

The goal is to understand what Ford is about: what its history is in delivery, what the vision says, and what the strengths and weaknesses are. Also, the corporate vision on autonomous vehicles and delivery will deserve a closer look.

For confidentiality reasons I'm not able to share all information I have received from Ford in this report.

Heritage

Ford is a company that has built a strong name with its Transit brand of light commercial vehicles (Figure 7.1). Since the first version in 1965, is has been popular. In 1972 it was declared the 'Britain's most wanted van' by the Metropolitan police. It was the go-to vehicle for bank robbers because of its car-like driving performance; other vans at the time were heavy and based on lorry-chassis (Moss, 2015). Now, the Transit is the second most sold light commercial van in the world, with 8.4 million vans sold. The third best selling van of all time is also a Ford: the E-series with 8.3 million sold. The number one selling van of all time is the Volkswagen Transporter series, with 12.4 million units (Campbell, 2017).

This heritage is something to keep in mind while designing a new autonomous system. People will perceive Ford with this history in mind, so connecting to the mental concept that customers have of a Transit in the product-story could strengthen the proposition.

Identity/vision

The Ford motto of 'people serving people', is quite a broad statement that communicates a feeling of a certain no-nonsense mentality, not placing themselves above the customer. This matches with the notion of 'democratizing mobility' (Ford, n.d.).

The strategy gets more concrete when it comes to sustainability:

- *We define sustainability as a business model that creates value by preserving and enhancing environmental, social* ***and*** *financial capital.*

This can act as a guideline to test new concepts; any concept should add to the three pillars.

Strengths

Ford has a name of being a partner that can be trusted, being able to supply a large number of vehicles through their extensive amount of factories. From a technological standpoint, Ford can create reliable vehicles that people and businesses can count on.

Weaknesses

When it comes to innovation, Ford is struggling to move fast, like most large companies. This is a weakness, as most of the competition in autonomous delivery at this moment comes from startups that can actually move faster.

Another problem is that Ford is lagging behind when it comes to the production of battery-electric vehicles. While other corporates like VAG, Toyota Group, Groupe Renault and GM currently all have proprietary battery-

Figure 7.2: *Test in Miami with modified 'autonomous' van*

and motor technology, Ford has to rely on buying those parts from other suppliers. This is a vulnerable position to be in as a vehicle manufacturer.

Autonomous strategy

Over the last few months, Ford has acquired cloud service company Autonomic that is creating an open cloud platform that every vehicle on the road could send an receive data from: the Transportation Mobility Cloud. Another acquired startup is TransLoc, a service which provides data-driven navigation tools for dispatching vehicles in urban areas (Martinez, 2018).

This focus on autonomous mobility comes at a time in which Ford struggles to keep up with developments. The production of large quantities of vehicles and internal combustion engines is getting outdated, because of shared mobility and electrification. Modern mobility does not need a lot of the things that Ford is traditionally good at.

That is why CEO Jim Hackett has announced the new focus on autonomous mobility, and more specifically: autonomous goods transportation. The motivation to get into this field is that not a lot of other companies are doing it, and Ford could therefore have an advantage of starting early (Business Insider, 2018).

A large opportunity area, as Hackett points out, is the empowerment of local retailers by creating a shared delivery system. Ford is testing this system in Miami together with an urban shipping company called Postmates since June 2018 with 70 local retailers that have sighed up to make use of the experimental vehicles shown in Figure 7.2 (Patrascu, 2018).

"The logistics opportunity is enormous, for small businesses, this is a big advantage. They have been suffering. In retail right now, scale drives out the small retai-lers."

- Jim Hackett, CEO, Ford

Figure 7.1: *Transit range (2013—1965)*

User research

In this second phase of the project, the aim is to generate new knowledge by performing user research among different groups of (future) users: local shop-owners, potential future clients of a medicine delivery service and inhabitants of Monkston (UK). The insights are highlighted throughout the phase.

8. Independent shop-owners

As seen in the previous chapter, Ford has a mission to enable independent shop-owners by providing them access to a shared autonomous delivery service. There is a pilot happening in Miami, and is coordinated by a United States based team at Ford. In this chapter, the validity of such a concept in Europe will be tested, through a series of interviews.

Why?

When designing an autonomous delivery system, knowing the way in which the system will be used is important. Insight into this group is important for the vision on delivery in the future that I am creating.

Expected results

The outcome of this phase is a list of key concerns and motivations per group of stakeholders, which can be translated into new requirements for the concept design phase.

Partners/users?

Independent shop owners are significantly different from the large parties that were interviewed in the 'Potential partners' section of this report. They differ to such an extent, that I would not consider them 'partners', but 'users' of a potential service that Ford could set up. Hence they are discussed in 'User research' section.

Research questions

The following research questions were defined for this part of the user research.

- What are the current problems with their delivery?
- Why would shop-owners choose to participate in an autonomous (shared) delivery system, and why not?
- Is there a difference between concerns in the type of shop they run?

Method

The research questions will be answered by focusing on independent shop owners and interviewing people working directly with these independent retailers. An explorative interview with a Chinese take-away owner in The Hague is executed — as Chinese dinner is the second largest delivery category in the Netherlands (Driessen, 2016). Because of time concerns, a meeting with one of the founders of the Smart Emma project (more details on the right of this page) Sarah Güsken is scheduled. Sarah is able to disclose concerns from her research with more than ten small business owners. Next to that, a call is scheduled with Linda Davies from Starship Robotics - who knows more about the collaboration with small retailers from a robot-operator perspective.

User insights

The insights from talking to different stakeholders in the small-business/delivery sector are summarized below.

Hang Yee: Chinese take-away restaurant

The first interview that took place was with Priscilla Lam from Chinese family restaurant Hang Yee, a take-away restaurant in The Hague (full conversation notes in Appendix 7). During this interview, a couple of things became clear. Most important of which, the service mentality that is omnipresent in the small restaurant business. The two things that the restaurant tell to a (new) delivery person is to be careful with the food and be very friendly to customers. While larger, more commercial delivery restaurants may be interested in automation, Hang Yee is certainly not because of this relationship that they intend to build between delivery person and customer (Insight 8A).

Smaller restaurants are often interested in **building loyalty by a human delivery** experience

Insight 8A

"We value the personal touch. We know our customers and our customers know us. Having human delivery personnel builds trust."

- Priscilla Lam, Hang Yee

What was also learned is that most takeaway restaurants are part of what originated as a listing website for restaurants, but ended up taking over a lot of operational tasks: a takeaway platform. Large parties in this sector are Takeaway.com and Just Eat, which became one earlier this year (Stil, 2018). 70% of orders that Hang Yee gets are through the *'Thuisbezorgd'* application, as it is called in the Netherlands. They provide a computer system that calculates the logistical costs, and facilitates the enforcement of the maximum delivery radius (2km for normal orders, 3.5 km for large orders). Hang Yee even leases an electric scooter through Thuisbezorgd. It is these intermediary companies that are in a position to 'push' smaller restaurants towards adopting new technologies (Insight 8B).

Online intermediaries and lease contracts are simple entrances for **smaller restaurants to adopt new tech.**

Insight 8B

"If we can make it work with food, then it will work with other products as well."

- Sarah Güsken, Smart Emma

RWTH: Smart Emma

The insights from the interview with Sara Güsken from RWTH will be discussed in this section (full interview notes in Appendix 9). During interviews that Sarah conducted with participants in the Smart Emma project, researcher Sarah found a problem with technology acceptance. As it turns out, most independent shop owners are between 40 and 60 years old, and so is their customer base. These people have ran their shop in a certain way for up to thirty years, and are not prepared to radically change. Shop-owners in this category usually have a bit of a sceptical attitude towards technology, which is not helpful for implementing autonomous delivery (Insight 8C).

New technology acceptance is generally low among small-business owners as well as **their customers**

Insight 8C

The reason for participating in Smart Emma for almost all the stores in the programme is that the system could get them new (and younger) customers. Most retailers have a fear that large companies like Amazon will take over 'their' customers if they do not innovate in some way (Insight 8D).

Survival of their business is the main reason for local retailers to **participate in shared delivery schemes**

Insight 8D

Smart Emma
A platform connecting local retailers

Smart Emma is a research project by the RWTH Aachen University. This project takes place in the city of Aachen, and aims to open up the benefits of online shopping for independent local retailers that sell unprepared food. Within the project, an online platform is being built where consumers can order from multiple connected stores at once. The idea is to combine 'shopping carts' from these different stores into one single bike courier delivery. The research focuses mainly on shaping the online platform, and on studying the feasibility of the concept. The logistics of the system are handled by a third party, called Neomesh GmbH.

Starship Robotics

The last interview conducted in this chapter is with Linda Davies, from Starship Robotics. The interview notes are to be found in Appendix 8. Linda has been involved in the operations of Starship in London - a programme that has been discontinued in favor of the Monkston location. In London, Starship supplied robotic deliveries in collaboration with Just Eat (Figure 8.1). Again, individual restaurant-owners were showing doubts and scepticism, but as Just Eat — already a partner — approached them with the robot-idea, they said yes more often than not.

In London, the food delivery sector is quite extensive, and often restaurants have to stop taking new orders as they lack delivery capacity. Here, the robots were mainly used by restaurant owners to deliver orders placed nearby, so that the more long-distance deliveries could be made by scooter. This combination of scooter and robot deliveries was quite popular because it made restaurants that would normally stop taking orders at a certain point more efficient in their delivery. Domino's in Rotterdam has plans for using robots in a similar way, once legislation allows it (Insight 8E).

Fulfilling **nearby orders with robots** can **free up scooters/drivers for long-distance orders**

Insight 8E

During recruitment for small businesses to join their delivery service, Starship found that many prepared (warm) food suppliers were not enthusiastic about participating. Concerns about warm food in the isolated boxes getting damp and limp were often heard. A fish

Figure 8.1: Starship & Just Eat delivering a meal in London

and chips supplier, for instance, is not participating as the warm food gets worse every minute, and robots simply take longer to reach their destination (Insight 8F).

Speed is an **important** factor **for warm food retailers,** making them **choose scooters over robots**

Insight 8F

One last concern that is omnipresent among individual retailers is that usually, the quality of delivery reflects upon a store. If a delivery goes wrong, people will blame the store. This is a risk that these independent shop-owners are not willing to take. The negative emotion of potentially losing customers is stronger than the notion that they could gain new customers (Insight 8G).

Delivery quality reflects upon a store, so retailers are keen on providing a **good experience during delivery**.

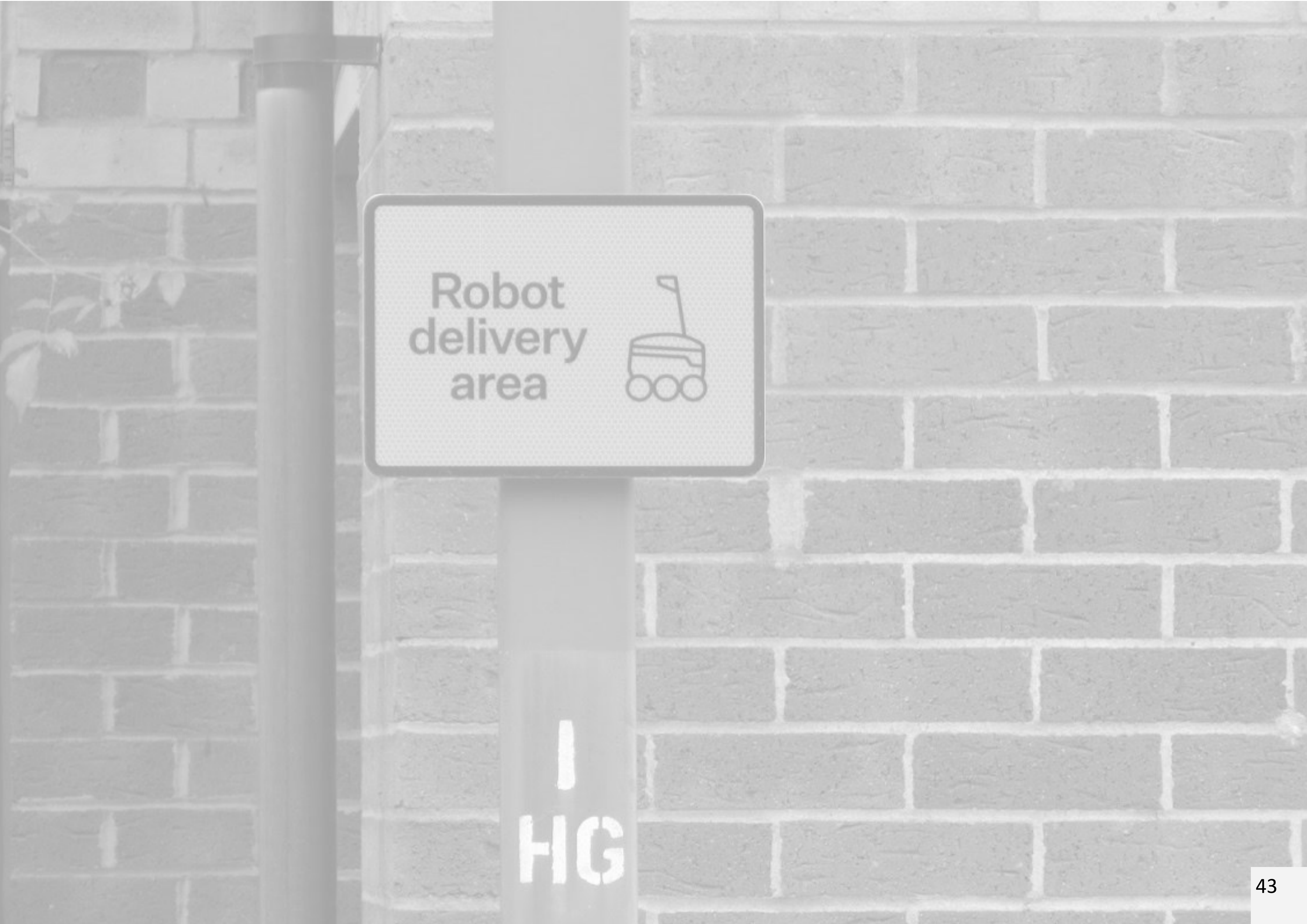
Insight 8G

Conclusion

Participating in a shared system is mainly interesting to small retailers if it attracts new customers. However, regardless of the type of shop they run, retailers are often satisfied with their current (non-shared & human) delivery method, or at least cannot really see past this reality. Reasons they mention for not implementing autonomous technology include fear technology or losing customers because of misbehaviour by a robot. All in all, for this project, these findings suggest that 'independent shop-owners' is an unsuitable group of users to begin implementing autonomous delivery technology with.

"Small business owners were truly afraid that they would be forced to close their doors if Starship ruined the deliveries."

- Linda Davies, Starship Robotics


Robot
delivery
area
HG

9. Human vs. robot: customer experience

After analyzing the last group of potential business-stakeholders of the system, it is time to focus on the end users of the system: the customers that get a parcel delivered. In this chapter, both the physical and cognitive ergonomics of autonomous delivery will be investigated in a tough user segment.

Why?

Every delivery system is influenced by the wishes of the customer. This human factor becomes especially important when introducing autonomy in a system. Designing a good human-machine interface for the handover of the parcel can only be done with proper insights on how customers perceive delivery.

Expected results

A user experience comparison between a traditional delivery person and an autonomous pod — comparing the experience on multiple levels — translatable into new requirements for the concept design phase.

Introduction

This chapter is about the end-users of the delivery system, the people, the customers. This section is about finding their concerns when it comes to receiving a parcel.

The concerns that a user has can be split into two parts:

- the concerns when in anticipation of a delivery
- the concerns during the handover interaction

This research will be focusing on the handover itself. But first, a closer look will be taken into the concerns when users are anticipating a parcel.

Standing-reserve

The concept of 'standing-reserve' was introduced by German philosopher Martin Heidegger. Yes, his political views were questionable at best (Losurdo, 2014), but his views on technology were unique at the time. Heidegger argued that technology should be a standing-reserve: a supplement to the lives of people, a stand-by asset. His observation was, ironically, that technology has a tendency to transform humans into a standing-reserve (El Khachab, 2013).

So instead of technology assisting people, people become part of a technological system that is outside of their control. This effect that technology can have is seen in many modern applications — especially in large technological systems like parcel services — and should generally be avoided (Insight 9A).

People should be able to remain in control within large technological systems.

Insight 9A

Figure 9.1: Mr. Bergsma, the deliveryman of the pharmacy

Interface

Human-machine interaction is usually solved by creating an interface. Interface was originally defined as "a way in which you interact with another thing", but has evolved into a synonym for "graphical user interface" in recent times (Krishna, 2015). In this chapter, the use of a graphical user interface on a touchscreen in a delivery scenario will be evaluated.

Research questions

The following research questions were defined for this part of the user research.

- What added challenges do people face while accepting a parcel from a robot?
- In which way does the perceived experience in both methods of delivery differ?

Method

To answer the research questions, an approachable address that facilitates deliveries was selected: a pharmacy owned by relatives in Leeuwarden. Please note that the customers of the pharmacy delivery are of an older age, usually have little affinity with technology, and often have difficulties moving about. One could say this is one of the least favourable cases when it comes to automated delivery acceptance, but their critical eye could lead to valuable insights.

The methodology in this research consists of the following two parts.

(1) **The benchmark.** This part is about setting a benchmark of how satisfied people are with the current way of delivery (Mr. Bergsma—Figure 9.1), and what factors are important. Data is gathered by letting nine clients of the pharmacy fill out a questionnaire (Appendix 10-A). At the end of the questionnaire, it is announced that - in the next weeks - a robot will bring their medication.

(2) **The confrontation.** During this part, a robot will take over the pharmacy delivery for a day, only for the same nine clients. Their first responses are recorded on video. Afterwards, they are presented with a similar questionnaire (Appendix 10-B) as the previous time, making a comparison possible. Also, there is room for qualitative feedback, which is noted.

The robot prototype that will be used during the test, is constructed by mainly using pre-existing components. A first-generation Carr-E prototype which was provided by Ford was used as the driving base. On top of that, a round carousel was placed with three compartments for medication. An iPad on top provided a graphic user interface (Appendix 11). The resulting robot is pictured in Figure 9.2.

User insights

The results are a direct comparison between Mr. Bergsma (the current delivery person), and a delivery robot.

First impressions

To communicate the first impressions, a short movie was compiled (stills in Appendix 12). This video is summarizing the reactions of people interacting with the robot for the first time, and is available upon request (Figure 9.3).

Figure 9.2: Prototype of the pharmacy delivery robot

Figure 9.3: Video-still of the first-impressions montage

Quantitative data

As the study only includes nine participants, the significance of the quantitative data that was gathered is inherently limited. While keeping this cautious mindset, a few patterns can be highlighted here.

Comparing the impression-grades that were given to the robot and the human delivery driver, a significantly lower average rating of the robot can be observed. Also, the standard deviation for the robot is larger, indicating the mixed feelings that people have about it (Figure 9.4).

The difference in why participants gave the impression-grades they did, varies as well. A human being is rated

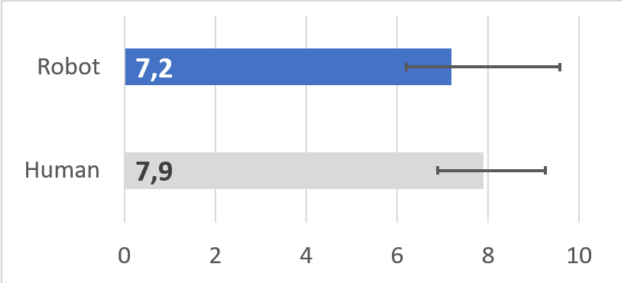


Figure 9.4: Average impression grades of the delivery methods

mainly on their friendliness - while a robot is rated mainly based on the way that the goods are handed over (Figure 9.5). Please note that this graph is about how many times certain motivations were mentioned, and it does not indicate whether people are positive or negative about the respective aspect.

In the next graph, the delivery robot and the human delivery driver are compared on different interaction characteristics through semantic differentials. The results are displayed in Figure 9.6.

From this graph, it can be concluded that the robot and the human are similar in their perceived speed and their ease of interaction. However, Mr. Bergsma scores significantly higher in how relaxed and trustworthy the interaction is. And while Mr. Bergsma achieved a unanimous 7/7 'high score' in friendliness, the interaction with the robot is rated less friendly (Insight 9B). This is the largest difference that was found. The only thing that the robot seems

A robot is currently perceived as **less trustworthy, less relaxed,** and **less friendly** than a human being.

Insight 9B

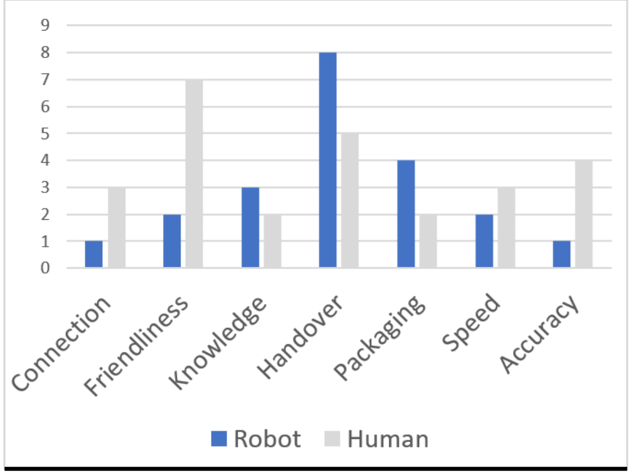


Figure 9.5: Motivation for impression grades: robot vs. human

to be better at is how stimulating it is. That excited feeling however, will probably fade in time.

Qualitative data

During the first visit, it became very clear to me how much mister Bergsma was loved among the clients of the pharmacy. He has been making deliveries for the *Centraal Apotheek Leeuwarden* for almost twenty years now. During those years, a deep connection was built between mister Bergsma and most of his clients. This connection often involves more than just the handover of the medicine. Sometimes, recipients are socially isolated. In these cases, a little joke or short chat with mister Bergsma can be the highlight of their day. This is something very important to keep in mind. At some point during the interview (after a robot was put in front of his door), a man started crying. Ever since his wife past away, he felt lone-

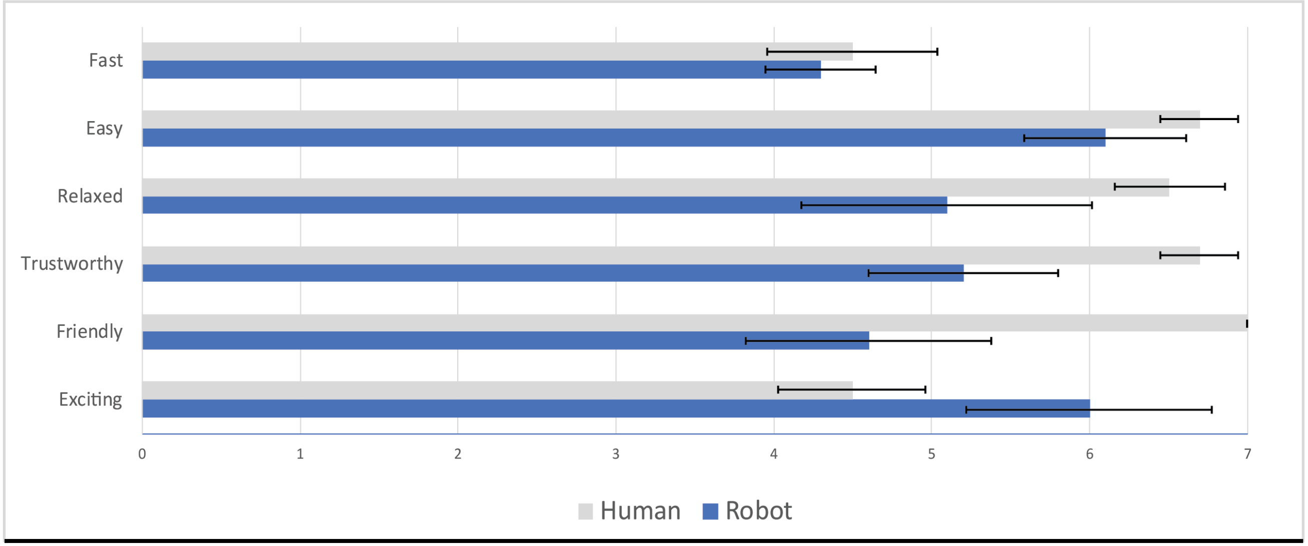


Figure 9.6: Interaction characteristics: robot vs. human

ly, he told us. Seeing mister Bergsma replaced by a robot literally made him cry (Insight 9C).

Taking away real human interaction from people that really need **it by implementing robots is unethical.**

Insight 9C

Several people that did not want the robot to replace Mr. Bergsma completely, mentioned a hybrid system. In such a system, the robot could do certain deliveries, but not all of them. People saw this as a way to keep in touch with their permanent (and favorite) delivery driver, as they considered a robotic future inevitable (Insight 9D).

A hybrid system of robotic deliveries and human deliveries would be accepted by several elderly people.

Insight 9D

Furthermore, interacting with the tablet interface proved to be unintuitive for the elderly recipients. More often than not, people read 'Hi, here is your delivery!' text on the screen, and started to try and open one of the compartments immediately. This was a more logical interaction for them than to press 'proceed' on the screen - which makes sense from their perspective as the human delivery works in a similar manner (Insight 9E).

This brings up another point: verbal communication. The prototype that the participants were presented with, did not possess any vocal communication. All communication was visual and happened through the touchscreen. There was, however, a tendency in people to start talking to the robot as soon as it arrived. For this user-base and this scenario, it seems logical to implement auditive feedback (Insight 9F), similar to modern voice-assistants like Google Assistant / Amazon Alexa (Strupp, 2018).

Graphic user interfaces on touch screens may not be the most suitable interface for all age-groups.

Insight 9E

Users will likely prefer **a robot that gives vocal instructions and feedback** in a delivery scenario.

Insight 9F

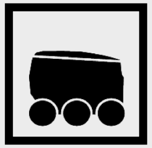
Conclusion

Returning to the research questions, additional challenges that people face while accepting a parcel from a robot were found. The main problems that were found involve missing out on the quick chat/joke with an actual human, and problems regarding the touchscreen interface. The experience with the robot is generally perceived as less trustworthy, less relaxed, and less friendly. These are metrics that can be used to test future concepts.

"You are not trying to replace mister Bergsma with a robot, are you?!"

- multiple participants in the research

10. Robots & livability



The implementation of autonomous delivery will affect society in a broader way. As the autonomous vehicles are on their way delivering parcels to people, they will have an impact on the livability of the city.

Why?

Ford has a vision on how the livable cities will look, and is taking a human-centered approach here. Technology helping people. In this chapter, research will be performed on how to make sure a city stays livable when introducing a fleet of autonomous vehicles into it.

Expected results

Insight in the real-world impact of an autonomous fleet of delivery vehicles. This insight could identify a direction on how to make sure (most) citizens will accept the self-driving vehicles.

Keeping the sidewalk human

The Center for City Solutions, which is part of the National League of Cities (United States) has criticized the 'conveyor' type of robots—the ones that roam sidewalks. Their argument is represented very well by Figure 10.1. One robot may be alright with most people, but once mass-adoption happens, it is a different story. The scenario in Figure 10.1 should be avoided, as it will likely negatively impact the perceived livability of a city by its inhabitants.

The NLC (n.d.) proposes a solution using 'porters' (i.e. people that carry things) and autonomous vehicles that drive on the road (Figure 10.2). The porters are good for keeping a human touch, and come in handy when overcoming the typical hurdles that are found in the last meters of a delivery: doorsteps, small stairs, fences, etcetera.

Small size matters

Size seems to matter as well, as Matt Delaney — CEO and co-founder of Marble — describes in an interview with Wired Magazine. Marble is a San Francisco based company that creates a sidewalk-roaming delivery vehicle as well. They have just launched a second version of their robot which is more compact on the outside, which is -understandably - something people do like. (Simon, 2018)

> *"What we found is that people just enjoy the vehicle more if it's smaller."*
>
> **- Matt Delaney, Marble**

The unique Starship fleet

While delivery-robot tests are usually run by only one robot prototype, there is one company that is ahead of everybody when it comes to the actual implementation of autonomous vehicles in delivery: Starship Technologies. They were mentioned earlier (Figure 5.3) as a com-

Figure 10.1: *The problem with conveyor robots (NLC, n.d.)*

Figure 10.2: *The 'porter' solution that is proposed (NLC, n.d.)*

peting technology supplier. Recently, they have transformed themselves into a service provider, performing (grocery) deliveries in cooperation with local shops for about €1 per delivery (HBS, 2017).

These delivery services are fleet-based, rather than incidental prototypes. The closest place to the Netherlands where such a fleet is deployed is Monkston, United Kingdom. Therefore, this is the ideal place to evaluate both the impact of small autonomous vehicles on the livability of a city and the practical problems they may encounter.

Defining livability

Measuring livability is an interesting branch of science, and there is no consensus among scientists what exactly defines livability.

What is clear though, is that there is an objectively measurable part about the livability of a specific place. These can be measured by gathering data, such as the amount of people per area, the amount of green and the availability of public transportation. This data is usually combined with a — normative — notion of what is generally perceived as livable (Figure 10.3). The Mercer index is a popular index for measuring 'objective' livability (Okulicz-Kozaryn, 2013).

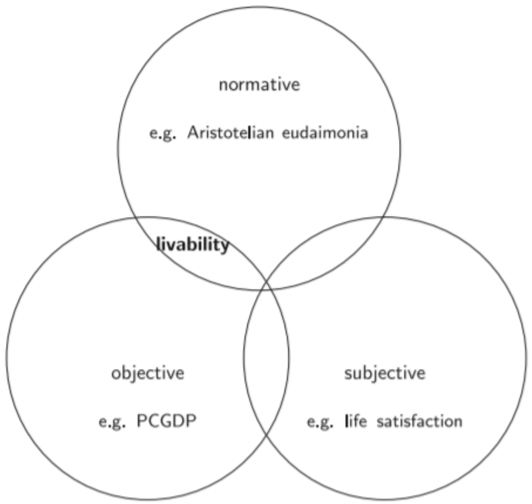


Figure 10.3: Livability as a science (Okulicz-Kozaryn, 2013)

In our case however, a more subjective approach is applicable. The subjective quality of city life is usually determined by asking questions to the people in the city. These questions revolve around how satisfied inhabitants are with life their city. (Okulicz-Kozaryn, 2013).

When it comes to subjective well-being, the pyramid of Maslow comes into play. In Figure 10.4, the pyramid of a place is displayed next to the pyramid of Maslow because the living environment can support inner needs that a person may have (Okulicz-Kozaryn et al, 2017).

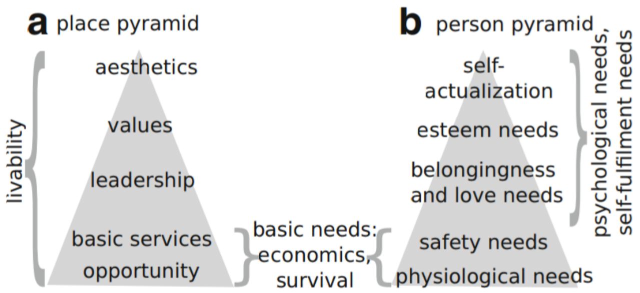


Figure 10.4: Livability & Maslow (Okulicz-Kozaryn et al, 2017)

Combining the insights from the papers mentioned above on this topic, the following indicators were selected to be relevant in the context of autonomous robots.

- **Utility/physiological needs**
  e.g. does the presence of the robots fulfil needs?
- **Trust/safety**
  e.g. to what extent do you trust the robots?
- **Freedom/opportunity**
  e.g. to what extent do the robots influence your sense of freedom?
- **Belonging/friendship**
  e.g. do you feel at home when you see the robots?
- **Aesthetics/beauty**
  e.g. do the robots affect the visual attractiveness of your neighbourhood?
- **Authority/control**
  e.g. to what extent do you feel in control over the robots on your street?

Research questions

The following research questions were defined for this part of the user research.

- What influence does the fleet of autonomous vehicles have on the livability of the city, as perceived by citizens?
- What practical problems do the robots encounter?

Method

The research method is a combination of experiential learning, observation and (semi-)structured interviews with both inhabitants of Monkston and Starship-employees who facilitate the operation of the robots.

Personal experience & participant observation

This is the non-talking part of the research. It is about experiencing the robotic grocery delivery service-first hand by signing up, becoming a user, and living in the neighbourhood for a few days. This part is also about observing the interactions with the city and their inhabitants that the robots have during their journeys towards customers.

Street interviews

Street-interviews are conducted throughout one day in the park of Monkston, with 31 inhabitants of the Monkston area of different age-groups

Figure 10.5: *Nyckle and a Starship robot*

Starship interviews

Next to that, the Starship-office was approached for learning more about the practical aspects of setting up this system.

Online question

As a fifth part of this methodology, a question about the robots is distributed online through the Monkston citizens Facebook group, finding 11 participants.

User insights

The insights will be discussed below, per part of the customer research.

Personal experience

Starting off with personal experience (Figure 10.5): cutting delivery costs like Starship does to 1 GBP (approximately 1.13 EUR), without a minimum order amount is a life changing difference. It is so convenient, that once you get used to it, it almost becomes a necessity. It really is an innovation on the level of - let's say - smartphones. Customers who would normally not think of getting items delivered will get on board as driving to a store themselves would be more expensive (Insight 10A).

As robots can **cut costs of delivery so drastically,** there will be a **large expected increase in customers/orders**.

Insight 10A

Also, the use cases are shifting. In this grocery delivery scenario alone, a whole lot of new use-cases are emerging. Ordering croissants for breakfast while still in bed, ordering a quick snack while at the park, etcetera. Usually these new use-cases involve low-volume and relatively low-cost items, which did not make economical sense to have delivered before (Insight 10B).

New use-cases are emerging, mainly involving the **shipment of low-cost (and low volume)** items.

Insight 10B

Observation

After following a robot on its half-hour journey to a recipient (myself), there are a few insights worth sharing. First of all: I witnessed a small crash. A girl and her dog walked right in front of it (probably in order to force it to stop). The robot did not stop and hit her (Figure 10.6).

While this may or may not be the girl's fault, the liability issues that arise here cannot be ignored. What I realised from this moment, is that eight cameras and computer vision algorithms are not perfect. If I witness one crash

Figure 10.6: *Accident with Starship robot that was witnessed*

while following the robot for 30 minutes, there will be more. Slow moving and lightweight vehicles—driving on sidewalks—can therefore help to learn about critical traffic situations without causing much physical harm. In these cases, bad behaviour will be regarded as 'clumsy' and no further (legal) steps will be taken (Insight 10C).

In pedestrian areas, a **lightweight/low powered vehicle** is useful for **minimizing damages to people** and goods.

Insight 10C

Furthermore, the low profile of the robot makes that it can be overseen by bikes and cars quite easily. One could call this 'the paradox of the sidewalk roaming robot', it has to be large in order for it to be seen well, but small in order to not cause damage. This is why Starship included a bright orange flag with a blinking light in it, which provides for better visibility without the need for the robot to be threateningly large in size (Insight 10D).

While a small sized robot is **perceived as less threatening**, it **should be visible for cyclists and drivers.**

Insight 10D

From the observation, sidewalk/cyclepath driving is incredibly slow and complex. A Starship robot takes about 30 minutes to complete a 1.0 kilometre journey from Coop to the AirBNB, while it would take 13 minutes of walking, and 4 minutes of driving/cycling. There seems to be room for improvement there, especially when the customer base gets more dense. In the current scenario, the amount of robot-traffic could easily get out of control in certain pedestrian areas (Insight 10E).

If **mass adoption happens**, the Starship model is flawed as the **amount of separate robots will be too high.**

Insight 10E

Street interviews

The street interviews are the core of my research in Monkston. 31 participants (15 male/16 female) are asked whether they think the neighbourhood has changed since the arrival of these [pointing at a picture of the Starship Robots], and in which way. The full datasheet with notes of all conversations can be found in Appendix 13.

For a start, people like the presence of the vehicles much more than expected. Out of 31 participants, only 6 people express a certain amount of doubt or neutrality, while 25 people are very enthusiastic about their presence (Figure 10.7).

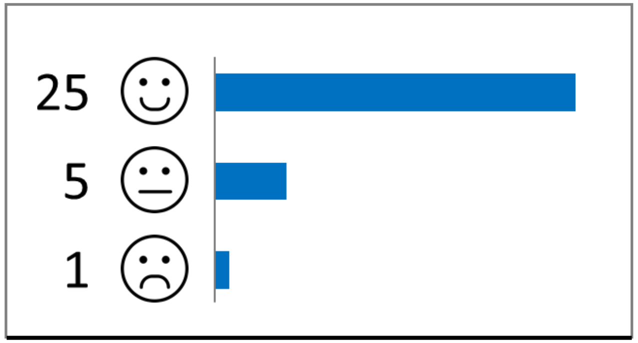


Figure 10.7: *Response to the Starships in Monkston by citizens*

Users of the Starship service are more likely to respond positively than non-users, but the differences in opinion between the other groups are fairly low (Figure 10.8).

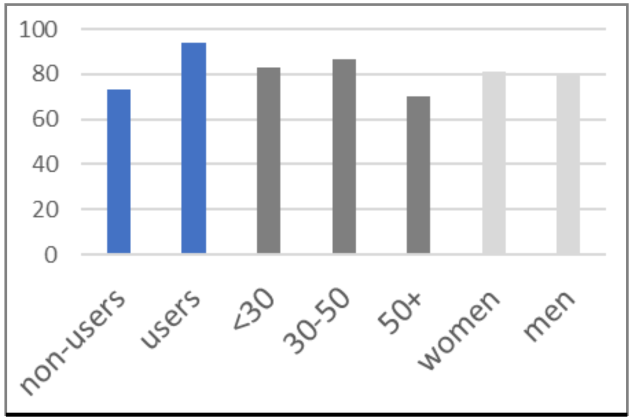


Figure 10.8: *Percentage of respondents liking the robots*

The qualitative answers are categorized by the livability factors that were found earlier in this chapter. The results of this categorization can be found in Figure 10.9.

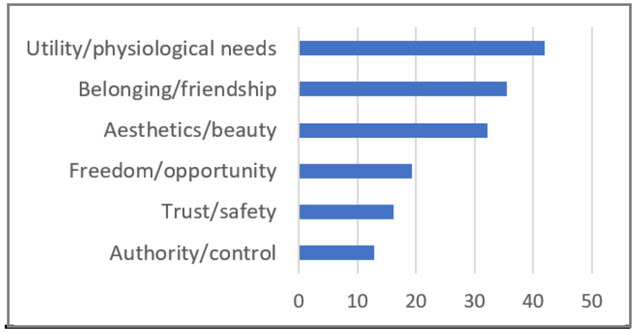


Figure 10.9: *Response to the robots in Monkston by citizens*

From this figure, it can be concluded that the utilitarian value of the vehicles is most often mentioned in the context of how they have changed the neighbourhood. Even if the usefulness of the robots did not directly affect the people themselves, they would still consider the value that the robots bring to others (friends/neighbours/elderly) first (Insight 10F).

The **most important aspect in robot-acceptance** appears to be their **usefulness to (other) people**.

Insight 10F

Close second are the answers in the 'belonging/ friendship' category. These people feel that the Starship robots have a certain character: people generally believe that they are friendly helpers in the neighbourhood. In quite a few cases, people are personifying the robots. Participants in the research unanimously refer to the devices as 'robots' instead of 'autonomous transportation vehicles'. This is likely the result of the branding efforts by Starship, but building a character in this way seems to be a good strategy for generating acceptance (Insight 10G).

Giving the vehicles a character and personifying them - calling them 'robots' - **aids technology acceptance.**

Insight 10G

Then there is the appearance that is mentioned a lot. The robots are generally perceived as cute. The little lights, the bright orange flag, and their overall small size are often described as contributing factors. Their sometimes 'clumsy' behaviour creates an endearing feeling and compassion to a point where people really want to help the robots - for instance when they are stuck.

The cuteness does not only increase acceptance from adults. In fact, the children seem to adore them the most. Children are petting the robots as if they were dogs and they make drawings which are put into the robots on their return journey. The drawings have found a nice place on the wall within the Starship office (Figure 10.10).

Figure 10.10: *Children's drawing of a Starship robot*

This enormous appeal to the children of Monkston seems to, in turn, increase the acceptance of the robots among parents as well (Insight 10H).

Creating an aesthetic that is perceived as 'cute' creates a **snowball effect of acceptance in a neighbourhood.**

Insight 10H

The amount of doubts and scepticism around the introduction of the robots in the neighbourhood was much lower than initially expected, but of course there was some. The doubts usually centered around macro-societal issues that the robots embody: either 'people getting lazy' or 'robots are taking our jobs'. On the more practical side, some people thought the robots were invading their private space too much - and their primal response was to kick it (Insight 10I).

Robots should **avoid people's private spaces**, and have to be able to **withstand a kick every now and then**.

Insight 10I

Online citizen interviews

People sometimes write more honest and unfiltered online. This is why the local Airbnb-host was convinced to place a request for opinions on a page called (all caps) "MONKSTON RESIDENTS ONLY". This request received interesting responses, like the one in Figure 10.11. The responses were not much different from the street interviews: they largely confirmed what was found on the streets. All responses can be found in Appendix 14.

Figure 10.11: *One of the comments on the Facebook-research*

Starship interview

To round up the Monkston visit, I had the chance to meet a Starship Field Assistant. It is a Field Assistant's job to facilitate the day-to-day operations of robot deliveries. We spoke very openly about the system, the users, and the future. All annotations from the interview can be found in Appendix 15. In this chapter, the user insights that followed from this interview will be covered.

First, the geographical part. Starship robots are not equally suitable for any city/neighbourhood. In Milton-Keynes, the company has tried the delivery system in multiple neighbourhoods. They discovered that low-income areas were less feasible: robots were vandalized more often and people were using their services less in general. The amount of elderly people is also determining for success. Elderly people usually have less affinity with technology, so they tend to use the service less (Insight 10J).

Robot-acceptance is higher in places with **higher income households** and **low amounts of elderly people**.

Insight 10J

The routing of the robots is optimized for speed and safety. This basically means that people are avoided. Busy routes will not be taken, this helps to make the delivery faster and safer (Insight 10K). This is also why robots will generally choose bike lanes over sidewalks.

Avoiding encounters with people during a sidewalk journey **makes a delivery safer and faster.**

Insight 10K

While the amount of deliveries per hour is extremely irregular in weekends, it is very predictable during the week. A large peak in orders is seen every weekday between 16:00 and 20:00. This is when children get home from school and people get home from work; these are the moments when people are actually home. While on average three robots are roaming the streets at any point, all twelve available robots will be busy during these daily peaks (Insight 10L).

People's routines cause delivery fleets to have **predictable peak times** when full capacity is needed.

Insight 10L

Conclusion

Overall, the introduction of the Starship Robots in Monkston has had a positive effect on the neighbourhood. It is one of the success stories of how robots and humans can coexist in a peaceful manner. The community welcomed the robots as a fleet of 'cute' helpers, and feel privileged for being the first. Concerning the second research question, a few practical problems were found. Problems include invasion of private space and potential collision damage. These findings can be translated into requirements for the design project.

Starship Robotics

And the decentralized future

Starship is working towards a very specific scenario. In the future, the Starship robots will live on the streets. The hub, that is currently the origin of every delivery, will not be there. Instead, battery swapping stations will be distributed decentrally within the city. The vision is that, after the system receives an order, robots will drive to the goods suppliers (supermarkets, shops, parcel providers, etc.) who will open and load the robots using a 'Starship Partner app'. Afterwards, the robot will drive to the consumer who placed the order. Slowly, services will be extended from only groceries to also delivering parcels and fresh food.

Design criteria

In this part of the project, the design project will be narrowed down with the findings from the contextual analysis and user research. First, an application area will be selected to design for. With this scope in mind, criteria will be listed. These criteria will guide the design project and align stakeholders in the process.

11. Application area

It has become clear that not every application area is equally suitable for introducing autonomous delivery. This chapter intends to further scope the project, creating focus during the design phase.

Why?

Trying to create an autonomous system that satisfies all stakeholders in all fields of delivery would be an incredible task, which likely would result in many unwanted tradeoffs and a weaker concept. Also, there are application areas in which it is considerably easier to implement autonomous technology than others. Identifying and designing for that 'beachhead market' leads to a viable product/service.

Expected results

In this chapter, a refined assignment brief will be made - one that is more tangible. Also, a final decision will be made on the ideal application area for this project.

To pick the right direction for Ford to proceed into, a virtual 'landscape' will be created ranking the potential application areas on both viability and feasibility. This chapter will explain the thoughts behind the graph in Figure 11.1.

Viability

To assess the viability of a certain delivery field, it largely comes down to one metric: the number of orders per capita. Fulfilment of a higher number of deliveries in a certain area equals higher revenue. One could argue that the profit margin on certain deliveries could be higher than others, but history has shown that market forces tend to drive prices for delivery to a minimum. This is why the horizontal axis of the graph in Figure 11.1 shows the number of potential orders per capita. The word 'potential' is added to make up for items like groceries, that are currently not delivered on a large scale, but are in fact needed on a large scale. Note that the viability graph is bound to change as time goes on, because demand for certain types of delivery may increase or decrease over time.

But in order for autonomous delivery to be viable, there is another factor that needs a place in the graph. Ford will need external parties (goods suppliers/parcel networks) as operational partners. This is where the diameter of the respective circles comes in; showing the enthusiasm that was sensed during conversations with stakeholders in that field.

Feasibility

The feasibility-scale involves technical and practical concerns. This is a qualitative scale, which means that the exact position of the circles will be up for discussion. Through conversations with the respective stakeholders in these fields, data has been gathered about what makes autonomous delivery problematic or great in certain sectors. The - ranked - qualitative considerations are displayed next to the graph, similar to a Guttman scale. This means that if an application area ranks relatively high on the 'suitable for autonomous transportation' scale, it fits all the considerations below that level. The colouring is intended to clarify this scale.

Direction

All in all, the larger circles in the top right of the graph represent the most suitable application areas for concept development. It shows that a high-density network of parcel delivery or a system for grocery delivery makes most sense for this project. The focus will be on creating a scalable parcel delivery system that allows flexibility for users - while keeping the option for performing on-demand express deliveries (like groceries) open. This is summarized in the following assignment definition.

To conceptualize a scalable system of autonomous vehicles for a high-density urban delivery network that offers both on-demand express deliveries and flexibility in time and place.

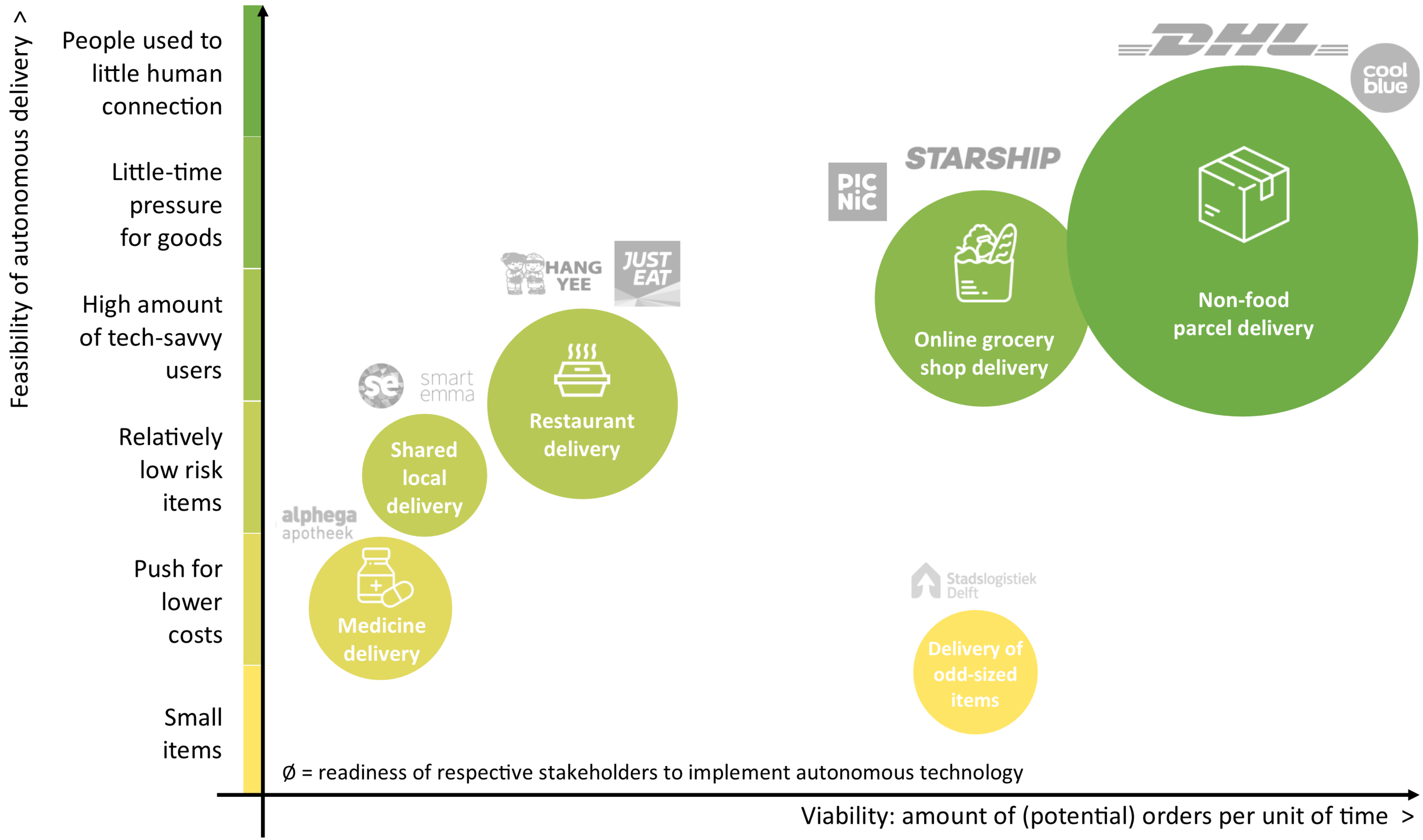


Figure 11.1: Feasibility and viability for different application areas

12. Requirements and wishes

Concluding the contextual analysis and user research, it is time to summarize the findings into requirements. Corresponding findings from elsewhere in this report are displayed in blue (Insight) or grey (Chapter) behind every requirement/wish.

Why?

Taking this step helps in aligning both Ford and TU-Delft stakeholders in the project, and provides clear boundaries of which solutions are a fit. The wishes will be consulted at a later stage to rank different concepts on suitability.

Expected results

The list of requirements will provide a framework of which problems to solve, and will help to identify whether concepts fit the design assignment. The wishes will be consulted at a later stage to rank different concepts on suitability.

Requirements

Vehicles and interfaces

Dimensioning

- The width of a sidewalk-roaming vehicle should not be larger than a (large) person—495 [mm]. 5C Ch.10
- The height of a sidewalk-roaming vehicle should not be larger than a (large) dog —650 [mm]. Ch.10

Dynamics

- The speed of a sidewalk-roaming vehicle should not exceed walking speeds (5km/h). 10C
- The vehicle should be able to overcome typical last-meter hurdles like curbs. 5D
- Vehicles should be able to climb or descent from 15% slopes without falling over. 5D

Durability

- The vehicles should be small impact resistant. 10I
- The vehicles should be able to function in bad weather (heavy winds, rain, ice and snow). Ch.10

Transhipment

- In the case of parcel-transhipment between multiple vehicles, no human personnel should be necessary. 3E Ch.11

Consumer flexibility

Time and place

- The system should allow users flexibility in time and place for their parcel handover. 3H 9A
- The vehicles in the system should be able to visit every home in a neighbourhood once a day. 10A Ch.11
- The system should be able to deliver urgent goods originating from a hub/shop in the neighbourhood (<2km) within 30 minutes. Ch.11

Inclusiveness

- The design should be suitable for use by all people that can walk the streets by themselves (democratizing mobility). Ch.7
- The vehicles should provide spoken instructions and feedback. 9F
- Incidentally, deliveries with human support should still be possible. 9C 9D

Emotion

- The vehicles interacting with humans should have a friendly/open character. 9F

Wishes

Urban livability

Fitting in

- The system should not cause chaos and/or congestion at peak delivery times. 10E
- The vehicles should be noticed by all other traffic: pedestrians, cyclists and drivers. 10D
- The vehicles should not be undesirably prominent in a city environment. Ch.10

Perception

- The vehicles should be perceived as 'cute' by other pedestrians. 10H

Emissions

- Vehicles that operate exclusively within a city should be zero-emission. 4D 5C

Vehicles and interfaces

Efficiency

- Vehicles should be able to carry as many separate orders as possible. 10E

Business

- The vehicles should be as appealing as possible to high-volume delivery networks like DHL, from a business perspective. Ch.11

Dimensioning

- The weight of a sidewalk-roaming vehicle should be as low as possible to avoid potential damage to people. 10C

Emotion

- The vehicles should come across as trustworthy as possible. 9B
- The vehicles should come across as relaxed as possible. 9B
- The vehicles should come across as friendly as possible. 9B

Consumer flexibility

Time and place

- Estimated time slots for home-delivery should be as small as possible. 6H

Inclusiveness

- Accessibility of the system should be as high as possible: people of all age groups should be able to make use of the vehicles. Ch.11
- Shipping costs to individuals should be as low as possible. Ch.11

Urban livability

Fitting in

- The system should need as little additional infrastructure in a city as possible. Ch.11
- The number of freight movements in a city should be as low as possible. 3A
- The urban area occupied by delivery vehicles per unit of time should be as low as possible. 4C Ch.6

Human factor

- The time of human employees should be spent for customer contact as much as possible, not 'behind the scenes'. 6N 9C

Emissions

- The system should be as environmentally friendly as possible, appealing to governments & parcel services. 4D

Conceptualization

The conceptualization phase starts with operationalizing the requirements found in the previous phase, as some of the requirements are not directly workable yet. Afterwards, the ideation phase starts: finding solutions to the problems found in the aforementioned stage. Through diverging and converging techniques, multiple preliminary concept vehicles (or sets of vehicles) will be created.

13. Operationalizing requirements

The design direction that was defined at the end of Chapter 11 is *"To conceptualize a scalable system of autonomous vehicles for a high-density urban delivery network that offers both on-demand express deliveries and flexibility in time and place."* This direction is not completely concrete yet.

Why?

Operationalizing the terms used in this sentence, is necessary to be able to work with them in the upcoming ideation phase. Once these parameters are truly understood and made tangible, they can be used to design something that connects to the real world.

Expected results

A more concrete understanding of the newly formulated assignment-direction, which leads to a concept that fits and is relevant within its (future) context.

Reading through the design direction that was framed in Chapter 11, three main challenges are implied. These three main elements were already used to categorize the requirements and wishes in the previous chapter.

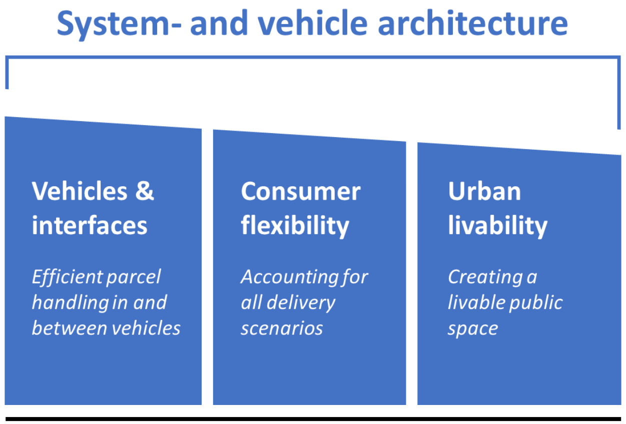


Figure 13.1: Ranked design challenges

Ranking the challenges

The sub-challenges for this design assignment are named 'vehicles and interfaces,' 'customer flexibility' and 'urban livability.' They are ranked by importance - in the aforementioned order. By solving these sub-challenges, a system- and vehicle architecture will be designed. This is summarized by Figure 13.1.

The division of volumes

An important parameter in the system is the size of the parcels themselves. Finding the odds of occurrence for different parcel sizes in the real world is really hard, as no single party except parcel providers has an overall overview on what sizes of parcels are being shipped typically. Sadly, no parcel provider actually discloses this information. Looking at paper-box suppliers was tried, as they sometimes disclose 'best sellers' on their website, but this only gives a small indication as most larger webshops are using per-item tailored packaging boxes instead of standardized units nowadays (TTM, 2017).

The answers to this volumetric question, were found on the streets. The streets of Germany to be precise. The parcel lockers ('Packstations') that are placed in German cities by Deutsche Post DHL have a clear volumetric division (Figure 13.2). The width and depth of each locker is 435 [mm] and 620 [mm] respectively, while the height varies from 80 (S) to 170 (M) to 360 (L) to 720 (XL) [mm] (GuteFrage, 2016).

The division of M, S, L and XL lockers happens to be extremely consistent across the different models (Figure 13.3): in 43% of orders S sized lockers are used, in another 43% of orders M sized lockers are used, and

Figure 13.2: Different executions of DHL parcel lockers in Germany

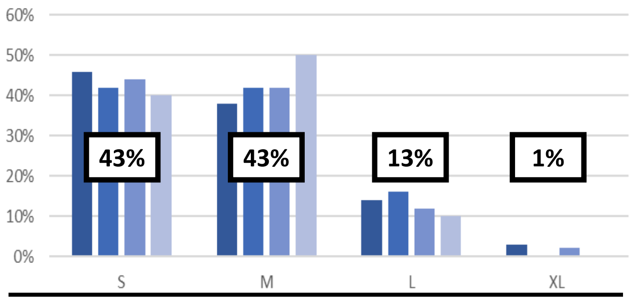


Figure 13.3: Spread in the division of box sizes in 'Packstations'

in 13% of cases L sized lockers are used. In a mere 1% of cases, XL sized lockers are used.

Together with the assumption of how much parcels will be delivered in the future - 1 parcel per house per day - this leads to a very tangible problem for every street.

The average street

There are 7.807.665 houses in the Netherlands (CBS, 2018), divided by the 263.679 named streets that are situated in the Netherlands (Over Straatnamen, 2018) this equals an average of about 30 houses in an average street.

Tangible problem

Together with the assumption of one parcel per house, the design problem looks like Figure 13.4. The figure shows 3D printed models — to make it more tangible in the ideation phase — of all the parcels and their respective sizes for an average street (Scale 1:20).

Figure 13.4: 3D printed assets to create a sense of scale during ideation

Hub to customer

Now that the size of the problem is known, the key elements and places shaping the last-mile of the future (2-5 years from now) need to be made concrete, so that the vehicles connecting these places are actually relevant. Therefore, it is time to envision what the important physical places in the future infrastructure will look like. Figure 13.5 details the expected future environment, in which the conceptual vehicles will operate. The elements in this schematic overview are explained below.

Urban hub

It was established in Chapter 6 that urban hubs — urban real estate owned by parcel services or retail stores—are gaining popularity. That is why it is sensible to assume this urban hub will be the 'origin' of the parcel within a city. From this hub onwards, the scope of this project starts.

Recipient

On the receiving end of the parcel journey, there is the recipient. This is the place where the parcel should eventually end up. The road towards this ultimate destination can be either direct or — as customers can tend to be not at home — with an in-between stop at either a local pick-up point or through some form of a parcel locker station.

Local pick-up point

Local pick-up points in this context are intended to be very local shops. They could be in the same street as the customer or in the next street, but no further away. If no local shops are available, unemployed or retired neighbours who are always at home could act as a pickup point — in exchange for a small compensation per handled parcel. In the Netherlands, services like ViaTim (ViaTim, n.d.) and Homerr (Homerr, n.d.) are offering these neighbourhood pickup points already. The latter has a partnership with DHL, indicating the seriousness within the industry about this type of initiative.

Parcel locker station

Parcel locker stations are expected to gain popularity as well (Chapter 3). These stations have two clear advantages over local pick-up points. The first reason for customers to use them is that the stations are open 24/7 so they are not put on reserve overnight. The second reason is that the locker stations do not require a payment per parcel which could make them a cheaper option to customers.

True flexibility

Looking at the requirements, it becomes clear that a 'mothership' in some shape will be necessary. The size-requirements for sidewalk driving constrain the volume that can be taken, and livability requirements prohibit the use of many small pods for long journeys. However, mothership-designs tend to put people on reserve, for instance by having a specific order of delivery.

In order to not put people on reserve, the following statement was formulated as a concrete guideline:

The physical location of an individual parcel within the system should be flexible for as long as possible.

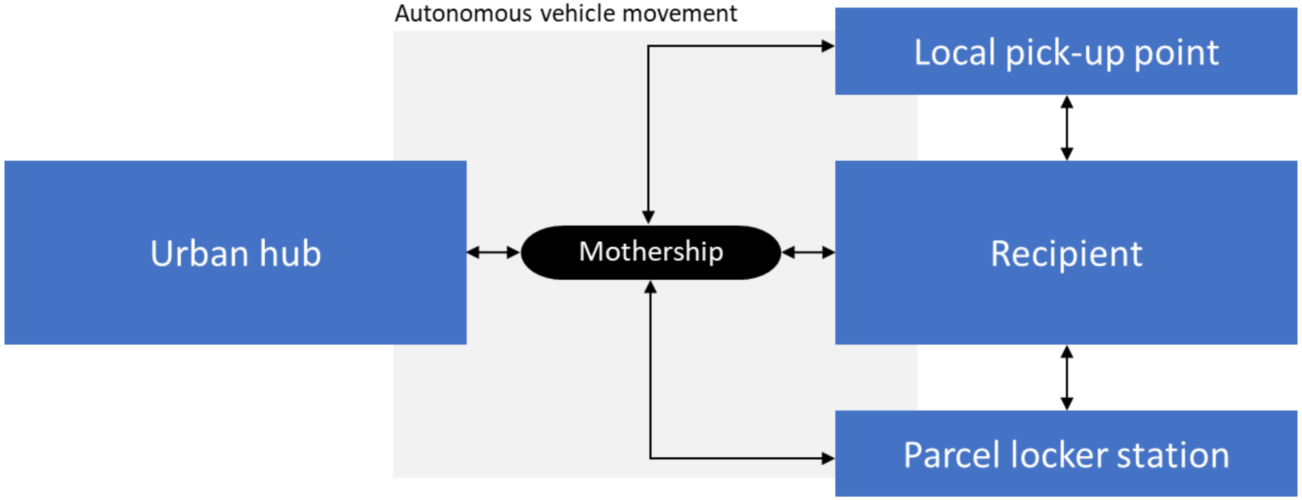


Figure 13.5: Schematic overview of key physical places in the system


VIATIM
bol.com

14. Ideation

Now that the challenges are concrete and well defined, it is time to proceed to the ideation phase.

Why?

The ideation phase is where it all comes together, where solutions to the identified problems will be created. The goal is to explore the space of ideas as much as possible, so that no directions are overlooked in the process.

Expected results

There is always a certain fuzziness to this process, and it can not be described as a straightforward A-to-B journey. In this chapter, insightful parts of this process will be highlighted.

The challenges

The main challenges that were tackled in the ideation process are the three 'pillars' in Figure 13.1.

- **Vehicles & interfaces**
  Integration of small pods and the mothership: How do vehicles interact? How do the vehicles transship parcels autonomously? How do they mechanically allow for different sizes of parcels?
- **Consumer flexibility**
  Parcel flexibility: How can the largest amount of flexibility in the location of an individual parcel be created? How can this be done in an affordable way?
- **Urban livability**
  Keeping the urban space livable: How can the necessary volume of parcels be transported without causing trouble? How can the height, width and area constraints be respected while keeping the intended functionality?

During the ideation process - little focus will be on the exact look and feel of the pod. Factors as 'cuteness' and

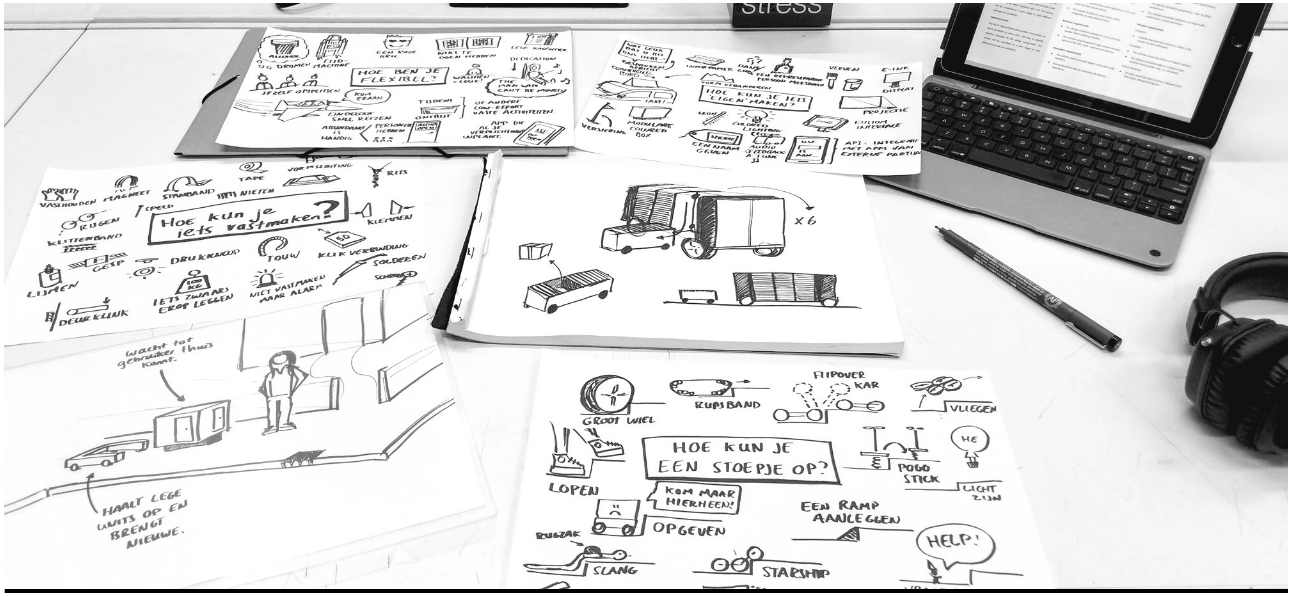


Figure 14.1: *'*How to...' exercises and preliminary combined drawings.

‘conspicuousness’ are considered details that could be applied to different designs in a later stage.

Solving subproblems

The ideation process started with ‘How to...’ sessions (Boeijen, 2014) on subproblems like ‘How to sort things?’ and ‘How to change the size of something?’. An impression can be found in Figure 14.1 and more imagery of this process can be found in Appendix 16.

After this, brainstorming on the three topics was started with inspiration from the aforementioned sub-solutions (Figure 14.2). In this way, a lot of different designs for motherships, pods and parcel containers were drafted.

Efficiency

Within this process, the physical challenge of packing as much parcel capacity in a mothership while maintaining flexibility in the order of delivery has proven to be a major challenge, especially since not all parcels are similarly sized. Large flexibility in the location of individual parcels tends to lead to a large mothership.

Next to that, minimizing the amount of actuators that are needed and therefore creating a cheaper, simpler and more robust system was a challenge. While this was not a direct requirement in the assignment, it fits Ford as a business to offer a reliable solution that is affordable in use (and therefore accessible to more people). If Ford does not find the simplest and most elegant way to solve the problem at hand, another manufacturer may find it, and outcompete Ford.

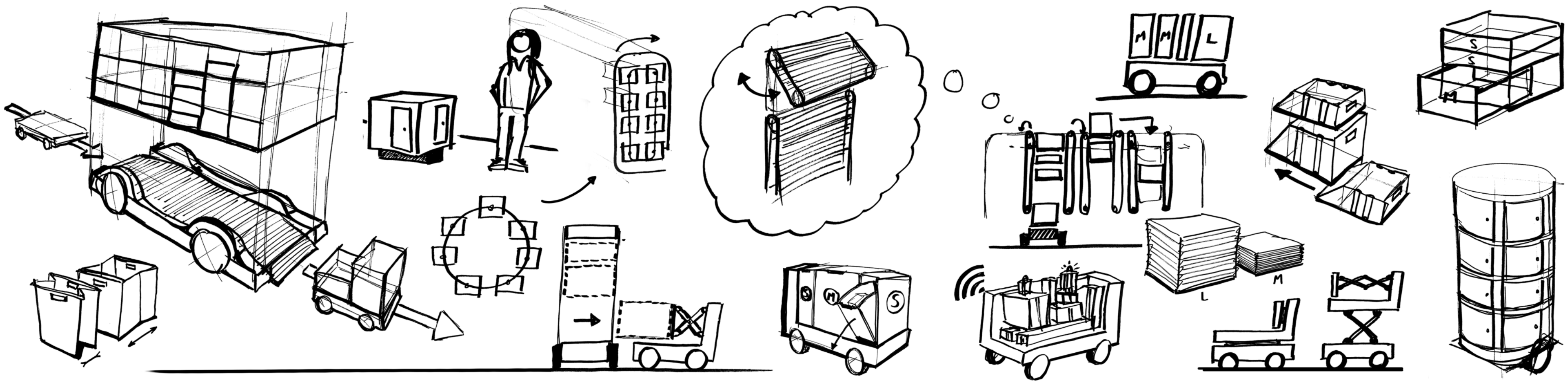


Figure 14.2: Drawings in the ideation process

15. Preliminary concepts

After exploring the idea-space, this chapter introduces four preliminary concepts that fit all the requirements that were set in Chapter 12.

Why?

Four concepts are created to show the possibilities that lie within the constraints of the requirements. Concepts are deliberately set up to be as different as possible from one another, so that the width of the spectrum is exemplified.

Expected results

The resulting four concepts are expected to be a base for validating with both the Ford-team and the responsible person at DHL for last-mile delivery optimization whether the project is going in the right direction. The ultimate goal is to identify and keep the best aspects of the four 'worlds' in the final concept.

Before discussing the actual concepts, the similarities in and differences between the concepts are evaluated.

Similarities

First, the similarities will be discussed.

Mothership + pod

All concepts feature a mothership and a multitude of pods. As discussed in the previous chapter, this is a direct result of the sizing constraints to a sidewalk-driving vehicle in the program of requirements.

Modular containers

Also, all of the concepts include a modular box (highlighted in blue, for consistency) around the individual shipments. In a way, this creates an inherent inefficiency. By introducing specific pre-defined sizes of containers, there will be empty space and therefore volumetric inefficiency.

However, in order to be flexible with individual shipments (while keeping them safe) and allow for autonomous transhipment, the boxes are quite necessary.

The contents of the containers can only be accessed by the recipient, in order to safeguard the payload during transit.

Differences

The differences between the concepts fall into the following categories.

Elimination of sequence effects

Parcels can be easily stored in a certain sequence, which causes flexibility to decrease. If a parcel is on top of a stack for example, yet urgently needed, then it could take a while before it is accessible. Pre-loading parcels in such an inflexible way is undesired. Different concepts allow for this flexibility in place in a different way.

Complexity in pod or mothership?

Also, the concepts differ in where the relative complexity lies. There are two concepts with a complex mothership and simple pods, and two with relatively complex pods and a low-tech mothership (Figure 15.1).

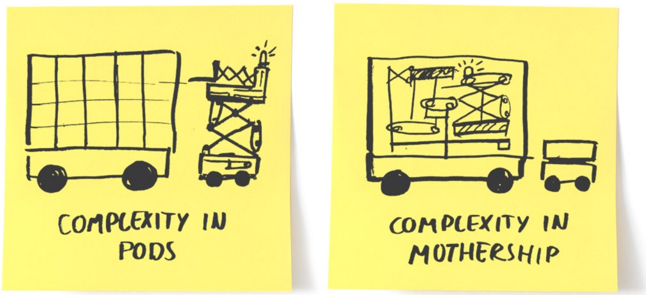


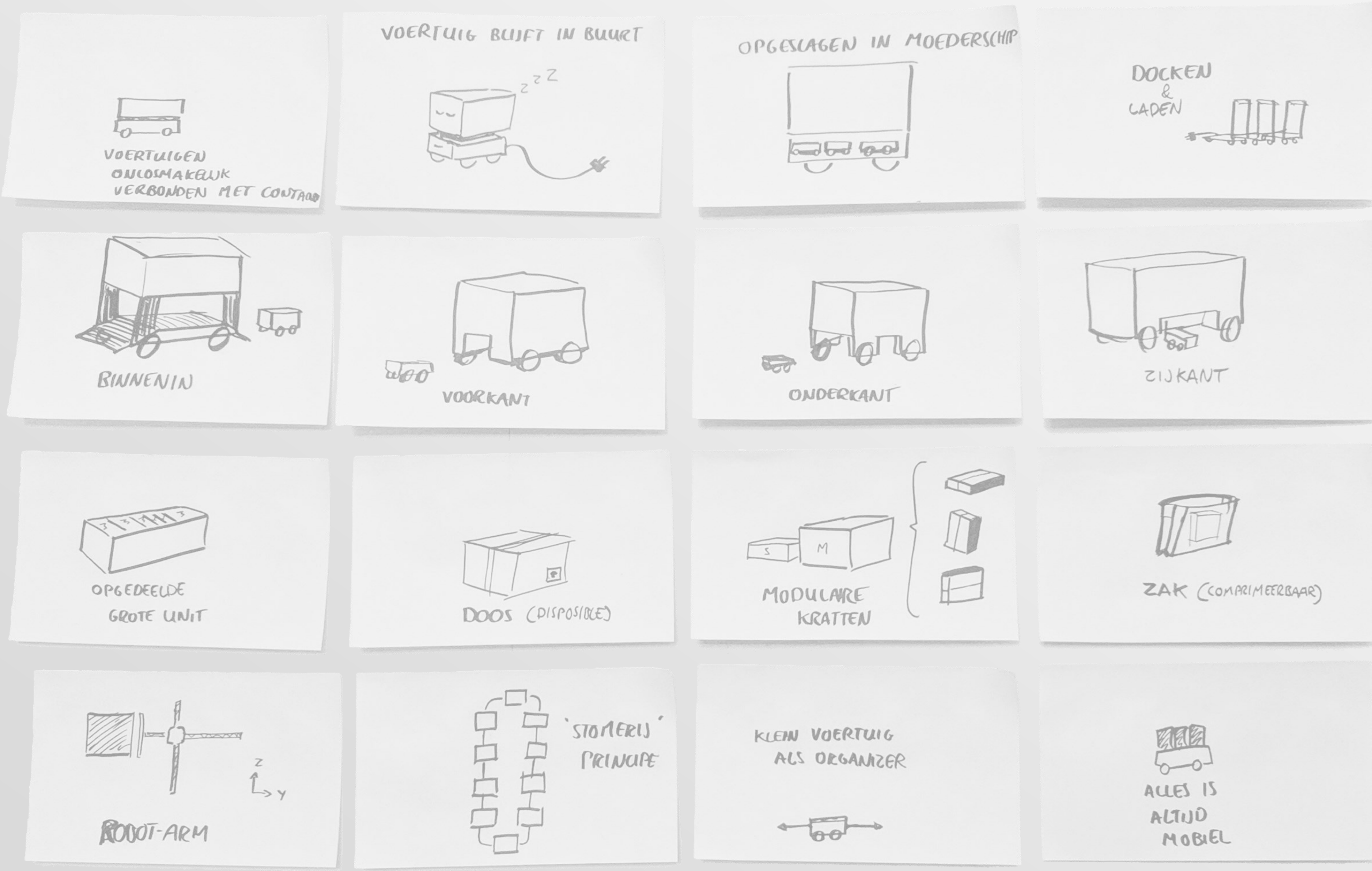
Figure 15.1: Complexity in pods vs. complexity in mothership

Overall size of the vehicle

Also, the total size of the vehicle differs between concepts, with the general rule that smaller is better for livability, and bigger is better for efficiency. This is a result of the program of requirements not being clear about which one to prefer.

Concept description

On the next pages, the four preliminary concepts are visualized and described.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KLEIN VOERTUIG
ALS ORGANIZER
ALLES IS
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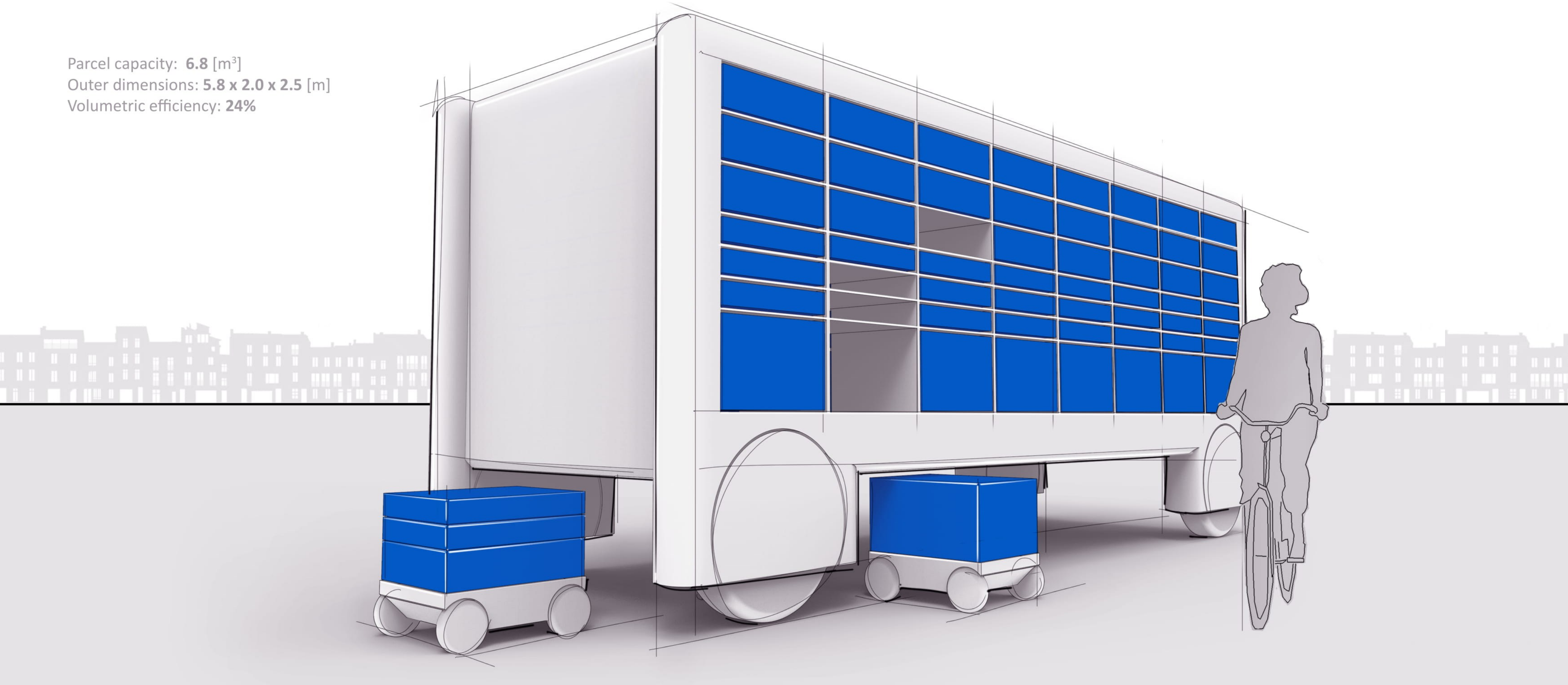
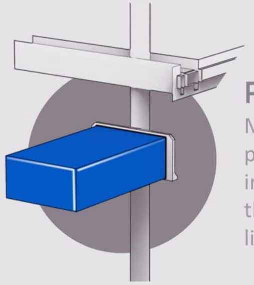
Concept 1: Huge

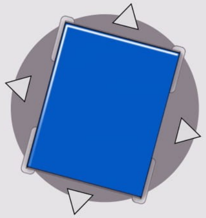
Parcel capacity: **6.8** [m^3]
Outer dimensions: **5.8 x 2.0 x 2.5** [m]
Volumetric efficiency: **24%**





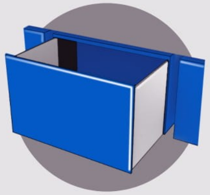
Robotic arms

Modular boxes are sorted and placed on the pods by robotic arms in the middle of the vehicle. When the mothership moves, the pods are lifted by these robotic arms as well.



360º pod access

Pods can drive underneath the mothership from all sides, providing flexibility in different traffic scenarios. Loading and unloading happen safely at the center of the vehicle.

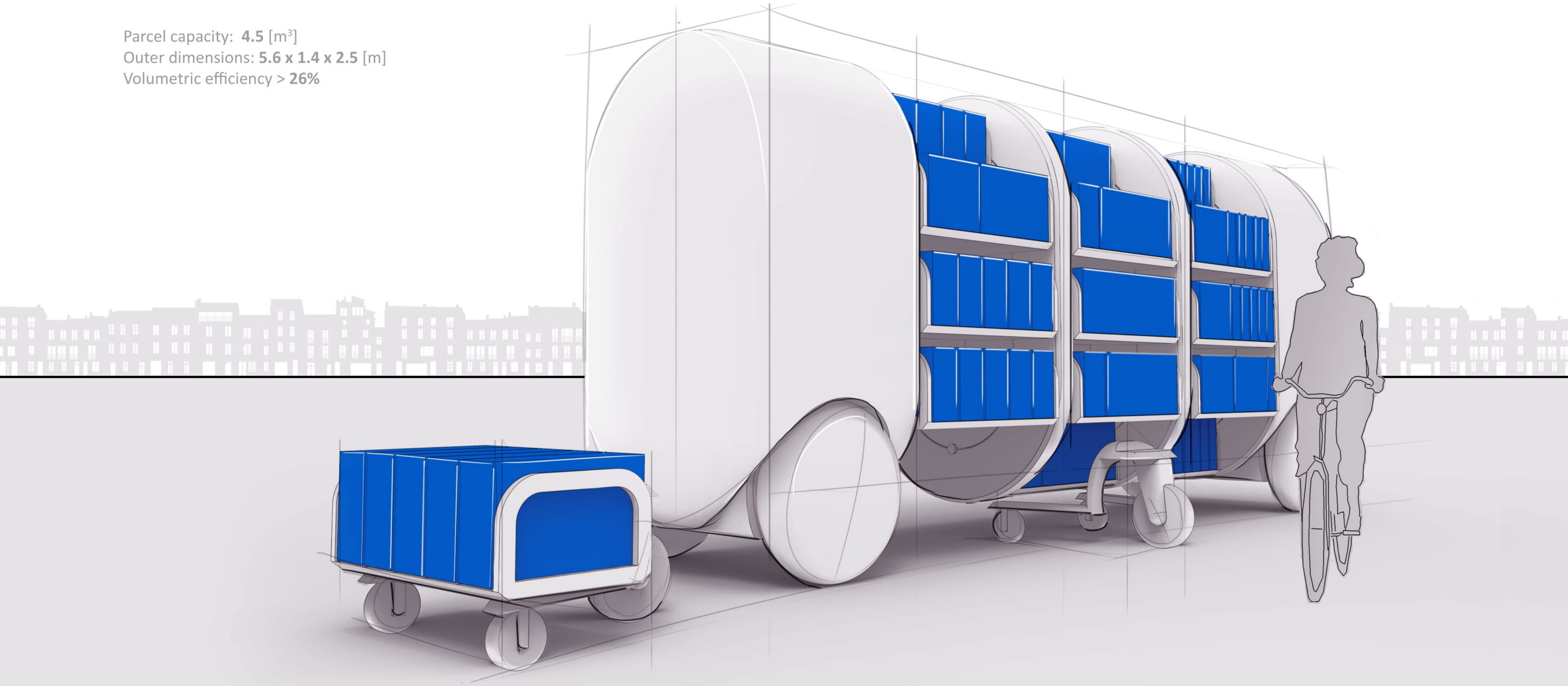


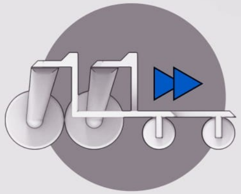
Modular boxes

Parcels are stored in modular boxes in standardized sizes with integrated drawers for easy access. Multiple shipments to the same address are combined into one box if it fits.

Concept 2: Loop

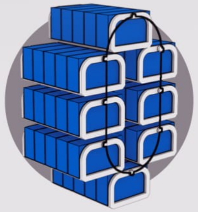
Parcel capacity: **4.5** [m³]
Outer dimensions: **5.6 x 1.4 x 2.5** [m]
Volumetric efficiency > **26%**





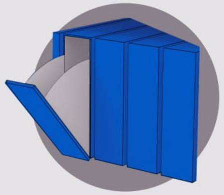
Dockable pods

The pods in this concept can be docked, similar to airport trolleys. Instead of staying with the mother-ship, pods can now be efficiently stationed in the neighborhood.



Revolving modules

Modules with parcels are rotated by a belt or chain, similar to a paternoster lift. This leads to efficient use of the limited space within the vehicle and easy transshipment into pods.

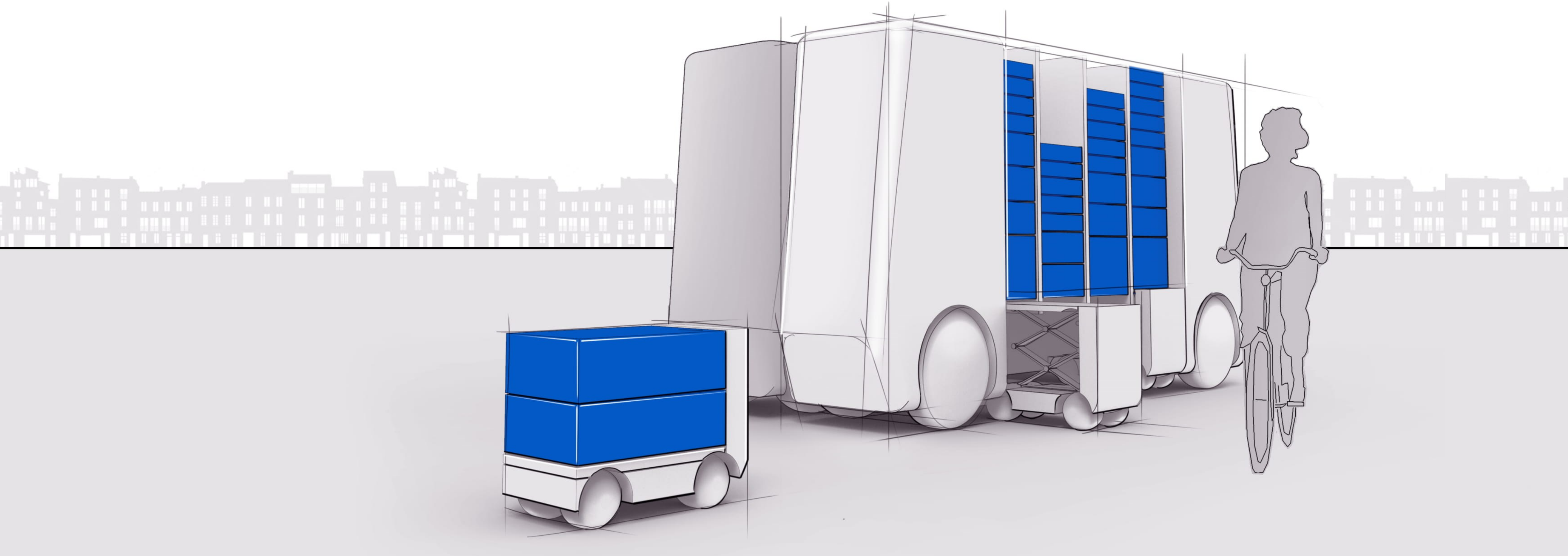


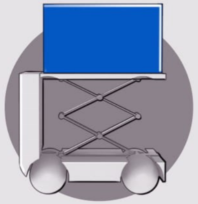
Modular boxes

Parcels are stored in modular boxes in standardized sizes which open on the side for easy access. Multiple shipments to the same address are combined into one box if it fits.

Concept 3: Lean

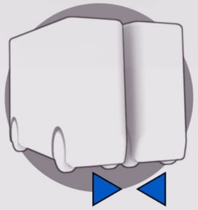
Parcel capacity: **2.0** [m³] *
Outer dimensions: **3.6 x 0.8 x 2.0** [m] *
Volumetric efficiency: **34%**
**For a single, unpaired mothership.*





Pods organize parcels

Pods are organizing the vertically stacked parcels using a scissors mechanism. The same mechanism lifts the pods into the mothership when driving to a new location.



Pairing motherships

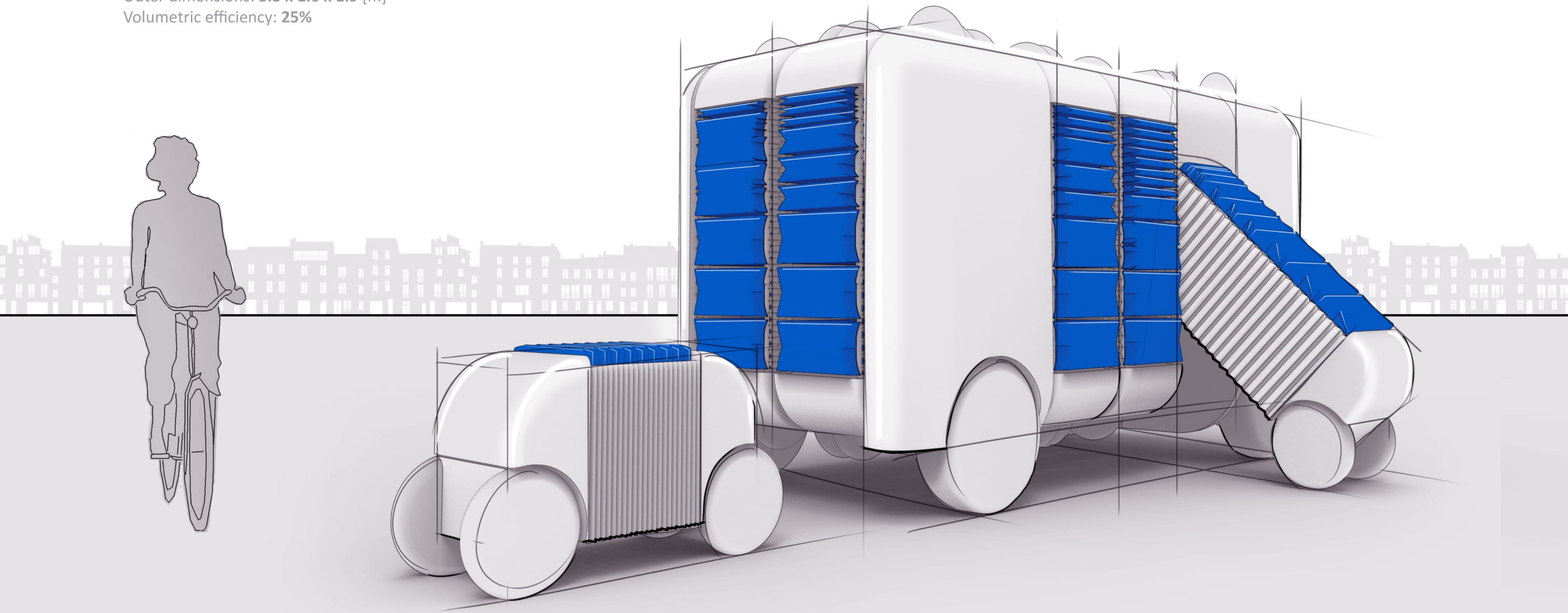
The narrow body of the mothership allows for pairing two motherships. They can drive next to each other as one vehicle (one freight movement), and split up when necessary.

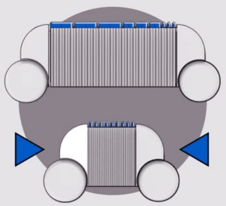
Modular boxes

Parcels are stored in modular boxes in standardized sizes with integrated drawers for easy access. Multiple shipments to the same address are combined into one box if it fits.

Concept 4: Join

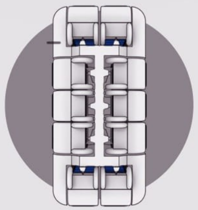
Parcel capacity: **2.5** [m^3]
Outer dimensions: **3.3 x 1.6 x 1.9** [m]
Volumetric efficiency: **25%**





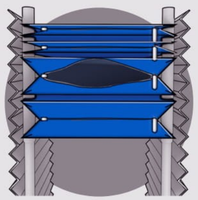
Flexible pod length

Pods become shorter after every completed delivery. In this way, the pods gradually become less of a burden to pedestrians and other sidewalk-traffic.



Pre-loaded pods

Pods are pre-loaded and simply hooked onto the mothership without a further need for individual transshipment of parcels during the delivery journey.



Collapsible bags

Pods are loaded with flexible nylon bags that hold the parcels. After each delivery, these bags can collapse to take up less space so that the pod can become shorter.

Towards a final concept

In this phase, these preliminary concepts are presented to the supporting team at Ford, and to a last-mile optimization representative at DHL. Next to that, the road of parcels before the last mile is investigated—as it is very relevant to take this into account in the final concept. Also, a further look is taken into the timing of delivery and the dimensioning of the vehicles—by setting up a basic logistical calculation model.

16. Fitting in: feedback from the industry

Now that the preliminary concepts are presented, their respective qualities and drawbacks need to be identified. A good first step in doing so, is reaching out to stakeholders from the industry.

Why?

Listing the positive and negative aspects of each concept makes sure that nothing is overlooked, and that a final concept including most of the good things can be constructed. Finding out the opinions of the business stakeholders is essential in this process.

Expected results

Industry stakeholders in this assignment currently fall into two categories: the client company (Ford) and parcel services (DHL, etc.). Their opinions are quite valuable in the search for the best vehicle architecture.

Ford

The first and most important stakeholder in this story is Ford. The concepts need to fit to their vision in order to have any chance of success.

There are three people at Ford closely involved in this project. Nicole and Walter from Aachen, who are in Mobility Research—and Kilian from Köln, who works on new vehicle development and has more technical input.

Mobility Research

The four preliminary concepts were first presented to the team in Aachen, which resulted in an interesting session full of ideas. The feedback per concept can be found in Figure 16.1, highlighted in ▶ **green**.

Vehicle architecture

Another session took place with Kilian, who was able to share his thoughts on the vehicle architecture as well, these can be found in Figure 16.1, highlighted in ▶ **blue**.

DHL Express

With this feedback from Ford in mind, a meeting was scheduled in Eindhoven, with DHL Express last-mile representative Ricky van Soest. While also giving feedback on the concepts (highlighted in ▶ **yellow**), he was able to show exactly how parcels are currently sorted automatically in the service center of Eindhoven.

“They are great concepts, they really make you think.”

- Ricky van Soest, DHL Express

The useful aspects

The scheme in Figure 16.1 (A-D) presents the most important points of feedback, together with Harris profiles of each concept based on the differentiating wishes.

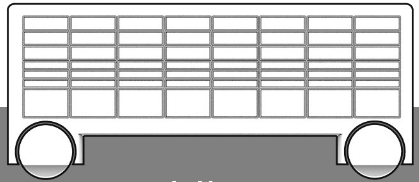
The first and third concept seem to be the best fit for the assignment. The flexibility that they offer on a parcel level is very large, which is very beneficial for not putting customers on reserve. A combination of these two concepts seems like a logical way forward. The unobtrusiveness and very high volumetric efficiency of ‘Lean’ could be combined with the omnidirectional accessibility and parcel sorting capabilities of ‘Huge.’

An aspect that can be used from the other concepts is the neighbourhood-stationed pods from concept 2. Stationing a (few) pod(s) with modular containers in the neighbourhood can offer ultimate flexibility in time. They could essentially wait for the customer to arrive and take their goods, and then ’refresh’ their stock once another mothership passes the street.

The most interesting part of the fourth concept is the flexibly sized containers. While these could be implemented into other concepts, the lack of robustness adds a possibly unnecessary risk.

Knowledge gaps

There are two main knowledge gaps that were identified after reflecting upon these preliminary concepts. (1) the chain before parcels enter the city has remained underexposed in this project, and (2) quantitative insight in how much time delivery takes, and the impact that different pod configurations have on this time.



1. Huge

Benefits

- The internal transhipment is safe, and 360° accessibility offers flexibility in parking.
- Could be loaded quickly in the hub, by placing the whole rack of modules at once.
- The drawers are convenient at low height.
- A large amount of parcels means less trips to the hub, which is efficient.

Drawbacks

- Kids could possibly crawl underneath.
- Using the vehicle as a parcel locker station only makes sense if stays in neighbourhood for long time. Timing = unknown.
- The volume of parcels has to be there, otherwise, taking a large vehicle is a waste.

Program of wishes

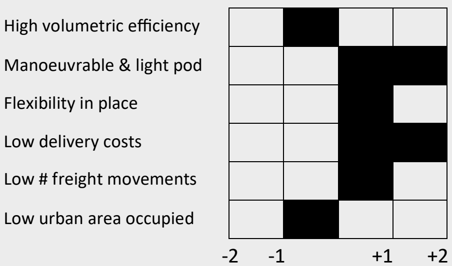
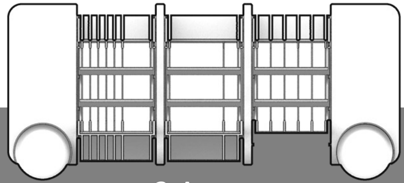


Figure 16.1A: Assessment of concept 1: Huge



2. Loop

Benefits

- Integrating the revolving system with the pod loading is space-efficient.
- The height of the shelves of parcels is adjustable, which makes this vehicle suitable for doubling as a parcel locker station.

Drawbacks

- Flexibility is lower, as items are always paired together through the fixed width.
- If pods stay in the street, they could serve a function, for instance taking returns.
- There is volumetric loss in the front and back elements
- Vertical orientation of boxes is not handy — as most parcels have a wide bottom side.

Program of wishes

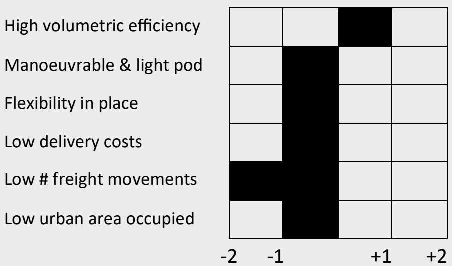


Figure 16.1B: Assessment of concept 2: Loop

3. Lean

Benefits

- It is unobtrusive, other traffic could pass it even if it is parked on the streets.
- The mothership allows for loading all the parcels at once in the hub.
- The scissors mechanism is easy to realise.
- Half the size means twice as effective: they could split up and serve two streets.
- Having actuating power in the pods creates room for passive street-based shelves.

Drawbacks

- Slightly more expensive pods.
- There is also quite a bit of volumetric loss in the front and back elements.

Program of wishes

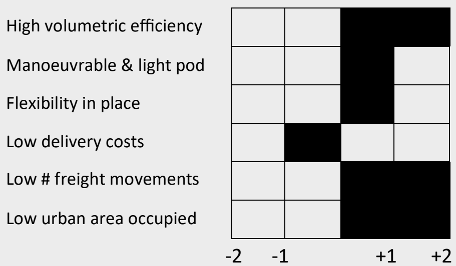
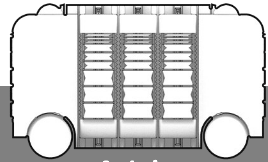


Figure 16.1C: Assessment of concept 3: Lean



4. Join

Benefits

- The idea of never transporting too much air is great, but I would orient them vertically.
- Pre-sorting for different streets is easy to do and happens all the time currently.

Drawbacks

- Flexibility is lower, as items are always paired together in the pods.
- The pods look less robust.
- The long pods are very hard to manoeuvre: tight corners & lifts become impossible.
- The pods seem rather large, is that the optimal pod-shape? Depends per street?

Program of wishes

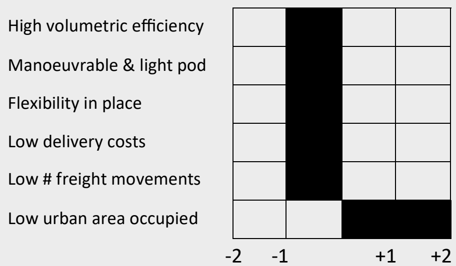


Figure 16.1D: Assessment of concept 4: Join

17. Before the last mile

One of the knowledge gaps that was identified in the previous chapter is what happens to parcels before they enter a (last-mile) delivery vehicle. As the conceptual vehicles will be part of a larger logistical chain, it is valuable to know how parcels are put into the delivery network on a regional level, and how they currently end up in vans.

Why?

A look into this chain is relevant, as this connection to the rest of the parcel chain was missing in the concepts. Being able to connect to the existing parcel chain is very important, as it speeds up the implementation of this innovation.

Expected results

If it is known how parcels are currently sorted and transshipped from one vehicle to another, the final concept can connect to this reality.

First of all, the stages that a parcel goes through in the system will be explained.

Airplane to lorry

This step only applies to parcels originating from other countries, and takes place at airports. Parcels arrive from multiple airplanes in typical air freight containers. These parcels are then *manually* transshipped into transparent lorry-containers that can be loaded and unloaded with forklifts. Lorries then bring these containers to the regional service centers. DHL Express in Eindhoven receives approximately 7 of these lorries every day, most of which originate from Brussels airport.

Lorry to van

Lorries are docked in a loading bay, and unloaded by a forklift. Afterwards, the contents of the lorry-containers are unpacked and put on a conveyor belt with the shipping label upwards (Figure 17.1). This is also done *manually*. After this, the automatic sorting system starts.

Figure 17.1: *Boxes are manually taken out of lorry-containers*

First, the barcodes on the parcels are being scanned by a laser scanner that is placed above conveyor belt (Figure 17.2). Now that the destination of the parcel and the position of that parcel on the belt is known, it is directed to the right van.

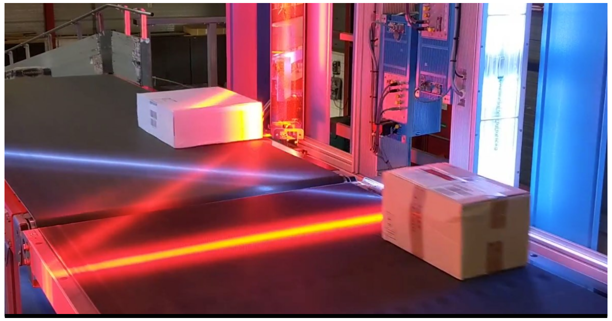


Figure 17.2: *Barcodes are scanned*

A series of actuators like the one in Figure 17.3, are used to steer the boxes in the direction of the right van. These actuators are basically a series of 'wheels' that can turn to guide a parcel in a certain direction.

Figure 17.3: *The 'wheels' guide the brown box to the left*

There are approximately 40 vans based at the Eindhoven DHL Express location: 20 leaving in the morning for a whole day, and 20 vans that drive two shifts per day. Together these are serving an area with a radius of about 30 kilometers around Eindhoven.


Figure 17.4: *Drivers picking parcels at the van bay area*

At the very end of the conveyor belt system, there are van bays on each side, with a conveyor belt in the middle. Vans are parked backwards behind the doors shown in Figure 17.4. Half of the doors are closed in the figure, as this was the early-afternoon sorting shift and not all vans were present. Normally, there would be a van parked at all these doors—and the doors would be open. What happens here at the van bays is that the human employees take the parcels (*manually*) scan the barcode again, and put them into the right vans.

City hubs

There is a third flow of parcels, which are sorted into 'Cubicontainers', small EUR-pallet sized containers (introduced in Chapter 6). These are pre-sorted for inner-city routes and taken to a City Hub in the respective city by a lorry. From there onwards, the small Cubicontainers are put on cargo bicycles or small Streetscooter-manufactured electric vehicles.

"In the past, we drove with six vans from Breda to Tilburg every day. Now we drive one lorry to Tilburg and small EV's take it from there."

- Ricky van Soest, DHL Express

Delivery with electric vehicles in this way is encouraged by municipalities. In Rotterdam for example, privileges like driving on bus lanes and in pedestrian zones are given to companies that are using zero emission vehicles.

Skipping the service centre: Next2Delivery

There is a new programme within DHL Express called Next2Delivery. This is about taking things originating from the city itself, to a destination elsewhere in the city. For example, a vacuum cleaner from Blokker could be delivered to a customer directly (or via the Hub): skipping the regional service centre altogether.

Conclusion

While the sorting system is quite advanced, there really is quite a lot of manual work still needed in the sorting centre. The manual labour is currently done by the same people who will take place behind the wheel of the delivery vans later.

The pre-sorting of parcels into modules (like the Cubicontainers) seems to catch on. DHL Express has two City Hubs currently, but plans to open six additional City Hubs in 2019. Pre-sorted modules could be implemented in the final concept as well. If so, it has to be considered that these modules will need to be transhipped from a lorry onto a vehicle at these Hub-locations.

Also, new initiatives of direct urban delivery (without going through a service centre) are being integrated in the network of DHL Express.

Ricky van Soest

Operational Field Support & GoGreen Specialist

Background
Ricky started out with DHL Express as a courier in 2008, delivering parcels for over two years. After that he worked as a supervisor of operations for five years, he recently started working for the Field Support team; a team that implements high level optimizations in the operations.

About the company
DHL Express is the internationally oriented branch of DHL. Their network has a lower density than for instance DHL Parcel (the national equivalent).

Why contacted them?
Ricky is in a position of overthinking new, innovative and more efficient last-mile solutions within DHL. Also considering his previous experiences in operational tasks, and his position at the Eindhoven service center, he has the overview on the whole chain of delivery.

Key learnings

- More emphasis on modular pre-sorting and how the parcels travel to the urban hub
- Mothership dimensions should be equivalent to how close the urban hub is

Interview notes in Appendix 17.

18. Timing & dimensions: basic last-mile optimization

As discussed in the previous chapter, there is an uncertainty at this point whether the concepts make sense in a logistical scenario. Because of the 'one delivery per house per day'-assumption, there are no applicable existing logistical optimization modules.

Why?

A basic understanding of the numbers is needed, to make a good judgement of which mothership-size is logical to pursue, how much pods are needed, what capacity they need to have and how much time a mothership would actually spend in a street.

Expected results

The resulting model will be used to draw conclusions on the ideal shape/aspects in the final concept.

Current situation

In the current situation, parcels are usually delivered by making a van-stop for every address that is receiving a parcel. If the addresses are really close, or parking space is not easily available, the delivery driver will sometimes make one stop with the van for multiple houses. The driver will then walk back and forth to the parked van to make the deliveries to nearby addresses.

Because of the lack of density that most current parcel services have in their networks, this is a logical approach. Route optimization in this day and age lies merely in the routes that are chosen between two delivery addresses. The famous example of UPS route-planners maximizing right turns and minimizing left turns to make routes more efficient (Rooney, 2007) exemplifies this extreme focus on the routing between streets. Looking at open source software for delivery optimization, it is also always about vehicle routing (Open Door Logistics, n.d.).

Within the street

The heart of the innovation that happens when introducing autonomous technology, is the pod. All of the concepts discussed in the previous chapter have a multitude of smaller pods, that can drive on sidewalks. These pods are the technological equivalent of a human walking from a van to a door.

While the traditional models make optimizations with van–routes, and basically ignores people movement, the model that will be created in this chapter takes into account the pod/mothership movements within the street.

Figure 18.1: Mothership stops for 1 house | Pod capacity = 1

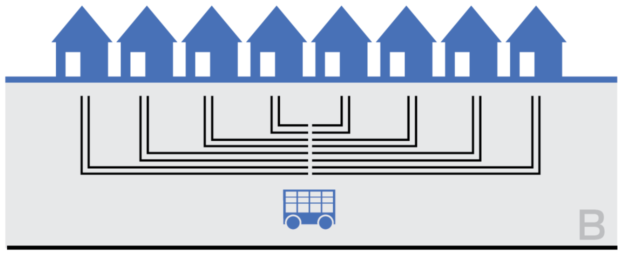


Figure 18.2: Mothership stops for 8 houses | Pod capacity = 1

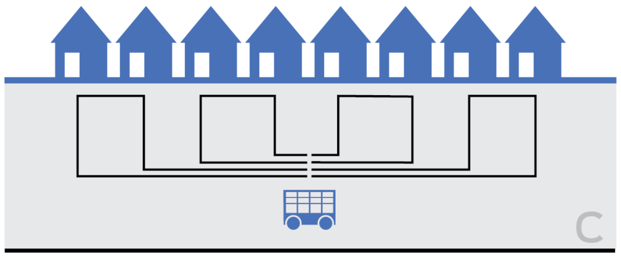


Figure 18.3: Mothership stops for 8 houses | Pod capacity = 2

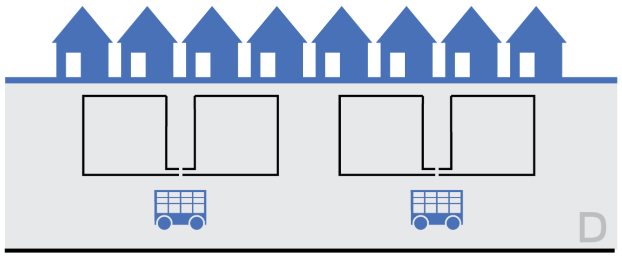


Figure 18.4: Mothership stops for 4 houses | Pod capacity = 2

Assumptions

To simplify matters, a few assumptions are taken. These are the most important ones.

- The model assumes that all houses expecting a delivery are equally distributed over the length of the street. This will never precisely be the case, but it should give a good indication of the overall timing.
- The model assumes that the pods will always take the optimal route (described below). This will not always be possible due to obstacles that may be in the way.
- The model assumes that the mothership needs a constant time (~30 seconds) to drive from one place to another. This constant value takes into account the time it takes to load and unload the pods, and the time for actual driving. As the latter is a relatively small time in comparison, it is decided to ignore it for this model.

Routing of the pods

The 'decisions' for the routing that are taken by the pods in the model are made according to the most optimal route. Figure 18.1—Figure 18.4 (A-D) depicts these optimal routes.

In Figure 18.1 (A), the mothership makes a stop for every house on the route, which gives the pod a straightforward journey back and forth to the door. This is optimal when the density of the network is low—as the mothership is assumed to be driving faster than the pods.

In Figure 18.2 (B), the mothership makes a stop for every 8 houses on the route. Here, the pod capacity is 1, so a single pod has to travel eight times from the mothership to a house and back.

In Figure 18.3 (C), the mothership makes a stop for every 8 houses on the route. Now, the pod capacity is 2, which decreases the total length of the pod journeys. Instead of 8 pod journeys, now there are 4: two shorter ones, and two longer ones.

In Figure 18.4 (D), the mothership stops two times, once for every four houses. Now, the distance travelled by the pods is quite minimal (could be even shorter if they had a capacity of 4), as the mothership takes over a certain distance.

Please note that if the delivery density gets smaller, the model will assume that houses are further away from each other but still evenly distributed—as mentioned in 'Assumptions.' For instance, in the case of the aforementioned eight houses, a 50% delivery density equals houses that are twice as far apart (Figure 18.5).

Figure 18.5: 50% delivery density

The model

Now that the routes that the pods are choosing are defined and the basic assumptions in the model are clear, calculations can be introduced. The model aims to find the lowest ***t_PerStreet*** which is the time it takes to deliver all parcels in a specific street.

The calculations are made in Excel. The formulas are included and explained in Appendix 18. In this chapter the input that the model gets will be discussed, and the significance of the output that the model generates.

In Figure 18.6, a typical list of values for the calculations is displayed. At the top, there are two constant factors—things that are not likely to change between concepts. Then there are input variables, things that are likely to change from situation to situation. At the bottom, important calculated values are being displayed to verify whether the input was as intended.

Constant values		
t_Handover (s)	**40**	s
V_Pod (m/s)	**1,2**	m/s
Input variables		
n_HomesPerStreet	**80**	x
%_DeliveryDensity	**50**	%
t_Start&EndMothershipTrip (s)	**30**	s
W_AVG_Home (m)	**6**	m
t_Start&EndPodTrip (s)	**30**	s
n_SidesOfStreet	**2**	x
Calculated values		
n_DeliveryAddresses	**40**	x
n_DeliveryAddressesPerSide	**20**	x
D_BetweenDeliveryAddressesPerSide (m)	**12**	m
L_Street	**240**	m

Figure 18.6: Values that are defined

Figure 18.8A: Typical inner city residential area (parking is hard)

Figure 18.8B: Typical outer city residential area (favorable)

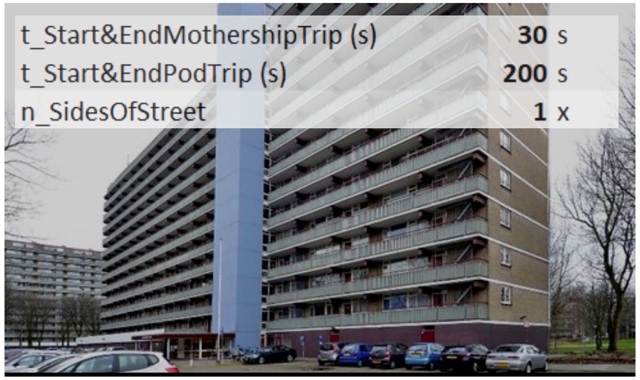


Figure 18.8C Typical apartment building (elevator takes long)

Explanation of the output

The model outputs a graph that shows the relation between the amount of homes per stop of the mothership and the 'total delivery time per street' (Figure 18.7A-D)

The horizontal axis shows the amount of houses that are served per mothership-stop. A value of 1 means that the mothership stops for every house, while a value of 20 means that the mothership makes a stop for every twenty houses.

The vertical axis shows the total time in seconds that It takes to complete all deliveries in a specific street.

The lines within the graph represent different pod configurations. The colouring has the following meaning: colors stand for different capacities. Blue are pods with a capacity of 1 parcel, green are the pods with a capacity of 2 parcels, orange are pods with a capacity of 3 parcels and grey are the pods able to take 4 separate parcels at once. Furthermore, darker shades represent a smaller amount of pods that can simultaneously operate variating from 1 to 3 pods at once.

Real-world environments

Applying the model onto real-world urban environments, the parameters shown in Figure 18.8 (A-C) were used as input for the calculation model. The outputs of the model for these cases are detailed in Appendix 19.

Conclusions

From observing the outputs in the real-world environments and the theoretical graphs in Figure 18.7 (A-D), the following conclusions can be drawn.

First of all, if the total amount of houses in a street is dividable by the 'houses served per mothership stop', the total time is lower, as less mothership stops need to be made. Stopping the mothership for every 10 houses is better than for every 9 houses, if you need to deliver to 20 houses. In the latter case, you would need to stop three times. This effect causes the 'jumps' in the graphs.

Secondly, concluding from the graph in Figure 18.7A and 18.7C, having one pod with a capacity of 1 parcel is only a good decision if the mothership stops at every house. From an efficiency standpoint, this is the least interesting pod configuration. While the most extreme pod configuration shown in the graph (3 pods with 4 capacity) is always the fastest, the model shows that, for most cases, 2 pods with a capacity of 2 parcels perform similarly.

Thirdly, Figure 18.7B shows a branch-like structure. When the amount of pods stays the same, making it a higher capacity only affects the total time if the mothership stops for a lot of houses at once (further right in the graph). So if the environment does not approve of moving the mothership very often, a higher capacity is preferred.

Then, if the delivery density is reduced (Figure 18.7D), the lines of all pod configurations go up. The model shows that in this situation, the lowest possible time is achieved by stopping the mothership in front of every house.

TOTAL DELIVERY TIME PER STREET FOR 'HOMES PER STOP', FOR DIFFERENT NUMBERS OF PODS AND POD-CAPACITIES

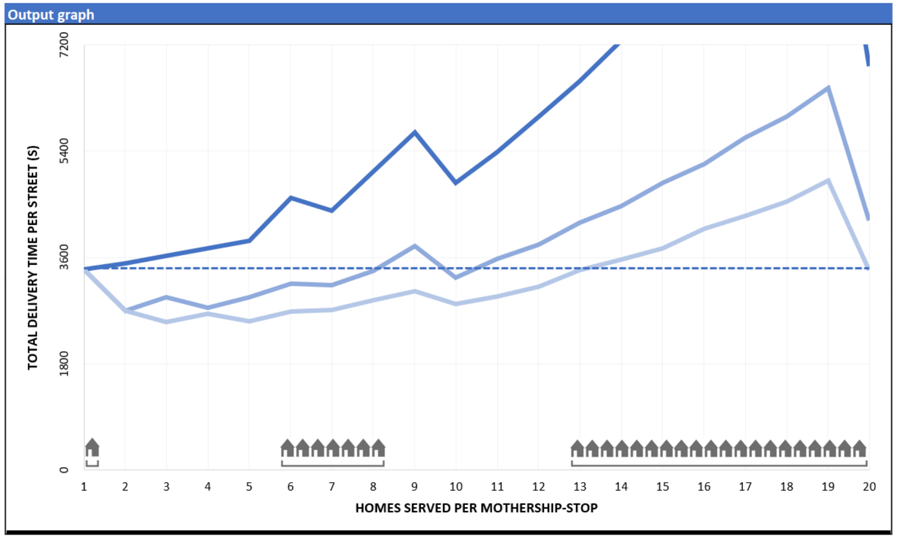


Figure 18.7A: 80 homes, 50% density, 1-3 pods with capacity 1.

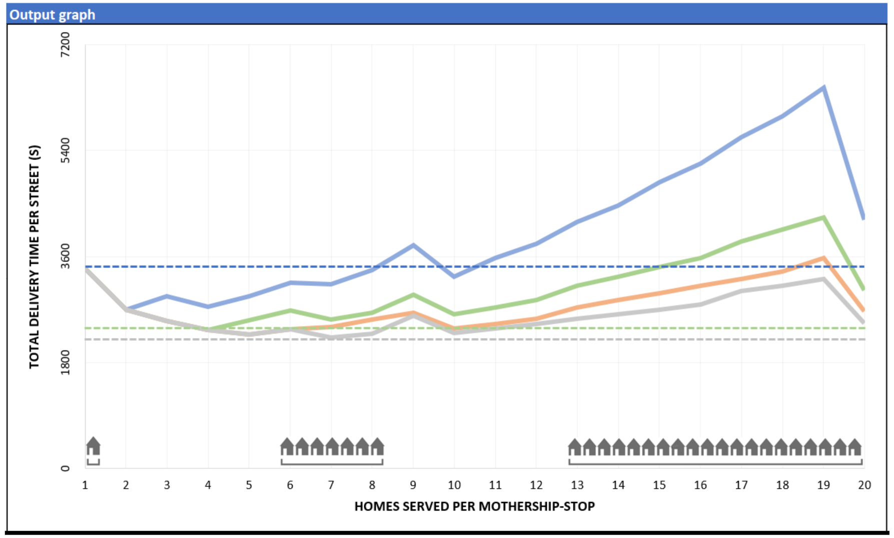
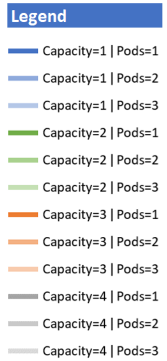


Figure 18.7B: 80 homes, 50% density, 2 pods with capacity 1-4.



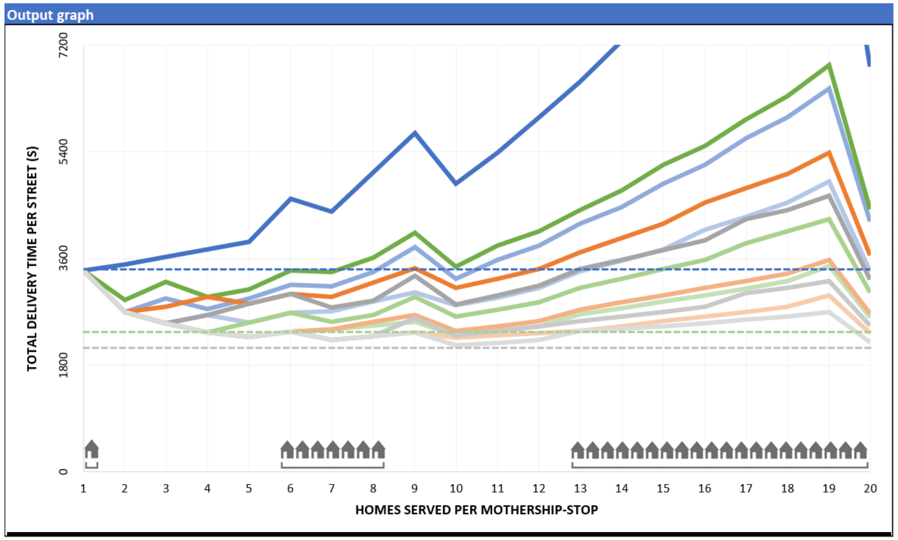


Figure 18.7C: 80 homes, 50% density, 1-3 pods with capacity 1-4.

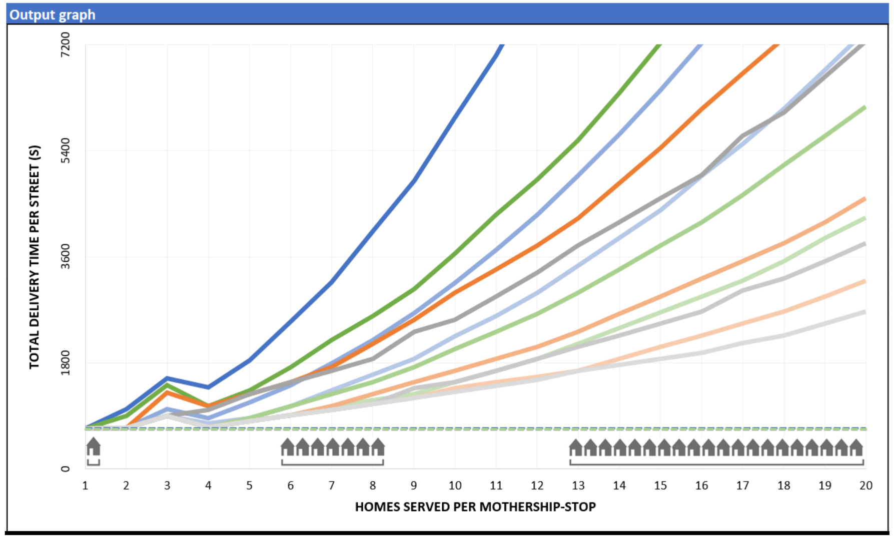
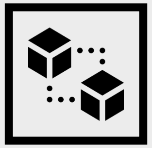


Figure 18.7D: 80 homes, 10% density, 1-3 pods with capacity 1-4.

Final concept

All the information that was gathered in the previous phases is used to create one final conceptual system. This system is explained in this phase, as well as the elements that it consists of.

19. Final concept: the system



With the new insights from the previous chapters, a final concept was developed—combining the best aspects of the four preliminary concepts.

Why?

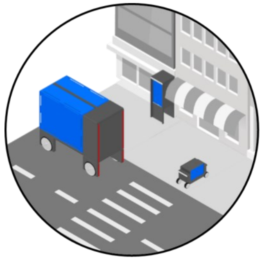
The high-level aim of this project, that was defined in the introduction, is *'to conceptualize an urban autonomous delivery system for European cities that is technically feasible, user-friendly and fits the Ford business'*. While the first chapters of this project mainly serve to make sure the concept is relevant—considering all the aspects included in the aim - this chapter introduces the actual concept (on a systemic level).

Expected results

In the first part, the system proposal will be introduced, providing an overview of the system in a city environment.

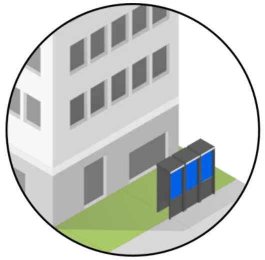
Introducing the systemic design

As first introduced in Figure 13.5, the system consists of a mothership, which forms the link between the urban hub and the customer touchpoints. The main customer touchpoint is the pod, which can perform home deliveries. Next to that, a new standardized static 'kiosk' element is added to the concept, that could be placed in front of apartment buildings, on neighborhood corners or in front of the ultra-local shops that were discussed before. This makes sure that the pod can actually supply these places autonomously, without a neighbor or shop owner having to help.



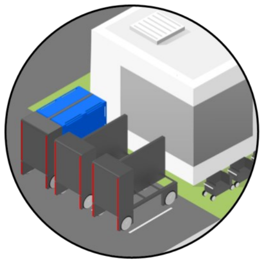
Supplying the kiosk

Pods can autonomously supply a kiosk, and take empty containers out of a kiosk.



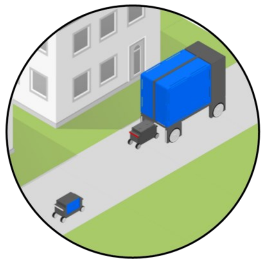
Apartment buildings

In front of apartment buildings, multiple kiosks can be connected to each other.



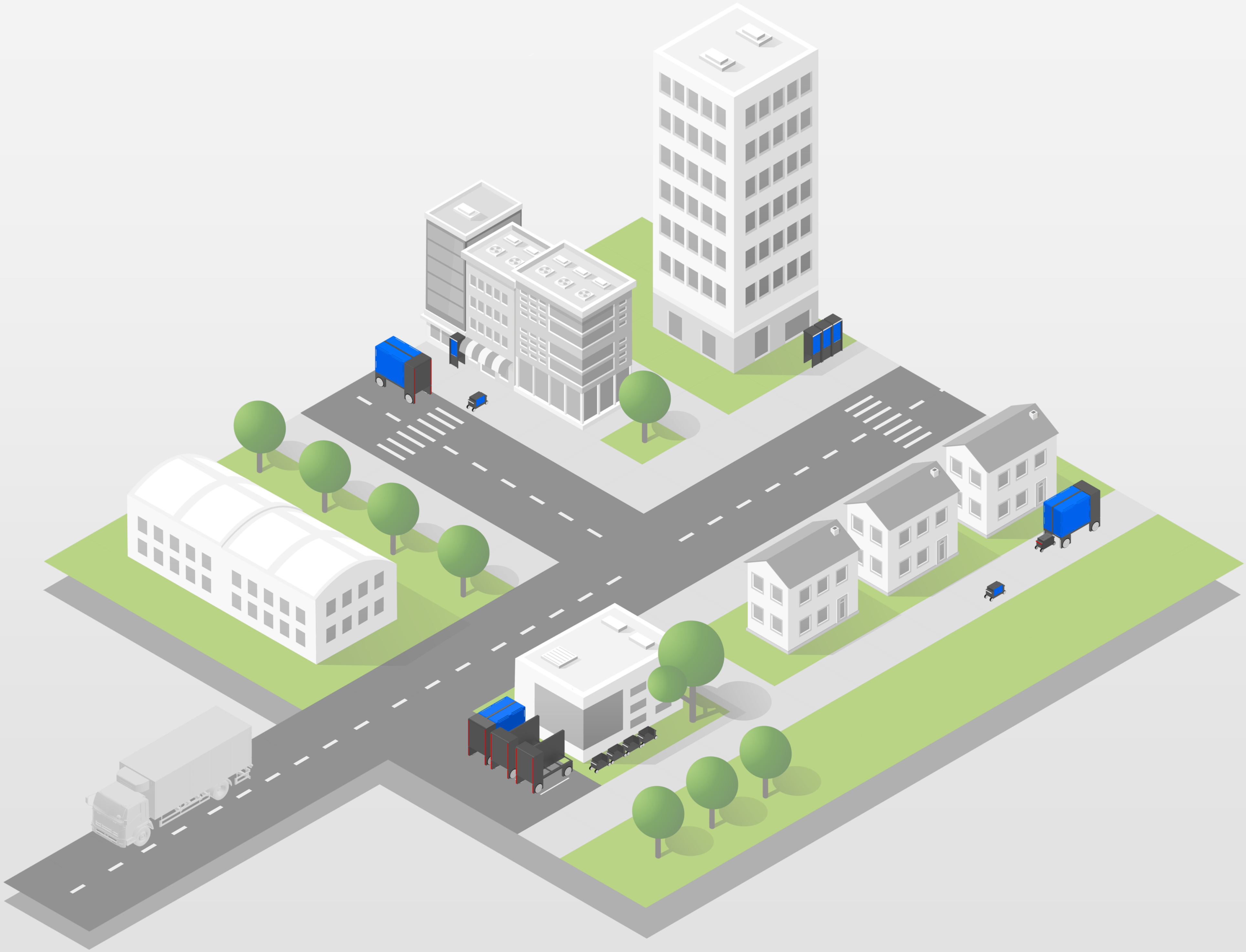
The urban hub

The hub is where motherships are stationed, loaded and unloaded. Also, vehicles are charged here.



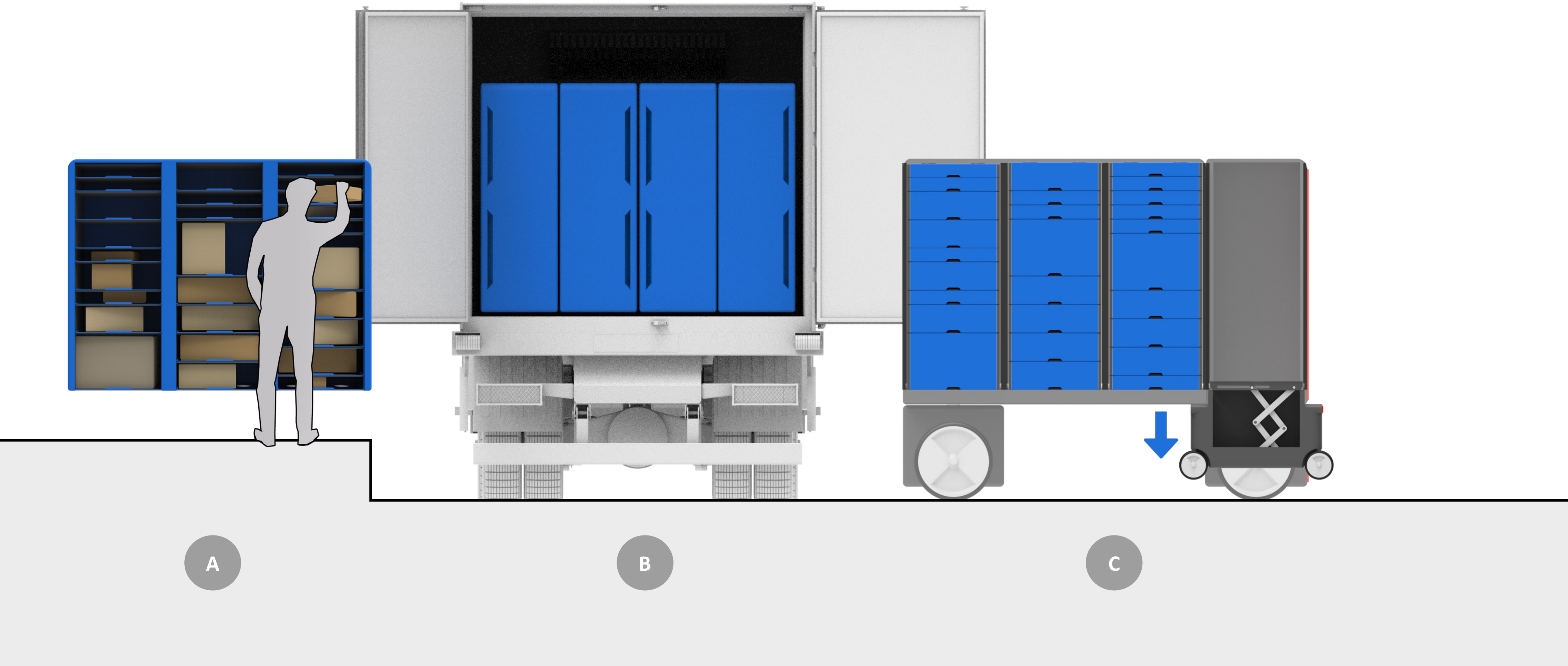
Pod deliveries

A decentralized parcel locker station, that can be supplied on-demand by the pods.

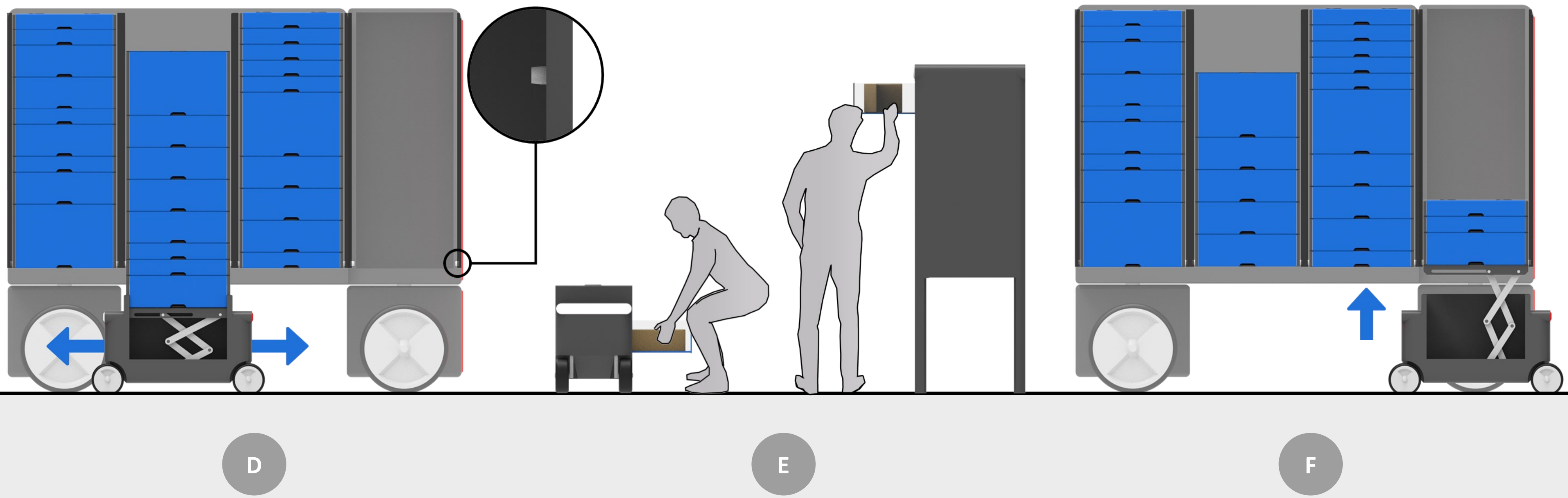


The parcel journey

In this concept, the journey of a typical parcel goes as follows. In a regional distribution center (where the scope of this project starts), every parcel gets assigned a modular container that fits its size (A) within a blue XL-container that is presorted for a specific neighborhood. These containers are transported by lorry (B), to an urban hub in the destination city. Note that the width of the containers is chosen so that four of these containers fit the width of a typical lorry. After arriving at the urban hub, the containers are loaded onto motherships. The motherships are equipped with pods. These pods can attach themselves onto the mothership (C), allowing them to move between delivery addresses as fast as the mothership itself. The pods are necessary (re)organizing the modular containers inside the mothership.



Near the final destination of the parcels, the pods are deployed. The pins securing the columns of parcel containers D are retracted and the pod takes out the necessary containers. After this, the pod can either take the parcels directly to the customer, or it can take the parcels to a kiosk near the customer's home E. When the customer has taken out the shipment and the modular containers are empty, the mothership can take the containers back to the urban hub. The first containers that have been successfully delivered will find their way into one of the two extra shafts F. These empty shafts allow for organizing the modular containers, and offer flexibility in the delivery order.



20. Final concept: the physical elements

The system that was introduced in the previous chapter is built up from different components. These building blocks of the system deserve more attention.

Why?

The physical elements of the system are the core of this graduation assignment. These elements make the vision tangible. The detailing of these elements serves two purposes in this stage: (1) credibility and (2) feasibility. Detailed elements make the vision look realistic, which makes it credible among business stakeholders and future customers, which leads to better feedback. During the process of trying to get the details right, creative problem solving takes place — this adds to the feasibility of the concept.

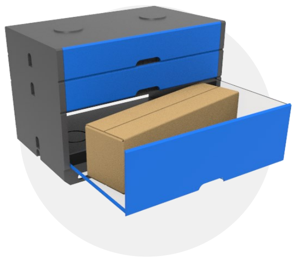
Expected results

Detailed physical elements which are credible for stakeholders and are feasible from a technological and logistics perspective.

Introducing the elements

The picture on the next page shows the elements of the proposed system in a single image. The physical elements — the building blocks of the system — and their underlying design choices will be explained in detail on the next few pages.

An overview of all the elements and their respective dimensions can be found in Appendix 20.



20A. The modular container

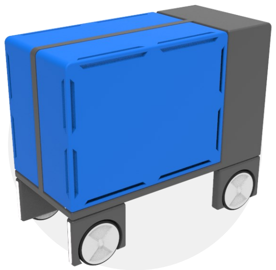
Stackable containers with NFC enabled drawers that can hold parcels.

20B. The pod

A sidewalk-roaming vehicle that takes parcels from the mothership/kiosk and delivers them.

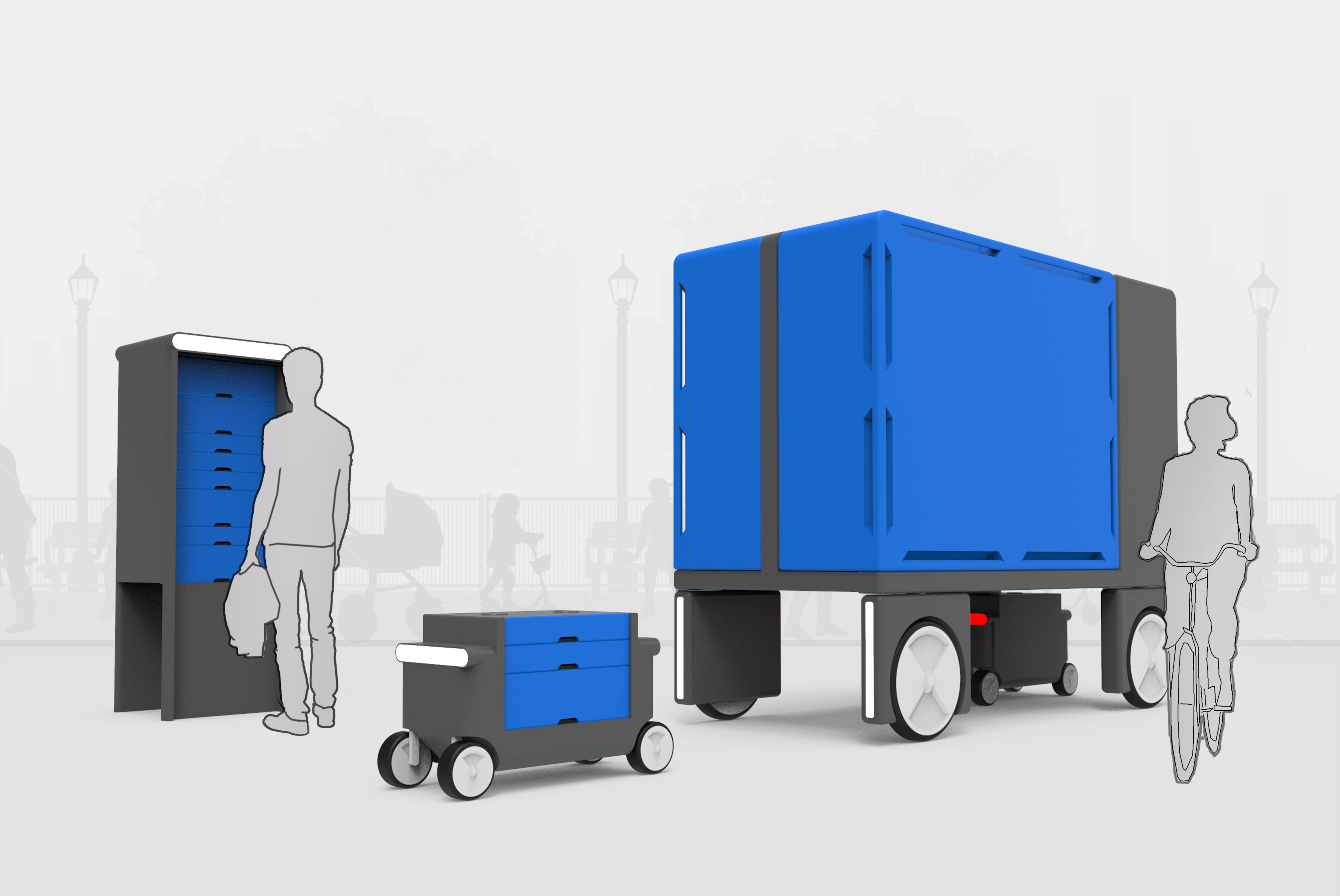
20C. The kiosk

A decentralized parcel locker station, that can be supplied on-demand by the pods.



20D. The mothership

A roadworthy vehicle with a small footprint that can carry sets of modular containers.



20A. The modular container

Key design choices

The following design choices were important in the creation of the modular container.

(1) Asymmetrical transparent drawers

Drawers are an ideal way to access the contents of a shelf that is in a low position, as they maximize the accessibility from the top. However, if something is in a high place, drawers can get in the way of accessibility, and a shelf would be preferred. The asymmetrical drawers are open on one side, so that when the module is in a high place, it basically functions as a regular shelf and the parcel can be taken out from the side. As visual oversight is also important when accessing a parcel from a high place, transparent plastic is added on the inside.

(2) Open at the back

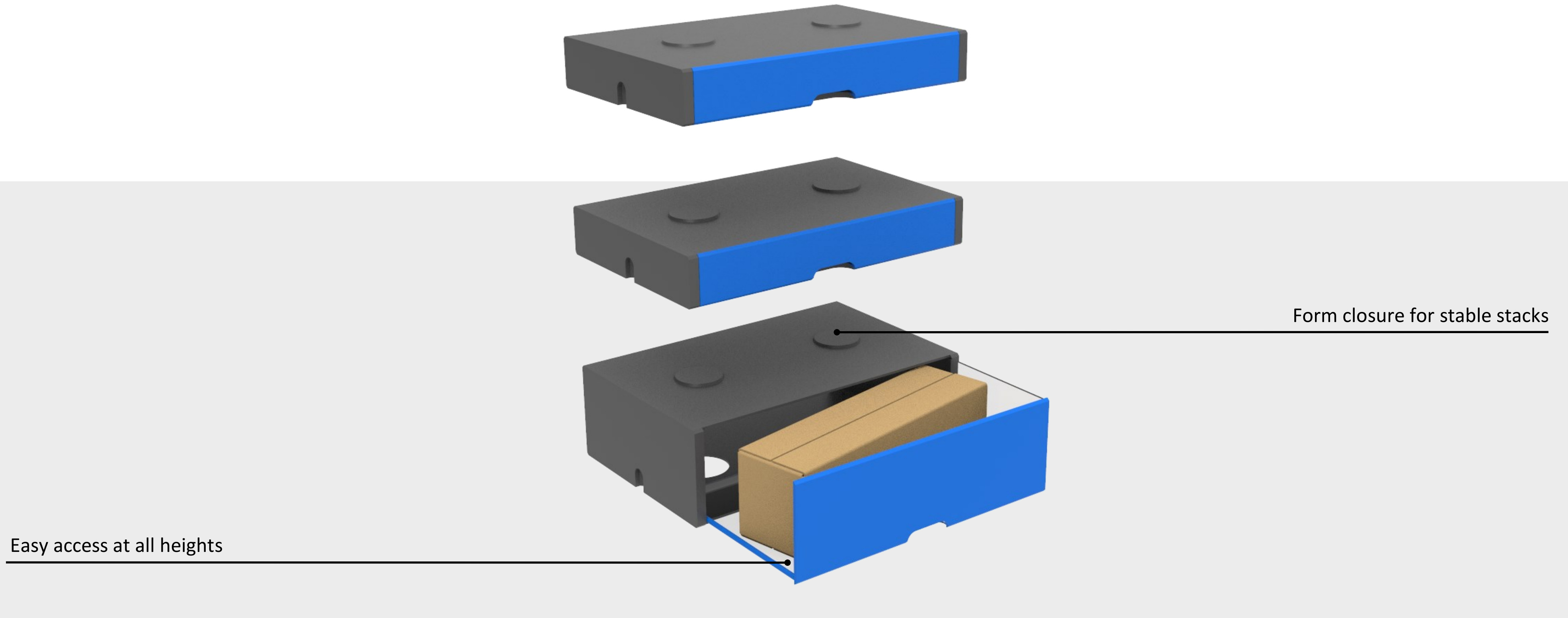
The modules are open at the back, for easy parcel-loading. More insight on this easy-loading concept is provided in section 19C (Mothership).

(3) Individually lockable

The drawers can be individually unlocked through NFC terminals. These require little power, and can be opened by both ‘analog’ cards (for elderly people) and phones.

(4) Different sizes

The sizes of the modules are based on existing parcel locker stations, but can be optimized over time, together with more exact data from parcel services.



20B. The pod

Key design choices

These four choices were important in the process of creating the pod-architecture.

(1) Scissors mechanism lift

The mechanism that was first introduced in preliminary concept 3 has been improved and is used for the pods in the final concept. The strength of including this actuation mechanism is that the pods can interact with inexpensive (almost) passive elements. Also, they can lift themselves to attach to the mothership.

(2) Length > width

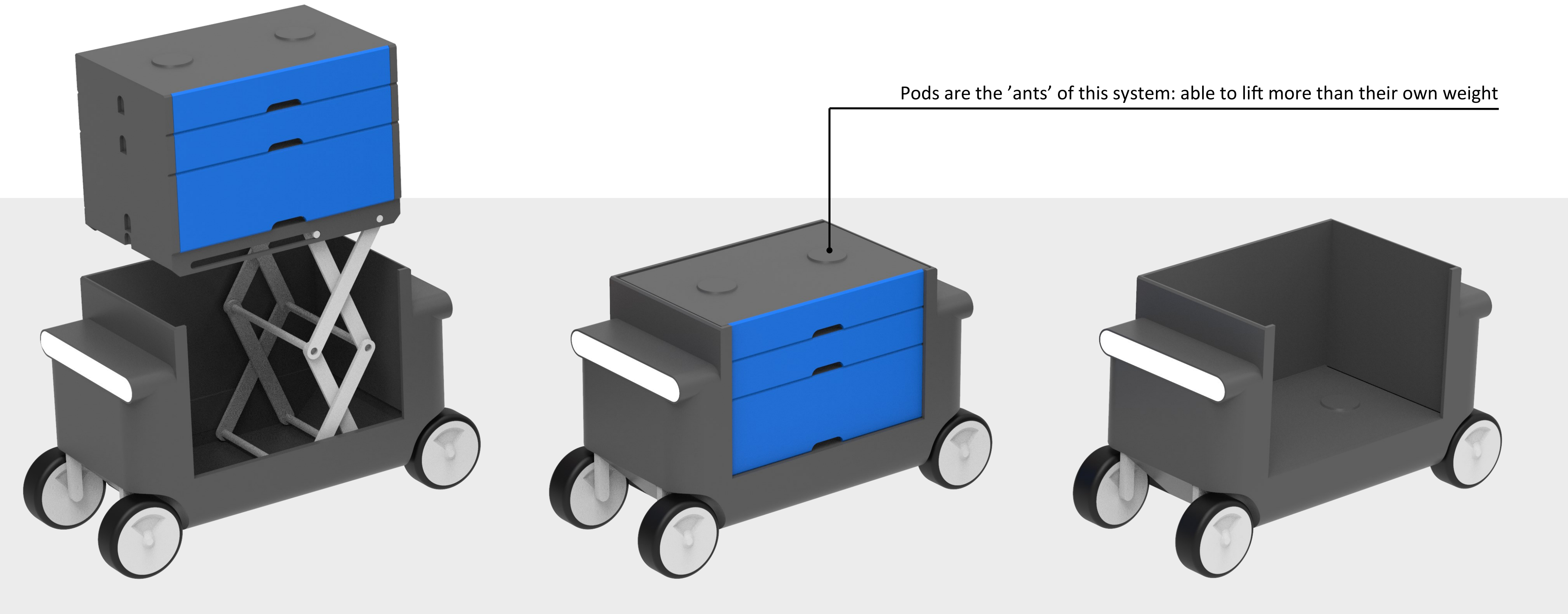
To create stable vehicle dynamics, the modular parcel containers are placed over the long axis of the vehicle.

(3) Independent all wheel steering & suspension

The suspension can be extended individually, so that the pod has more ground-clearance, and the parcels can stay level, even when the street is not. This flexibility helps when driving on rough terrain and when driving over small curbs. For a small turning radius, all wheels steer.

(4) Reversible design

Pods can drive in both directions. The only thing that changes is the LED-bar, which changes from headlight-white to taillight-red. This means that, after finding the right parcels underneath the mothership, the pod can drive away in any direction safely.



20C. The kiosk

Key design choices

Call it a kiosk, a decentralized parcel locker station, or a shared modern-day letterbox: these choices were important in the design process of the kiosk.

(1) Supplied by pods

Every time a pod is unable to deliver a parcel to a home directly, it could choose to deliver that shipment to the neighborhood kiosk (if the user desires). Pods drive through the kiosk from the side.

(2) Inexpensive & minimal

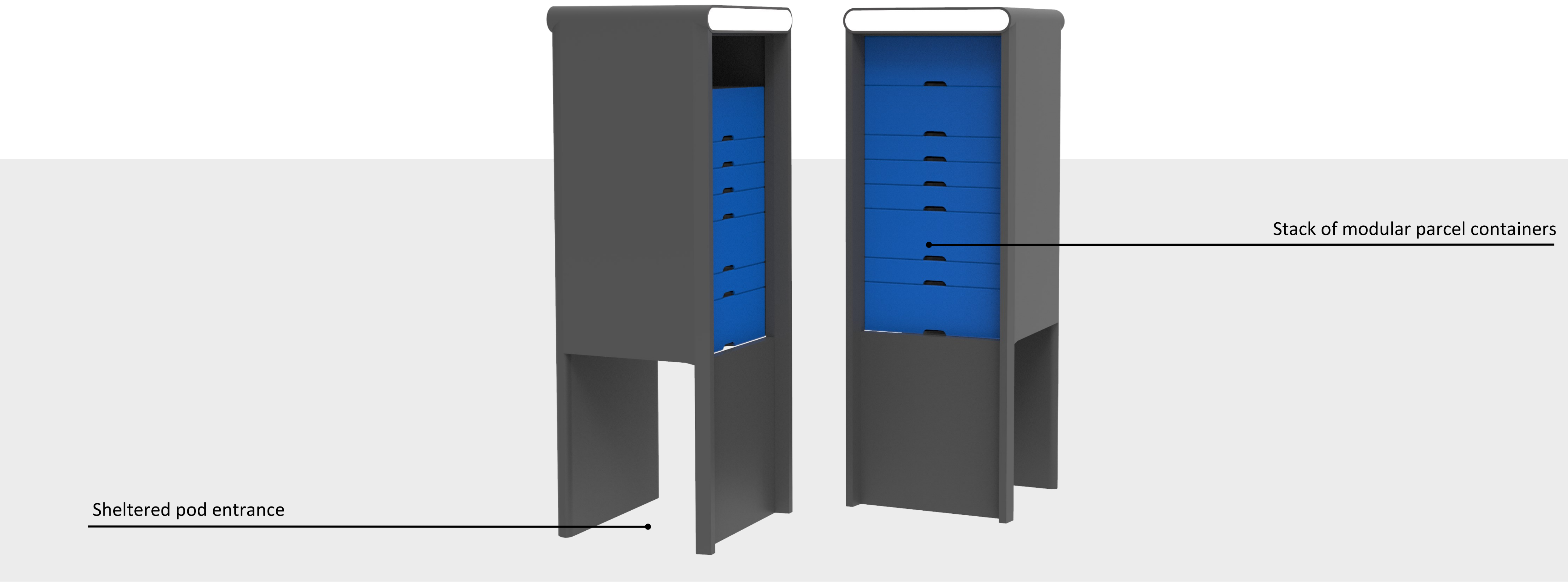
The only active part is a pin that holds the modular parcel containers in place, this could work on solar energy. Apart from that, it should be cheap to produce and distribute. Local shops could easily afford it—as it would draw extra people to their storefront.

(3) Scalable design

As established in Chapter 13: having the possibility to safely store goods in the destination street is of great value, but space is usually rare. The minimal outer volume and the small footprint makes it somewhat easy to find a place for it. Therefore, a scalable design was adopted. One could be placed, or more next to each other, depending on local demand, essentially creating a tunnel for the pods.

(4) Return shipments

Once a few parcels are taken out, the empty modules could be assigned to be used for return shipments.



20D. The mothership

Key design choices

The following decisions were key in the process of designing the mothership vehicle.

(1) Access underneath the vehicle

Pods load and unload themselves underneath the mothership vehicle: this is both safe (they likely will not encounter other traffic there) and it limits 'visible' vehicle movements. Also, pods can drive underneath from all sides.

(2) Pre-sorted XL-modules

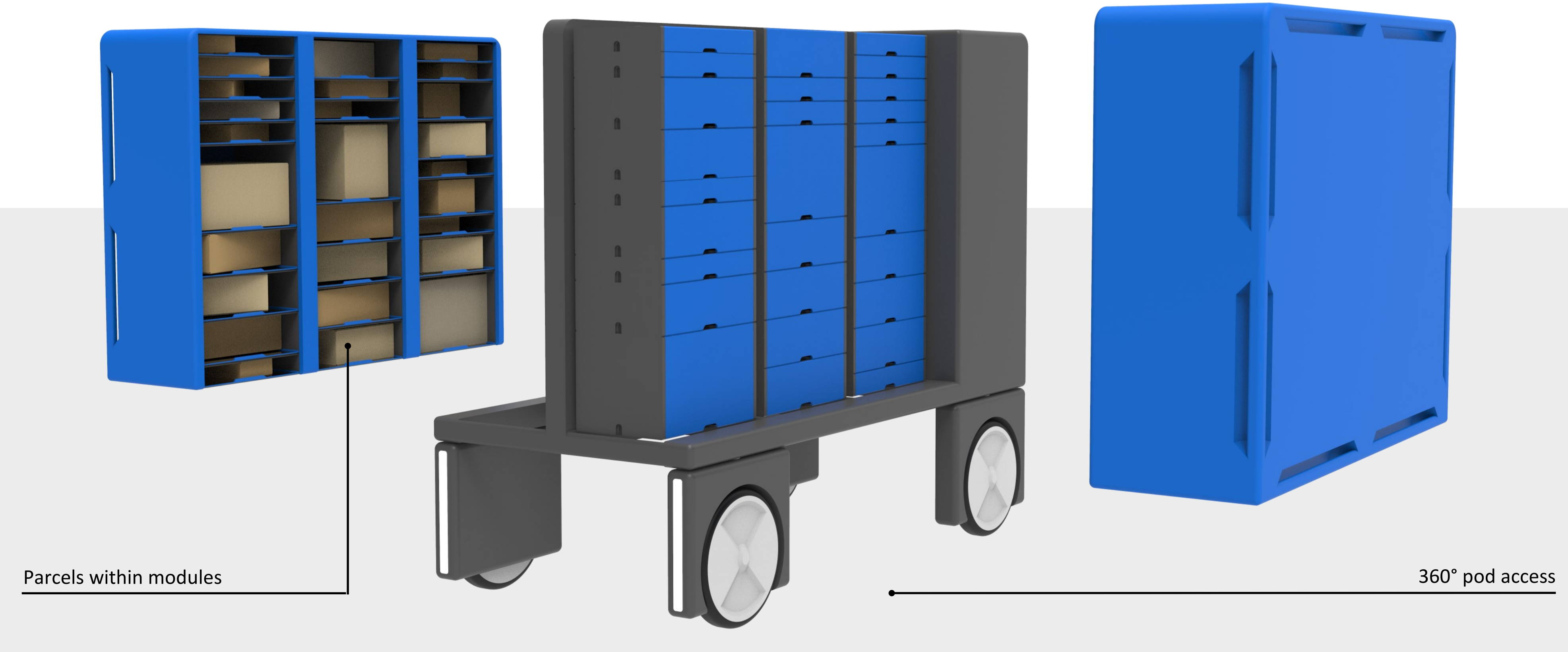
The blue XL-modules have three shafts and are designed to fit about 30 modular parcel boxes (an average Dutch street) each, which can be pre-sorted and delivered to an urban hub by lorry. Pods can reorganize these modules by taking them out of one shaft and placing them back into another. The XL-modules themselves are 2.0x1.6x0.6 meters in size. This means that four of these modules fit next to each other in a typical lorry.

(3) Pre-loading through the opened back

The back of the modules (large and small) is completely open, which makes it easy for delivery employees to load the modules and it gives officials easy access and instant oversight, should problems arise.

(4) Empty shafts

The design features two empty shafts at the back: these make sure that empty modules can be stored together.



Prototype & validation

During this phase, the conceptual system will be validated with (future) users. In order to present these people with a tangible vision on the future of delivery, a prototype of the major user touchpoint—the pod—will be constructed.

21. Constructing the physical prototype

In order to be able to validate the concept with users and business stakeholders, a prototype of the most important user touchpoint was created: the delivery pod (or, as it will be communicated to the customers: ‘delivery robot’).

Why?

If executed convincingly, making the vision tangible is important to be able to perform tests with users, to communicate the design within Ford and among Fords partners. If a building block from the conceptual system is placed in the real world, it changes from being just an idea to being an actual part of the world: a physical vehicle like this can be a powerful communicator.

Expected results

It is expected that—by the end of this chapter—a small vehicle is created that can be remotely controlled, has modular drawers, and looks convincing. Also, the building process is summarized.

This chapter gives technical insight in how the prototype was constructed. Please note that the prototype was built and assembled by one person in 14 days, which explains that some shortcuts have been taken.

Before starting the actual prototyping, a plan and cost estimation was made (Appendix 21).

The pod

First, the prototyping of the actual vehicle will be explained. Other sections will cover the modular boxes, the voice, and the app.

A driving chassis

To save time, the battery, steering, motors, remote controller, board computer and wheels were taken from a brand new 12V children's car (the one where a child can actually sit in) which was dismantled for this purpose.

This specific vehicle was mainly selected based on its width, so that the axle and steering mechanisms would not need to be enlarged or scaled down in size.

While the width of this children’s EV was almost perfect, the length was too short for the new purpose. As the electronics in children’s EV’s are directly mounted onto the injection molded plastic unibody, a chassis had to be built to serve as a base for the pod.

This chassis was constructed by 3D-printing mounts for the driven motors and the steering motor. To make sure these parts would not break, several tests were conducted (Figure 21.1) to make sure there was a tight

Figure 21.1: Early test of a 3D printed motor mount

fit and the plastic was strong enough. The final mounts were printed with a large 1mm nozzle out of black PLA using a Prusa i3 MK3 printer, and bolted onto two 40x40x2 [mm] aluminum L-profiles (Figure 21.2) to form a frame that Is 950 [mm] in length.

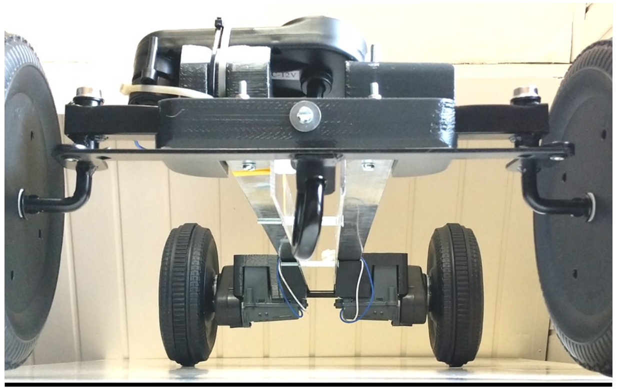


Figure 21.2: Black motor- and steering mounts on the chassis

After bolting the 3D printed parts to the aluminum profiles and screwing the steering mechanism and motors to the 3D printed parts, the driving chassis was finished and tested for drivability. After these tests, it was decided to wire the steering and motors in such a way that the steering would be at the rear of the pod. The conceptual pod has independent steering on all wheels, due to time concerns, this was not incorporated into the prototype. But to make the prototype steer in a different/unusual therefore felt right. The finished driving chassis is displayed in Figure 21.3.

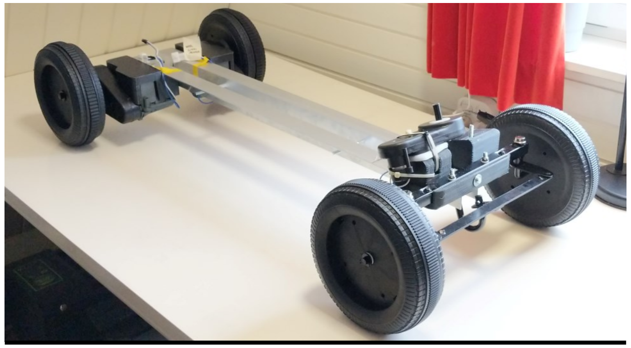


Figure 21.3: Finished chassis assembly

The bodywork

The heart of the bodywork is the 'core module', positioned in the middle of the chassis, the modular boxes will be placed inside this module later. The core was designed to provide strength to the construction, as it was lasercut out of sturdy (9mm) plywood (Figure 21.4). After

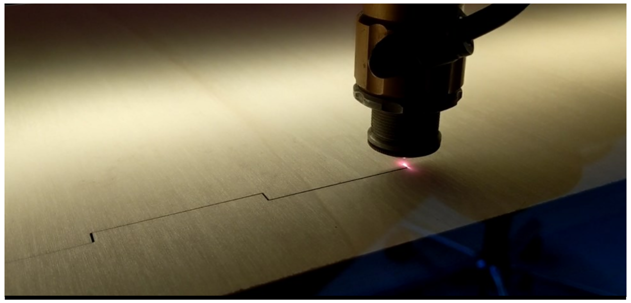


Figure 21.4: Lasercutting the core module

the plywood was glued together, primed and painted grey, the core module was bolted onto the middle of the chassis. Afterwards, the pod looked like Figure 21.5.

Figure 21.5: Core module placed on the chassis

With the chassis and the core module in place, the bare functionality of having a driving platform that can transport modular containers was in place. Now it needed to look good.

The lower end of the front and back of the vehicle were carefully measured, and 3D-printed parts were designed to function as wheel-arches, and as a cover for the electronics (Figure 21.6). As the printer has a limited build

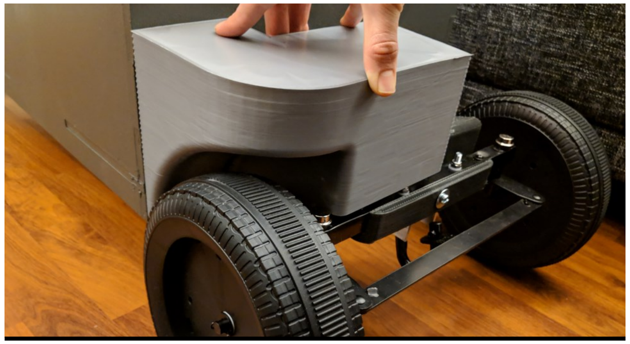


Figure 21.6: 3D printed rear part

volume, both the front and back parts were split in two for 3D-printing (Figure 21.7). The CAD model had to be incredibly accurate in its measurements, as each of the

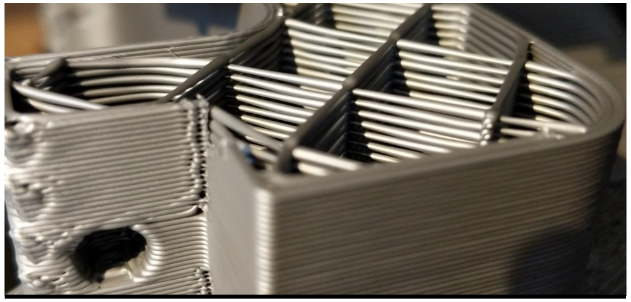


Figure 21.7: Front part during 3D printing

four parts has quite a complex shape, and printing takes 12 hours and half a kilogram of PLA material. After 48 hours of 3D-printing, the parts were finished, put together and plastered (Figure 21.8). The 3D printed part on the front of the pod has a door through which the battery can be swapped for a full one. This battery-door is secured by strong neodymium magnets which were glued in place.

Figure 21.8: Plastered plastic rear part with wheel arches

To finish the look of the conceptual model, a part was designed covering up the rest of the front and back of the pod. As this is a rather large part, it was CNC-milled out of Styrofoam (Figure 21.9). These parts are therefore

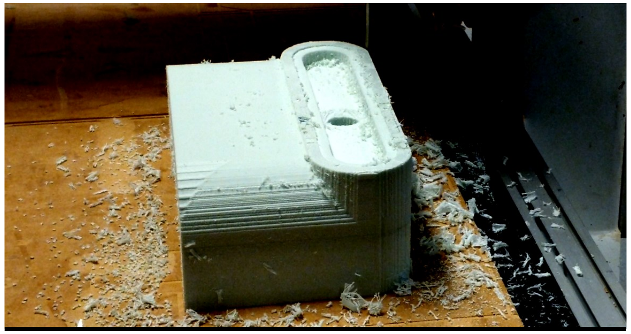


Figure 21.9: Milling of the Styrofoam front/back

not as strong as the 3D-printed parts, but they are less expensive and faster to produce. Note that both the front and back CNC-milled parts contain a slot to house the light units and a dark frosted acrylic cover, hiding the LED's when they are not turned on. An impression of the assembly so far is displayed in Figure 21.10.

Figure 21.10: Unfinished 3D-printed and CNC-milled parts

These parts were later sanded, primed and painted grey. The result of this can be seen in the section 'Final assembly.'

The scissors mechanism

An integral part of the pod design is the mechanism that lifts the modular containers. The scissors mechanism was not meant to be used during user tests. It was built particularly as a way to showcase the mechanism.

The arms of the scissors and the frame (Figure 21.11) were lasercut out of low-friction acrylic material.

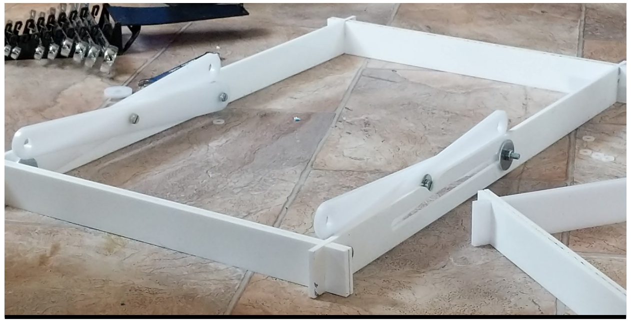


Figure 21.11: Acrylic frame of the scissors mechanism

Slotted bolts, spacers, nylon sliding bearings and lock nuts were used to attach the arms to the frame and to each other. For stability, PVC pipes were introduced, connecting the two sides of the mechanism.

After a lot of patience, tweaking and rearranging the elements, the scissors mechanism worked as intended (Figure 21.12). However, during this process it was discovered that acrylic material handles peak forces quite badly. It has a tendency to suddenly break when under pressure, almost like glass.

Figure 21.12: Working scissors mechanism

As the mechanism was only intended as a showcase, the build continued. But it was decided at that moment that instead of pushing the mechanism upwards by a 200N linear actuator (like in the concept), it would cause less strain on the material to lift the platform up from the top. Therefore, a steel cable was connected to the same linear actuator, and the actuator was placed vertically in the back of the vehicle — between the steering and the core module — as seen in Figure 21.13.

Figure 21.13: 200N linear actuator (photo taken from the top)

The modular containers

An important part of the user experience are the modular containers of different sizes that hold the parcels. Their construction was relatively straightforward, except for the locking, which had to work through NFC.

So the first step was to find a lock that could be used. After some time, a suitable module was sourced: it is a modular component that has an NFC terminal and locking motor that was placed inside the drawer. And another component with a locking pin that was mounted to the non-moving part of de module using a 3D print (Figure 21.14).

Figure 21.14: Locking pin attached to the modular container

The modular boxes themselves were lasercut out of 5 and 12 [mm] plywood, screwed together, primed and painted grey.

The drawers, were also lasercut, but out of 3mm acrylic material instead of plywood. The drawers are transparent on the bottom and on the sides, which—if lasercut— can be best made out of acrylic (plexiglass). The front was also made out of acrylic (blue) to make it look like a final product instead of a prototype.

Figure 21.15: Gluing the acrylic

The acrylic was glued together (Figure 21.15) with contact-glue which makes for a strong bond. However, as these drawers are such an integral part of the user test, they had to be extremely strong. That's why small attachment blocks were designed and 3D printed (Figure 21.16). Sometimes these are screwed in place (at places which are not seen by the user) and sometimes they are glued in place with 2K epoxy-glue. Finishing up these modular drawer slide inside the modules, aluminum guiding rails were glued into the modules (Figure 21.17).

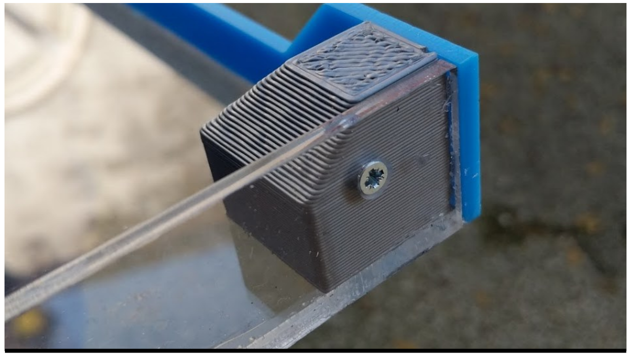


Figure 21.16: Strengthening the drawers

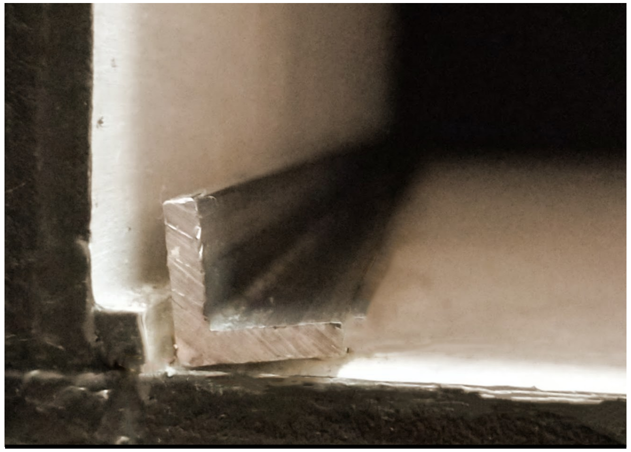


Figure 21.17: Aluminum guiding rails

The final assembly

After painting it all, it was time to bring everything together for assembly. Some extra components were introduced to make everything fit together nicely.

Connecting the electronics

The vehicle is composed of two main 12V electronic circuits: one for the driving and the R/C control and another one for the lights and the linear actuator + control system (i.e. all the electrical systems that were added for the prototype). They were connected in parallel to the battery so that the added systems would not cause damage to the existing driving electronics. The wires were routed with tie ribs along the aluminum ▶

chassis and subsequently connected (Figure 21.18).

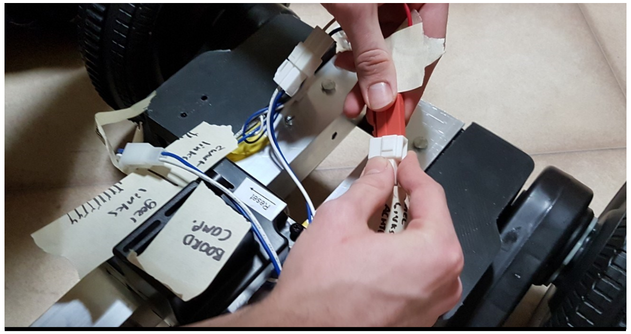


Figure 21.18: Connecting the electronics

The LED-rings were placed inside 3D printed holders which had Velcro tape (Figure 21.19) to it to attach the dark acrylic cover. These holders were press fitted into the CNC-milled part.

Figure 21.19: 3D printed LED-ring holder with Velcro

The linear actuator was fitted with a control switch and control board to make it move up and down by remote control.

To finish up the electronic work, the two parallel systems were equipped with two separate switches on the bottom (Figure 21.20).

Figure 21.20: Switches controlling the parallel systems

Assembling the pod

The assembly was quite straightforward (Figure 21.21), all components were fitting well (this was already carefully planned in the CAD-model). Stronger parts, such as the 3D prints and wood were attached by glue or bolts, depending on whether there could be a need to detach that part later. More delicate parts, such as the CNC-milled parts, were connected using double-sided tape or Velcro tape. This has a good combination of being strong, but also detachable (for maintenance).

Figure 21.21: Assembly of the pod

The finishing touch

To give it a finished look, the wheels were equipped with 3D printed (and painted) rims (Figure 21.22), which were attached with Velcro tape, so that the wheels can come off later.

Figure 21.22: Placing rims on the wheels

Also, a rubber strip was glued on to soften the edges of the lasercut, and vinyl stickers for the NFC terminals were designed and placed on the drawers (Figure 21.23).

Figure 21.23: Vinyl stickers indicating the NFC functionality

This concludes the summary of the building process. A picture of the final result is displayed on the next page. See Appendix 22 for the prototype of the app.

22. User validation

Now that the prototype is ready, it is time to take it to the doorstep of customers and examine the value that it brings as a delivery service.

Why?

The voice of the end-user, the customer, the person that actually decides to order a parcel, has not been heard since the start of the conceptualization phase. One of the goals of this project is to create a design that is 'user-friendly'. Therefore, it is important to evaluate the final conceptual design with these users, and check whether they are happy with the developments.

Expected results

As time is limited during a graduation project, the research results can be considered explorative rather than definitive.

Introduction

The users of the future system are split in multiple groups of people: logistics company workers (in service centers and hubs), maintenance workers and field assistants who would essentially be the concierges of the system. The last and largest group of users are customers interacting with the pod and/or the kiosk: their thoughts and opinions are examined in this chapter. For confidentiality reasons, the rest of the system operations cannot be shared with delivery companies at this point, limiting the user research.

Research questions

The following research questions about the user touchpoints were set up to validate the concept.

- To what extent do customers agree with being visited by this pod, instead of a human delivery person?
- Would customers prefer delivery though the kiosk or through the pod?
- Is there a difference in opinion between different groups of customers?
- What are the most important reasons for customers to choose for autonomous delivery?
- To what extent are customers currently inclined to trust the unmanned delivery through the pod?

Method

The methodology for this research is set up to make the robot delivery service comes to live in front of people, at their home. It is essential that participants feel that they are there by themselves, interacting with the pod.

For this test, 22 participants, acquaintances and friends of friends — unfamiliar with the project, were visited in their home, and asked to imagine that they had ordered something online. They were then given an iPhone running a prototype of an app (Appendix 22), providing tracking information about the parcel.

Then, the pod entered the scene, and stopped near the door or on the sidewalk near the house. It quickly explained the advantages of autonomous delivery (Figure 22.1) through a custom soundboard and proceeded to instruct the customer to open the drawer through the app. The customer then took the parcel out (Figure 22.2), closed the drawer and the pod drove away.

> Hello, I am a delivery robot.
> In cooperation with other robots, I deliver the things that you order online. Because I am a robot, I am never tired, that is why I deliver 24/7. I am efficient and electric therefore, my parcel deliveries are cheaper.
> Because I am a robot, I do not get paid by the hour, therefore I could - for instance - wait until you come home.
> Next to delivering parcels I can also come to pick up a parcel, for instance a return shipment.
> Use the app to unlock me.

Figure 22.1: The introduction of the pod

Afterwards, participants were presented with a short survey, which they were asked to complete on an iPad.

Figure 22.2: Impression of the user test: taking a parcel out of the robot (more video stills of the user test in Appendix 24).

Results

The results of the survey will be discussed in this section.

Pod and kiosk

For Figure 22.3 the willingness of people to use a delivery pod/kiosk was tested among the 22 participants. Scores range from 'negative' to 'neutral' to 'positive', with 'neutral' representing the current (human) delivery experience. The scores for both options show a tendency towards the right of the graph, indicating a positive opinion. As the standard deviation shows (displayed through error bars), the opinions on the kiosk are more divided.

Online ordering behavior & age

For the results in Figure 22.4 and 22.5, an average of the scores given to the pod and kiosk is taken, which equals a total score for the proposed new system. The grey dots represent this average. For a complete overview, the grey dots are supplemented by an orange dot that represents the average kiosk-score for that specific group, and a blue dot that represents the average pod-score for that specific group of participants.

Figure 22.4 shows the average willingness to adopt the new system, for three groups of participants with a different frequency in how often they order something online.

Figure 22.5 shows the average readiness for the system per age-group.

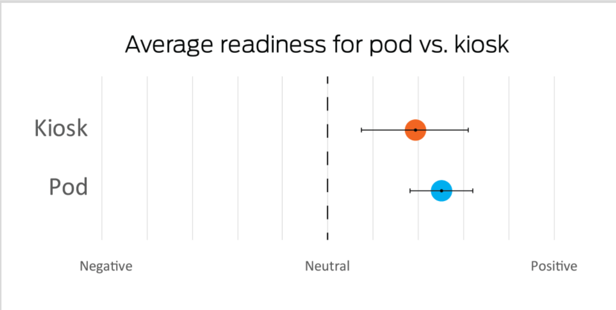


Figure 22.3: Average readiness for pod vs. kiosk

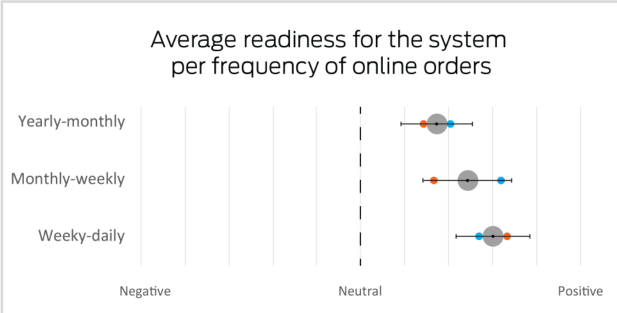


Figure 22.4: Readiness for the system per frequency of orders

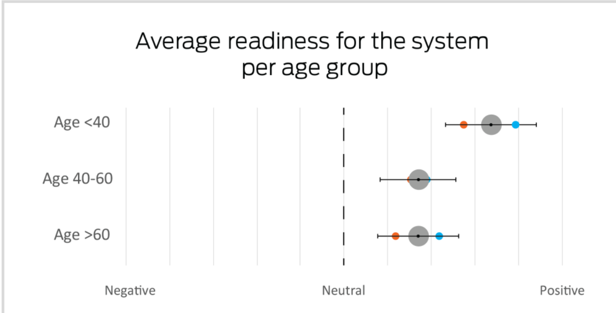


Figure 22.5: Readiness for the system per age group

Perceived advantages

The results in Figure 22.6 show an ordered list of perceived advantages. Participants were allowed to select a maximum of three advantages of the autonomous delivery system that they considered most important.

Future usage & trust

Figure 22.7 shows the categories of products participants would consider having delivered with the autonomous delivery service. Participants were allowed to select as many as they wanted, but it was stressed to only pick categories that they themselves would actually want to have delivered through autonomous delivery.

Conclusions

Overall, the pod seems to be a more attractive proposition for most people. Opinions on the kiosk seem slightly less positive, and they fluctuate more—probably because people did not get to experience the kiosk first hand.

Correlations indicate that people with a lower age, as well as people who often order things online, have a higher tendency to like the new system. No other significant correlations (on living environment, distance from city center and how often people are home) have been found.

The four most important advantages as perceived by customers across age-groups are flexibility in time, ease of returning goods, inexpensiveness, and the ability to receive orders in the evening and at night.

When it comes to trusting the new system, there is a general tendency of not wanting to use the autonomous delivery system to deliver high value items such as passports and expensive electronics.

Preliminary validation

As there is limited time within this graduation project, only 22 participants were visited during this user test. Enough to give a sense of validation, but definitely not enough to convince investors and/or higher management to invest large sums of money in executing this system. Suggestions for a more elaborate user test include a larger number of participants from different cities and living environments, delivering actual parcels that participants have ordered, having a control group with a traditional delivery system, and setting up a functional kiosk in the street as well.

Some results have been left out for simplicity, full results and qualitative feedback are to be found in Appendix 24.

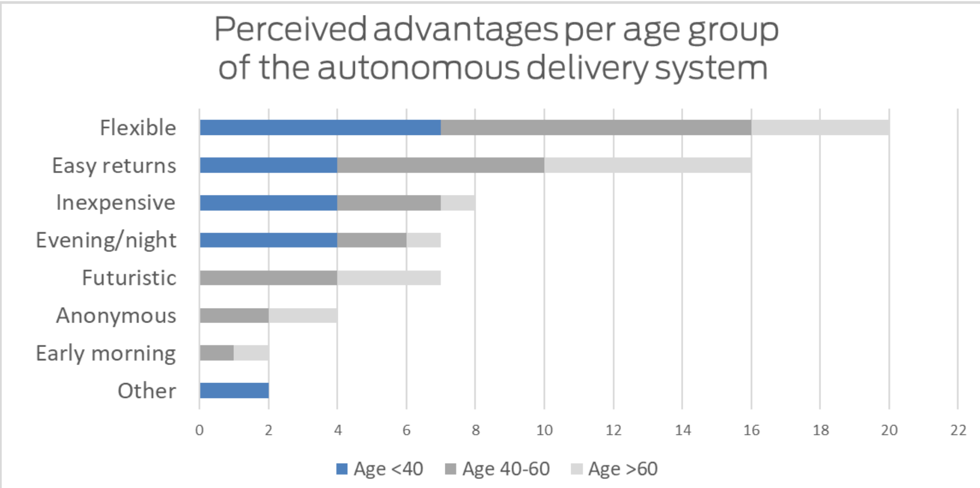


Figure 22.6: Perceived advantages of the autonomous delivery system

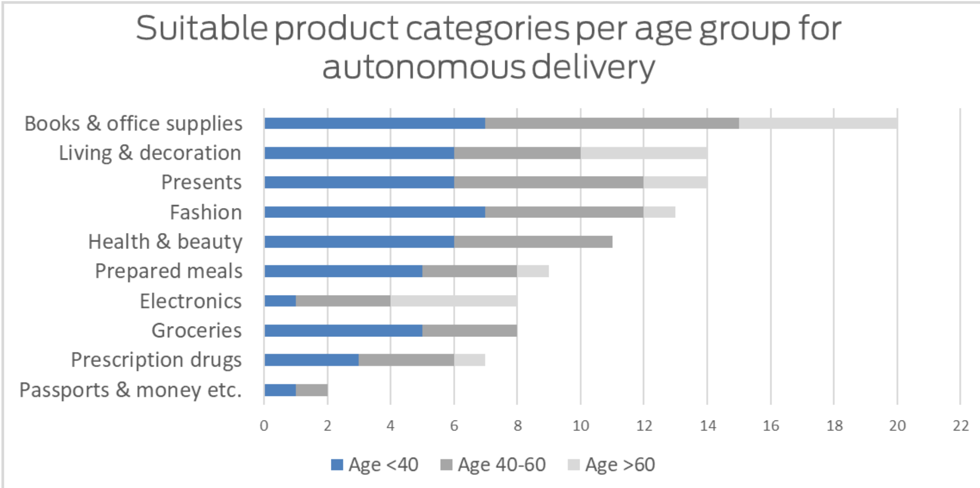


Figure 22.7: Suitable product categories for the autonomous delivery system


na 60 m
uitgezonderd

Further development

A plan for launching a robotic delivery system is detailed in this phase. After that, this report will be concluded by assessing how the eventual concept fits the original project goals, and providing recommendations for further development.

23. Implementation plan

Now that the system is preliminarily validated by its future users, an implementation plan for this concept within Ford is created.

Why?

The proposed system requires several steps, each requiring increasing amounts of funding. This seamless scalability has been a major goal since the start of the ideation phase.

Expected results

This chapter will explain how this gradual upscaling can be executed in practice. This will be done by means of presenting a roadmap, including the main stages of development, technology, organization and research topics.

Failing fast

In systems design, there is a principle called ‘Fail fast’. Practicing this principle entails experimenting a lot, and embracing the potential failure (Scott, 2018). The principle has roots in Agile methodology, and is especially suitable when trying out completely new things.

For this new system, it is suitable to take an approach like this. It is suggested to start experimenting with the most fundamental and/or least expensive elements of the system.

The roadmap on the next page shows a four year plan for implementing the new system. This is a suggested plan from the current standpoint. If experiments indicate a different route or system setup could be more suitable, the plan should be altered immediately. Therefore, the end of each ‘stage’ in the top section of the roadmap can be seen as a ‘gate’ - a decision moment, whether or not to continue in the planned way.

Scaling up in stages

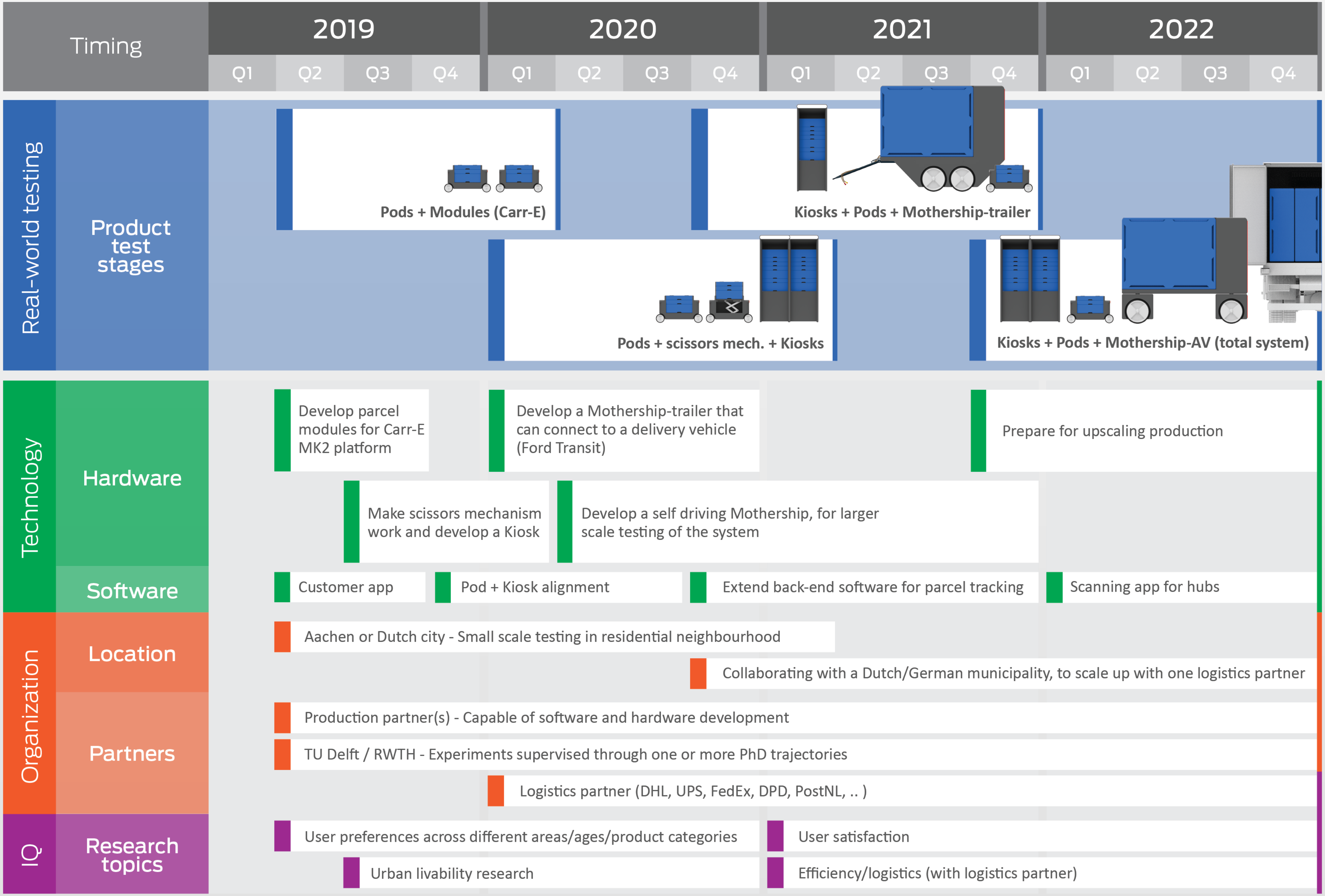
As the plan on the next page indicates, scaling up can be approached in several steps.

- **Stage 1: Pods + modular containers**
  During the first step, the Carr-E MK2 platform can be fitted with modular containers, allowing parcels for multiple recipients to be carried. This allows for more elaborate testing of the robot delivery concept—before working with a logistics partner.
- **Stage 2: Pods + Kiosks + Human restocking**
  A logistics partner (e.g. DHL) can join the experiments. Delivery personnel can leave the parcels for a selected neighborhood in a set of kiosks, from where the robots can do the deliveries. During this step, the full front-end of the system can be validated with users, and the UI can be finetuned.
- **Step 3: Pods + Kiosks + Mothership-trailer**
  Extending the trial with the logistics partner, a larger area could be served by adding a trailer which can be placed in a central location by a delivery van (Ford Transit) and functions as a mothership.
- **Step 4: Pods + Kiosk + Mothership-AV**
  This is the situation as explained in the concept. There are pods which can handle modular containers autonomously, there are kiosks which function as decentralized pickup points, and there is an autonomous mothership for bringing and returning parcels to/from the neighborhood. This stage is essentially about making everything cost-effective and competitive.

Managing the implementation

Management of the implementation plan can be done at Ford internally, at an external company (joint-venture or startup), or at a university.

The core management team preferably needs (1) a lead (system) designer for integrating business-, user- and technical demands (2) an expert from a production partner that can fund and plan large scale manufacturing and (3) a transport/logistics engineer from a logistics partner for a seamless introduction in real-world parcel delivery.


Timing
2019
2020
2021
2022
Q1
Q2
Q3
Q4
Real-world testing
Product test stages
Pods + Modules (Carr-E)
Kiosks + Pods + Mothership-trailer
Pods + scissors mech. + Kiosks
Kiosks + Pods + Mothership-AV (total system)
Technology
Hardware
Develop parcel modules for Carr-E MK2 platform
Develop a Mothership-trailer that can connect to a delivery vehicle (Ford Transit)
Prepare for upscaling production
Make scissors mechanism work and develop a Kiosk
Develop a self driving Mothership, for larger scale testing of the system
Software
Customer app
Pod + Kiosk alignment
Extend back-end software for parcel tracking
Scanning app for hubs
Organization
Location
Aachen or Dutch city - Small scale testing in residential neighbourhood
Collaborating with a Dutch/German municipality, to scale up with one logistics partner
Partners
Production partner(s) - Capable of software and hardware development
TU Delft / RWTH - Experiments supervised through one or more PhD trajectories
Logistics partner (DHL, UPS, FedEx, DPD, PostNL, ..)
IQ
Research topics
User preferences across different areas/ages/product categories
User satisfaction
Urban livability research
Efficiency/logistics (with logistics partner)

24. Conclusions & recommendations

This last chapter concludes the journey of this graduation thesis, and some suggestions for further development are summarized.

Why?

As with most things in life, the time that can be spend on a graduation project is limited. Therefore, there is more to work on. This last chapter gives a summary of what has been developed during this project, and lists some tips on what can be looked into during further studies.

Expected results

The expected outcome of this chapter is an assessment of whether the goals that were set in this project were met. Also, recommendations for further development are summarized: subdivided into technologic, livability and user interaction concerns.

Conclusions

Looking back at the original project statement, *"to (A) conceptualize an urban autonomous delivery system for (B) European cities that is (C) technically feasible, user-friendly and fits the (D) Ford business", the following can be concluded about the success of the project.*

(A) An autonomous delivery system

During this graduation project, a conceptual system of delivery products (vehicles and static elements) was created. This system fits the newly found requirements for livability, scalability, daily parcel volume and flexibility in time and place. The delivery system is tailored to a future in which the need for delivery has increased to up to one delivery per house per day. By studying current high-volume logistics networks, the system is designed to be compliant with logistical back-end operations such as parcel sorting centers and urban hubs. Also, the dimensioning of the pods is justified by building a model based on real-world living environment parameters.

(B) European cities

The concept was developed based on analysis and research within the European context. The scope of this underlying research was the Netherlands and Germany — with a short trip to the UK in between — as these were the most approachable places. In the end, the user touchpoints of this system were preliminarily validated by 22 inhabitants of the city of Leeuwarden (the European Capital of Culture).

(C) Technical feasibility

The final concept does not rely on futuristic hardware that is unavailable today, which was the main goal in 'technical feasibility.' Granted, like most other conceptual vehicles, this system will need some engineering steps before they actually gets produced.

The pod is relatively straightforward, and can be directly based upon the Carr-E MK2 platform that has already been developed. Constructing the mothership and making it drive autonomously is more challenging. A good example of an engineering challenge here is the relatively high center of mass of the mothership. As it is a low speed vehicle that is considerably smaller than a Ford in length, width and height (Figure 24.1), this should be a manageable task.

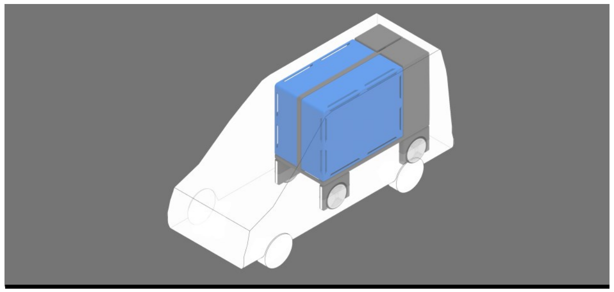


Figure 24.1: Mothership compared to Ford Transit L2H3

(D) The Ford business

The hardest part to consider in this project was to tailor the proposition to the Ford business. There seem to be a lot of unwritten/unspoken rules about what makes a concept a Ford-concept. Next to that, for this new and futuristic design, Ford wanted to put less emphasis on its heritage, and more on the future opportunities.

Recommendations

For future research and development, here are some recommendations. Recommendations are based on insights from working on this project and feedback from users and other experts.

Technologic recommendations

▶ **Positioning of batteries**

The mothership design as presented is a bare framework: the most minimal framework that is necessary for the intended transshipment-functionality. Space for battery has therefore been a point of discussion. Figure 24.2 shows a few suggestions for battery placement: onto the back (1), widening the middle section (2), or even closing the sides (3). A decision on the best position can be made based on vehicle dynamics test later on.

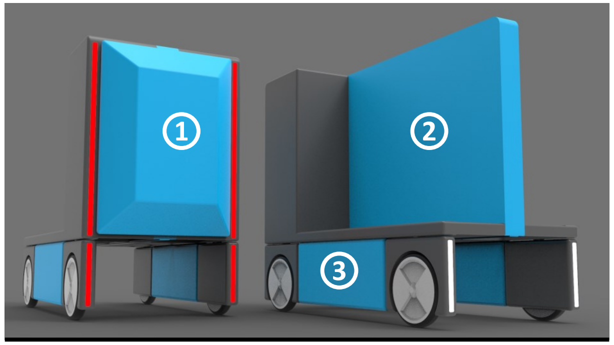


Figure 24.2: Suggestions for battery placement in mothership

▶ **Swapping batteries**

For optimal efficiency, it is important to make battery swapping as easy as possible. The time on the road should be maximized for both the mothership and the pods. For this, there could even be a small modular container (for pods) or XL-container (for motherships) that is fitted with a few batteries.

▶ **Container sizes**

The exact sizes of the modular containers should be adjusted to future needs. This can be done in cooperation with a logistics partner that has insight in the exact dimensions of parcels being shipped.

▶ **Scissors mechanism**

During prototyping, it was learned that the scissors mechanism can be quite easily constructed, but the choice of strong materials is vital. As the lifting capacity of the mechanism needs to be quite high, it is advised to construct the mechanism out of an aluminum alloy, directly attached to the frame of the vehicle.

▶ **Hub motors**

In order to connect the wheels (including hub motors) to the mothership, some more space is needed than indicated in the concept. This can be managed by increasing the width of the wheel-units outward. This also results in increased stability.

Livability recommendations

▶ **Naming of the pods**

From a livability perspective, it is important to make the workers of the system, the pods, an integral part of the community. Calling the vehicles 'Robots' instead of 'Pods' will definitely help. Apart from that, giving names to individual robots is identified as something that people seem to like.

▶ **Community**

For implementation, it is important to create a supportive community around the robots, treating them more or less like new inhabitants of a neighborhood. This can be done in close cooperation with municipalities.

User interaction recommendations

▶ **Displays in the pods**

To finish the friendly look of the pods, and their capability of interacting with the environment, there could be LED displays between the round front/back lights (see mockup in Figure 24.3) conveying simple messages or emotions.

Figure 24.3: Mockup of a possible pod-display

▶ **Tone of voice**

It could be interesting to study different tones of voice for different groups of people. This could result in a tailored interface for each person, enhancing the user experience.

References

The references to the different sources that have been consulted while writing this report are to be found on the next pages.

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