PRODUCT REPORT

AALBORG UNIVERSITY | JUNE 2019

INDUSTRIAL DESIGN | MA4-ID7

SEKUR

fusion creatives

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Title page

Title

SEKUR

Project module

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Project group

MA4-ID7

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Abstract

Dette specialeprojekt omhandler mobilitet i arbejdssituationer for ejendomsserviceteknikere i Danmark med mål om at forbedre effektivitet og arbejdsgangen for teknikerne.

I Danmark findes over 600.000 offentlige lejemål, som huser mere end 40% af den danske befolkning. Fælles for disse offentlige lejemål er, at en del af huslejen, der betales månedligt, går til istandsættelse og service af ejendommene. Til disse opgaver er ejendomsserviceteknikere ansat og varetager hovedsageligt opgaver som reparationer af lejemålene, kontrol med forbrug af vand og varme samt den daglige drift. De seneste år har boligforeningerne været underlagt en solidarisk effektiviseringsplan, hvilket har betydet stor omlægning af den daglige drift og arbejdsopgaver for den enkelte ejendomsservicetekniker.

Dette projekt tager udgangspunkt i målet om effektivisering af den offentlige boligsektor og arbejder med at optimere arbejdsgangen for både økonomisk gevinst i boligforeningerne, men i lige så stor grad for at give den enkelte ejendomsservicetekniker bedre forhold til at håndtere de opgaver, der giver større arbejdstilfredshed. SEKUR er en løsning til transport og organisering af værktøjer og materialer på cykel, som støtter ejendomsserviceteknikeren i at have muligheden for at have det korrekte værktøj med til ofte dårligt definerede opgaver. Dette sparer teknikeren for spildt transporttid og frustration over at mangle det nødvendige værktøj.

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SEKUR

Introduction

In Denmark, more than 40% of the population live in the 600.000 public housings spread across the country. (dst.dk, 2019) Public housings are rental properties that typically are paid for on a fixed rate each month. (danmarkbolig.dk, 2019) Part of this rent is used to employ Property Maintenance Technicians whose job it is to manage the daily operations in the housing associations.

Since 2016, the public housing associations in Denmark have agreed to lower operations costs by 1.5 billion Danish kroner until 2020 in a streamlining plan - something that has caused a new working situation for the Property Maintenance Technicians. (almeneffektivitet.dk, 2019)

Prior to the streamlining plan agreement, the technicians spent most of their time keeping the outdoor areas of the departments tidy, handling garbage and monitoring usage of water, heat and electricity. At that time, when residents had technical issues in their apartments, the housing associations would outsource the tasks to electricians, plumbers, carpenters or other craftsmen.

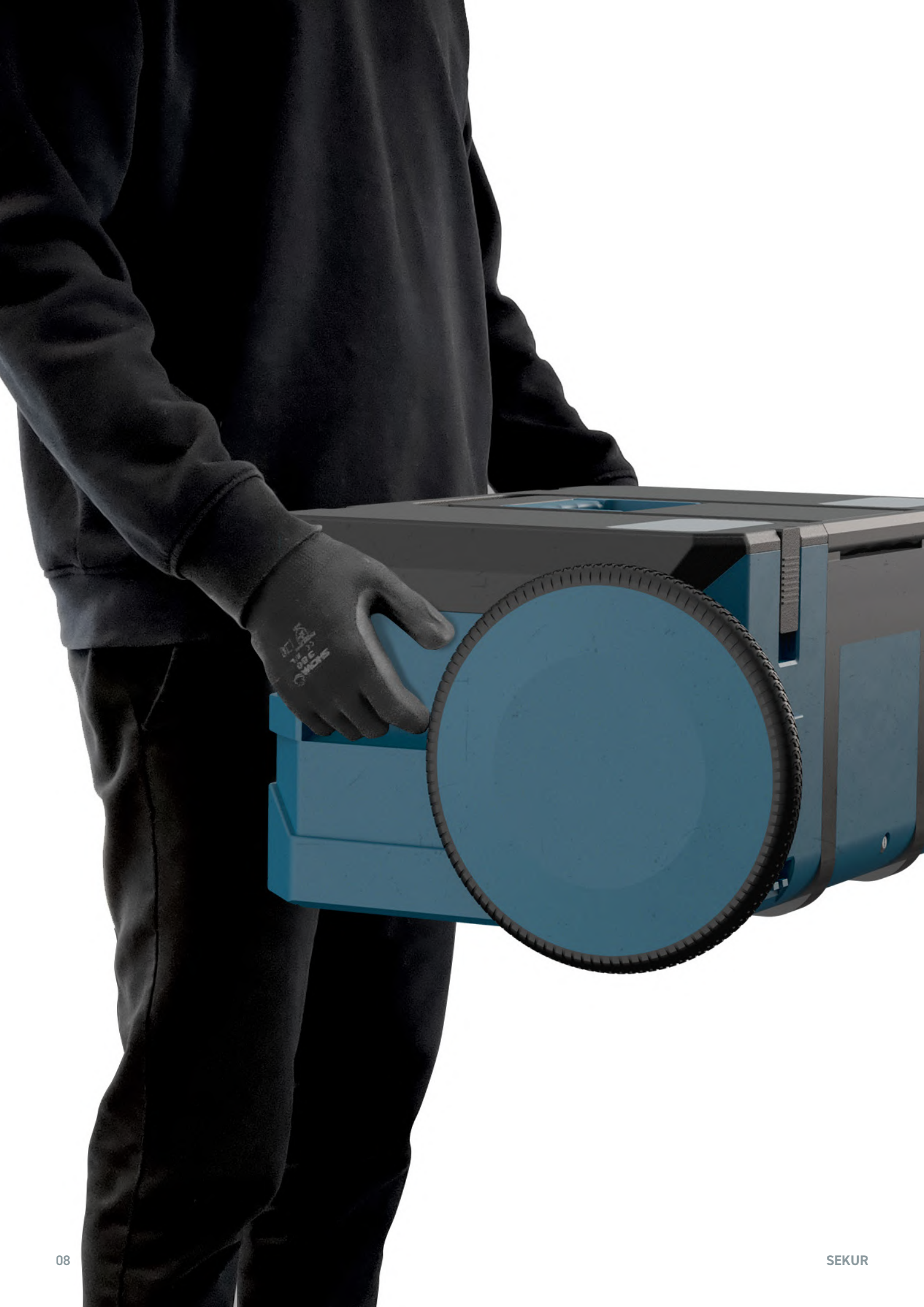
Today, to lower the operation costs, the housing associations ask the Property Maintenance Technicians to take care of these tasks. These residential tasks that previously were small tasks and a small part of the job suddenly became the overshadowing part of the job.

The housing departments are often dense areas with short distances between buildings and apartments. To get around between tasks, many Property Maintenance Technicians use bikes that are convenient and able to get through narrow passages.

However, the bikes are a means of transport brought along from before the streamlining plan and have not been developed to the new circumstances for the Property Maintenance Technicians. They are still a very cheap option compared to other motorized vehicles seen in the departments, and they are still perfect for getting around swiftly between tasks and locations. What they are not suited for are the many changing tasks during the day and the large amounts of tools and equipment these require. To overcome this problem, the technicians have developed their own solutions - often in the form of milk crates installed in front and back of the bikes - that partly solve some of the difficulties of bringing heavy tools around on two wheels.

Streamlining of
1.5 bio.
Danish kroner
before 2020

*based on observations



SEKUR HIMO 39

SEKUR HIMO 39 is the new toolbox developed to support craftsmen that need to be highly mobile in urban areas. The SEKUR attaches to any standard dimension bicycle and instantly transforms it to a high capacity utility vehicle that stores most tools and equipment for small and medium-sized tasks.

Currently, there are no available products that are specifically designed for transporting tools and materials on traditional bicycles and which provide safe storage when left unattended. The traditional bicycle is a low-cost investment and able to go through the narrow spaces of the city, making it a perfect choice for employers and workers that navigate in cities with traffic and limited parking options.

SEKUR is developed to provide a smooth transition from riding the bicycle to rolling the SEKUR toolbox along when the bicycle is parked. Being specifically targeted towards working in the urban scene, the obstacle of stairs and elevations has been a key area to develop the SEKUR to pass with ease. With the two large wheels on each side of the toolbox, it is possible to roll along and up stairs to lower physical strain on the user.

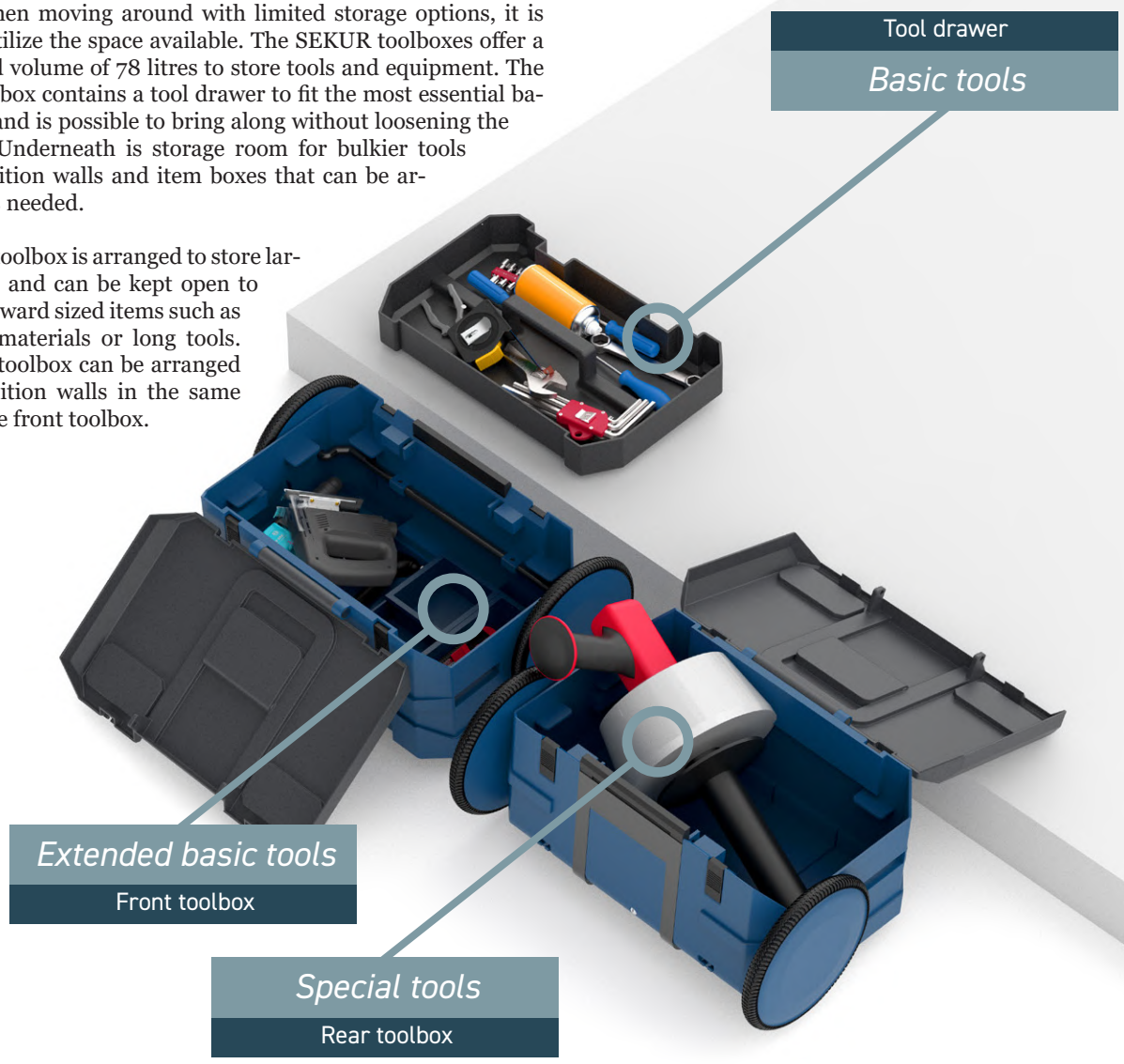
- ***Safe storage***
- ***High capacity***
- ***Fits any standard bike***
- ***Uncompromised mobility***

SEKUR HIMO 39

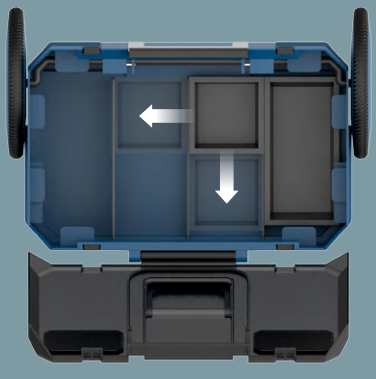
Bringing the right tools

Property Maintenance Technicians and other craftsmen have large toolsets with basic tools to handle the most common tasks and more specifically oriented tools and equipment for other tasks. When moving around with limited storage options, it is vital to utilize the space available. The SEKUR toolboxes offer a combined volume of 78 litres to store tools and equipment. The front toolbox contains a tool drawer to fit the most essential basic tools and is possible to bring along without loosening the toolbox. Underneath is storage room for bulkier tools with partition walls and item boxes that can be arranged as needed.

The rear toolbox is arranged to store larger items and can be kept open to store awkward sized items such as buckets, materials or long tools. The rear toolbox can be arranged with partition walls in the same way as the front toolbox.



Organizing



Item boxes can be moved around between partitions

Partitions can create small and large separations in the toolboxes

Joinable toolboxes help minimizing strain

When carrying around two toolboxes, it often becomes strenuous if carried by hand. On top of each SEKUR is a slot that is similar to the one on the bike rack and makes the toolboxes fit on top of each other. When placed in this slot on another SEKUR, the toolboxes can be joined by the four hinges found on both longsides. When joined, the toolboxes can either be lifted and carried by the handle on top or by retracting the telescopic handle and roll the toolboxes along on the wheels.


SEKUR
SEKUR

Theft-proof in urban environments

Leaving expensive tools and equipment unattended and unlocked in crowded environments almost calls for theft. To secure the toolboxes, a central locking system ensures the SEKUR toolboxes are locked to the rack which is safely attached to the bike. In continuation of the attachment to the rack, the lid is locked by two electric locks, preventing the lid to be opened for access.

To unlock and gain access, the user must display a RFID tag on the front of the front toolbox and back of the rear toolbox to unlock the central locks. The RFID tag is small and fits into a keychain or can be worn in a wristband for even less hasslefree interaction. When presented, the locks will open for the user to deattach the toolbox from the rack and open the lock. When toolbox and lid are left for more than two minutes, they will automatically lock themselves.

With you all the way to the task

SEKUR is developed to assist the user all the way from workshop to the apartment. Working on tasks in apartments in urban areas typically means travelling a short distance on roads or paths, walking to stairways and finally taking the elevator or stairs before arriving at the task destination.


SEKUR
SEKUR

Safe in all environments

During winter time, Property Maintenance Technicians work many hours in the dark. With large parts of the job consisting of moving around on roads and between buildings, it is important that they are visible to other road users. Using a reflective adhesive material on selected areas of the SEKUR, the Property Maintenance Technicians are visible from all angles when lit upon.

Market approach

Cost price

SEKUR's cost price depends on the materials and components used. The price of PPC plastic and 7020 aluminium is estimated on the weight of resin and amount of sheets, respectively, whereas the price for standard components vary, depending on the quantity needed.

Distributor and retail price

The retail price of SEKUR is in the price range of similar top of the line toolboxes on the market. Distributor price is 3000 Danish kroner and with mark-ups, the retail price is at 7000 Danish kroner.

Cost price
445 DKK

Distributor price
3000 DKK

Retail price
7000 DKK

Project start

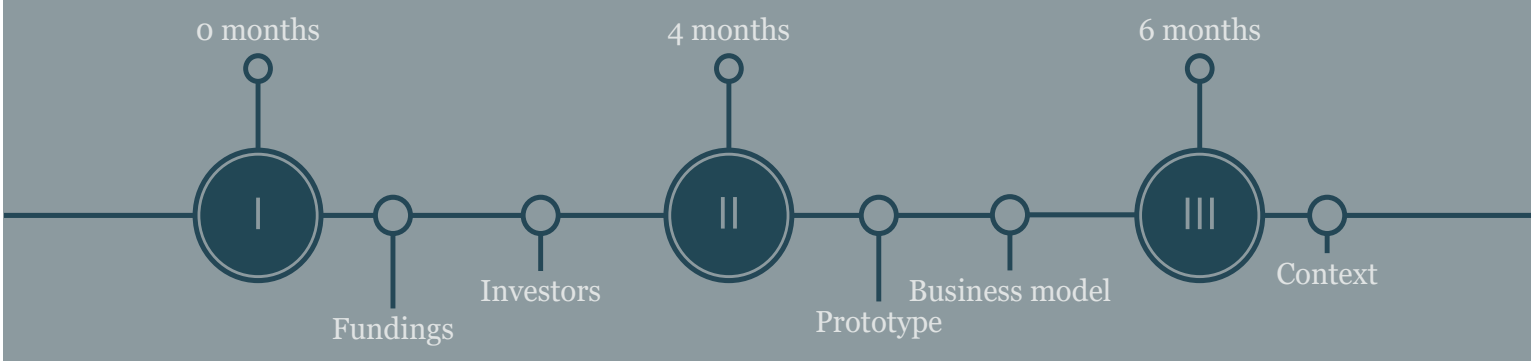
To kick off the project, SEKUR will seek fundings and interest from investors. The team will need to finance initial production costs e.g. facility rent, purchase of machinery, moulds and labor.

Development

Prior to developing a product, SEKUR will utilize their own competences to create a functional prototype but also use outsourced expertise for material and technical engineering.

Testing

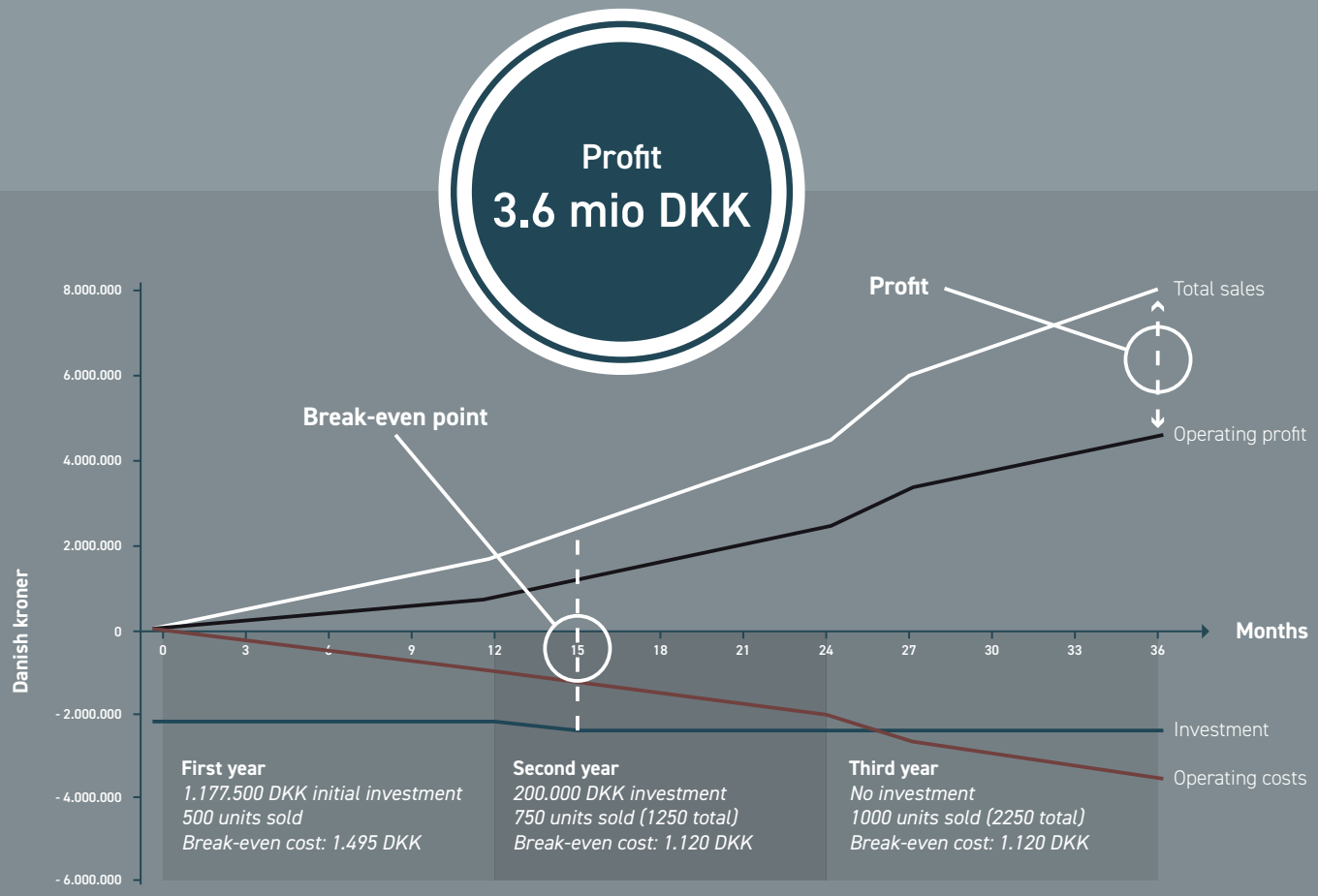
The initiation of the prototype as well as functionality of electrical components and strength of materials will be tested. For sufficient test data, SEKUR will be exposed to a variety of relevant contexts.



Implementation

Payback time

With an initial investment of 1.17 million Danish kroner and an estimated 500 SEKURs sold within the first year and 750 sold the following year, the payback period will be reached 14 months after production start. After three years and 1000 units sold - 2250 units in total during three years - a total profit of 3.6 million Danish kroner will be obtained.



Final development

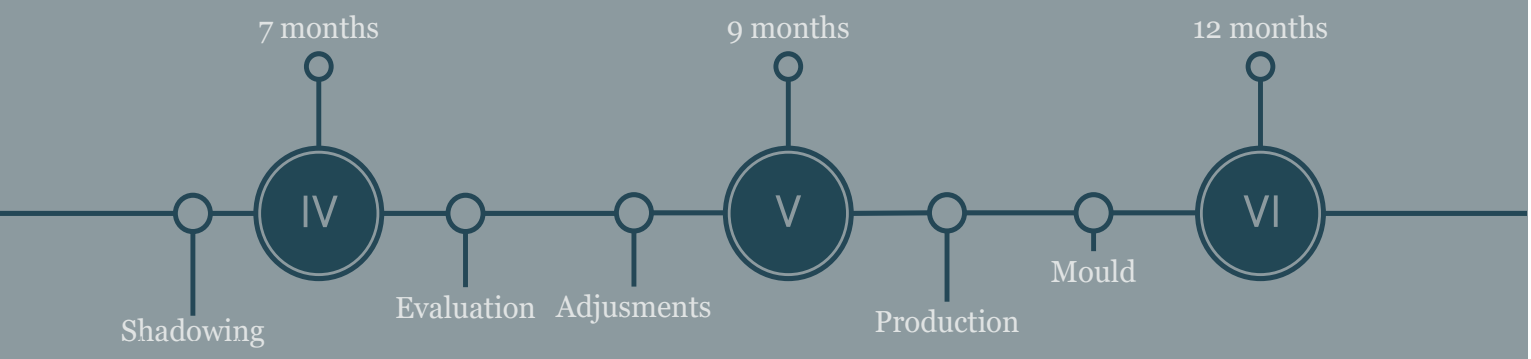
The feedback from the prototype and findings from observations will be evaluated. The identified changes will be added to the final production of the SEKUR.

Manufacturing

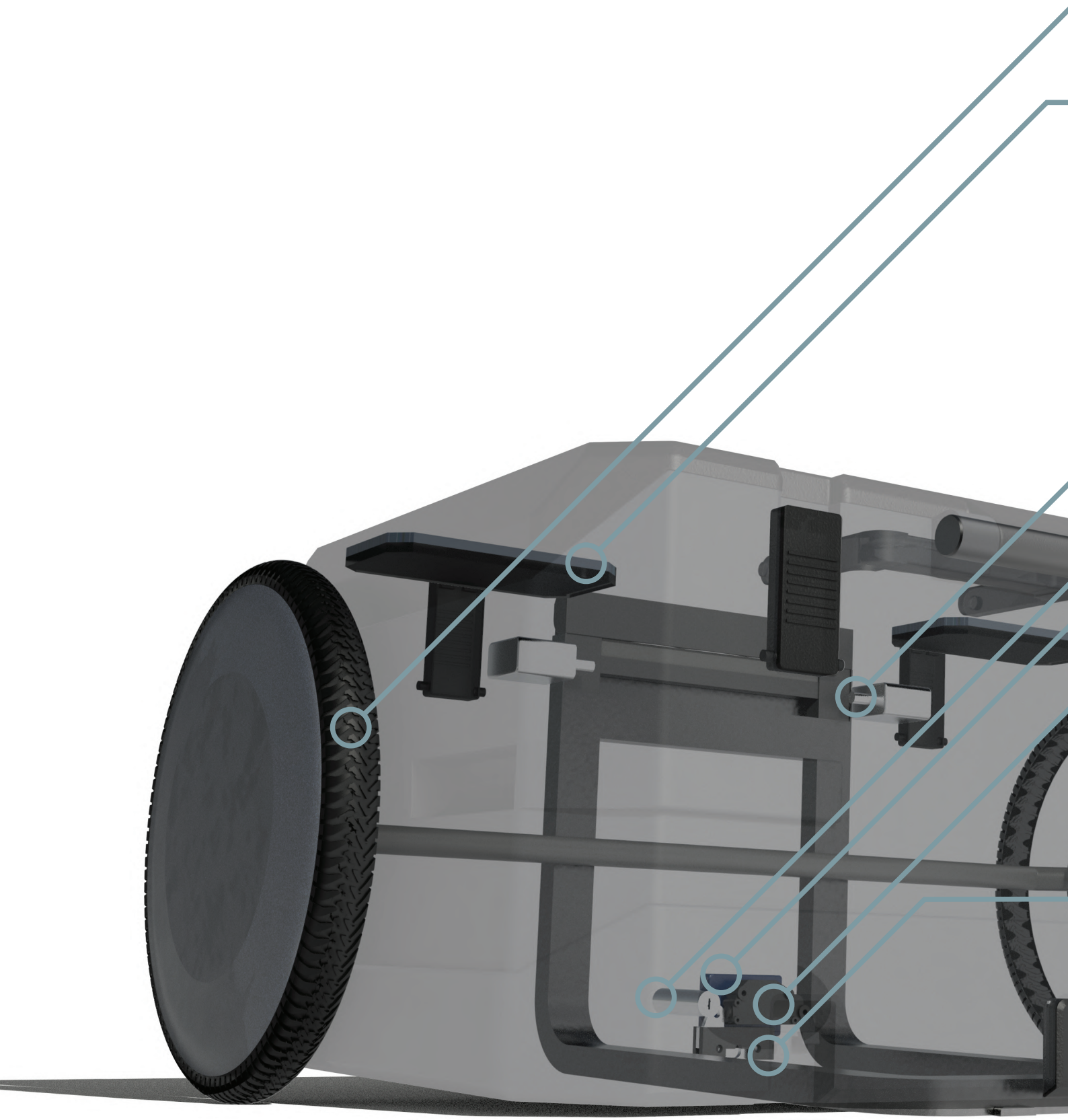
SEKUR is ready for production and the invested materials and machinery will be used. Alongside the manufacturing of the physical product is the production of packaging for the product.

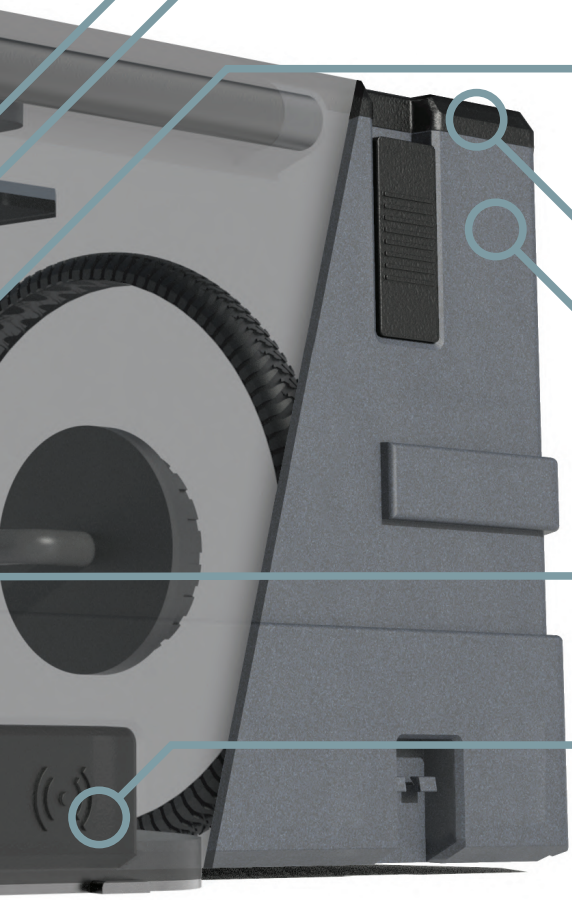
Launch

To launch SEKUR, the team will use external labor. Expertise in business approach will help pursuade potential users of SEKUR to invest in the product.



Components and construction





All-terrain tires

Durable solid rubber tires with thread designed for passing through uneven terrain and grip the stairs when rolling up.

Solar powered system

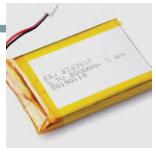
Two solar panels on top of the SEKUR absorb sunlight and generates electricity for the battery. Full charge of battery is four hours.*

Bolt locks prevent theft

Two bolt locks prevent the top lid from being opened when not activated by the RFID reader.

Mechanic lock for safety

The mechanic lock ensures access to the SEKUR if the electronic system fails or battery is empty. A key will open the SEKUR.



2000 mAh battery

The centrally placed battery powers locks and RFID reader. On a full charge, the system is tested to endure a full working week.**

Push actuator

The push actuator is activated when a positive RFID ID is swiped on the front of SEKUR, releasing both locks in lid and from the rack.

Sturdy materials

The SEKUR lid and box are injection-molded using polypropylene copolymer - a material that is highly resistant to impacts and scratching.

Reinforced casing

The polypropylene copolymer is molded with a 3 mm double-walled thickness, securing a light and resistant product at 4.7 kg.

Latch lock

The latch lock ensures the SEKUR is fixed to the bike rack when left unattented, providing safety and preventing theft.

RFID reader

The RFID reader on the front of the SEKUR registers IDs from the PMTs and makes sure SEKUR is only accessible by authorized personnel.

* Based on perfect sunny conditions - charge time may be higher when cloudy

** One working week consisting of 37 hours and regular use

Literature and illustrations

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PROCESS REPORT

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Reading guide

This Master's thesis project is documented in two reports; firstly the process report that documents the development of the design process including reflections and conclusions and secondly the product report that showcases the final design proposal. Enclosed material is appendix that includes various investigations, data sheets and finally the technical documentation of the final design proposal. The team recommends reading the reports in aforementioned order; product report and then the process report. References are listed using Harvard referencing (Aarhus Universitet, 2015) and are indicated by the format: (Author, year). Figures and tables are numbered according to the phase number, ie. figure 02.3 describes phase 2, figure number 3). (Jensen, A. N., Bie, S. B., Holmgreen, U., 2019)

Preface

This project is a Master's thesis in Industrial Design at Aalborg University. The project has been carried out from the 20th of March to the 6th of June in close collaboration with Sundby-Hvorup Housing Association.

Thanks to...
... supervisors Louise Møller Haase and Raino Mikael Larsen for feedback and guidance throughout the project.

... staff from housing associations John Martin Sørensen, Søren Spaun, Peter Ingemann, Kent Jørgensen, Ole Fauerholt and Henrik Lykholt for continuously providing insights and feedback to the team and always being helpful.

Working hypothesis

The working hypothesis was implemented in the initial phases of the project based on reports in national media on issues of craftsmen having problems getting to customers in urban areas and personal observations of PMTs at housing associations moving around in the city on bicycles carrying their tools and materials. This created the spark for the initial working hypothesis; do PMTs move around in an effective way? Is it possible to be a craftsman, with all the tools and materials that includes, on a bicycle? This lead to several visits to different housing departments that confirmed, corrected or expanded the understanding of the issues, ultimately leading to a specification of requirements that sums up latent as well as obvious needs.

Throughout the report, the following icons will mark significant events, insights or defining discoveries - with a description to follow.

Finding

Finding - new finding or discovery that creates the frameset for the user needs.

Correction

Correction - new insights or events change the course of the process radically.

Confirmation

Confirmation - a hypothesis or working principle has been substantiated.

Elaboration

Elaboration - something needs further clarification before moving to next step or phase.

User need

User need - a user need has been discovered, either directly or latently. Describes both needs elicited from users as well as design needs discovered through research and testing.

Word abbreviations

Following words are recurring during the report and will be mentioned by their abbreviation from this point.

PMT: Property Maintenance Technician

PM: Property Master

SBH: Sundby-Hvorup Housing Association

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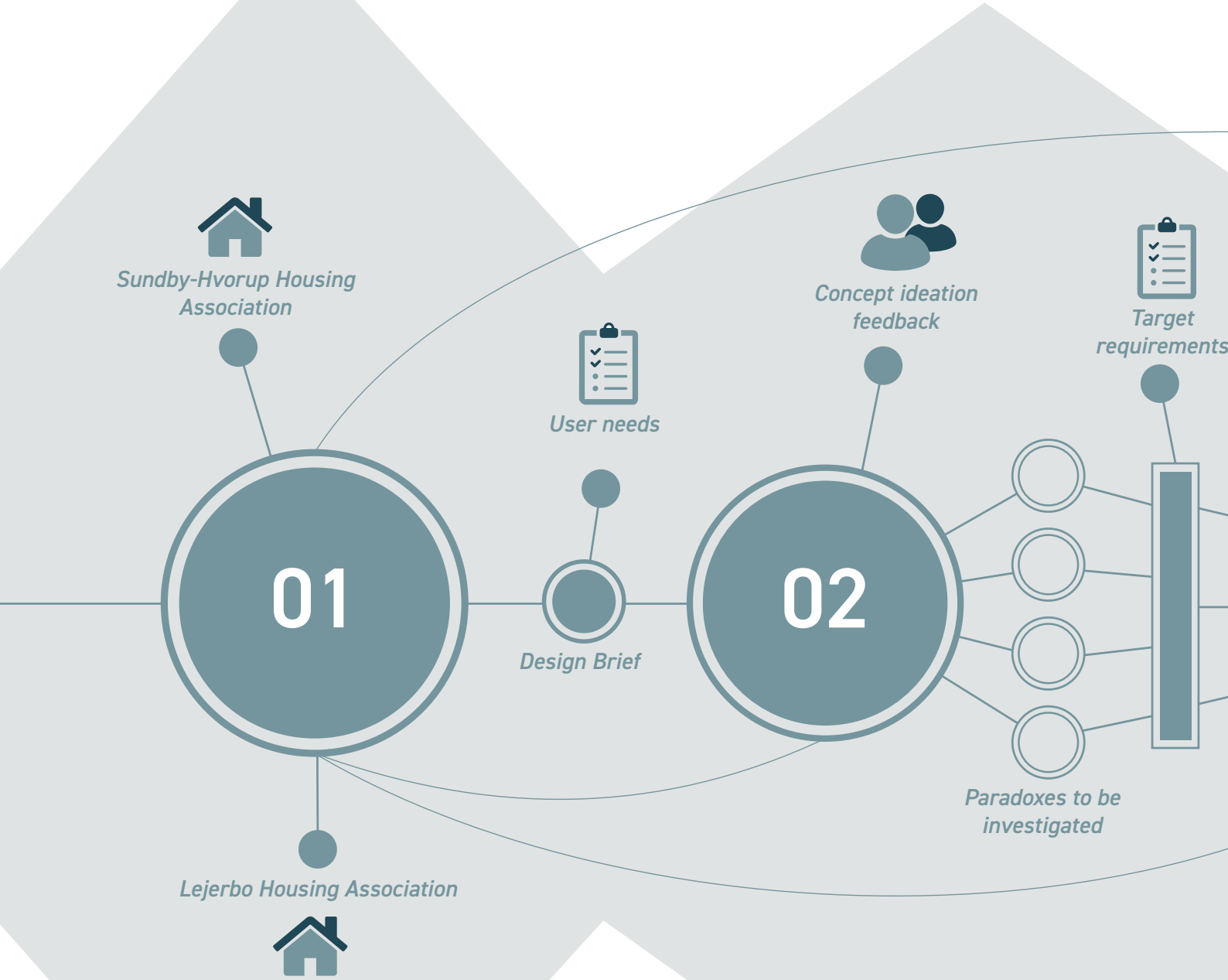
INTRODUCTION

00.1 | Process model



Process model

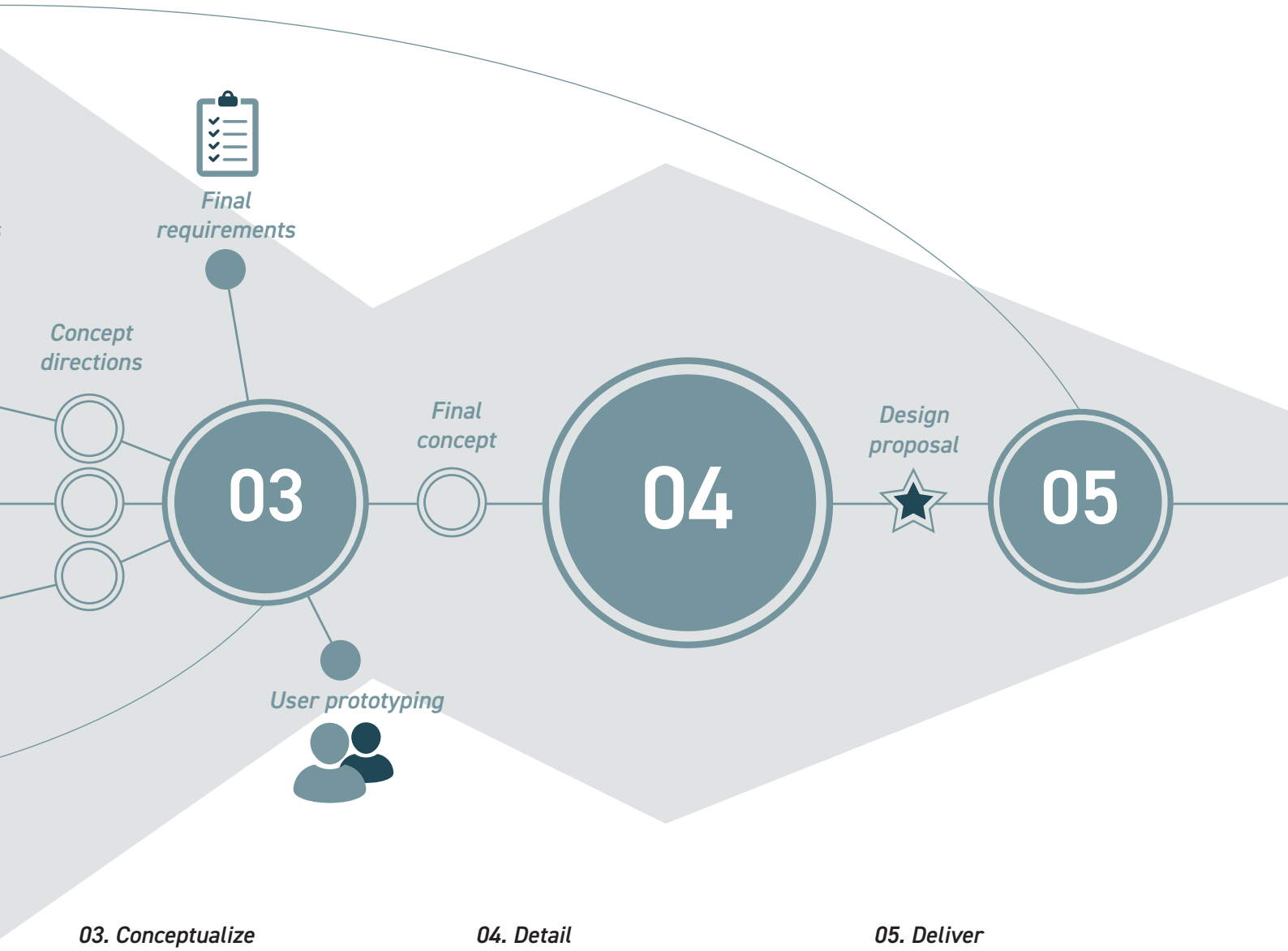
This illustration indicates how the design process have progressed throughout the project. It is displayed as a lineary process with iterations between the phases. The size of each circle indicates the amount of time spent in each phase.

01. Understand

The first phase consists of research and initial findings from the context and the focus group. Further during this phase the market and business potential have been investigated to ensure the future potential of a design solution. All findings are presented in a design brief in the end of the phase, before initiating the ideation phase.

02. Ideate

Utilizing the findings from the previous phase the team investigates possible solutions and ideas. Four different paradoxes were identified based on interviews with the focus group. These were all challenges in order to explore the full solution space.
Before initiating the conceptual phase the four paradoxes were combined in three concepts, which all comply with the established target requirements.



03. Conceptualize

With the final requirements specified, the concept development narrows down to one clear concept that combines the qualities from the three concepts in the ideate phase. This leads to iterative phases with emphasis on feedback from the user group, testing of functional models and defining the visual characteristics that ultimately defines the boundaries of the concept.

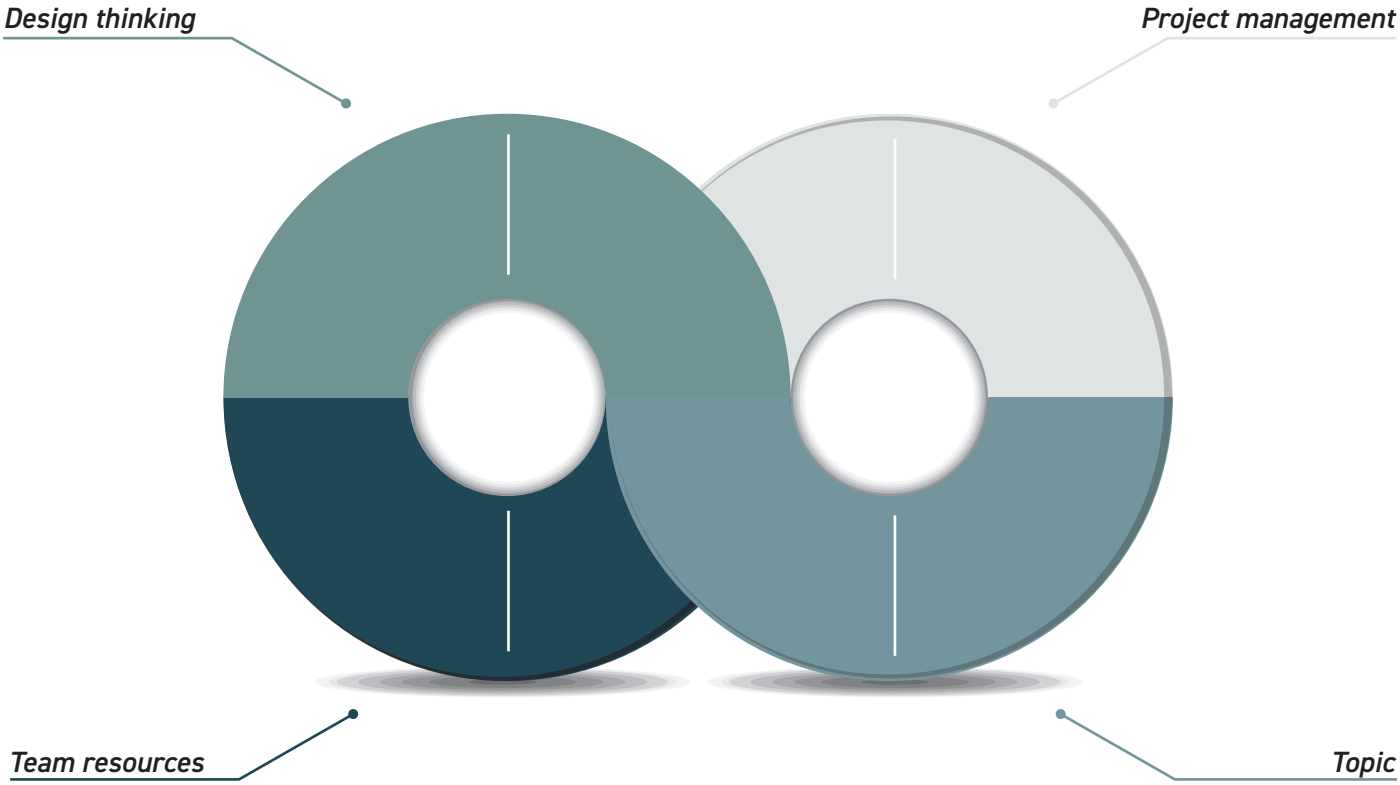
04. Detail

In this detailing phase, the final decisions in regards to materials, production and final principles are made clear. Different approaches and courses of action are discussed and weighed against each other to ensure making the most sensible decisions. The result is a fully defined final concept.

05. Deliver

The final phase consists of the business aspects of the realization of the concept. This includes a business plan and thoughts on how to launch a product as well as a strategy.

00.2 | Approach



Design thinking
The methodology used for this master thesis project is characterized by design thinking by combining all the different aspects of a design process into an integrated solution.

The focus of this project is to streamline the daily work of the PMTs by motivating them in their work and utilizing their time for meaningful tasks. The PMTs have been actively involved in the whole design process; from understanding their daily work life with unsatisfactory 'dumb' tasks to providing feedback on concepts and testing out prototypes.

Different methods within qualitative and quantitative approaches have been used to collect data, which together have created the foundation of the project. Based on the collected data, the team created requirements for the project and used these to design upon. Decisions and improvements on the concepts were made through tests and feedback from the users.

Team resources
The team consists of three individuals with different professional skills as well as preferences. The team has their strength in the mid to final stages of the design process. This provides the possibility to improve personal competences within the early stages and ensures that the motivation for the project is high and work ethic is high.

Project management
This project has been managed by using daily scrum meetings two to three times a day; in the morning, at noon and at the end of the day. This was done to ensure sharing of knowledge between the team and plan future tasks in collaboration. The team has also used timeboxing to increase effciency within the different tasks - this was done due to previous experiences where the team often spent a lot of time discussing instead of producing material.

Topic
This Master's thesis project is about increasing efficiency in the working environment of the PMTs. The team finds it an interesting topic as it is an opportunity to create value for a large user group in a real context. Furthermore, it is also interesing to work with a focus group of professionals who has specific demands and wishes for a new product - compared to a mass produced product designed for everyone.

01/

UNDERSTAND

This phase introduces the problem from a larger perspective and scopes to the specific user group and context that serves as the foundation for the process. After introducing the bigger perspective, exemplary dives into the daily struggles of the user group, coping strategies and motivations are unveiled to create an in-depth understanding of the context.

After that, an early clarification of business potential and competitors follows - leading up to the design brief that sets the constraints for the following ideate phase. Alongside understanding the project frames, a parallel concept sketching phase is performed to liberate immediate ideas and thoughts.

01.1 | Craftsman transport in Denmark

In Denmark, most craftsmen are depending on their vehicle on a daily basis in order to go to customers. In fact, most actually view the vehicle as their most important tool in their daily operations (hfk.dk, 2019). The vehicle works as a tool for getting to customers. The popularity is also evident when looking at the numbers; in 2018 more than 33.000 new vans were registered and company transport accounted for 14% of the total transport in Denmark in 2016 (bilimp.dk, 2019, Danmarks Statistik, 2017). The types of craftsmen depending on their vehicles differ across many different crafts - carpenters, painters, locksmiths, woodworkers and the list goes on.

In recent years, with the increasing number of traffic on the roads, it has become more and more difficult for craftsmen to find parking spaces close to their customers and especially in the urban areas. This has actually led to more than one third of asked companies in Copenhagen turning down customers because it becomes a big problem having to go look for parking spaces and potentially waste time and in worst case not being able to park within reasonable distance (TV2 Lorry, 2017).

To overcome the problem, more and more craftsmen choose alternative transport forms. Various types of the bike has proven very efficient in the busy traffic, making it faster to get to the customer and park nearby (bygtek.dk, 2018, minby.dk, 2016). One of the popular bike variations is the cargo bike with its practical and rather voluminous storage capacity, perfect for craftsmen doing small tasks that does not require bulky tools or equipment (TV2 Østjylland, 2019). Often, these cargo bikes are assisted by small electric engines, making it a breeze to move forward at a steady pace and the electric bikes are really something that has gained popularity in recent years with sales skyrocketing year after year (Statista, 2019).

246%

INCREASE OF E-BIKE SALES IN DENMARK FROM 2013-2016.

(statista, 2019)

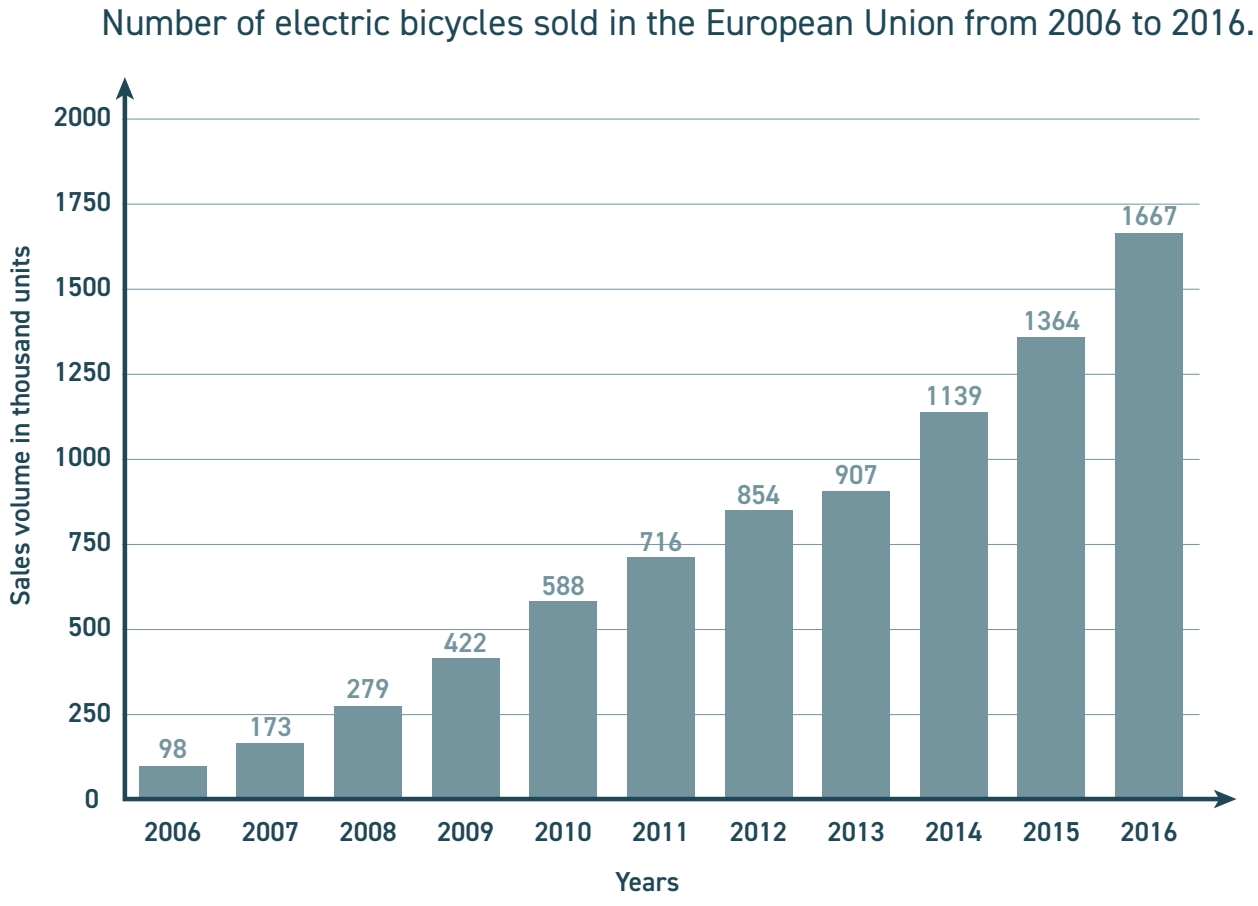


Figure 01.1 *Statistics over the number of electric bicycles sold in Europe from 2006 to 2016 (statista, 2019).*

Figure 01.2 *A PMT on his way to an apartment where he has to take care of a faulty sink.*

01.2 | PMTs and mobility

In housing associations around Denmark, PMTs have their daily working operations. The PMTs have unpredictable workdays and always need to be prepared for sudden changes to the original plan if anything urgent occurs. PMTs are responsible for maintaining the daily operations of housing associations in regards to most of the practical work; keeping green areas neat, handling trash, controlling water and heat usage, inspection of apartments and general repairs. Typically, when something urgent occurs - a water leakage in an apartment for instance - the PMT must stop the ongoing task and take care of the leakage.

Being adaptable to sudden changes and many different work locations during the day also means that the PMTs have to be highly mobile and have access to transport around their departments to respond to tasks. In most cases, they are dependent on different types of vehicles for mobility; small tractors, golf cars, bicycles etc. Besides being mobile, the PMTs also need to be equipped to respond to the broad variety of craft trades which means that they need a big portfolio of tools and equipment to bring along.

Contrary to most other craft branches, the PMTs are often better suited moving around in smaller and mobile vehicles. This is due to the geographically small areas they need to cover - typically a couple of connected building blocks within a few kilometers. Between the building blocks and around the adjacent outdoor areas, it is not optimal to have a large vehicle. As many of the daily tasks are inside the buildings, being able to park close to the stairways of the apartments saves the PMTs a lot of walking and carrying tools and materials over distances.

The team decided to take a further look into the daily operations of the PMTs and how they move around in a dense context. During these visits, it quickly became evident that the way PMTs move around maybe could be improved - partly by listening to disconcern from the users, but also by the fact that they have a broad portfolio of different vehicles - possibly an indication that an ideal solution is still missing.

With this, the initial working hypothesis of PMTs needing an optimized type of transportation was established, leading to visits at different housing associations to observe if the need is valid and other potentially uncovered needs might occur.

1.01 The PMTs move between many locations during the day

1.02 Mobility is one of the most important things when working in the housing department context

1.03 Small and highly mobile vehicles are preferable when moving around between buildings and green areas

01.3 | Sundby-Hvorup Housing Association (SBH)

According to Statistics Denmark, there are 600.000 public housings nationwide with as much as 42 percent of the Danish population being tenants (dst.dk, 2018). Amongst these rental properties are what is called public housing associations. What defines a public housing association is that it is a non-profit association, meaning that all of the money that each tenant pays for rent is kept internally within the respective associations and is spent on maintenance of housing departments and the construction of new ones. (danmarkbolig.dk, n.d.)

SBH is one of eight housing associations that are part of a cluster of public housing associations called Bo i Nord that roams over more than 20.000 public housings (boinord.dk, n.d.) Sundby-Hvorup Housing Association has more than 4.000 public housings and much like many other public housing associations it is custom to have a Board of Directors either elected by or consisting of residents of the respective departments. Because it is the residents' money that finances the expenses for maintenance they too have influence on what the money of their department will be spent on, including delegating the finances for tools and equipment for the PMTs. (sundby-hvorupboligselskab.dk, n.d.) (alabubolig.dk, n.d.)

In 2014, however, it was decided by the government and Danske Almene Boliger to streamline the operational expenses of public housing associations nationwide. This action was decided due to climbing housing prices. (almeneffektivitet.dk, n.d.) According to Danish Transport, Construction and Housing Authority these cutbacks should come to a total of 1.5 billion kroner by the year of 2020, a saving of 2.800 kroner per public housing. (trafikstyrelsen.dk, n.d.)

How does the effectuation plans affect the housing associations practically - on both a higher level and down to the PMT?

1.04 The housing associations are urged to optimize their operations to lower total costs

Overview of Nørresundby departments of Sundby-Hvorup Housing Association

- Lindholm
  - *Department 03*
  - *Department 10*
  - *Department 20*
  - *Department21*
  - *Department 31*
  - *Department 32*
  - *Department 43*
- Løvvangen
  - *Department 12*
  - *Department 13*
  - *Department 22*
  - *Department 28*
- Nr. Uttrup
  - *Department 07*
  - *Department 08*
  - *Department 15*
  - *Department 19*
  - *Department 34*

Communication channels

The residents of the housing association often only interact with the PMTs when moving in and out of their apartments - or in case of issues in their departments. In case of issues, the residents have to get hold of the housing association themselves and explain the issue in order to create a case. In the housing association, it is typically the PM that handles the contact with the residents - either physically at his office or on the phone during office hours.

The PM is the link between the residents and the PMTs. His job is to assess and have an overview of the tasks in his department and make sure they are planned for the PMTs to do. The tasks consist of both the residential issues, but also recurrent tasks and general maintenance of the departments and the surrounding areas. These tasks need to be compressed into daily schedules that he continuously plans when new issues occur. The system used to handle the tasks is called ”Docospot”. When the PM types in a new task on his computer and assigns it to a PMT, it will be visible on the PMTs’ smartphones. In ”Docospot”, the PM is also able to view how much time is spent on each task, making it possible to potentially optimize the process.

On the smartphone, the PMTs receive the tasks to view in the ”Docospot” application. If it is an urgent task, the PM will call the PMTs to ensure fast action is taken. If not, the task will be fitted to the schedule. In SBH, the residential tasks are always placed on Mondays, Wednesdays and Fridays - on Tuesdays and Thursdays, the time is reserved for tasks outside the apartments. When a task is due, the PMTs go to the appointed apartment and take care of the issue. The residents might be home to let in the PMT - otherwise the residents have to deliver an apartment key to the PM office no later than the day before.

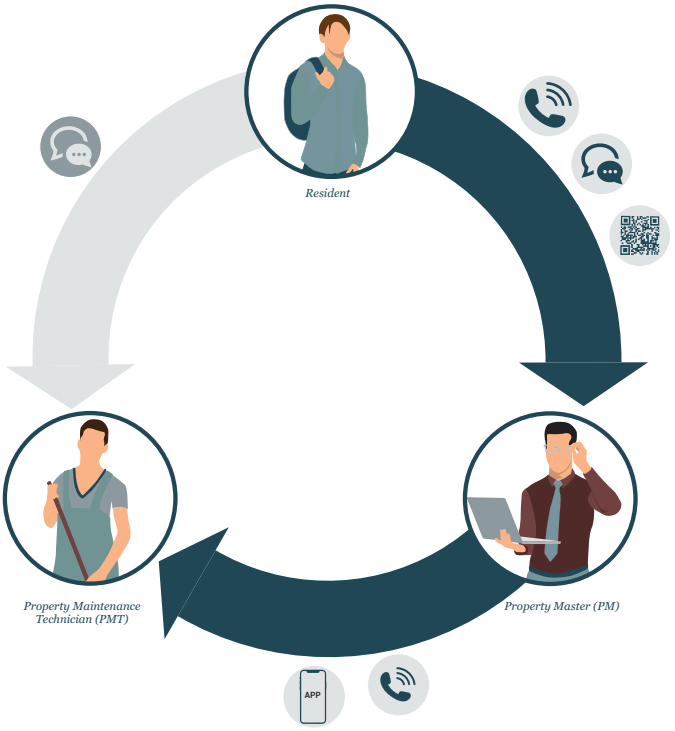


Figure 01.3 *The residents can report tasks to the housing associations in three different ways; calling the PM, visiting the HQ during office hours or by scanning a unique QR code placed in the residents own apartment. To see how it looks now, you can scan the QR code or see appendix xx (please do not send a report if scanning the QR code). When the PM recives a task, he decides if it is urgent or not. If urgent, he calls the PMT directly and if not urgent, he schedules it through a smartphone application called ‘Docospot’ for the PMT to view. The residents are also able to contact the PMTs in person if they see them around their department and make appointments to fix problems.*

How is the communication channel with little or no direct contact between residents and PMTs affecting the work of the PMTs?

1.05 PMTs need to be prepared for urgent tasks when required - their schedule might be changed instantly

Figure 01.4 *PMs from Lindholm and Løvvangen telling and showing the team how they manage the daily operations.*

01.4 | Context story

The problem story is a fictional story describing the problems and frustrations faced during a typical work day of a PMT. The story is based on key insights, observations and statements from the PMTs and thus presents a credible look into the daily operations.

Being a PMT is a very broad job description. Basically, you need to be able to take care of almost the full spectre of practical tasks in and around the building blocks you are assigned to.

In a typical day, the PMT Peter clocks in at 7 AM and drinks his morning coffee while getting an overview of his tasks for the day. After that, he grabs the tools and materials he knows he will need for the tasks in the morning and packs them in the milk crates of his bike. Before taking off for the first task, he has a weekly routine of checking if water and heat usage is at normal levels. After that, he takes a tour at the apartments to check for bulk waste such as sofas and tables which he later picks up on one of the motorized vehicles with trailer.

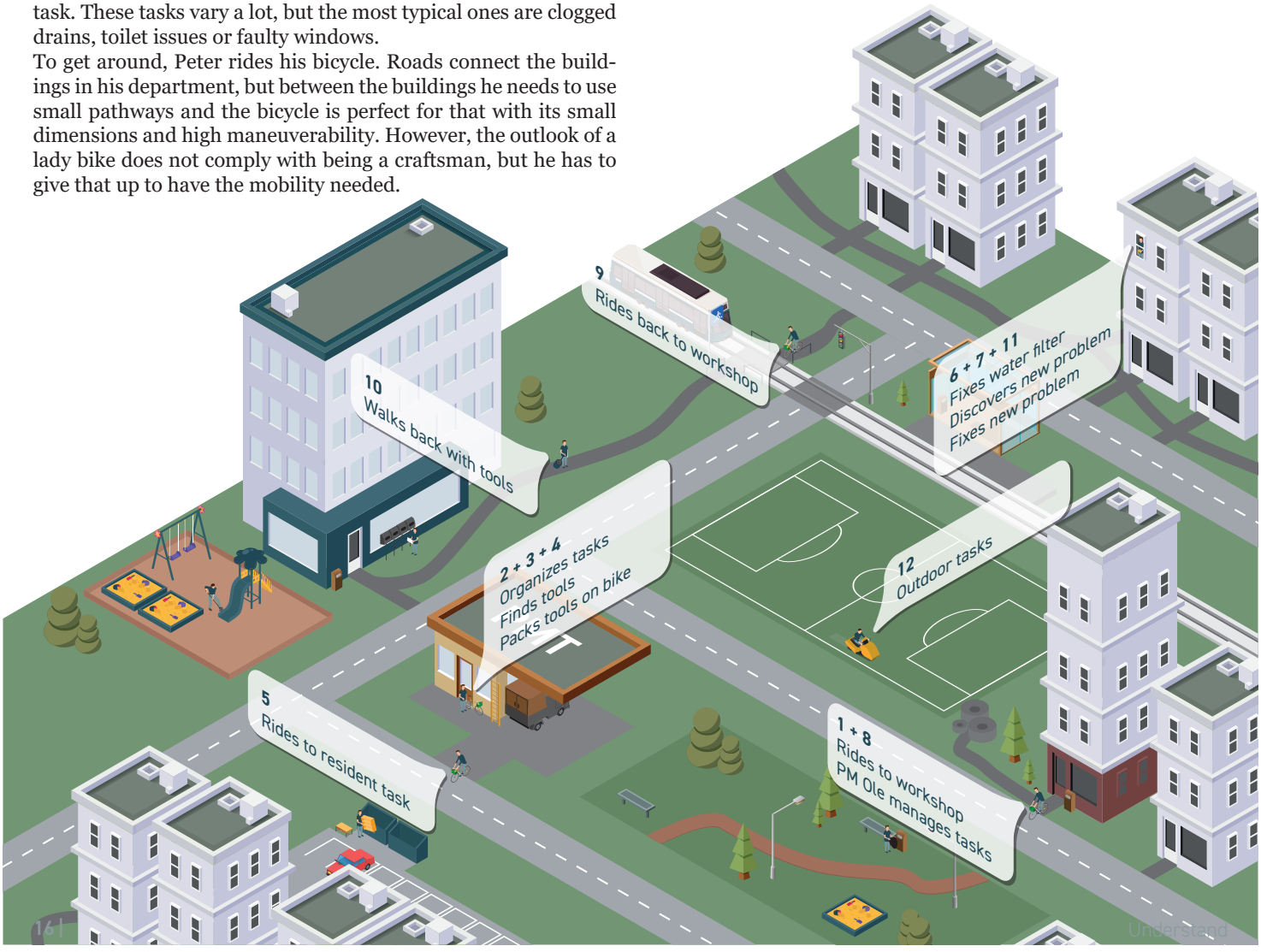
Most departments have Moloks installed - underground trash containers - that the municipality empties every fortnight. Some buildings, however, still use trash chutes and then Peter needs to go to these and empty them weekly. Also, in the green areas are trash bins that also need to be emptied.

When all these regular tasks are done, Peter has time to do the residential tasks. He schedules a time span - either before or after lunch - with the resident in which he will come by to fix the task. These tasks vary a lot, but the most typical ones are clogged drains, toilet issues or faulty windows.
To get around, Peter rides his bicycle. Roads connect the buildings in his department, but between the buildings he needs to use small pathways and the bicycle is perfect for that with its small dimensions and high maneuverability. However, the outlook of a lady bike does not comply with being a craftsman, but he has to give that up to have the mobility needed.

When all the operational and residential tasks are finished, Peter sometimes - but rarely - has time to work on the outdoor areas - mowing the lawns, painting of facades, maintaining playgrounds etc. However, with the savings plan of 1.5 bio. DKK for the housing associations in Denmark, keeping outdoor areas neat has become a very low priority.

With this, the following problem themes should be further explored to understand struggles and coping strategies:

- *Problematic communication; not knowing the specific details about the tasks.*
- *Compromise in tools and equipment; only having capacity to bring the bare minimum - and not the optimal.*
- *Waiting time; wrong tools and equipment brought makes the residential tasks take longer time.*
- *Frustration; having to commute back and forth because of limited space for tools and equipment.*
- *Heavy or bulky equipment; not suitable to bring in the milk crates.*
- *Time; no or little time to keep the outdoor areas neat.*
- *Identity; unprofessional expression riding on a lady bike.*



After the daily morning coffee with his colleagues, Peter jumps on his bike back to his office and workshop where he has his tools, equipment and materials stored. He is responsible for about 150 apartments in a department called Søparken in Nørresundby.

At his office, Peter gets an overview of his tasks and starts to plan what to bring for the day. On the phone, he sees a description of the task, where and when it is and how much time he has assigned to finish it. On Mondays, Wednesdays and Fridays, he does tasks in the residents' apartments.

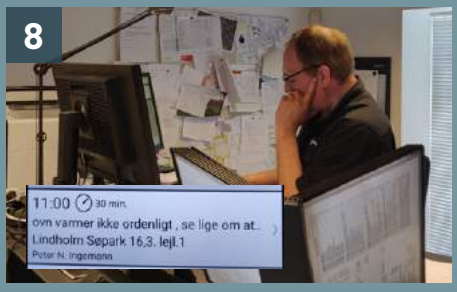
Next to his office, Peter has his workshop where he keeps tools and materials. Here he packs what he thinks he will need for the tasks into containers such as toolboxes or buckets. Peter tries to bring as much as possible to be prepared for unexpected tasks.

With his tools and equipment packed into the green milk crates on the bike, Peter is ready to move onto the first tasks of the day. He is just barely able to fit the things into the milk crates.

With a bucket in one hand and both milk crates packed, Peter rides to the first task of the day - a report of a faulty water filter. Luckily it is a relatively short and unobstructed ride, so he manages to unprobematically balance all the things he brings.

Peter knocks the door and the resident is happy to see him. She expresses the frustration she had with her faucet and how she looks forward to it being fixed. She shows him how it is a problem in both kitchen and bathroom.

The water filter is quickly replaced - Peter has done this many times before and gets it done in less than a minute. As he tests the filter, he notices that the problem is more than that; the drainage is almost fully blocked and will not let water pass through. This is not the problem he was reported in the system.



At the main office, Ole takes calls and mails from residents and assigns tasks to the PMTs in the department. Ole assesses the expected duration of the tasks and puts that into the description. The tasks are laid into the system and onto the smartphones for the PMTs to view instantly.

To fix the problem, Peter has to go back to his workshop and collect his drain cleaner machine. The machine is bulky and quiet heavy at almost 16 kg with all attachments. With the unexpected problems, he is in risk of delaying the following tasks as he is only assigned 30 minutes to complete the task.

Too bulky and heavy to carry on the bike, Peter packs the machine in a toolcase with wheels on it and walks back to the apartment.

Back in the apartment, Peter quickly cleans the drainage. With the extra time spent on walking back and forth, he is now almost 25 minutes behind his schedule after his first task.

On rare occasions, Peter has extra time in the end of the day. He spends this time on keeping the outdoor areas as neat as possible by trimming bushes, planting plants or painting facades, if needed.

01.5 | Meeting the PMTs and PMs

The focus group consists of three PMTs and two PMs from SBH and one PMT from Lejerbo Housing Association. The PMTs were approached initially by reaching out to various housing associations in the Aalborg area that provided contact to PMTs who were willing to show how they work.

The user profiles are reflections of interviews and talks held with the four PMTs as well as the two PMs (app. 02-13). The interviews provide a deeper understanding and a personal aspect to the challenges and circumstances which the PMTs and the PMs are working with. Based on the user group, it will be possible to create personas to refer to in the concept development phases. The personas can be read from pg. 30.

Educational background

The PMTs have many different educational backgrounds, but have similar reasons for working in a housing association. The majority of the PMTs and PMs are middle-aged men who are former craftsmen educated as carpenters, electricians, farmers, gas installers, plumbers etc. Many of them decided to leave their former jobs due to stress, long working days and physically exhausting jobs. The younger PMTs typically have an almost four year long education to be a PMT where they are introduced shortly to the different craftsman trades mentioned

Personal professionals

The PMTs are very proud of their professions as former craftsmen and values the personal relation to their residents. They appreciate the gratitude they get when they are helping out a resident by utilising their skills. The PMTs also value the more personal relation to their residents and want to know the names of the residents to establish a more personal relation.

After the first visits to the housing departments, a simple understanding of the context was established in regards to the primary users and related issues. With that, it was decided to proceed working with the mobility of the PMTs with focus on vehicle and organisation of tools and materials.

From this point, a description of currently available vehicles, tools and typical equipment should help understand the physical constraints, while an investigation of the coping mechanisms will help understand the behaviour and adaptability of the PMTs.

User group profiles - PMs

Henrik, 65, PM
SBH, Løvvangen department

Motivations
- Creating a good environment for his staff
- Using his long experience as a craftman

Key challenges
- Making his department sustainable
- Being the ”guinea pig” of the housing association

Henrik is the PM of the Løvvangen department and his job is to have the big picture and plan work accordingly in his department. He has been in SBH for 28 years and the last many years had the responsibility for Løvvangen. Henrik loves new challenges and always look into how new technology or workflow can improve his department. He is a trusted leader - something he has become by listening to his staff and implement their ideas and thoughts. (app. 19)

Ole, 54, PM
SBH, Lindholm department

Motivations
- Having responsibility for employees
- Bringing the ideas of his staff to life in the department

Key challenges
- Providing detailed descriptions of tasks in apartments
- Keeping tasks handled by his own staff
- Keeping costs on equipment and maintenance low

Ole is a former construction manager for many years, but chose to take the job as PM to have stable working hours. Ole has lots of experience in motivating his staff and being responsible for decisions. Being a relatively new PM, he has observed several areas to improve the working conditions of his staff. Those areas are better information on tasks and smarter acquisitions of new equipment - something he is currently working on improving. (app. 18)

User group profiles - PMTs

John-Martin, 24, PMT
SBH, Lindholm department

Motivations
- Personal relation to residents
- Learning new skills
- Keeping work separate from private life

Key challenges
- Large amount of transport time
- Tools often fall out of toolbox
- Cannot bring neccerssary tools
- Ambiguous resident reports

John-Martin is a newly graduated PMT. Currently, he works closely with Søren from whom he learns a lot of practical things about operating a department. At school, he learned the most basic skills but he still has a lot to learn and leans on Søren to gain those insights. John-Martin is responsible for two smaller building blocks as he is still inexperienced, but often helps Søren in his departments as he often has more tasks being an experienced PMT. (app. 15)

Søren, 47, PMT
SBH, Lindholm department

Motivations
- Personal relation to residents
- Varied tasks
- Teaching his skills to others
- Balanced work life

Key challenges
- Feeling monitored through ”Docospot”
- Lack of ”social time” with residents

Søren is an experienced PMT with many years at the housing association. He is responsible for three major apartment buildings and often finds himself piled up with work - which also means he has been stressed lately. Søren is a former carpenter and that is something the housing association finds really useful when those kind of tasks arise as they do not need to call in external professionals for those tasks. (app. 14)

Peter, 54, PM
SBH, Lindholm department

Motivations
- Keeping his department neat
- Personal relation to residents
- Varied tasks
- Fixed working hours

Key challenges
- In need of time to do green work
- Bringing the right equipment

Peter used to have his own farm prior to becoming a PMT. Here he were used to fix all kinds of issues himself, so he taught himself a lot of different trades. He had to sell his farm eventually as he spent too much time working and felt he might become stressed. Instead, he took the PMT job and appreciates the fixed working hours. His drive as an independent farmer still shows as he works really effectively and wants to finish all his tasks in one go. (app. 16)

Kent, 46, PMT
Lejerbo, Aalborg department

Motivations
- Keeping his department neat
- Personal relation to residents
- Varied tasks
- Managing time himself

Key challenges
- Lots of transport time on foot
- Hard to carry tools for several tasks

Kent has been a PMT the last couple of years and really enjoy sit. He likes to be around the department and interact with the many different persons in it. Prior to being a PMT, Kent was a plumber. He spent a lot of time working back then and had to stop as he became ill of stress. In the PMT job, he finds himself setting the pace and no superior watching all his moves. In the department, Kent is well liked and many residents have a relationship to him and greets every time they meet him. (app. 17)

Figure 01.5. *Various pictures from the interview rounds and visits to the housing departments. Top left: Kent telling the team how he requests new equipment through the administration. Top right: Peter showing his daily schedule and which values he needs to measure for water and electricity. Center left: Henrik telling about the new cargo bike one of his PMTs is about to receive. Center right: Peter giving a tour of his workshop and showing the various tools and equipment he uses. Bottom left: Peter showing how he uses his tool case. Bottom right: John Martin about to go to a residential task.*

Main points from interviews with the PMTs and PMs

Between 25th of March and 1st of April, five rounds of interviews were performed alongside shadowing the work of both the PMTs and PMs. In the following, the main points from these interviews and shadowing procedures will be presented. For full interview data, see app. 02-13.

Physical activation

Most of the PMTs mention without being guided in that direction, that they are happy to gain the physical activation it provides them by either walking or biking around. They see the health benefits and enjoy keeping their bodies activated while working.

Stabilization of tools and equipment on bikes

One PMT (John-Martin red.) mentioned that he fears dropping his tools when biking over uneven terrain. It was also evident during the shadowing procedures, that it easily becomes an issue with the open milk crates providing no cover or stabilization.

Physical space for tools and equipment

All PMTs refer to their ”basic tools” for doing the most common tasks. However, quite often they need special tools as well and the physical space available in either milk crates or in hands is very limited.

Mobility

The PMTs all stress the importance of being mobile. That means going through narrow corridors, between buildings and through green areas, but also quickly getting from one department to another.

Electrical assistance

The PMTs mention the possibility of having an electrically assisting motor as a great addition to the bicycle. That would limit the strenuous climbs uphill and support when carrying heavy equipment along.

Getting things done more effectively

The PMTs often mention what they describe as ”dumb work”. ”Dumb work” is having to leave a task they are working on to collect tools or equipment they need to finish the task. A lot of time is spent on this issue to no gain for anyone.

Economical concerns

The PMs are always open to introduce new equipment to their departments if they see the relevance and profits obtainable. That means offering something robust in terms of price, economical and efficiency gain and finally low maintenance level.

Theft

Both PMTs and PMs are aware of and mention the risk of theft - especially in socially deprived areas. Still, from the shadowing procedure, it is clear that the PMTs leave their equipment on the bike when working on tasks in apartments.

Creating time for meaningful work

With ”dumb work” often mentioned, the PMTs talk about how they feel a lack of time to do other meaningful things. One PMT (Peter red.) says he has not had the time to work on the green areas for five months - something he sees as meaningful work as it benefits all residents in the department.

1.06 *Physical activation is important to the PMTs*

1.07 *It is difficult to bike safely with many tools or equipment packed into the milk crates*

1.08 *The PMTs often need additional equipment that they cannot carry on the bike or in their hands*

1.09 *Small and narrow passages need to be passed to get around in the departments*

1.10 *Assistance uphill or with heavy load on the bike is a wish from the PMTs*

1.11 *”Dumb work” is to no gain for anyone*

1.12 *Inquiries of new equipment is heavily based on economical and effeciency gain*

1.13 *Theft is an issue when leaving tools or equipment in the open*

1.14 *Meaningful work is of big value to the PMTs*

01.6 | Current means of transport

Competitive benchmarking information

Commercial success is based on how, if and where a new product fits into an already established market. By mapping current available products, it is possible to identify areas to improve or differ in relation to the competition. The Blue Ocean canvas (app. 21) is used to map the current market of transportation options for PMTs. The selected products is a selection of observed products from the context as well as products identified suitable for the purpose through desk research. The parameters are selected by assessing the needs and wishes from key stakeholders as well as latent needs discovered through observations as well as desk research. The mapping of the products is primarily based on raw product data, user reports and our perception - in that respective order preferably.

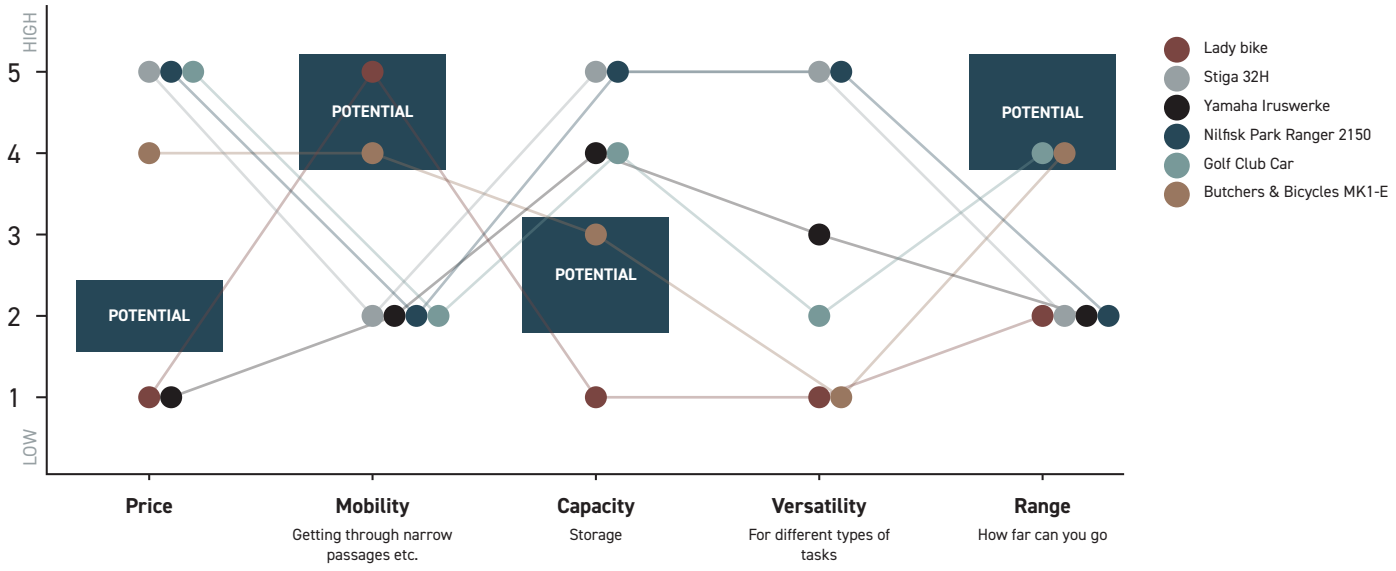


Figure 01.6. *The canvas shows how current competing products perform on selected parameters. With the mapping, it is possible to examine specific parameters that possibly could have potential to emphasize on in the design process in order to make the product differ on the market*

In the Blue Ocean canvas we are able to identify areas of opportunity - these areas are marked with the blue areas. The areas of opportunity suggest a market gap - either an unexploited potential or a previously tested and failed opportunity area. From the Blue Ocean Canvas, it is evident that there are certain key areas that could be exploited to create a product of great value to the stakeholders:

- ***Low cost price***
- ***High mobility with medium-sized storage***
- ***Increased range***

1.15 *There are no vehicles available at a low cost price that are highly mobile and have sufficient capacity*

1.16 *There are no vehicles available that offers great range at a low cost price*

Lady bike

The lady bike with milk crates for storage is a self-improvised solution seen at SBH as well as other housing associations. The bikes are available to all staff and are a cheap and mobile solution.

Negatives

- Low capacity for tools and materials
- Range depends on physical ability of user
- Not ideal in wintery or slippery conditions

Stiga 32H

The garden tractor is a diesel-driven multi vehicle that is suited for tasks such as mowing grass, clearing snow, spreading grit or moving materials (stigalawnmowers.co.uk 2019).

Negatives

- Expensive
- Requires lots of maintenance
- Slow to move around in
- Space-demanding

Yamaha Iruswerke

This is a gasoline-powered machine produced between 1960 and 1970 with the primary purpose of sweeping trash and dirt as well as snow in the winter. It is also used for transport of trash, utilities and garden waste.

Negatives

- Slow to move around on
- Poor handling
- Space-demanding

Nilfisk Park Ranger 2150

The Park Ranger is highly appreciated of the PMTs using it because of the closed cabin with heating and its overall versatility. However, annual maintenance is costly.

Negatives

- Expensive
- High maintenance costs
- Slow to move around in

Golf Club Car

In SBH they have one of these electric golf cars rebuilt with a locker for tool storage on the trunk. It carries most of the tools needed and is fast to move around in.

Negatives

- Expensive
- Immobile
- Space-demanding

Butchers & Bikes MK1-E

This electric cargo bike has gained great popularity due to its great maneuverability. More and more craftsmen in large Danish cities choose this option rather than the traditional van (tv2ostjylland.dk 2019).

Negatives

- Expensive
- Serves few purposes

Figure 01.7. *The vehicles found in the context and selected for the Blue Ocean canvas mapping. See app. 21 for detailed descriptions of vehicles.*

01.7 | PMT tools

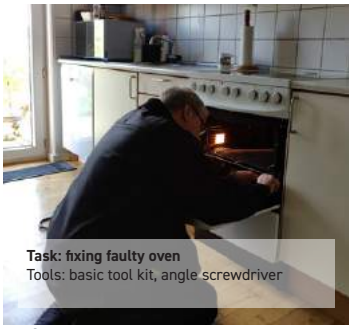
To reach a deeper understanding of the situation of the PMTs, they were asked to talk about their tools and equipment and how they use them. This serves as an overview of the wide range of utilities they have to bring around and also proves the point that they cover tasks within almost all thinkable crafts. The overview will help defining marginal and ideal values for the specification of requirements in regards to storage and organization of tools and equipment.

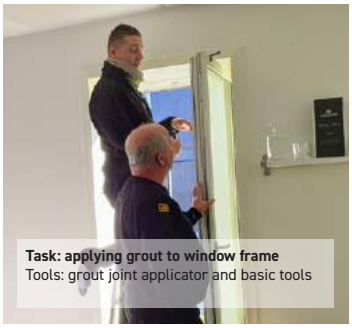
While observing the PMTs in the user group, it was noticed that all of them were carrying what they referred to as their "basic" tools. In all cases, these "basic" tools were carried in a tool insert case with a handle on it (see fig. X.X). With this tool insert, they are able to bring the most common tools to fix simple things such as power outlets, small repairs on sinks, windows, kitchen and toilet appliances. In relatively many of the tasks observed, these basic tools were sufficient to deal with the issues - some simple repairs and some with alternative use of the tools to fix the issues.

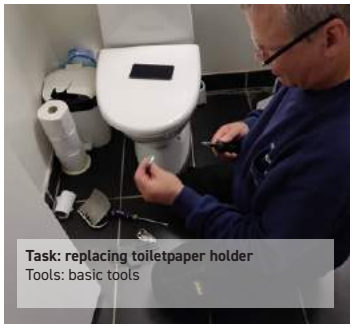
However, in many tasks, the PMTs also had to bring extra tools besides the "basic" tools (see fig. X.X). These tasks were often the more demanding ones and workarounds were not possible. Below is a mapping of the tools used in the daily work of the PMTs - the "special" tools refer to tools that are not used on a daily basis, but are used for unregular tasks or tasks that the "basic" toolset does not handle. For some tasks, the PMTs also have "tool kits" that consist of more than one tool.

Tool kit	*Used for...*
 ***Basic tools*** Screwdriver, bit screwdriver, bit set, mini electric screwdriver, umbraco set, pliers, ruler, universal grease, universal lubricant spray	*Small and relatively uncomplicated tasks in apartments or around the department. Examples: changing water filter in faucets, creaking or skew hinge windows, faulty radiators or kitchen drawers not aligning.*
 ***Extended tools*** Drilling tool kit: drilling machine, bit set, cup drills, various drills for different materials in different sizes	*Many different tasks - installing lamps, fixing windows, installing kitchens etc. This drilling machine is only used for larger tasks - if it is a matter of a few screws, the small drilling machine in the "basic" tools is sufficient.*
 ***Special tools*** Drain cleaning equipment: drain cleaner machine, bucket, floodlight, transport trolley	*Cleaning drains that are packed with food waste, hair or other blocking items. The bucket is used to ensure spillage does not occur and the floodlight makes it easier to see what they are dealing with.*
 ***Garden equipment*** *Shovel, broom, weed remover, chain saw, pitchfork, lopping shears, snow shovel, ladder, saw, crowbar*	*General outdoor maintenance; cutting branches, digging holes for plants, cutting hedges, clearing snow etc.*

Figure 01.8. *General mapping of the tool kits the PMTs use for tasks. The basic and extended tools cover the most common smaller tasks while larger or more rare tasks are covered by the special and garden tool kits for specific tasks.*


Task: fixing faulty oven
Tools: basic tool kit, angle screwdriver

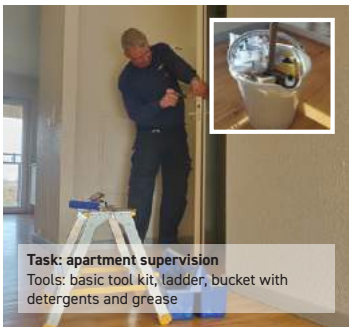

Task: applying grout to window frame
Tools: grout joint applicator and basic tools


Task: replacing toiletpaper holder
Tools: basic tools

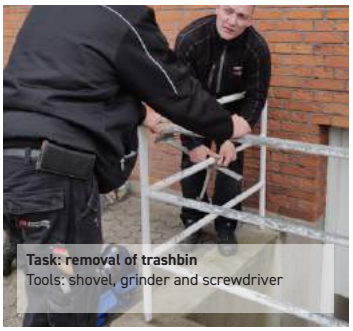

Task: fixing uneven window hinge
Tools: basic tools

Special tool	*Used for...*
Gripper bar	*Picking up small litter and cigarette buts around the common areas of the department. Is often used shortly after weekends where litter has built up.*
Jigsaw	*Customizing things such as kitchen and bath tables to fit sink and water tap or making room for piping through tables or cabinets.*
Grout joint applicator	*Applying grout to kitchen tables and walls to prevent moisture and dirt assembling in crevices.*
Sewer cleaner	*Cleaning packed sewers - often after heavy rainfalls.*
Pressure water pipe machine **Hacksaw**	*Cutting and adjusting of water pipes for installation of water in kitchens or bathrooms.*
Insulated electrician screwdriver set	*Smaller work on electricity - connecting lamps, switch fuses etc. Major electrical work must be done by electricians.*
Multi angle steel cutter	*Shortening and adjustment of steel kitchen edges.*
Industrial vacuum cleaner	*Cleaning dust and debris when working in the residents' apartments.*
Grinder	*Cutting metal pieces - i.e. trashbins that are cast into the earth by concrete.*
Angle screwdriver	*Getting through to screws and bolts in tight areas - i.e. in kitchens, windows or bathrooms.*
Bolt cutter	*Breaking chains or locks on locker rooms or bicycles that need to be removed.*

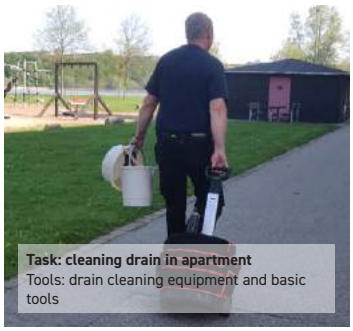
Figure 01.9. *Mapping of special tools used both often or seldomly. The special tools are necessary to overcome the tasks faced and display the many crafts the PMTs must handle.*



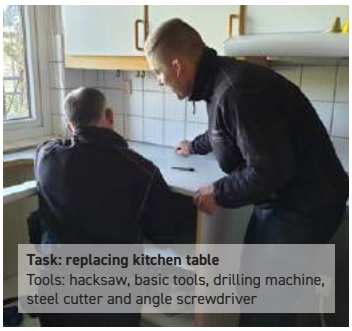
Task: apartment supervision
Tools: basic tool kit, ladder, bucket with detergents and grease



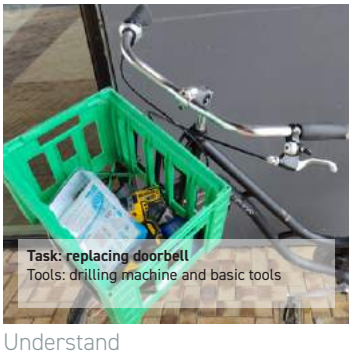
Task: removal of trashbin
Tools: shovel, grinder and screwdriver



Task: cleaning drain in apartment
Tools: drain cleaning equipment and basic tools



Task: replacing kitchen table
Tools: hacksaw, basic tools, drilling machine, steel cutter and angle screwdriver



Task: replacing doorbell
Tools: drilling machine and basic tools

Task: collecting trash in shared spaces
Tools: gripper bar, garbage bags

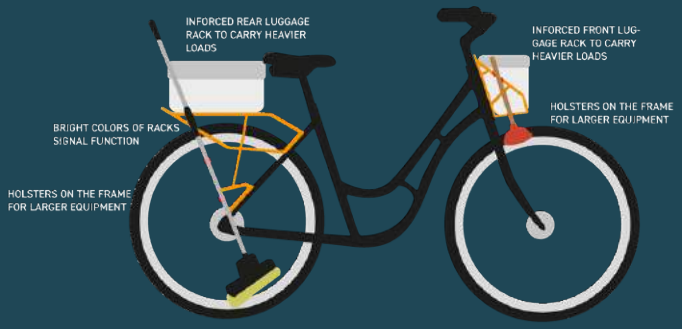
1.17 The PMTs take care of many small and large tasks and need basic as well as special tools for those

1.18 The PMTs always bring their basic tools - and switch between special tools and tool kits for certain tasks

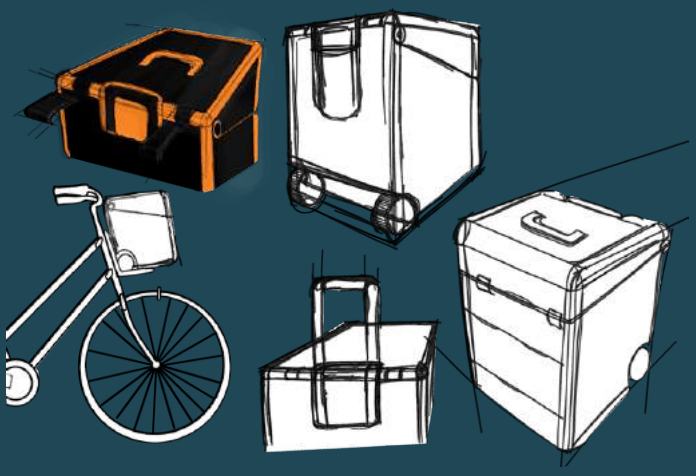
01.8 | Initial ideation

Alongside understanding the context and the users in it, sketching was initiated to release premature ideas and principles and put them to paper. This was done to save potentially good ideas for later and avoid them to bias the design process, but also to share ideas across the group. Preliminary user needs and latent observed needs serve as the foundation for these sketches, although in these phases, they are still raw and vague.

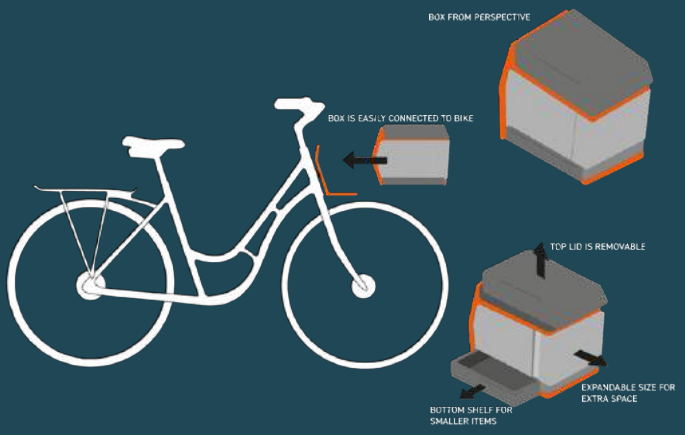
The ideas mainly revolve around the observed need that the PMTs have trouble bringing their tools with them in a comfortable and stable way. As observed, they pack their tools in milk crates on their bikes and it is clear that this is not an optimal solution. Although they express relative contentment with the solution, it is clear to the group that that contentment is based on it being a habit - the normal procedure - and not how it potentially could be a better, more suited solution for the purpose. With this acknowledgement, the ideas deal with how the tools and equipment could be carried in an optimal and more stable way, while also providing the space for the necessary equipment.



Concept 01.3 *This concept attempts to challenge the craftsman on a lady bike paradigm by adding strong, bold orange structures to the rack. Also, the thought of being able to carry larger equipment such as shovels or brooms is implemented into the concept.*



Concept 01.1 *A concept that looks to make an incremental change to the milk crate solution. The idea of having storage for tools in front of the bike is retained, but in a closed container with handles to lift and pull behind you for rolling. Having tools in front also provides the PMT with stability when riding.*



Concept 01.4 *This concept focuses on the interaction between user and product. The box is easy to attach and deattach in a day with many tasks. Also, organization of smaller tools is possible in the lower part of the box.*

Concept 01.2 *Inspired from bags for bike vacationing, this concept has the toolboxes attached to the both sides of the rear wheel. The guiding thought is that this provides better stability and easier handling of the front wheel with no weight upon it.*

The way the PMTs see their own identity as well as how the residents perceive them needs to be dived further into. Does a lady bike conform with being a craftsman - if not, what conforms with being a craftsman in the eyes of the PMTs?

Also, it should be investigated further how organized the PMTs actually want their tools to be - what fits their work and preferences?

01.9 | PMT coping strategies

The PMT job consists of many things and there are just as many ways that the PMTs do those things. In order to understand how the PMTs cope with the struggles and frustrations uncovered from p. 16 to 19, the identified themes are probed and sought to reach an understanding of how the focus group cope with these problems. The coping strategies are based on shadowing the focus group while at work as well as based on interviews (app. 02-13).

Theme: problematic communication

The PMTs often experience lacking communication about the reported tasks from residents to the PM and the message they finally receive about the task. When residents of SBH report an issue, they either call the PM headquarters or report it using a QR code placed in their apartments. Here, they have to state what the problem is, when it happened and at what time a day they would prefer to get it fixed (p. 15).

Vague reports

The reports are often very vague. The PMTs often experience this when for instance a drain is blocked that the residents only write that. The PMTs do not know which drain is blocked - if it is in the kitchen or bathroom - and furthermore, is it the toilet, bathtub or sink? The tools needed for unblocking a drain differs depending on what type of drain it is, and thus is it important that the PMTs know exactly what type of drain it is. One could then question why they do not just bring all the different tools - and then there is no problem - except the fact that some of the tools weigh up to 16 kg. As if this is not enough, the residents often do not know the exact matter of the issue, leading them to guessing and eventually reporting an issue based on this.. Then, when the PMTs arrive at the apartment, with specifically brought tools to solve the reported problem, the reported problem is not in fact the problem, it is some other problem which requires another set of tools.

Different coping strategies

In order to deal with these scenarios, the PMTs have different coping strategies. John-Martin, who rides on his bike with one milk crate, has a limited amount of space on his bike and therefore only brings his basic tools - unless he is certain that he needs special tools. In case of a wrongly described task, he has to ride back to his workshop if the basic tools are not sufficient. Otherwise, he will try to make workarounds with basic tools if possible. Peter, who has two milk crates on his bike and therefore a bit more available space, tries to plan ahead and packs what his experience tells him he might need. If he needs extra tools, he goes back to his workshop to pick them up. Søren, who rides the Nilfisk Park Ranger (p. 21) and has more space for tools compared to Peter and John-Martin, packs the trailer on the Park Ranger with what he knows he might need and then some other tools - just in case.

1.19 The PMTs either bring too much or too little equipment when tasks are vaguely described

1.20 Residential tasks are often vaguely described - leading to waste time and frustration

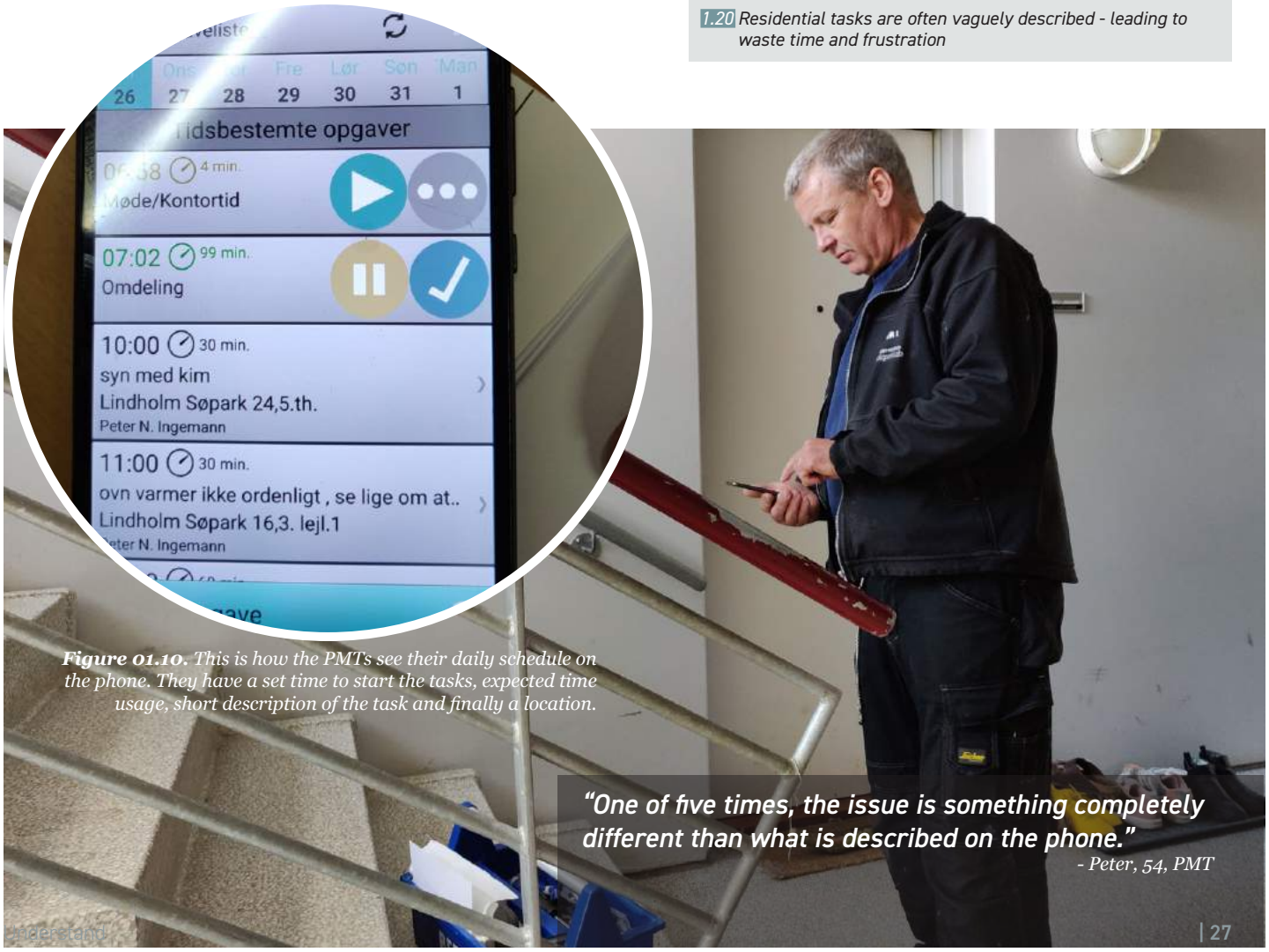


Figure 01.10. *This is how the PMTs see their daily schedule on the phone. They have a set time to start the tasks, expected time usage, short description of the task and finally a location.*

"One of five times, the issue is something completely different than what is described on the phone."

- Peter, 54, PMT

Theme: not enough time

The PMTs have a busy schedule and a lot of different tasks during the day. In order to save money, Denmark's General Housing association and the Danish Government urge the housing associations to use their own staff for tasks instead of outsourcing. This means that the PMTs have more work inside the apartments than earlier and therefore less time to fix the outdoor areas and keep them tidy.

Untidy outdoor areas - reflects upon the PMTs

The PMTs are also responsible for the outdoor areas of their respective departments and therefore it is important for them that the areas look good. However, when the time for these kind of tasks is reduced, the PMTs fall victim of criticism from the residents if the areas look bad. Peter and John-Martin have on several occasions experienced that residents have commented on the looks of the outdoor surroundings and that they are not satisfied with how they look. They find this frustrating because they get the feeling that they are not doing their job properly.

Coping strategies

Many housing associations have turned to automation to handle some of the tasks the PMTs used to work on in the outdoor areas. Robotic lawnmowers cut grass on large fields - something that releases many hours from the PMTs in the summer period. In addition to that, many housing associations have also chosen to get rid of plants, flowers and bushes that require maintenance and instead opted to have plain grass areas to minimize costs on green keeping.

1.21 Residential tasks have become the main work of the PMTs - previously, it was outdoor tasks

1.22 Residents of the departments are not satisfied with the lack of work on the outdoor areas

"Since November I haven't done any work outdoors. I never go home with the feeling that I have done all tasks of the day."

- Peter, 54, PMT

Figure 01.11. *Top: John-Martin removing a trash bin. Left: John-Martin picking up cigarette butts. Right: John-Martin and Søren in a rare moment working on the green areas.*

Theme: limited mobility

The PMTs have many different vehicles available and all of them have their limitations. When riding on bikes, the PMTs are not able to carry all the tools or materials they need and sometimes have to use other vehicles that have the capacity. As presented on p. 23, the PMTs have golf carts, mini tractors and Iruswerkes. When driving in either one of them, the PMTs have to take other, longer routes that take longer time compared to when riding on bikes. Also, in comparison to bikes, they are expensive in maintenance and require fuel or electricity as a power source.

The bike is a lot faster to use compared to the other vehicles and is not physically limited by small roads or between buildings. It has its limitations though - when the bike is packed with tools, it is difficult to balance it and avoid things from falling off. The storage room of the golf cart can be locked ensuring the PMT to store all tools without the fear of them getting stolen.

Coping strategies

In Løvvangen, a department of SBH, they have invested in a cargo bike as a new solution to the challenges of being very mobile while having the needed storage capacity. The cargo bike has a lockable trunk space and an electric motor to provide assistance when carrying heavy equipment. Though the cargo bike seems to solve most of the challenges, it is still troublesome to navigate through narrow spaces - especially moped and railway barriers due to its size.

1.23 *Going through narrow passages and pathways it is important to get around to tasks without wasting time*

1.24 *A vehicle the size of a cargo bike is too large to go through the most narrow spaces in the departments*

1.25 *It is difficult to balance on a bike with many tools packed into the milk crates*

1.26 *Tools and materials are in the risk of getting stolen when left unattended and unlocked on the bike*

Figure 01.12. *In the Løvvangen department, one PMT was provided a cargo bike with lockable trunk. He is able to store all the things he need for almost all tasks - his only problem is getting around the most narrow spaces in the department and has to go alternative ways. Image: ebikecenter.dk*

"Other potential solutions for transportation could be a golf car or an e-bike - but these can not maneuver between the speed barriers."

- Jonh Martin, 24, PMT

Figure 01.13. *Bikes are perfect for getting quickly around to tasks and can store the basic tools. When bigger and heavy equipment is needed, it becomes difficult to balance and store it on the bike.*

Figure 01.14. *The large vehicles are great for getting around with tools and materials - but lack the size to get around on narrow paths.*

Figure 01.15. *John Martin has to ride carefully when carring big tools, to ensure they do not fall out.*

Figure 01.16. *Kent prefers to walk to tasks in his department. That means he has limited capacity for tools and materials and often finds himself walking back to pick up additional equipment.*

Figure 01.17. *Peter often overloads his bike to ensure that he has the right tools with him.*

Theme: compromise in tools and equipment

As a consequence of the problematic descriptions of tasks, the PMTs have to decide what tools they think they will be needing based on the short information available on the smartphone. The coping strategies for this issue are very different from PMT to PMT, with either one being troublesome.

Bringing the minimum

John Martin always only brings his basic tools when he is riding on his bike, though at times, when he knows he is in need of extra tools, he might choose to use the Iruswerke. Alternatively, if he is on his bike at a task and needs additional tools or materials, he will call one of his colleagues who has a golf cart at his disposal to deliver him what he needs. John Martin prefers to use his bike to get around since it is much faster and it provides him physical exercise. During shadowing at field trips, it was noticed that he always brought his basic tools to tasks and in about 75% of the tasks, he had to ride back to his workshop to pick up extra tools. This resulted in extra transportation time and increased duration of the task at hand, ultimately postponing following tasks and appointments. From the observations, it was measured that on an ordinary day, 69 minutes were spent on transport and packaging of tools (see app. 50 (business case) for more details).

Having to pick up extra tools also lets the residents he is servicing wait even longer for the task to be completed, leaving a poor service impression. Another problem is that even though John Martin primarily just brings his basic tools, he often experiences that he has to be careful when riding over road bumps since he is afraid that his tools might fall off of the milk crates, see fig. 01.15. The tools are also put directly into the milk crates without being stabilized - and when riding on uneven ground, it makes a lot of noise and the tools might be damaged or worn.

Bringing as much as possible

Peter is quite opposite of John Martin and brings as much as he possibly can if he is in doubt of what to bring. He often overloads his milk crates with equipment and sometimes rides his bike with one hand to hold extra equipment in the other, see fig. 01.17. He finds satisfaction in providing the best possible service for the residents and thus prefer to bring more tools than necessary to limit the risk of suddenly needing something he did not bring. He is not able to carry some of his large equipment, such as the drain cleaner machine, so he has to carry it in a tool case on wheels and walks with it from his workshop to the apartment he works in - see fig. 01.18. John Martin transports this on his bike and not in the milk crates - but on top of his shoulder. Though it is heavy, uncomfortable and bad for his back, he prefers to do it this way so save time.

When shadowing Peter to one of his many tasks where he overloaded his bike, it was observed that he only used 2-3 different tools out of the 15 he had brought. This happened more than once, and it seemed to the team that it was a waste of resources to bring all the tools when he only used as few as he did.

Søren, another PMT, prefers as well as Peter to bring as much as possible. Though he explained that he has to carry everything with him, he cannot leave anything on the Nilfisk Park Ranger since he is worried his tools might get stolen. Peter is also aware of the wasted resources of bringing excessive tools, but he also still prefers to do it.

1.27 Tools are unstable and noisy when transported in milk crates on bikes and might be damaged or worn

1.28 A lot of time is "wasted" on transport time to retrieve tools or equipment not brought initially

1.29 Heavy equipment is difficult or slow to carry on either bike on foot

1.30 It is difficult to pick the "right" amount of tools for residential tasks

Figure 01.18. *Different ways of carrying heavy equipment; Peter (left picture) carries the drain cleaner in a small tool case on wheels, while John Martin (right picture) shows the team how he carries the drain cleaner or large toolcases on top of his shoulder on the bike. He uses his other hand to handle the bike.*

01.10 | From the residents' perspectives

The residents of the housing departments serve not only as service receivers but also as employers of the PMTs - they pay their salaries through their rent, but also expect some kind of service for that salary. To explore how the residents in the housing associations perceive the PMTs and their work, the group approached different residents with different backgrounds and circumstances to hear their stories and experiences.

Student, 22 years old

Resident for 3 years
In a relationsship

"My lock was rusty, so I had to call the office and find a time for it to be fixed. They made it fit with when I was home. The guy was really nice and I think the communication was really good. He already showed up on the next day. I also had an oven that needed to be fixed and they called some technician that came and fixed it. One time they also helped me find the key for my bike down at the bike stands.

I think a good service from their side is doing the service fast and if they plan the task so that it fits with my schedule."

School teacher, 28 years old

Resident for many years
Married and one small child

"Yes, I had them come over previously. They are here really fast, usually within a couple of days and once the day after I called. I have not been home the times they have been at my apartment, but it does not look like anyone has been there, so that is positive. He put my key in the mailbox after he finished.

I am not sure who they are - but I think I have seen them around before. (A good service red.) is them being easy to reach out to, they clean up after themselves and are quick to solve the problem."

Retired couple, 75 and 68 years old

Residents in the SBH since 1993
Former janitor and receptionist

"I (with my previous experience as a janitor red.) have some expectations. We have always been satisfied with the work they have done. Today, it is mostly craft work in the apartments - in my time as a janitor, we never did any work in the apartments. We did tasks outside - the green areas, trash and keeping it a beautiful department.

In my days, we used to walk around to the tasks. I think it is fine they bike today - they have great distances to go. We did not back then. They are easy to talk to, friendly and answer to our questions."

Student, 22 years old

Resident for 1 year
In a relationsship

"Yes, (they have been here before), because the apartment is new and there were some things missing when we moved in. I think they are really easy to get hold of and get to help when something is broken. I notice them around here because of their work jackets.

The area is beautiful and our newborn child can move around here. It is a nice and tidy area.
I think good service consists of quick response - at least that they have seen our message (on the website red.)."

Based on the impressions from the residents, it is clear that they share similar core expectations and experiences with the PMTs - they had good service when needing so and they had fast responses from the PMTs. Apart from that, the wishes are a little different - the young residents value fast and uncomplicated service and do not value visibility and the personal contact with the PMTs highly. The family values the visibility of the PMTs and that their requests are responded to and finally the retired residents value the personal contact and that they are able to pose questions directly to the PMTs.

With this, it should be specified further what the good overall service experience consists of to cater to a broad demographic group. Also, the communication channels between PMT and residents should be investigated - could it be improved? Can it help the PMT to be more effective?

01.11 | Stakeholders

When developing a product, it is important to understand the primary users. However, knowledge of all other involved parties - stakeholders - is just as important as these potentially either have the power to decline or accept the product or interest to make the product relevant in the first place.

Looking at the typical organizational setup in a housing association, the PMTs are low in the hierarchy when it comes to purchasing decisions regarding equipment. However, as observed, they often propose acquisitions of new equipment to the PM - typically to streamline work, minimize physical load or simply to replace broken equipment. The PM is interested in keeping his staff happy, so he is open to new suggestions. If he rates the value both economically as well as personally, he will be inclined to accept the PMTs' proposals. Normally, the PM is allowed to purchase equipment for his staff up to 20.000 Danish kroner. At amounts above that, he has to consult the Economic and Operations Managers. They have to accept those purchases that often consist of larger vehicles and equipment.

Above the Economic and Operations Managers, we find the Chief Executive Officer. His job is to take responsibility for the major decisions in the housing association such as purchase of new departments or investments. He finally needs to answer to the resident executive committee that consists of elected residents that represent all the residents in their specific housing departments. Their job is to ensure the wishes and demands of the residents are cared for when taking major decisions - after all, the money in question is the rent that they pay monthly. Ultimately, the decisions proposed from the administration of the housing department can be declined by the resident executive committee and in extreme cases, they can demand the Chief Executive Officer to step out of his position.

1.31 Purchasing decisions below 20.000 Danish kroner are decided by the PMs

1.32 Purchasing decisions above 20.000 Danish kroner must be accepted by the Economic and Operations Managers

1.33 New equipment and machines must be economically and personally viable to be considered

RESIDENTS	PMT	PM	ECONOMIC MANAGER	OPERATIONS MANAGER	CHIEF EXEECUTIVE OFFICER	RESIDENT EXECUTIVE COMMITTEE
Little to no influence on purchases.	*Can propose purchase of new equipment to PM.*	*Can buy equipment up to 20.000 Danish kroner range. Above that, needs to consult with Economic and/or Operations Manager.*	*Decision taker in equipment above 20.000 Danish kroner. Takes decision in cooperation with Operations Manager. Mostly big vehicles or expensive tools.*	*Takes decisions in collaboration with Economic Manager.*	*Responsible for decisions of larger amounts such as building new buildings or acquisitions of departments. Needs to answer to resident executive committee regarding decisions.*	*Able to overthrow any decisions proposed by the housing department. Typically involved in heavy purchasing decisions above 500.000 Danish kroner.*

Figure 01.19. *General stakeholder overview of housing associations in Denmark. The overview shows the different decision takers in the purchasing process and responsibility degree, ranking from low responsibility at the left to high responsibility to the right.*

01.12 | Business potential

Since 2016, the public housing associations in Denmark have been urged to collectively make savings in operation costs of 1.5 billion Danish kroner before 2020 in an efficiency plan. The reason for this is that operation costs have risen significantly since mid-2000's which has resulted in a bump upwards in rent prices that residents ultimately have to pay. (almeneffektivitet.dk, 2019) To meet the savings target, the housing associations have made several successful initiatives so far - for instance implementation of digital solutions that minimize waste of resources (water, heat etc.), joint procurement between departments, effective waste management and minimizing external workforce needed by keeping tasks in-house. So far, the initiatives have provided savings of 1 billion Danish kroner from 2014 to 2017 (almeneffektivitet.dk, 2019).

One of the major things that many housing associations point towards in terms of streamlining is the handling of tasks in apartments done by the PMTs - contrary to before 2014 where the tasks often were contracted to external professionals.

The business potential is based on insights into the context and statements from various stakeholders. With these, it is possible to set up a realistic scenario of how the concept potentially could benefit the housing associations economically. During the initial investigations into the context, it became obvious that a lot of time was spent on transport. Transport is a natural part of the PMT job, having to go from one department to another to do tasks, but the insights also showed that many of the trips were due to bad planning ahead in regards to tools and equipment. If some of this transport time could be reduced, the overall economic savings would be significant from a broad perspective - and possibly also minimize a lot of frustration for the PMTs as well as residents.

We really have the incentive to be as effective as possible (in Frederikshavn red.) because if we do not have the best residences at the best rates, we will not be able to rent them out. It is different in the big cities where the demand for residences is gigantic - and the rent is not a competitive factor. It is just a question of locating a vacant residence."

- Steen Møller Andersen, CEO at the Vesterport Housing Association in Frederikshavn (Trafik-, Bygge- og Boligstyrelsen Video, 2019)

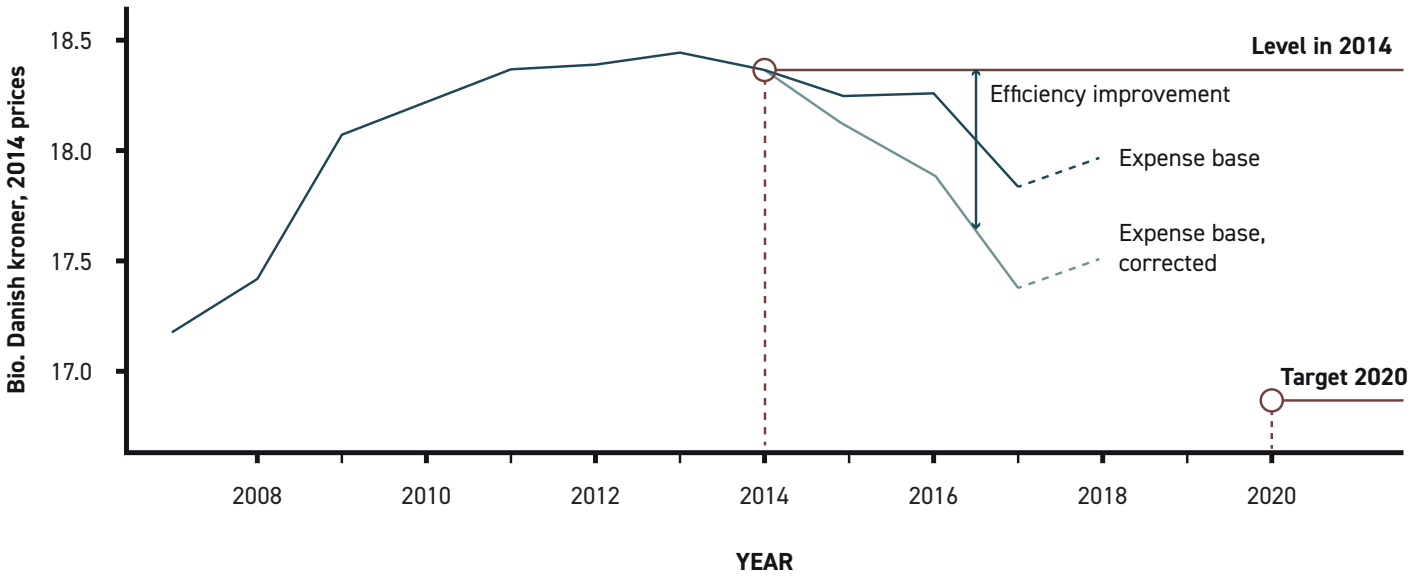
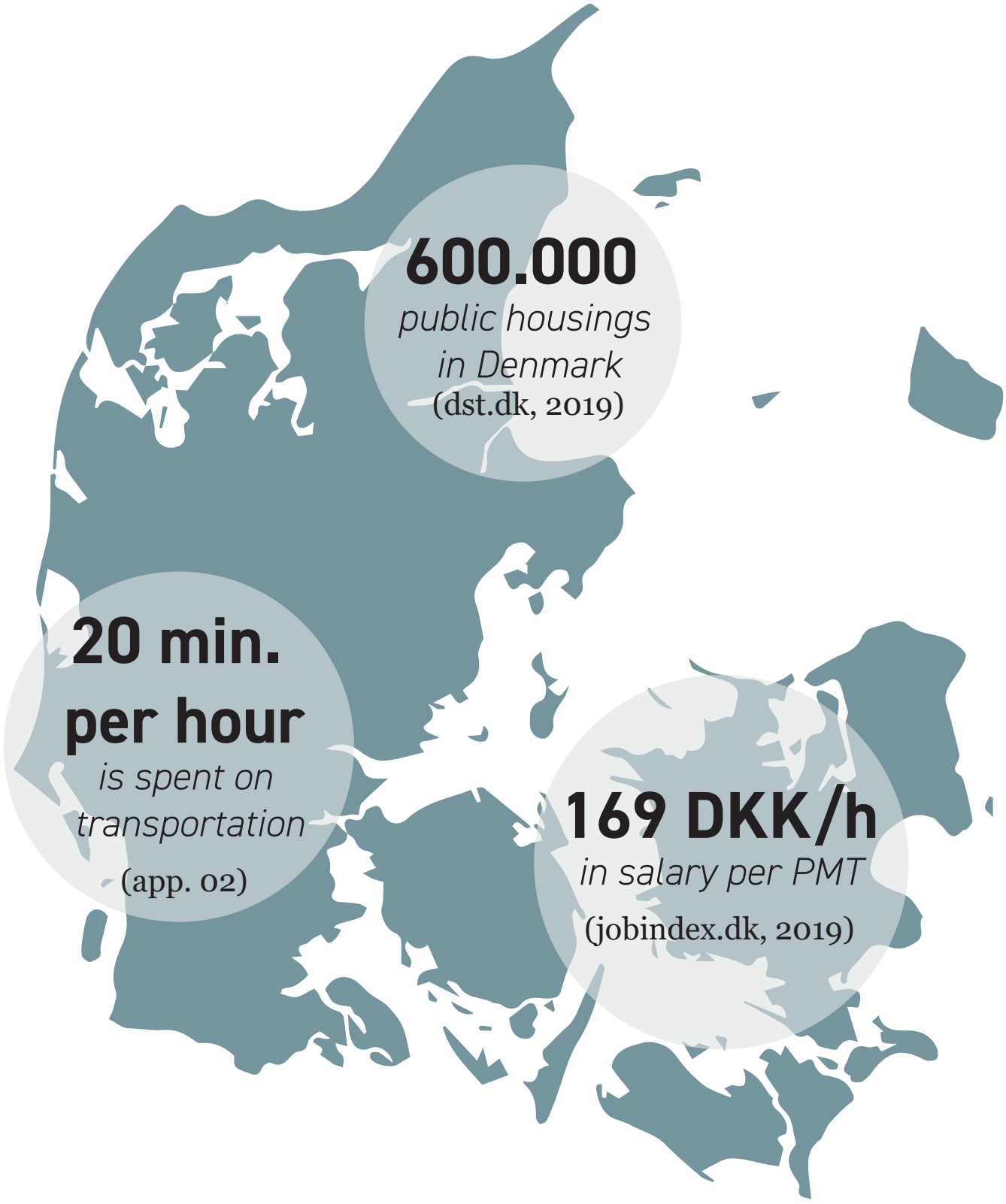


Figure 01.20. *The graph shows how the expenses have increased between 2007 and 2013 and dropped after initializing the effectivity plan from 2014 until 2017. The target is savings of 1.5 billion Danish kroner before 2020. (almeneffektivitet.dk, 2017)*


600.000
public housings
in Denmark
(dst.dk, 2019)
20 min.
per hour
is spent on
transportation
(app. 02)
169 DKK/h
in salary per PMT
(jobindex.dk, 2019)

01.13 | Personas

Using personas, it is possible to define a certain group of people that share similar traits, interests and motivations. The personas are useful when discussing how likely certain user groups are to accept and use products or services. The personas are based on the initial interviews and insights into the user context (p. 18, app xx and xx).

Kent, PMT *Peter, PMT* *John-Martin, PMT* *Søren, PMT* *Ole, PM* *Henrik, PMT*

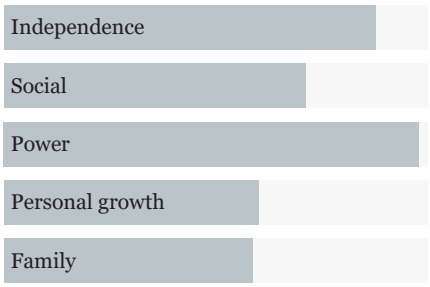
John, PMT *Michael, PMT* *Mogens, PMT* *Poul, former PMT*

Hans - the experienced Property Master

Age 57
PM for 7 years
Civil status Married
Arch type The falcon eye

"I try to take care of my men and plan in their interest first and foremost."

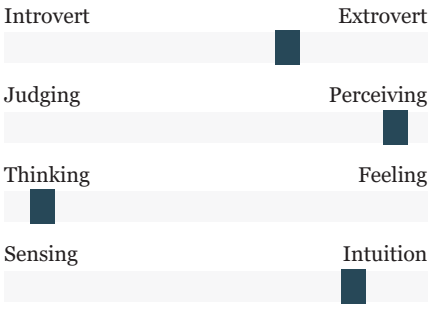
Motivations



Biography

Hans is the PM of 11 departments with six PMTs to organize. He is responsible of planning the tasks in the department and uses his experience as a former construction manager to keep things in order. He stepped down as construction manager as he spent too many hours and felt too big a pressure being so. Instead, he feels the responsibility of being a PM is appropriate, and he puts great joy in motivating his men and implementing their ideas into practice. At home, Hans lives with his wife and dog and still works on separating work and private life after many years in the construction business.

Personality



Goals

- Motivating his staff
- Implementing new ideas
- Feeling of being important
- Balanced work life

Frustrations

- Not being able to leave work when home
- Being unable to motivate his staff

Thomas - the recently graduated, young PMT

Age 24
PMT for 2 years
Civil status In a relationship
Arch type The beginner

"I try to learn as much as I can to hopefully soon be independently working."

Motivations

- Independence
- Social
- Power
- Personal growth
- Family

Biography

Thomas lives just a short bike ride from his department with his girlfriend and one year old daughter. Currently, he works closely with the seasoned PMT from whom he learns a lot of practical things about operating a department. At school, he learned the most basic skills but he still has a lot to learn and leans on him to gain those insights. Thomas is responsible for two smaller building blocks as he is still inexperienced, but often helps the seasoned PMT in his departments as he often has more tasks. Thomas likes to shut his work out when he is off and spend time with family and friends or playing football.

Personality

Introvert — Extrovert
Judging — Perceiving
Thinking — Feeling
Sensing — Intuition

Goals

- Starting a family
- Learninga to work independently

Frustrations

- Wasting time that could be used better
- When things do not work as planned

Svend - the seasoned PMT

Age 53
PMT for 13 years
Civil status Married
Arch type The mentor

"Good service is if I have done a service and the residents are happy."

Motivations

- Independence
- Social
- Power
- Personal growth
- Family

Biography

Svend is an experienced PMT with many years at the housing association. He is responsible for three major apartment buildings and often finds himself piled up with work - which also means he has been stressed lately. At home, Svend lives with his wife and often finds himself having a hard time letting work go - so he spends a lot of time in his garden keeping it tidy. Svend is a former independent plumber and that is something the housing association finds really useful when those kind of tasks arise. His drive as self employed still shows as he works really effectively and wants to finish all his tasks in one go.

Personality

Introvert — Extrovert
Judging — Perceiving
Thinking — Feeling
Sensing — Intuition

Goals

- Teaching his know-how to others
- A balanced work life
- Close personal relation to residents
- Neat outdoor areas

Frustrations

- Spending time on "stupid" tasks
- Not being able to finish tasks timely
- "Stupid" work

01.14 | Design brief 1.0

Problem statement

"How do we create a new transport solution for the PMTs that streamlines their work by being adaptable to the unpredictable residential tasks, but also assists them in their routine operational tasks?"

Vision

Creating the future for mobile craftsman tool and material transportation in urban environments.

Mission

The team wants to contribute to the PMTs' feeling of being on top of things in their everyday work by creating time for satisfactory tasks and decreasing "dumb" work and help the PMTs avoiding physical overload.

Interaction vision

Trustworthy

(pngindir.com, 2018)

... like being in shelter in a bunker.

Versatile

(grejfreak.dk, n.d)

... like duct tape.

Value vision

Proud

(Skive Garnision, 2011)

... like a child that just learned to bike.

Flexible

(piedrasenequilibrio.blogspot.com, 2015)

... like helping your child with homework after a long workday.

Efficient

(homedepot.com, 2019)

... like an all-terrain vehicle.

Project overview

Being a PMT comes with a job description involving a multitude of various assignments and duties. One of many continuous issues is the solving of ambiguously described residential tasks, typically resulting in the PMTs packing a needless amount of equipment or wasting time rushing back and forth to get the precise tools - often long distances away from the actual tasks and in some cases they also have physical overload as they transport the heavy tools in an inappropriate way. Codeveloping with PMTs from the Sundby-Hvorup and Lejerbo housing associations will function parallel throughout the project. The PMTs will function not only as problem owners but due to their experience and professions also as experts in their respective fields.

Target group

The target group is broad and consists of not only PMTs but also other craftsmen - carpenters, electricians, plumbers, locksmiths and the like. The user groups of the project consist of four PMTs representing the primary users of the design solution and their superiors, the PMs, being the buyers of the proposed solution. Both focus groups will provide feedback on concepts and prototypes.

Scope

The proposed solution aims to solve transport issues across different craftsman branches but in this case, the scope will be to develop a vehicle solution that primarily solves the challenges from the PMTs point of view.

User needs

Based on the findings observed throughout this Understand phase, it is possible to establish the initial user needs. These needs are not rated in importance and need further probing before deciding if they are valid to base the specification of requirements on. Each need below refers to one or more findings - see reference finding number for clarification.

Delimitation

The secondary primary target group of craftsman branches will not be a part of the development process as that would require extensive fieldwork to map routines, needs and insights to create a basis for a holistic solution. Instead, the probability of how the proposed solution could be of advantage to the secondary primary target group will be discussed on a lower level.

Business potential

Based on the initial insights in the daily work of PMTs, it is obvious that a lot of time is spent on either walking or cycling back and forth in the departments due to the limited options of bringing tools and equipment along. Also, the lack of rich details about residential tasks pose a problem in the preparation for the PMTs that often have to take a chance on which tools to bring along. By either increasing the possibility of bringing more tools and/or create clear communication, the PMTs will potentially avoid wasting lots of undesirable time on transport. In a bigger perspective, this waste transport time accounts for many work hours weekly - time that could be spent on other tasks. This will benefit all stakeholders both financially as well as personally - creating more time for satisfactory tasks for the PMTs, better response time for residents and more time for residential tasks that are of high value economically to the housing association.

Need no.	*Finding no.*	*Need*
1.01	1.6	The solution keeps the user physically activated
1.02	1.10	The solution limits the need for walking
1.03	1.7, 1.25, 1.27	The solution stabilizes tools over uneven terrain
1.04	1.5, 1.17, 1.18, 1.28	The solution has space for needed tools
1.05	1.5, 1.8, 1.30	The solution has storage for extra equipment to be ready for unclear tasks
1.06	1.19, 1.20, 1.28, 1.30	The solution makes information on residential tasks clear
1.07	1.2, 1.3, 1.9, 1.15, 1.23, 1.24	The solution is small enough to go through narrow passages
1.08	1.1, 1.4, 1.11, 1.28, 1.29	The solution assists the PMTs in getting the tasks done effectively
1.09	1.4, 1.12, 1.15, 1.16, 1.33	The solution is financially attractive
1.10	1.13, 1.26	The solution prevents theft of tools and materials
1.11	1.11, 1.14, 1.21, 1.22	The solution appeals to the PMTs functionality

02/

IDEATE

After defining the design brief and listing user needs, the team started looking at different types of vehicles to accomodate the identitfied needs. The team found that the existing vehicles in the context are not sufficient to handle the change of working areas and tasks. What is needed, is a highly maneuverable solution that can pass through narrow spaces while still having the capacity to store the necessary tools. To ensure that the team investigated all the different aspects and challenges identified during the analysis of coping strategies, the ideation phase was divided into four focus areas; mobility, storage, communication and identity. Before intiating the conceptual phase, a final design brief and requirements are defined.

02.1 | Mobility ideation

The first of the four focus areas which were investigated was mobility. The mobility ideation is focused on passing through narrow spaces with a vehicle able store all necessary tools identified in the ”PMT tools” on p. 24. The team initially focused on the cargo and e-bike platforms in general as these initially seemed optimal solutions to be quickly implemented. To ensure this was the optimal solution, the team decided to explore the full solution space by creating different vehicle platform to sketch and ideate upon; bikes, small scooters, Segways, cargo bikes, golf cars, garden tractors and wheel barrows. The team collected pictures of existing vehicles on a common platform on Pinterest to share inspiration and principles (app. 30). Selected sketched ideas are shown below and the rest are available in app. 33.

Figure 02.1. *A small foldable e-scooter with storage room for tools. The scooter has a backrest instead of a seat to provide support.*

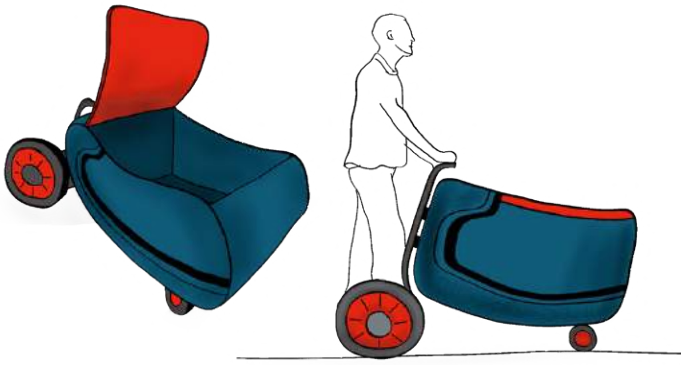


Figure 02.2. *This idea is a combination of a Segway and a tractor. The vehicle is navigated the same way as a Segway and has room for both basic tools, special tools and materials.*

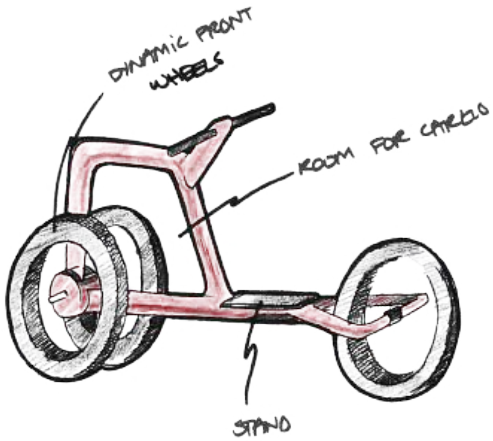


Figure 02.3. *A three-wheeled e-bike with room for a cargo box between the wheels.*

Outcome

From the selected directions and common inspiration board, the team diverged to develop several ideas. This inspired to a new unexploited potential of using Segways and mini e-scooters as means of transport for craftsmen. The team discussed potentials and limitations and chose three platforms to develop further on; Segways, mini e-scooters and the cargo bike. The team developed three concepts for each direction.

The first concept (fig. 02.4) is a mix of a mini tractor and a Segway, combining the storage room from mini tractors and the easy maneuverability of the Segway. The second concept (fig. 02.5) is the mini e-scooter that is easy to get on and off - similar to the first concept. It has storage room in the front center with a fitted toolbox.

The third and last concept is inspired from the cargo bike. It has toolboxes accessible from three sides. On top there is a smaller storage room to create an easy access to smaller items.

The team decided to present these concepts to the users to get their immediate reaction to some of the principles incorporated. Especially the idea of not being able to sit was important to present as the PMTs are used to sit on their existing vehicles.

The first two concepts have no seats as there were doubts of the necessity to sit as it was previously discovered that the distances traveled often were of short duration. Clarifying this could potentially alter the perception of the design demands.

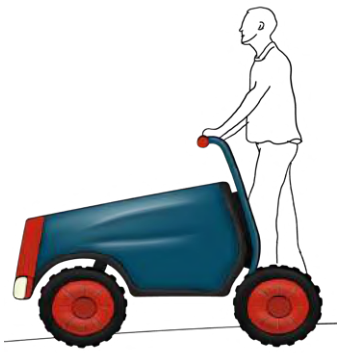


Figure 02.4. *Concept 1 - Tractor/Segway.*

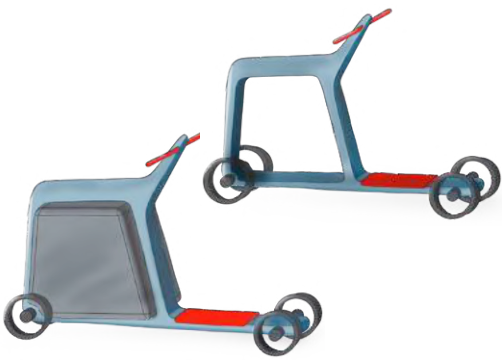


Figure 02.5. *Concept 2 - Mini e-scooter.*

Figure 02.6. *Concept 3 - Cargo bike.*

02.2 | Design parameters

While ideating on mobility, the team realized that the main focus during the shadowing and interview procedures were on identifying latent problems and coping strategies. To get further insights into the personal likes and dislikes of the PMTs, three main themes were set up and investigated. This were done along with presenting the concepts on previous page.

Prior to the visit at SBH (app. 09-10), the team developed three sets of parameters with the purpose of probing into the preferences of the PMTs in regards to a new transport solution. Each set focused on one of the identified main themes; mobility, storage and identity. The focus area of communication was not included in this investigations as this theme did not relate closely to vehicle focus. The parameters should serve as design guidelines throughout the project.

Mobility parameters

The mobilty focus intaled six different parameters. See fig. 02.7 for parameters. Each parameter was ranged from one extremity to another, and to avoid any misunderstandings of words or pictures, both were added to the parameters to strengthen the understanding. (app. 36)

Prior to meeting with the PMTs, the team mapped their assumptions of how the PMTs would respond to the parameters. The presumptions are marked with a grey rectangle and black outline. As fig. 02.7 indicates, the presumptions were not entirely accurate.

Mobility result

It is interesting that the PMTs' preferences on the capacity of tools contradicted with what they are currently doing. From shadowing Peter, the team learned that he brought more tools compared to both John-Martin and Søren, though he prefered to have a capacity of only his basic and special tools - whereas Søren and John-Martin wanted capacity for all tools and materials.

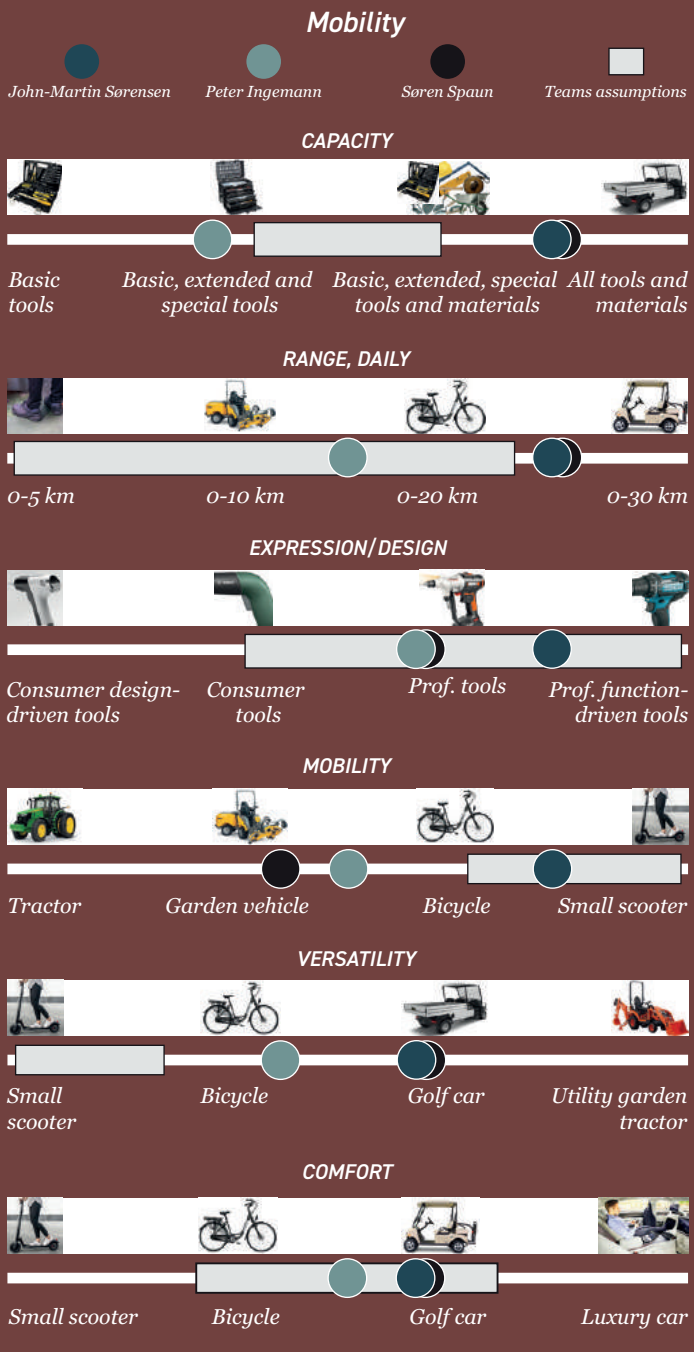


Figure 02.7. *Mobility parameters with answers from PMTs John-Martin, Søren, Peter and the teams own presumptions.*

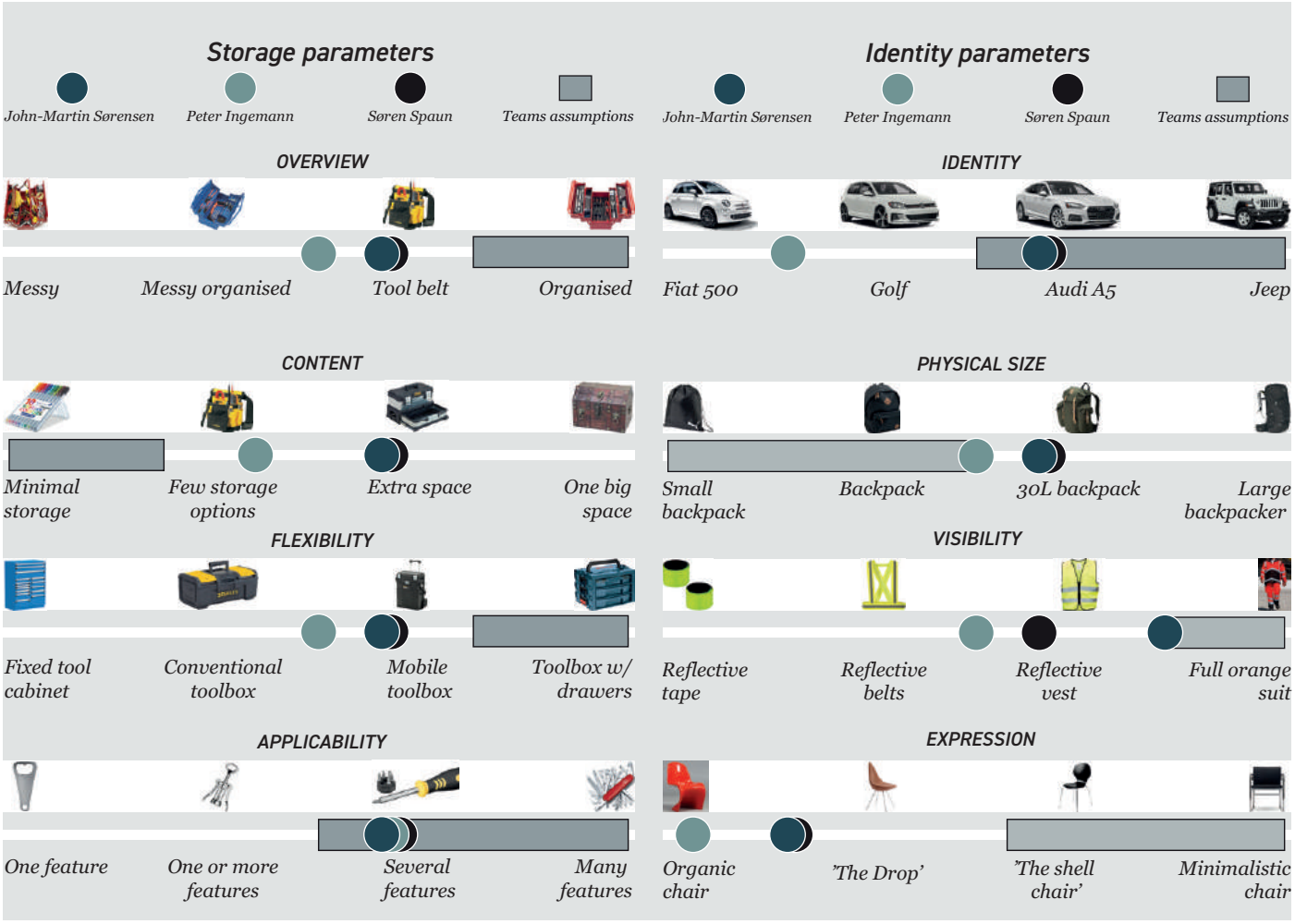


Figure 02.8. *Storage and identity parameters with answers from PMTs John-Martin, Søren and Peter and the teams own presumptions.*

Storage parameters

The storage focus was divided into four parameters. See fig. 02.8 and app. 37-39 for details. The intent of the storage parameters was to uncover how the PMTs prefer tool organization and flexibility.

Storage result

Similar to the mobility parameters, the presumptions of the team and the PMTs' responses did not correspond. Based on observations, the team assumed the PMTs prefered to have just enough room for their tools to make the size of their toolboxes as small as possible and thus easier to bring along. Furthermore, the team had observed that the degree of organization of the tools were limited as the PMTs often had messy workshops with tools seemingly unorganized.

It was expected that the PMTs would prefer to have their tools organized and create order in chaos. The PMTs had a different opinion - they prefered to have more space with few rooms to help organize their tools - but having a strict division of their tools were not necessary.

Identity parameters

As with the storage parameters, the parameters for identity were divided into four. See fig. 02.8 for parameters. The results of this helped build a visual identity for the conceptualization work ahead. The PMTs agreed on a distinguishable and abstract visual expression. Contrary to the previously presented parameters, the team presumptions this time came close to the preferences of the PMTs.

Almost all the results were as presumed by the team besides the expression parameter. Here, the PMTs all agreed that they preferred an organic, non-stringent expression. The presumption was a more masculine and strict expression.

Another interesting point came up when discussing the identity. The PMTs mentioned that visibility as in being visible in traffic and dark conditions is very important. When working outside close to road and traffic, it is important to be visual to avoid being overlooked.

- 2.01 *The solution has capacity for basic tools*
- 2.02 *The solution has capacity for extended tools*
- 2.03 *The solution has capacity for special tools*
- 2.04 *The solution has capacity for extra equipment*
- 2.05 *The solution has a daily range of 15 to 25 km*
- 2.06 *The solution has an organic, non-stringent expression*
- 2.07 *The solution makes the PMTs visible in traffic*
- 2.08 *The solution is as mobile as versatile as the lady bike*
- 2.09 *The solution has better comfort than the lady bike*
- 2.10 *The solution has an abstract visual expression*

02.3 | Mobility concepts

After the PMTs voiced their opinions on the presented design parameters, the three concepts on p. 41 were presented to the PMTs to get their evaluation and immediate reactions on principles, expression and practicality.

Tractor/Segway

Peter saw the potential in having storage room for all his tools and talked about the opportunity to use the room for garden waste - and specifically mentioned one hour worth of waste would be appropriate. He also added in addition to that, that a tiltable container would be good for that purpose. The easy getting on and off as on a Segway was also very appealing to Peter, and he added that he would not have the same challenges of balancing the concept like he has with his lady bike. Furthermore, he noticed he did not need to sit down when driving around as the distances are so short. John-Martin and Søren both prefered to at least have the option to sit down. Also, they were concerned whether it would be able to fit through the barriers at the railway crossing (narrow crossing between departments in SBH).

Mini e-scooter

All of the PMTs saw the potential in the Mini scooter, though Søren was concerned if he would be able to carry all his tools on it. Both Søren and John Martin noted that they liked the look of the Mini scooter. Peter raised worries that the wheels seemed fragile and he feared they would be too small to go through various terrain. As with the first concept, John Martin and Søren both mentioned the lack of a seating possibility.

Cargo bike

Søren liked that the tools were close to him and not easily accessble from the sides and that the top drawer could be closed to prevent theft. He suggested that the room underneath should be totally inclosed to also prevent theft of the bottom parts. Peter was not at all attracted to this solution compared to the other concepts. He explained that by comparing the convenience of the two others to this concept, talking about how ease of getting on and off is important to him. He also expressed a concern of not being able to access his toolbox from the sides, making it unappropriate to use in his daily routine. He prefers access from the top to his tools and equipment and use the lower part for large tools or garden waste.

With the feedback from the users, new insights and perspectives were uncovered that create the following new user needs:

- 2.11 *The solution has option to sit down*
- 2.12 *The solution provides access to tools from above*
- 2.13 *The solution has storage for one hour of garden waste*
- 2.14 *The solution has a tiltable cargo compartment*
- 2.15 *The solution has sturdy wheels for various terrain*
- 2.16 *The solution is secured against theft*
- 2.17 *The solution maintains ergonomic positions when lifting tools or materials off*

Figure 02.4. *Concept 1 - Tractor/Segway.*

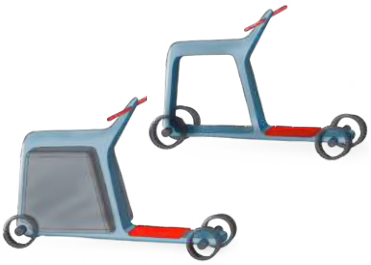


Figure 02.5. *Concept 2 - Mini e-scooter.*

Figure 02.6. *Concept 3 - Cargo bike.*

Tractor/segway	Mini e-scooter	Cargo bike
+ Storage room for all tools	+ Easy on and off	+ Locked top drawer
+ Storage room for garden waste	+ Easy to pass narrow spaces	+ Seating possibility
+ Easy on and off	+ Attractive expression	- No access to tools from the top
- Too wide to pass narrow spaces	- No seat	- Can not store garden waste
- No seat	- Less space for tools	

Figure 02.7. *Key points from the PMTs' comments on the concepts.*

Figure 02.8. *Presenting the three concepts to John-Martin and Søren.*

02.4 | Storage ideation

With the results from the design parameter investigation, it became obvious that storage should be a key element in the concept. Using both sketching as well as low-fidelity mock-ups as tools to explore the solution space, several principles were developed. Prior to this, a screening of possible storage solutions and principles were performed to widen the solution space. See app. 29 for more details.

Sketches

The sketches mainly revolved around how to divide the toolbox into compartments for organizing and the interaction of these. Two principles were tested; one with just a fixed shape of the toolbox with small compartments hidden within to store small items (fig. 02.09 and 02.10).

The second principle is several toolboxes that are joined to form one toolbox (fig. 02.11). The separate boxes can be brought along separately or joined together based on what is needed for the task.

The third principle works with providing the PMT a quick overview of what is inside the toolbox (fig. 02.12). By rethinking the open and close mechanicm, the main door slides upwards and opens up the full side of the toolbox.

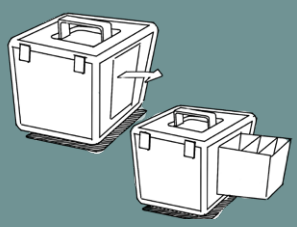


Figure 02.09. *Fixed toolbox shape with small hidden compartments.*

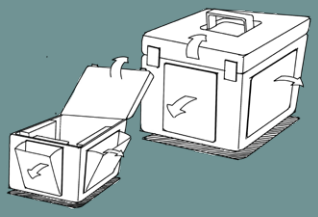


Figure 02.10. *Different approach to small hidden compartments.*

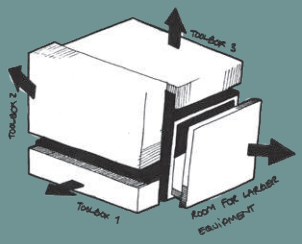


Figure 02.11. *Small separate boxes can be brought separately or form one large toolbox.*

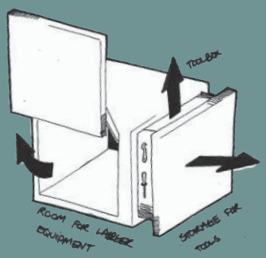


Figure 02.12. *Working with alternative principles of opening toolboxes to get better overview.*

Mock-ups

Accessibility and proper working positions are two of the main areas the PMTs pointed towards when the concepts were presented. To investigate the possibilities of handling heavy or unhandy tools and materials, simple physical mock-ups were created to quickly prototype different principles. By adding a tiltable compartment for larger and heavier items, a lot of strain will be removed from the user. On the right is a selection of the principles developed. By performing small scenarios on the various principles, it was discovered that;

- A front facing opening makes it possible to drag out tools or materials instead of lifting them through the top
- Just slight angling of the compartments helps making it easier to pull items or trash out
- By adding a system that tilts the compartment by foot press or push by arms from an upright position, strain on the user can be minimized

The experiences from investigating organization ideas and compartment principles should be forwarded into the following ideation phase. Further investigations into the needs for tools and cargo storage should also be performed to know what the exact needs are.

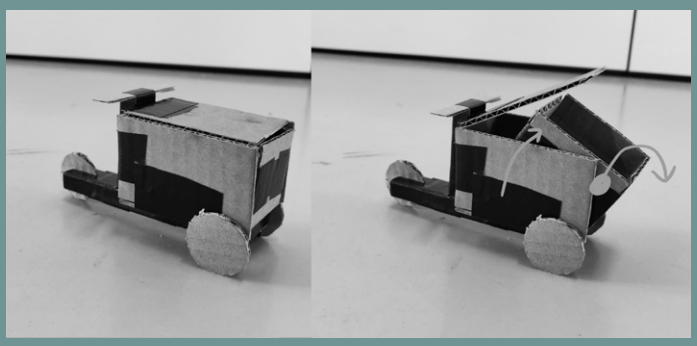


Figure 02.13. *The cargo compartment is closed when moving around and can be tipped forward to drop items or garbage off.*

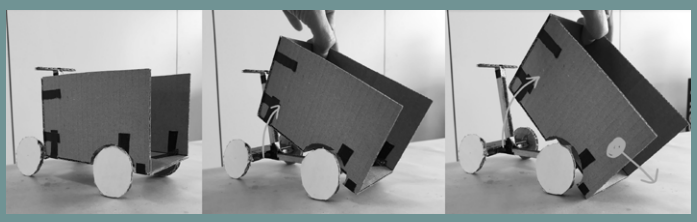


Figure 02.14. *The container is a separate box that rotates around the front wheel axle to assist the user in loading materials or tools off.*

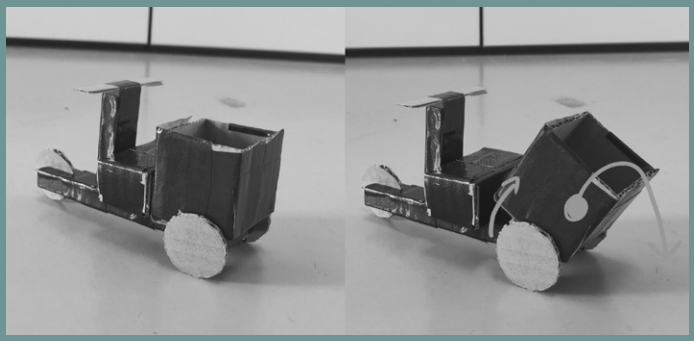


Figure 02.15. *The front of this model is a container for large items and the small box behind contains space for toolbox and small items.*

02.5 | Communication ideation

From the insights presented in the Understand phase, it was obvious that the lack of clear reports on the residential was a big part of the problem of waste transport time. In an attempt to embrace the major factors of the bigger problem, it was decided to include the communication aspect to possibly create a better solution.

The PMTs often mentions that, if possible, they prefer direct dialogue with the residents to be able to ask questions and understand their issues better. This both provides a social aspect between resident and PMT, but also a better basis for the PMT to plan what tools and materials to bring to solve the issue (app. 06).

The team decided to probe the opportunities to incorporate better communication into the solution and started ideation with the keywords *"personal, yet professional"* to establish the personal connection, but maintain the identity as professional craftsman Further keywords such as *"informative"* and *"easy accessible"* were established to ensure the right amount of information regarding tasks was provided and that the communication between resident, PMT and PM still were easy accessible.

Some of the concepts only took inspiration in some of the keywords, while others tried to implement all qualities. Figures 02.17 and 02.18 were based on rethinking the entire communication system, either by focussing on the entire system or the direct interaction between resident and PMT. Other concepts, fig. 02.19, 02.20 and 02.21 would involve little or no interaction and merely focus on the simplicity of providing either resident or PMT with information.

The presented ideas are both incremental and radical changes to the current system. The chosen path of developing a vehicle to provide more effective time is difficult to connect with these concepts. With this acknowledgement, it is decided to delimit from working deeper than concept level on improving the communication aspect of the problem. A scenario presenting the thought principles and flow of the communication will be developed and presented.

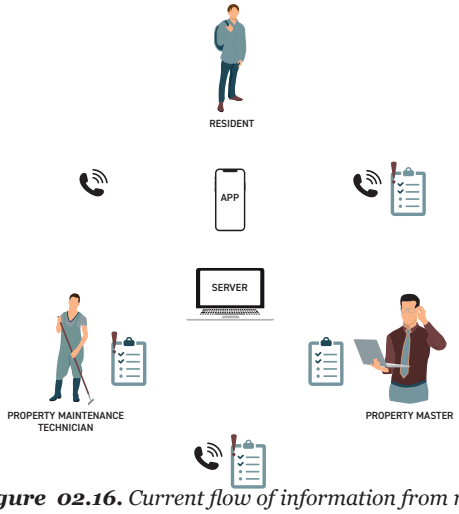


Figure 02.16. *Current flow of information from resident to PM and finally PMT.*

Figure 02.17. *An artificial intelligence PMT asks elaborating questions and provides personalized information to give the feeling of personal contact.*

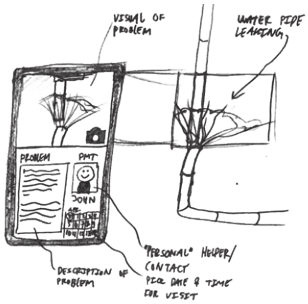


Figure 02.18. *Incremental changes to the current system. Asks more detailed questions and shows the local PMT.*

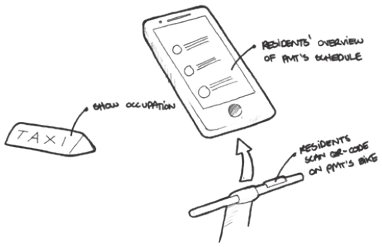


Figure 02.19. *Residents contact the PMT on his bike and can view his schedule to see free time slots.*

Figure 02.20. *Conservative solution that urges the resident to give detailed information on the issue.*

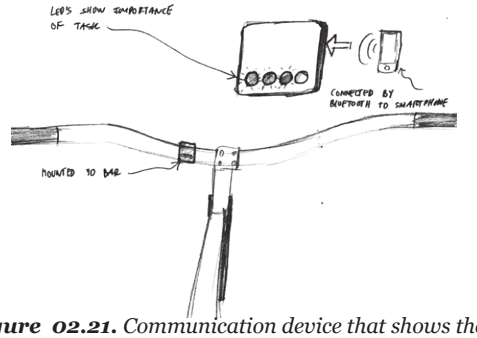


Figure 02.21. *Communication device that shows the PMTs new tasks and their rated importance on the bike handle bar.*

02.6 | Identity ideation

The team noticed a clear paradox in the desired professional identity pinpointed in the parameter investigation (p. 43) to the identity associated with being a craftsman and riding a lady bike. Although the lady bikes meet the needs of mobility, versatility and comfort pointed towards by the PMTs, they are far from satisfying the expression, contents space and physical size desired (p. 42-43). The sketching on identity thus consists of trying to implement those desired parameters by combining flexibility, versatility and space for desired amounts of contents with the professional expression, the PMTs want to associate themselves with.

The five vehicle concepts seen below are all fully or assisted electrically driven. From the elaboration of the three mobility concepts (p. 44), these five concepts take inspiration from principles of either scooters or Segways. These types of vehicles are quick to get on and off, satisfying the desire of high flexibility. The expression of objects and vehicles from the work and professional profiles of the PMTs, i.e. tools, toolboxes, tractors etc. was the inspiration for the expression of the six identity concepts, hence appealing to the wish for a professional character.

It was a challenge for the team to ideate on a vehicle that combines all the desires from the parameter investigation. The ideation was a challenge, not only because a concept should combine the flexibility and maneuverability of a lady's bike with enough storage space for tools and waste carried by the PMTs, but most importantly for this ideation, the concept should satisfy the needs for visual expression set by the PMTs.
Although being challenging, the team created concepts that met the aforementioned criterias.

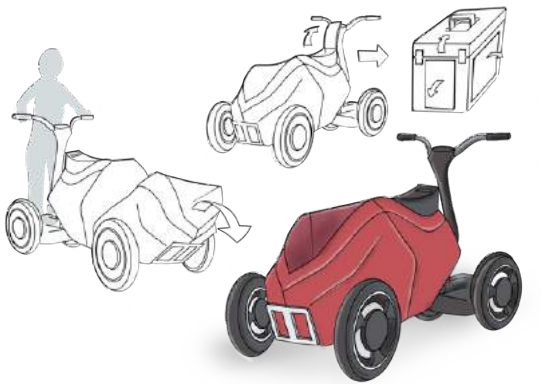


Figure 02.22. *The concept is as a combinantion of an ATV and a segway. The cargo compartment can be tilted when stored with garden waste. The toolbox is enclosed closest to the rear.*

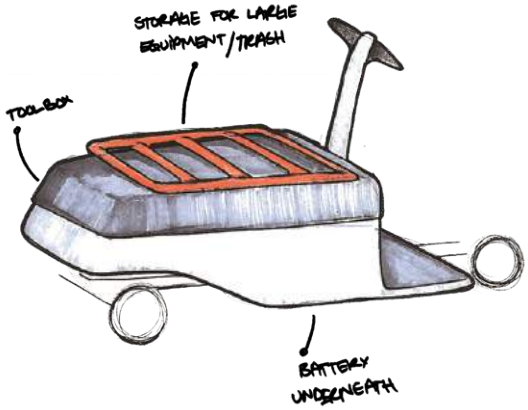


Figure 02.23. *The concept is thought of as an e-scooter with storage for toolboxes as well as large equipment on top.*

Figure 02.24. *This concept can be used as a scooter in standing position and as a scooter in seated position as it has a retractable seat intrgrated. The tools etc. are stored in the front and the cargo hold in the front can be tilted for offloading.*

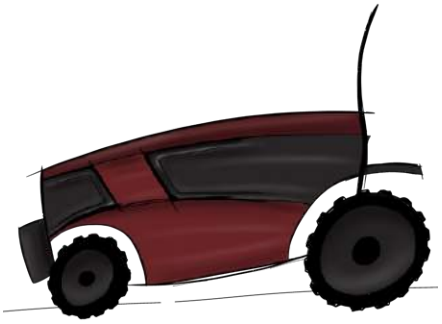


Figure 02.25. *The concept takes aesthetic inspiration from tractors and handling principles from Segways. There are both room for storage, garden waste as well as toolboxes.*

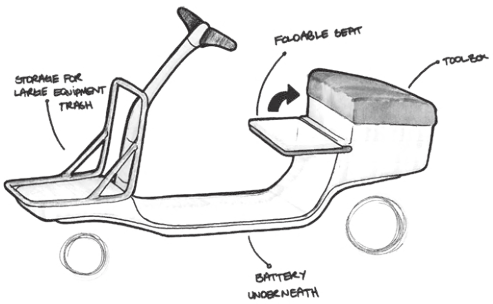


Figure 02.26. *This concept is a scooter that can be used in both standing and seated position. In the front are storage for larger equipment and in the back room for toolboxes.*

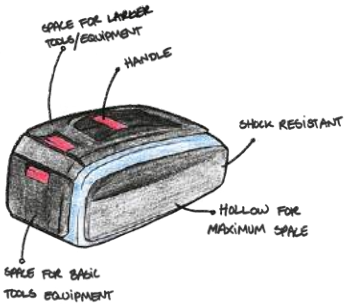
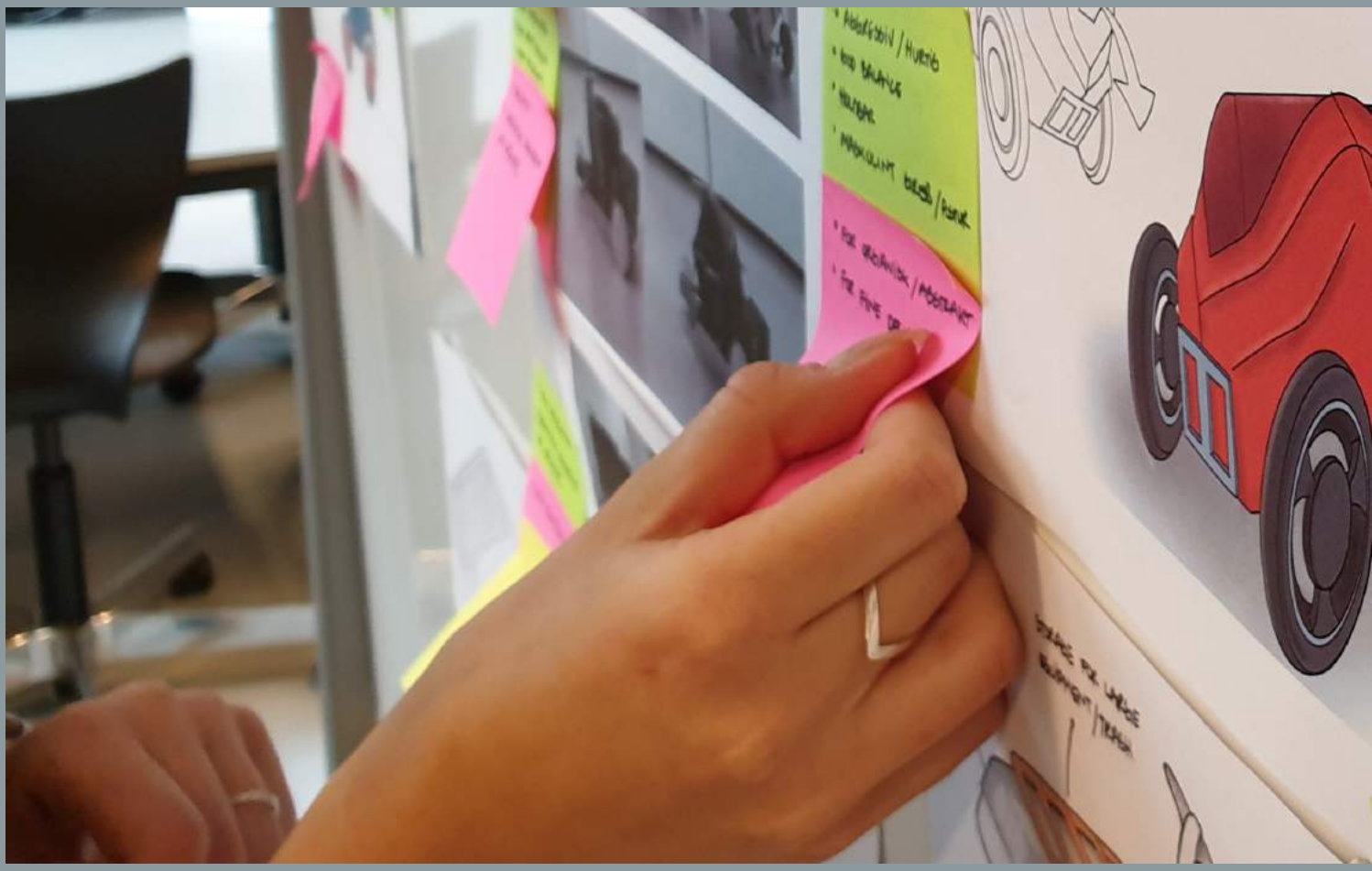


Figure 02.27. *This concept is a toolbox with interaction surfaces marked with a bright red color. The toolbox has departments for both basic tools as well as larger tools and equipment.*



02.7 | Combination of parameters

The design parameters acted as design guidelines for the following ideation phase. Initially, the team presented three concepts of the mobility parameters to the PMTs and afterwards their preferences and wishes were identified through the design parameter investigation. The three mobility concepts became the base for the further ideation.

The team decided to exclude the platform of the traditional cargo bike as it turned out SBH already had declined getting one as it was too large to pass through some of their premises. Instead, focus were directed to the mini tractor and the mini e-scooter as they were assessed to pose bigger potential to comply with the needs and wishes identified. Riding on mini e-scooters is also becoming increasingly popular in urban areas around the world (Ajao, 2019) and the team saw this as an opportunity for using the platform for other contexts than presently intended.

From the two ideations upon storage and identity, the team chose concepts for further exploration and combination possibilities. The chosen concepts and principles are listed below. These form the guidance for the further development of the vehicle solution.

Storage

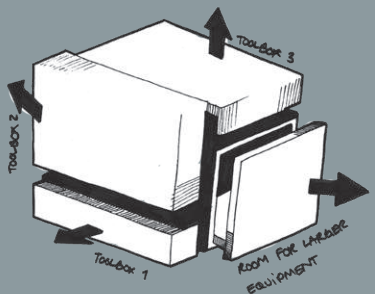


Figure 02.28. *Several small compartments joined to become one big toolbox. Possible to bring as many as wanted.*

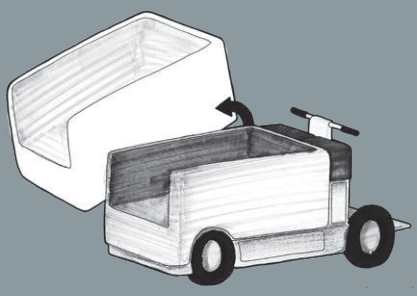


Figure 02.29. *Storage compartment is tiltable to let off materials or garbage easily and with less physical strain on user.*

Communication

Figure 02.30. *An artificial intelligence asks questions to get full details on residents' issues and creates an artificial feeling of personal contact.*

Identity

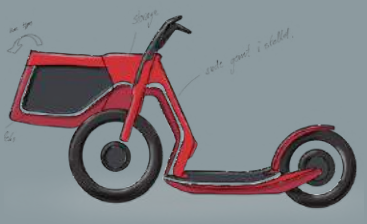


Figure 02.31. *E-scooter concept with integrated retractable seat provides comfort or flexibility on long or short rides.*

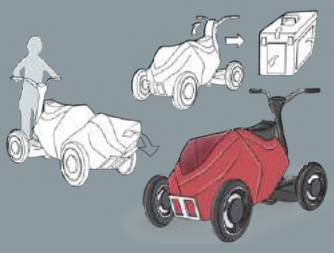


Figure 02.32. *Agressive and abstract expression that gives a feeling of craftmanship and masculinity.*

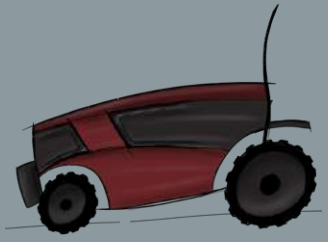
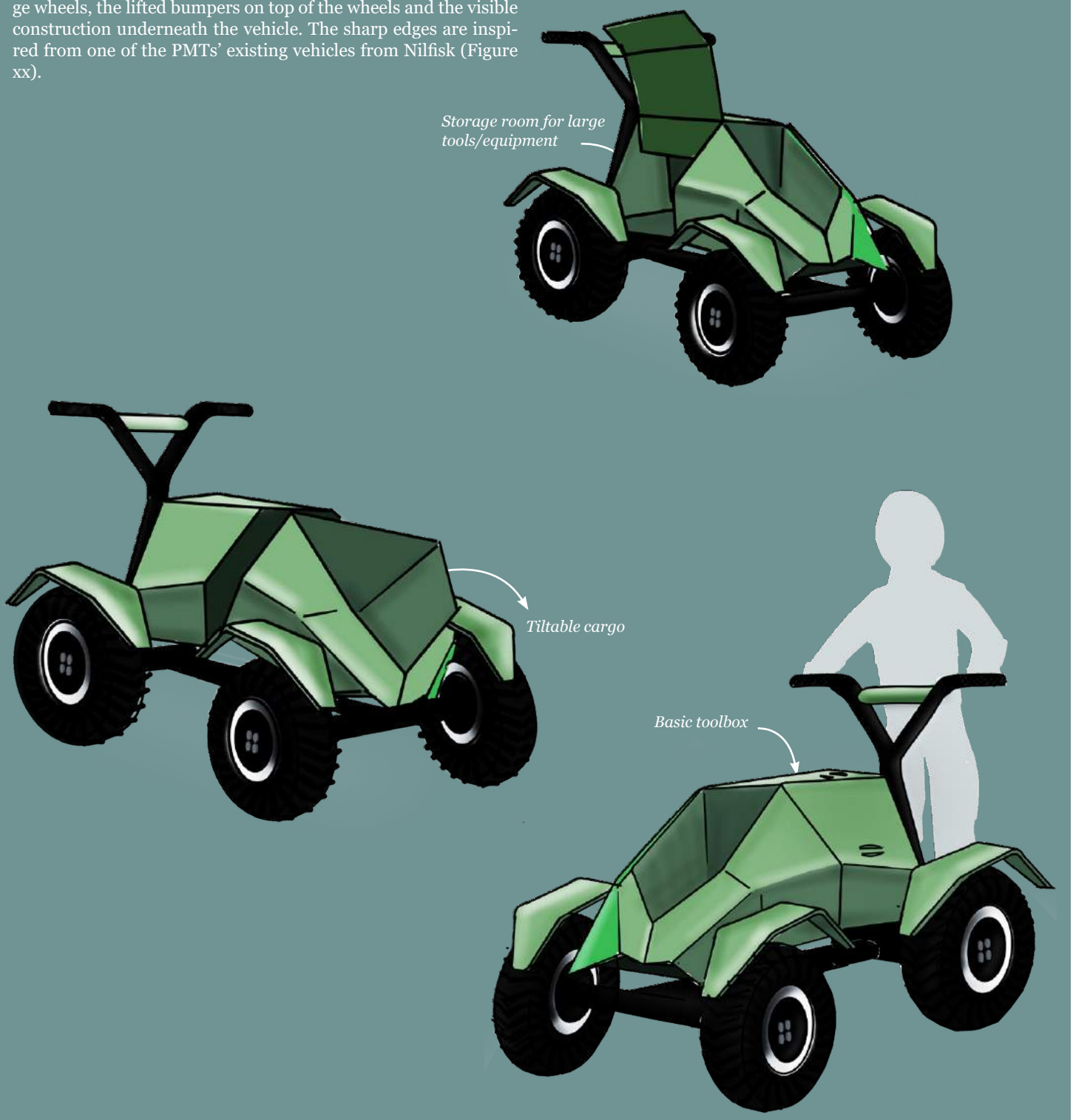


Figure 02.33. *Lines that creates direction and sense of downforce inspired from tractors.*

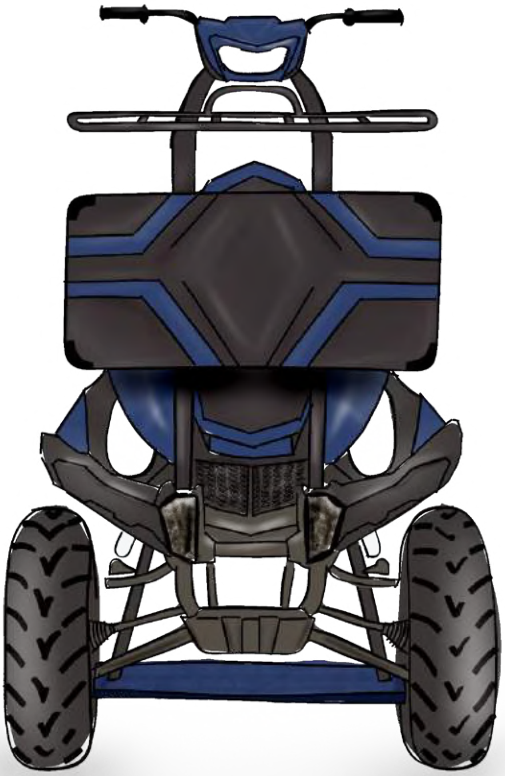
02.8 | Viper Ride

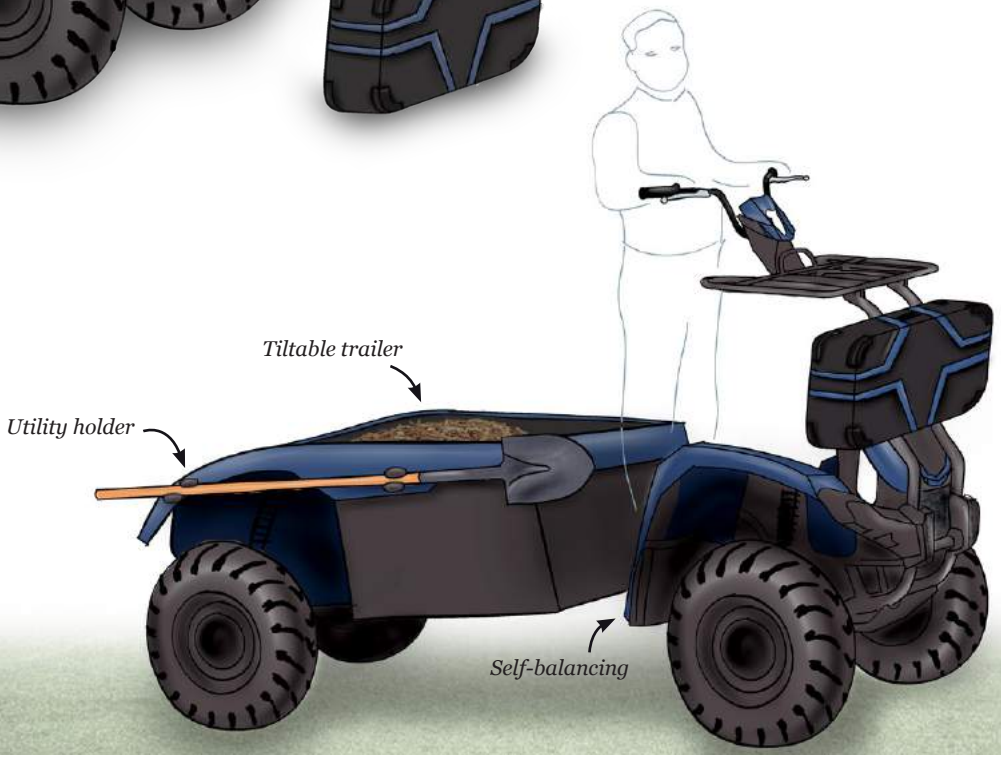
Viper Ride is based on a previous concept which is a combination of a Segway and an ATV. The Viper Ride is a vehicle with a platform the users stands on while riding. In a work situation, the PMT quickly jumps on the Viper Ride and is ready to go. There is a retractable seat hidden within the rear. The front of the Viper Ride can be tipped to unload garden waste or it can be used to store large equipment and tools as well. Close to the rear are storage room for both basic and special tools which are enclosed within the vehicle - only accessible for the PMT by key. The wheels on the Viper Ride is able to go through rough terrain, making it suitable for winter as well.
Aestheically, the Viper Ride is inspired from an ATV with the large wheels, the lifted bumpers on top of the wheels and the visible construction underneath the vehicle. The sharp edges are inspired from one of the PMTs' existing vehicles from Nilfisk (Figure xx).



02.9 | **QuadTrac**

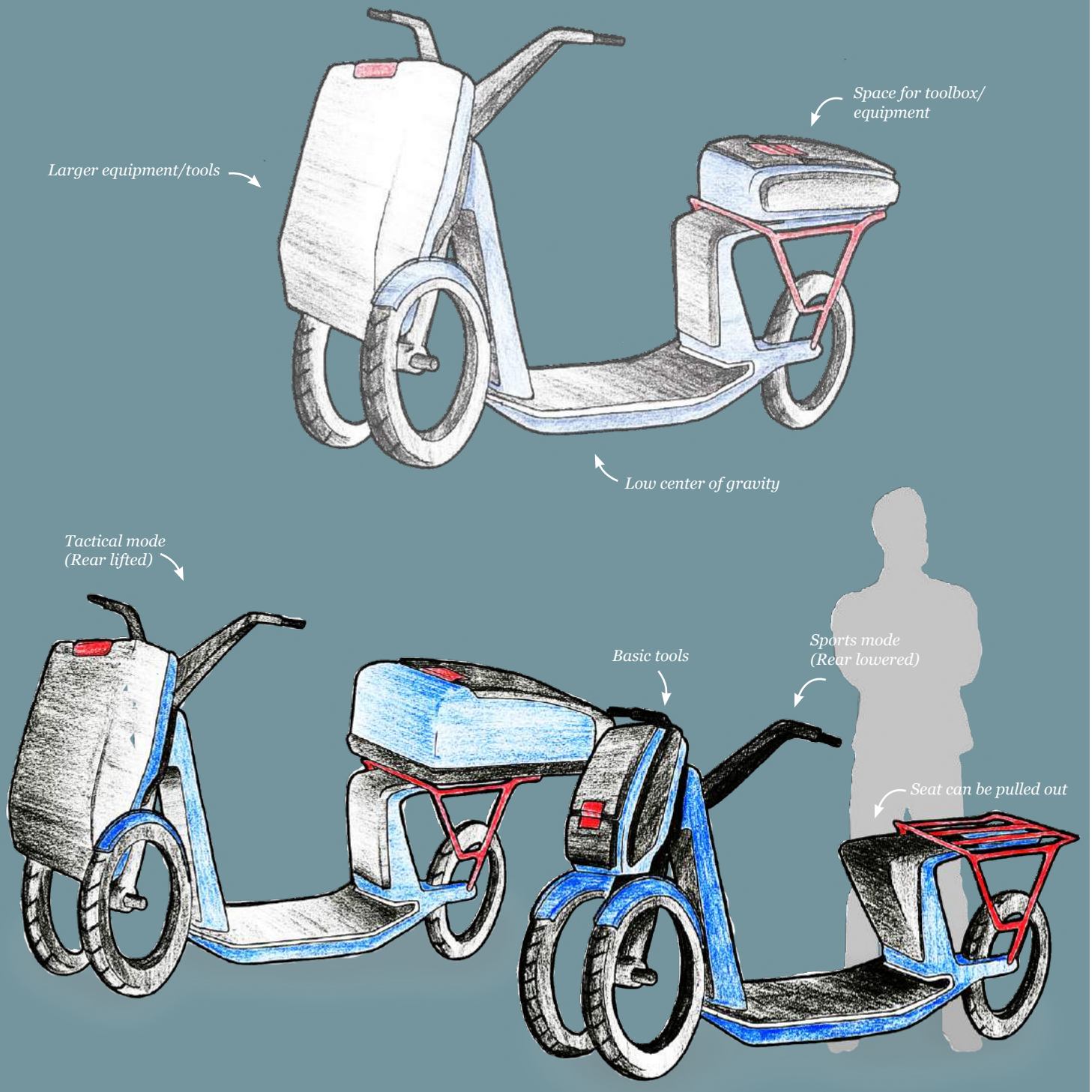
This is the QuadTrac - this concept has as well as the Viper Ride been inspired from ATVs. The idea is that the QuadTrac is a highly mobile electrically driven vehicle on two wheels carrying the basic tools on the front. When in its basic form, the QuadTrac stabilizes itself using gyro sensors. To add more capacity, it is possible to attach a trailer to the rear of the QuadTrac. Emphasis on this concept has been on developing a raw and masculine look that helps define what the janitors jobs consist of. You see these aggressive lines and high clearance to the wheels and instantly feel the brutality and capability to go through rough terrain no matter the task.

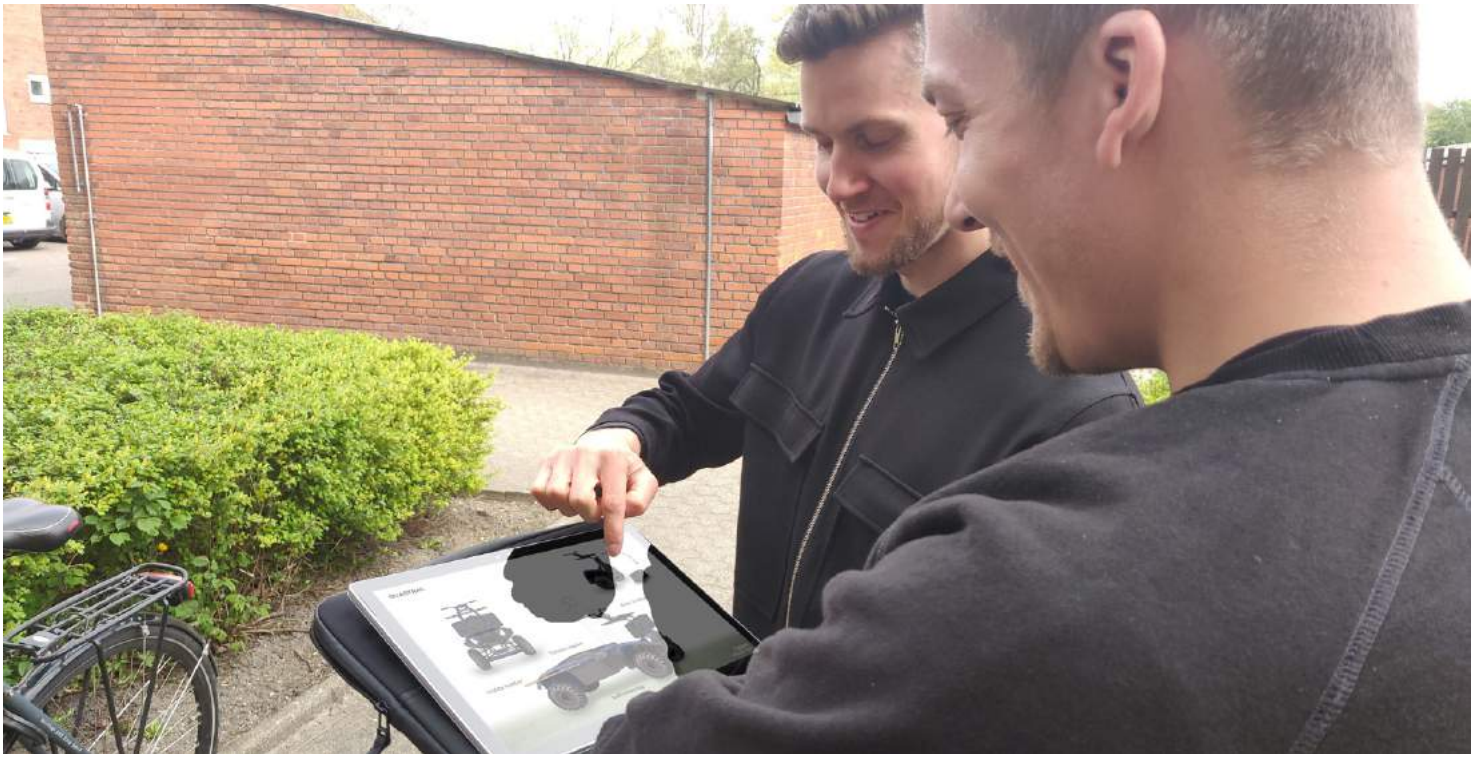




02.10 | Kickbike

The Kickbike also takes inspiration from two previous concepts. The concept is a versatile vehicle with the possiblity of carring different sizes of toolboxes depending on the needs of the PMT. The Kickbike is an electrical scooter and can be used in both standing and seated position defined as the ”tactical” mode or the ”sports” mode. In ”sports” mode, the rear can be lowered so the user can reach it. A seat can be pulled out underneath the red frame in the back.





02.11 | Concept evaluation

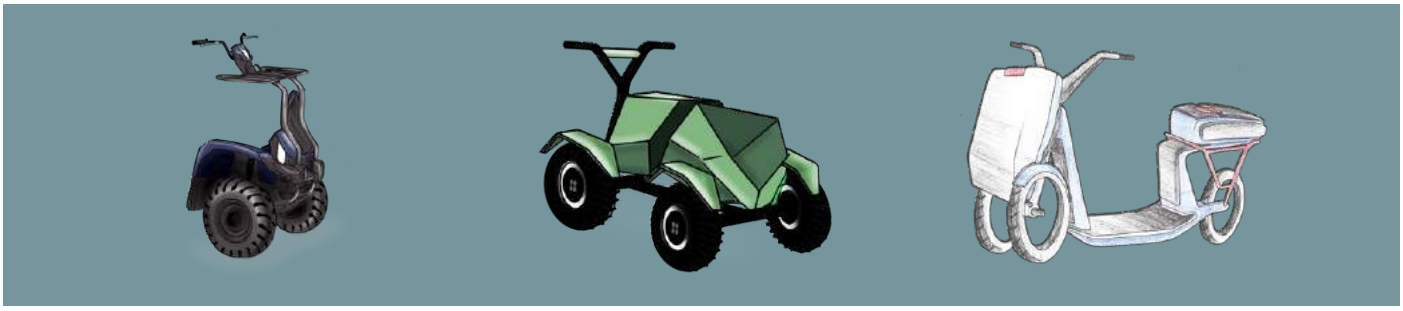
The three concepts; Viper Ride, QuadTrac and Kickbike were all presented for the PMTs and PMs. The objective for presenting the concepts was to define a final direction for the project and to collect the focus groups' feedback and thoughts on the concepts. The concepts were presented one by one to each PMT and PM and described of its features and general use.

QuadTrac
John Martin was the first to be presented for the concepts. He was most positive towards the QuadTrac as he thought he could be able to get through narrow spaces with it. Further, he argued that he liked that he had the possibility to attach a trailer in case he needed to bring larger equipment. Søren, another PMT, was also very positive towards the QuadTrac. He agreed with John Martin that having a trailer connected when needed, and be able to pass through narrow spaces solved many of the issues Søren has experienced with the current vehicles.

Viper Ride
John Martin and Søren saw it as a good potential that Viper Ride had a tiltable cargo to unload garden waste or big equipment, though they both argued that it would be to difficult to navigate through narrow spaces which is one of the biggest challenges with the current vehicles.

Kickbike
Søren was really fond of the Kickbike as he could divide his tools into several different boxes to be brought along according to his needs. Furthermore, having two positions for both seated and standing position was something he liked as he often have to ride between departments located far from each other.

Based on the feedback and the teams own intuition, the team chose the QuadTrac to work on further. The team decided to delimit themselves from detailing the gyro sensor vehicle systemsimilar to Segways and instead build on the basis of a Segway as an add-on or modification to that.



QuadTrac

- \+ *Able to go through narrow spaces*
- \+ *Stores the basics*
- \+ *Can be extended with trailer*
- \+ *Easy on and off*
- \- *No seat*

Viper Ride

- \+ *Storage room for all tools*
- \+ *Storage room for garden waste*
- \+ *Easy on and off*
- \- *Too wide to pass narrow spaces*
- \- *No seat*

Kickbike

- \+ *Dividing of tools*
- \+ *Good visual expression*
- \+ *Seat*
- \- *Looks fragile*

02.12 | Change of scope

The team presented not only the concepts for the PMTs but also Ole Faurholt, the PM in the department of Lindholm. The team wanted to get further insights into the processes and considerations when investing in new equipment.

The team learned that if the amount of a new vehicle or equipment exceeds 10.000 Danish kroner, the PM needs to write a requisition. If the amount exceeds 30.000 Danish kroner, they need to consult the technical department within SBH for approval. The estimated selling price for either of the three concepts presented on previous page is between 25 to 40.000 Danish kroner (insight 1.16), and with that, the PM will need to get the purchase of a new vehicle approved by the technical department before being able to purchase.

Ole argued that for their department (Lindholm department), to invest in a solution such as one of the three concepts, the features and usability of it will have to either match or exceed their existing vehicles - the Nilfisk Park Ranger or the Stiga (app. 21). Ole suggested that if the solution and features of the concepts could be implemented into an add-on to one of their existing vehicles, it would be easier for them to implement and an economically more attractive solution (app. 50). He also stated that when they look to buy new equipment, they are not looking at brand or price - but what the potential return is in terms of saved man hours, less maintenance costs etc.

Change of scope

After the new insights from Ole Faurholt about their decision making when buying new vehicles, the team learned that there needs to be very convincing reasons if SBH has to invest in new large vehicles - such as really competitive price level, added functionality and a return of investment within reasonably short time span. To explore to which extents the solution space cost-wise expands, the team created following cost model. The model shows how cheap the product theoretically can be - the minimum viable product - and how expensive it might be - with both extremes covering at least the primary requirements. The team made this cost model to show that the add-on product to the lady bikes is the minimum viable product that still covers the primary or most important requirements. Based on this fact, it is chosen to work in this direction as it is a solution they housing associations seem more likely to invest in. The team found that the design principles from the presented concepts still are relevant to some extent into an add-on solution.

Correction: We choose to work with the add-on solution based on new information from Ole Faurholt. The add-on solution is easier to implement in the existing setup of the housing associations and does not require heavy investments. This also makes the business case stronger as the housing associations are more willing to invest the estimated cost price as the risk is lower.

"We spent 17.000 kroner on a cargo bike in the Vangen department and it is around that amount we set the limit for the vehicles. If it is above that amount, it needs to be some utility vehicle. The tractor (Nilfisk Park Ranger 2150) is a lot more expensive but it also serves important purposes such as grass mowing, clearing snow and transporting heavy things."

- Ole Faurholt, PM in Lindholm department of SHB

Add-on to existing vehicle	Incremental change to existing vehicle	Radical new product
Using vehicle already in use at the housing associations · Add-on to bicycle, Segway, scooter	Incremental change to existing platform or principle · Redesign of cargo bike, Segway, scooter etc.	Completely new product, no use of established platform or principle
+ Positive aspects	**+ Positive aspects**	**+ Positive aspects**
Using vehicle already in use at the housing associations · Add-on to bicycle, Segway, scooter	Incremental change to existing platform or principle · Redesign of cargo bike, Segway, scooter etc.	Completely new product, no use of established platform or principle
- Negative aspects	**- Negative aspects**	**- Negative aspects**
· The marginal solution (compromises are made)	· Expensive initial investment for housing associations	· Expensive initial investment for housing associations · Expensive production startup

Figure 02.33. *With a shift in scope, the intended solution goes to being a add-on to an existing vehicle from positioning itself somewhere between a radical new product and an incremental change to an existing vehicle.*

02.13 | Final requirements

With the change of scope, some of the requirements change or become insignificant in regards to an add-on solution. These changed or insignificant requirements are marked in the list of requirements below. Many of the needs and requirements elicited are still relevant in the new scope and are not corrected as they are still obtainable. All metrics refer to key insights and needs made during the process and are trackable.

The marginal and ideal values describe acceptable target values to implement during the development of the concept. These values are based on the Blue Ocean canvas mapping (app. 20 and 21) to target similar or better performance data on the identified potential areas to stand out on the market on. Values not extractable from the Blue Ocean canvas mapping are estimated values based on interviews, observations or desk research.

Metric no.	Need no.	Metric	Imp.	Units	Marginal value	Ideal value
1	1.01	**Physical activation of user** *The PMTs that use bikes to get around express that they are happy with the exercise they gain from biking to and from tasks and view it as good exercise.*	****	Binary	Yes	Yes
2	1.02	**Steps on a work day** *Even though the PMTs appreciate the exercise from biking around, they do not want to walk too much around as it is ineffective time wise.*	****	Binary	Yes	Yes
3	1.03	**Damping in toolbox when passing over standard curbstone** *When the PMTs fare over uneven terrain, the tools rattle in their toolboxes and they risk it falling off. This metric describes how much rattle is acceptable.*	****	Subj.	-	-
4	1.04, 2.01	**Storage capacity for "basic tools" (app. 22)** *"Basic toolset" consists of the most frequently used tools in tasks i.e., fixing a doorbell (small drill, doorbell etc.), adjustment of window hinge (screwdriver with bits). See pg. 24 or app. 22 for further details on "basic toolset".*	****	List	screwdriver with bits, umbraco set, pliers, ruler, small drill	screwdriver with bits, umbraco set, pliers, ruler, small drill
5	1.04, 2.02	**Storage capacity for "extended basic tools" (app. 23)** *"Extended basic tools" are the tools used for very specific tasks, i.e., leaking water tap (gasket), change kitchen table (jigsav, dewalt wrench, cup drill) See pg. 24-25 or app. 23 for further details on "extended basic toolset"*	****	List	Dewalt wrench	Hammer, Dewalt wrench, jigsaw, impact drill, gasket, cup drill
6	1.05, 2.03	**Storage capacity for "special tools" (app. 24)** *"Special tools" are the tools used for very specific tasks, i.e. blocked drains (Ridgid K-45AF, Ridgid K-50-7, tub, gloves etc.), apartment supervision (ladder, DeWalt DC500 etc.) See app. 24 for further details on "special tools".*	***	List	Ridgid K-45AF	Ridgid K-50-7, Ridgid K-45AF, DeWalt DC500
7	1.04	**Integrated storage for tools or toolbox** *The PMTs carry what they refer to as their "basic" toolbox with them. This toolbox should be integrated into the solution as it is a vital part of their equipment.*	****	Binary	Yes	Yes
8	1.05, 2.04	~~**Storage capacity for "garden tools" (see app. 25)**~~ ~~*Garden work has become a small part of the PMT work, but it is still a part of the job. The garden tools would be good to be able to bring on the solution.*~~	*	List	No	Yes
9	1.07	~~**External width of solution**~~ **> Total width of add-on and bicycle combined** *External width of system is the biggest distance in width measured when bicycle is fully equipped with add-on and tools. Width is critical in regards to passing through narrow spaces and complying with vehicle regulations.*	****	mm.	700	500
10	1.07	~~**External length of solution**~~ **> Total length of add-on and bicycle combined** *External length of system is the biggest distance in length measured when bicycle is fully equipped with add-on and tools. Length is critical in regards to passing through narrow spaces and complying with vehicle regulations.*	****	mm.	2200	1700
11	1.08, 2.08	~~**Top speed**~~ ~~*Top speed is an important metric as the PMTs are unlikely to accept a solution that slows them significantly in getting around compared to the bicycle.*~~	****	km/h	12	16
12	1.08, 2.08	**Track time on test route "Lindholm Brygge to Søparken" (see app. 27)** *The test route is a typical distance travelled in the SBH housing association. On the bike, it is possible to cross a railroad to shorten the distance, while the other vehicles have to go a different, longer route. The test route is a worst case scenario showcasing the advantage of having a mobile vehicle.*	***	sec.	300	241
13	1.02, 2.05	~~**Electrical engine integrated**~~ ~~*Some of the PMTs liked the idea of being assisted when going uphill with a loaded bike. However, the problem was not very significant and only a wish rather than a need.*~~	*	Binary	No	Yes
14	1.08, 2.05	**Improving daily operations** *To be relevant for both housing association and PMTs, the solution must offer something different than existing products to improve the daily operations. To carry out a test on this, a fully developed product could be trialled by PMTs to see the effect on daily operations.*	*	Subj.	Yes	Yes

Metric no.	Need no.	Metric	Imp.	Units	Marginal value	Ideal value
15	2.07	**Visible in <200 meter visibility** *Working around traffic in especially winter time poses a danger to the safety of the PMTs. To stay safe, they must be visible to other road users when conditions are poor.*	****	Binary	Yes	Yes
16	1.09	**Unit manufacturing price** *Manufacturing price should be kept as low as possible to make it attractive to invest in for the housing association. Manufacturing price also affects the sales price.*	****	DKK	2000	1500
17	1.09	**Price level compared to competing products** *There is often a reluctancy when investing in tools and equipment that differ from the usual. To be considered by the ones purchasing equipment, the price level must be appropriate.*	***	List	Equal	Lower
18	1.09	**Return of investment** *The PM of SBH housing association estimates 10 years lifetime for new vehicles and expects them to have returned the investment before so.*	***	Years	6	4
19	2.11	~~**Seat integrated**~~ ~~*All PMTs express that they would like the option to sit down on the solution if needed. However, it is not absolutely necessary, especially when having very short distances between points.*~~	***	Binary	No	Yes
20	1.09	**Service intervals** *Interviews with PMs revealed that they consider maintenance costs very detailed as well when purchasing new equipment.*	***	Days	365	730
21	1.11	**Time from getting off product to being locked** *When getting on and off the bicycle many times a day, the add-on should be easy to lock in order not to disturb the rhythm.*	****	sec.	<5	<3
22	1.10, 2.16	**Insurance approved lock** *As tool boxes often contain expensive equipment, they are also prone to theft. With an insurance approved lock, the housing association has some safety net in case of theft.*	***	List	Yes	Yes
23	1.11	**Automatically locking lock** *Observations showed that the PMTs do not lock their bikes when leaving them. By adding an automatically locking lock to the add-on, the risk of possibly leaving it unlocked is eliminated.*	****	Binary	No	Yes
24	2.15	**All-terrain tires** *Peter voiced his concern regarding the wheels (p. 44) of a concept as they did not look sturdy enough for the terrain he passes during the day.*	**	List	-	-
25	1.08, 2.08	**Average decrease in time spent on transport daily** *The PMTs spend a lot of time on transport daily and that is one of the key things the add-on helps decrease.*	**	%	5	10
26	2.13	~~**Cargo capacity for one hour of garden waste**~~ ~~*The PMTs would like to carry smaller amounts of garden waste and take it to garden waste containers.*~~	**	Binary	No	Yes
27	2.17	**Upright body position when offloading tools and materials** *When showing concepts from sketching V3.2 (see app. 32), it was mentioned by the PMTs that it is important to have an upright position when loading things off the vehicles.*	****	Binary	Yes	Yes
28	2.12	**Open container for materials or tools** *The PMTs sometimes have to transport materials or tools in odd sizes and need open containers to do so.*	**	Binary	Yes	Yes
29	Design demand	**Perpendicular edges around all flat surfaces** *By ensuring all flat surfaces have perpendicular surfaces, the risk of tools or materials falling off are decreased significantly.*	***	Binary	Yes	Yes
30	2.07	**Active illumination in dark contexts** *During the parameter investigation (p. 42-43), the PMTs expressed the importance of being visible especially on dark days during winter time.*	***	Binary	Yes	Yes
31	Design demand	**CE-approved** *In order to sell the product on the European market, it needs to be CE-approved.*	****	Binary	Yes	Yes
32	1.11	**Perceived user satisfaction after two weeks trial** *Helps assess the effect in daily operations and if the "stupid" tasks are decreased because of the add-on.*	****	Subj.	Medium	High
33	2.10	**Appeals visually to the PMTs** *The visual appeal of the add-on should be based on the parameters investigated in the user group. See app. 35 for more details on parameters.*	****	Subj.	Yes	Yes

03/

CONCEPTUALIZE

The focus of the following phase is based on the change of scope that ultimately led to the final requirements. The final requirements define the framework for the conceptualization phase where a more detailed, diverging approach to the concept development will take place. Eventually, the concepts will be modelled in full scale function models that enables the team to test and adjust dimensions and principles according to the observed scenarios, tools and equipment described in the prior phases.

03.1 | Ideation on rack

During previous visits, the PMTs expressed an interest in a flexible solution that holds multiple boxes and equipment for different purposes. This was initially the main focus for the development of the bike rack - to be able to store equipment in odd sizes such as garden tools (need no. 1.05, 2.04). Several concepts were developed with the focus on attaching these odd sized tools. Two of those are presented below - the rest can be seen in app. 41.

Concept for storing odd sized tools

The concept is to be installed to the front and rear of the bicycle, providing the PMT with an overview of their tools and equipment. The odd sized tools can be attached into two small arms in an upright position. On top, there is a platform to store the toolbox.

The concept of adding storage for odd sized tools was discussed as it was the understanding in the early phases that the time available for gardening had become scarce. Even though Peter mentioned he would like the option to carry it, the discussion concluded that it was more a wish than an actual need and not an important factor. With this conclusion, it was decided to not further develop this feature and instead emphasize other, more important aspects.

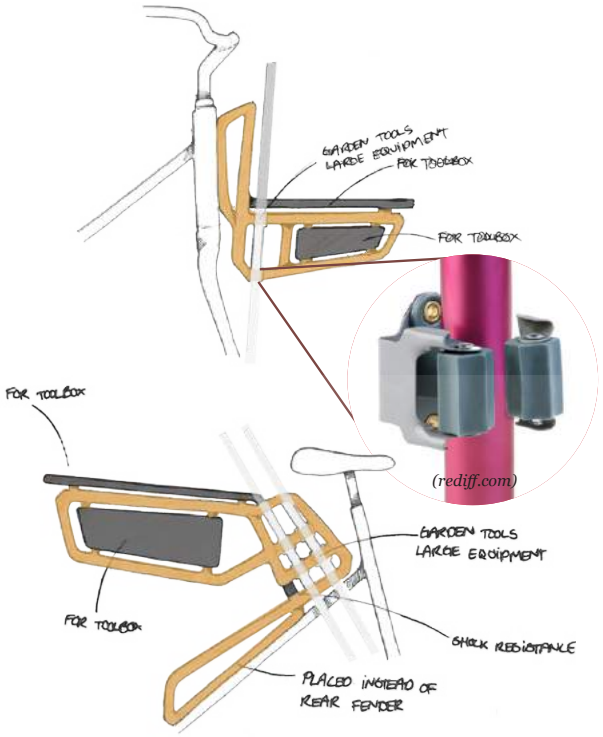


Figure 03.1. *Small arms are able to grab and hold long, thin items such as brooms, shovels, rakes etc. between the toolboxes that are also attached to the rack on both front and rear of the bicycle.*

Functional approach

Continuing the ideation on the bike rack, the team took inspiration from already existing bike frames and storing possibilities (app. 41). The previous aesthetically focus changed to a more functional approach, with the team looking not only at existing bike racks, but also different possibilities and principles of how to attach the rack to the bike. This led the team to also looking at how to secure the toolbox to the bike rack as this is an important aspect in the interaction scenario. It is previously discovered that the solution must not slow down the daily work, making the scenario of placing and dismounting a toolbox on the rack a key aspect.

The team drew inspiration from docking solutions for bags to be mounted to motorcycles on the gas tank. (oxfordproducts.com, 2019) From concept 1 to 3 (fig. 03.1, 03.2 and 03.3), the team decided to focus on a more robust and streamlined expression, which is why the profiles were changed from cylindrical to rectangular shapes.

Conceptualizing on securing the toolbox to the rack, the theme of securing the tools to prevent theft arised. Previously, the PMTs mentioned the issue of fearing theft when leaving their tools unwatched. This theme should be part of the concept development. Also, how the toolbox can be kept steady to avoid rattling tools when passing uneven terrain should be dived into as well.

3.01 The solution locks the toolbox to the rack to prevent theft

3.02 The solution makes it possible only for the PMT to access the toolbox

3.03 The solution is installed on the bike so it can not be easily dismounted and stolen

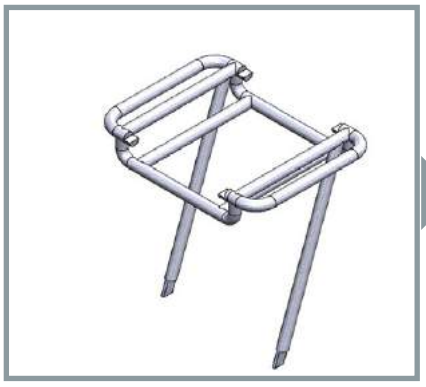


Figure 03.2. *Docking concept 1 - simple cylindrical construction.*

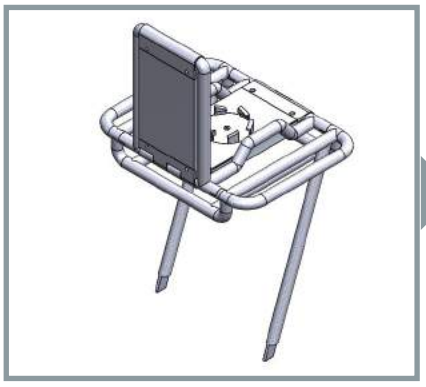


Figure 03.3. *Docking concept 2 - detailed cylindrical construction with the dock inspired from motorcycle bags attached to the gas tank.*

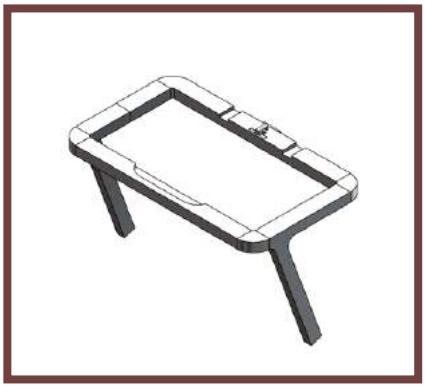


Figure 03.4. *Docking concept 3 -*

03.2 | Weight distribution test

Alongside ideating on the bike rack principles, the position of tools, toolboxes and materials were discussed. To gain insights into how the bicycle behaves physically when loaded at different points, the team decided to build a physical model to test the distribution of the weight. Prior to building the model, the team felt the greatest potential in having weight positioned just above the wheels as this would provide a good height for mounting and dismounting of toolbox and materials. By placing the weight on the sides of the wheels, the body position would be less appropriate for lifting heavy toolboxes - and with this motion many times during a work day, it could potentially pose great strain to the lower back.

To validate how the tools were best stored, the team made a wooden mock-up and mounted it to a bike to test three different positions of the weight placement. Inside the wooden model,
The weight were tested in three configuration (see fig. 03.5):

- Highest setting (1); bottom of weight aligning with front rack
- Medium setting (2); bottom of weight aligning with wheel hub
- Low setting (3); bottom of weight 200 mm from the ground

From testing the settings, the team found that the low setting (3) was the most difficult to handle the bike at when turning the bike. The best position for handling the bike was the high setting (1) of the weight.

The team increased the weight of the wooden model by adding bricks weighing 20 kg. to simulate the maximum weight allowed to carry according to labor regulations (apvportalen.dk, n.d.). The bricks were placed equally on each side of the wheel and also in a setting with side distributed weight to simulate uneven balance. This made the handling of the bike very difficult, and it was necessary to support with a foot to the ground for stability.

From this test, the team decided to aim for placing the weight of the add-on above the wheel to create better stability and handling of the bike when turning.

3.04 *The solution has the toolbox placed above the wheel*

Figure 03.5. *The physical model for testing weight distribution. The three different height settings were tested in regards to how easy the bike was to handle and for stability.*

Figure 03.6. *With the weight at the low setting (3), it became very difficult to keep balance when turning the bike.*

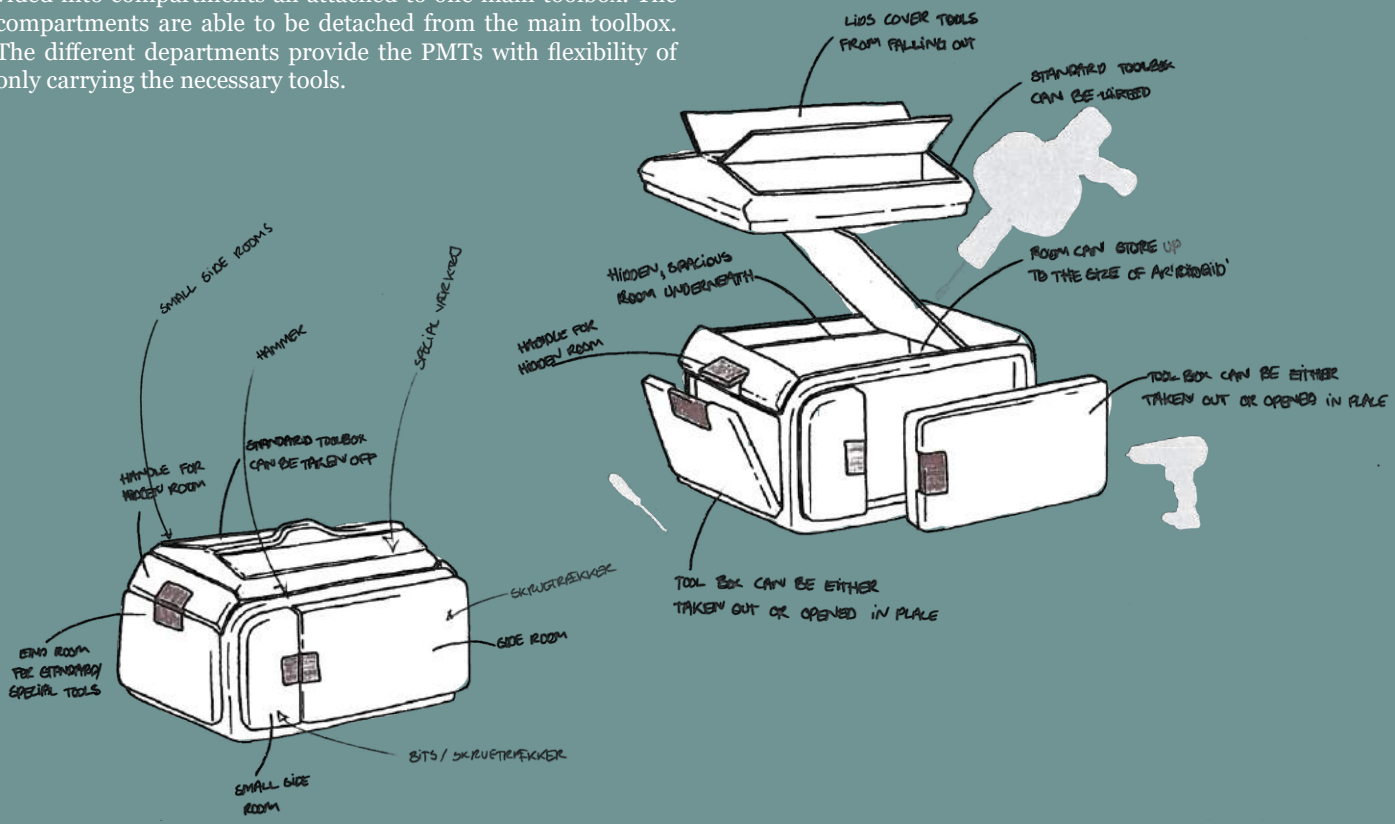
Figure 03.7. *On the medium setting (2), it was still difficult to keep a good balance on the bike when turning.*

03.3 | Ideation on storage box

Continuously with the ideation on the bike rack, the team ideated on the toolboxes. The team started by looking back on earlier ideation and concepts of storage (p. 45) for inspiration. These were developed further by sketching followed by mock-ups.

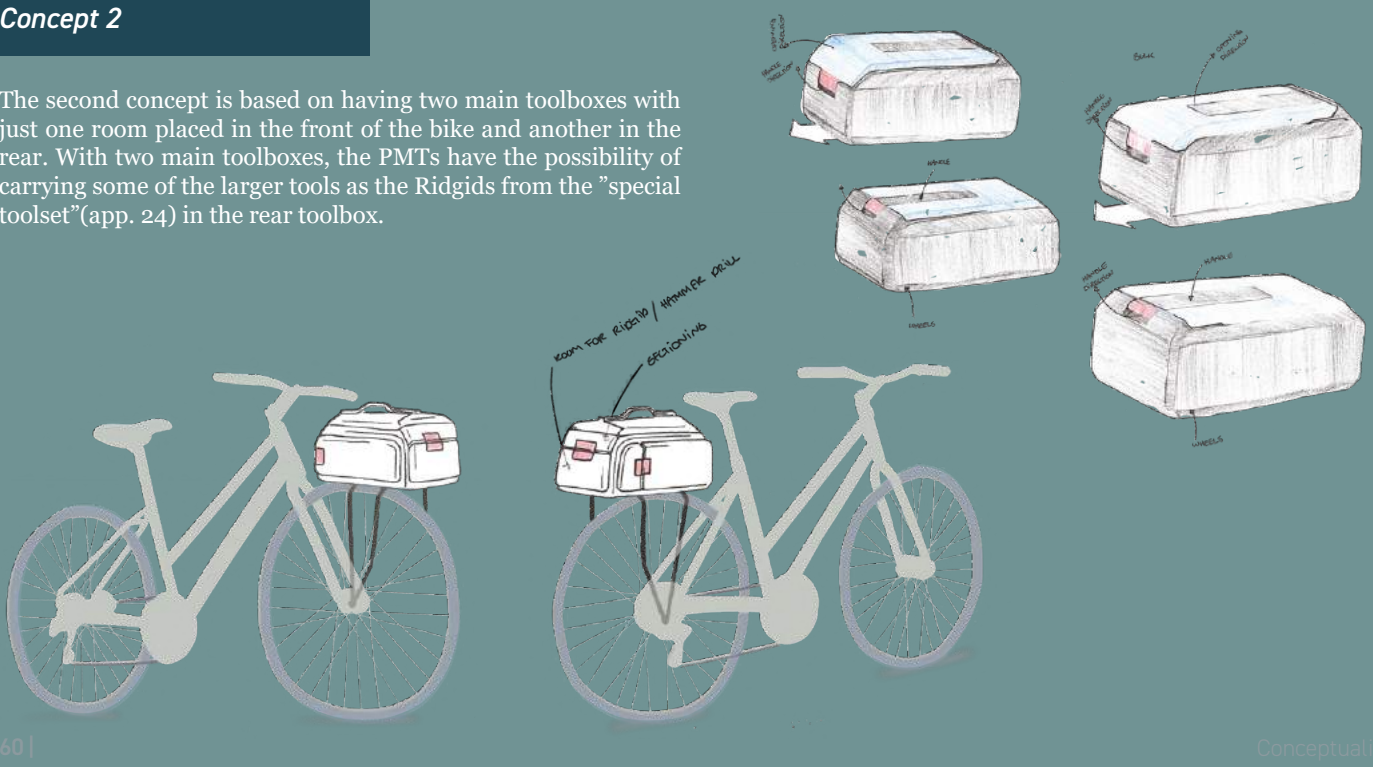
Concept 1

In the first concept, the tools and equipment of the PMTs are divided into compartments all attached to one main toolbox. The compartments are able to be detached from the main toolbox. The different departments provide the PMTs with flexibility of only carrying the necessary tools.



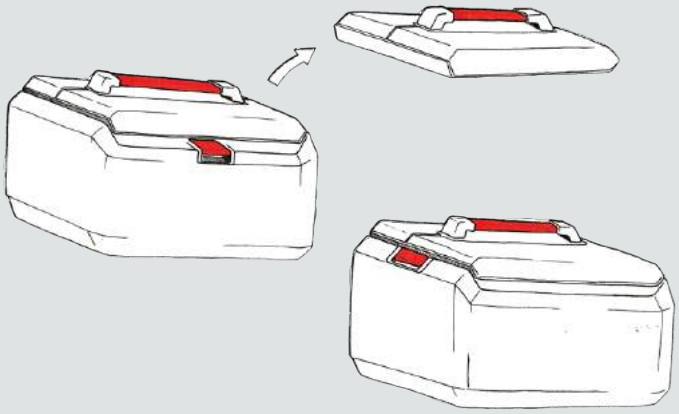
Concept 2

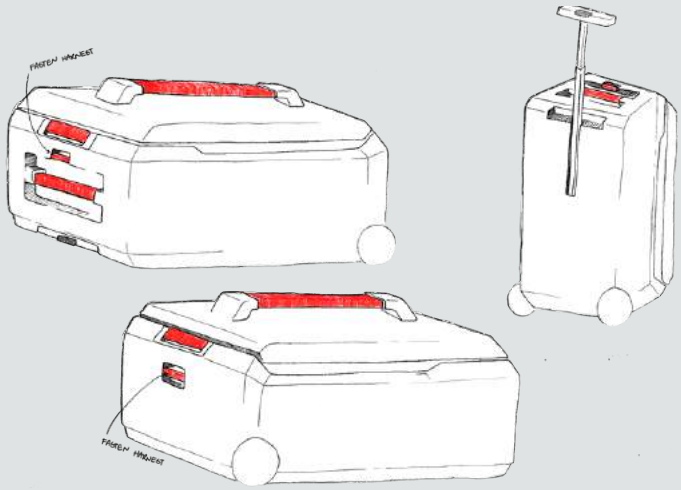
The second concept is based on having two main toolboxes with just one room placed in the front of the bike and another in the rear. With two main toolboxes, the PMTs have the possibility of carrying some of the larger tools as the Ridgids from the ”special toolset”(app. 24) in the rear toolbox.



Concept 3

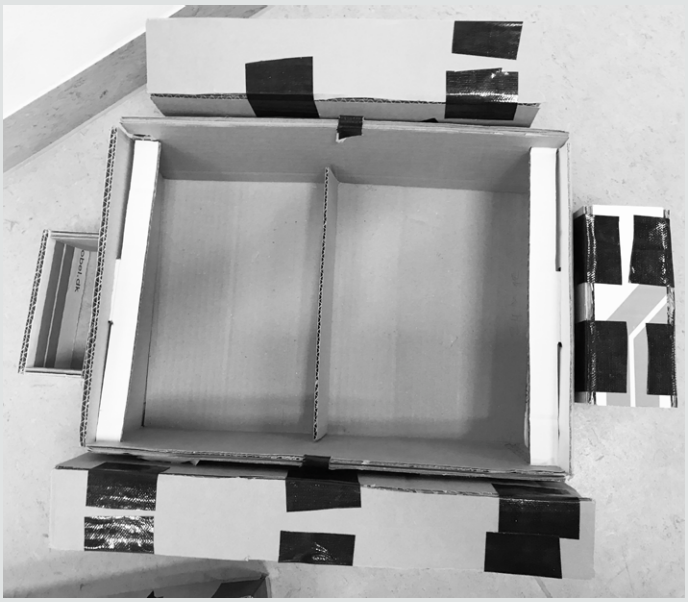
The third concept is a further ideation on concept two. The front toolbox has a smaller toolbox for the basic toolset (app. 22) attached on top. This can be detached and brought along. Below the ”basic toolbox” is room for the ”extended basic toolset” (app. 23). In order to accommodate the wish for organizing the tools, dividers can be placed. From observations, the PMTs prefer not to carry the heavy equipment by hand and instead utilize options for rolling the tools on wheels. Therefore the team decided that the back toolbox should have wheels to ease the means of transportation. Further, the PMTs prefer to carry heavy tools in the back and have their basic tools in the front.





Mock-ups: concept 3

The team decided that they needed to get a better understanding of the dimensions of the toolboxes and started making mock-ups. Making the first concept, it became clear for the team that having several different compartments raises some concerns; firstly, the size of the toolboxes and, secondly, the need for all compartments to be locked (p. 29). The locking mechanisms will require too much space and therefore the first concept is being discarded. The team then decided to work further on the third concept.



To get a better understanding of the scenario of bringing tools along for tasks, the team produced a scenario to act-it-out. How do the resident report a task? How do the PMT receive it? How do they bring the toolboxes?

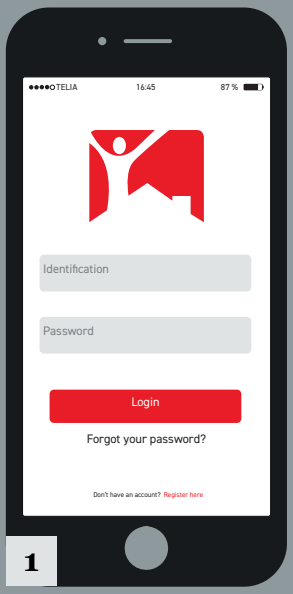
- *3.05 The solution has wheels on the rear toolbox*
- *3.06 The solution has the possibility for the toolbox to be divided*
- *3.07 The solution can be separated to make it possible to only bring the “basic toolbox” along*
- *3.08 The solution has the “basic toolbox” stored in the front of the bike*
- *3.09 The solution has the “special toolbox” stored in the rear of the bike*

03.4 | Communication

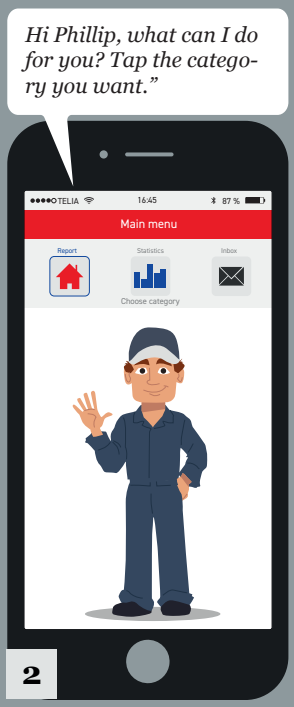
Currently, the communication between residents, PMs and PMTs is troublesome and results in a lot of waste time both for the PMTs as well as the residents (p. 27). The team ideated on a solution to solve some of these issues. The concept the team chose to elaborate on was an application based on an artificial intelligence platform.

Reports from residents

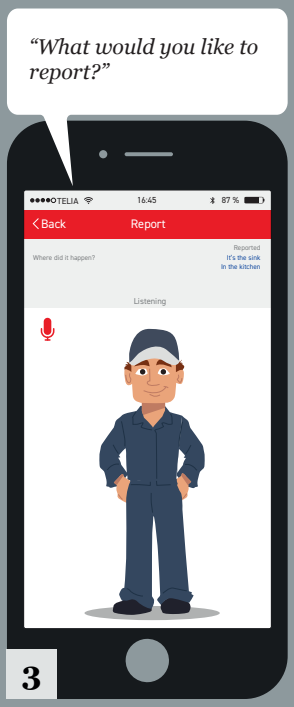
The AI platform should create an illusion of talking directly to the PMT responsible for the residents' department. The intent with the AI platform is to provide a more personal relation between PMT and resident. Further, the AI would build upon the PMTs professional background and ask elaborating questions and request the resident to provide pictures of the issues they want solved. The team have created the scenario below where resident called Philip is using the new application from SHB to report an issue. Phillip's faucet is leaking and his sink will not drain - an issue often only described as 'broken sink' to the PMTs.



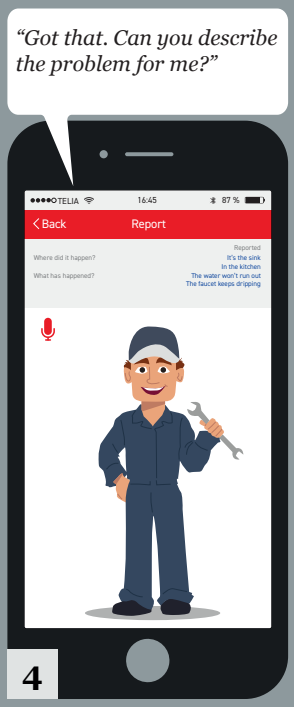
Each resident has a personal identification number and password.



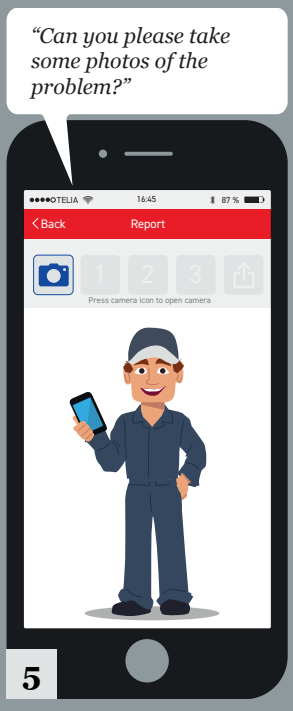
Phillip logs in and can now choose from three categories.



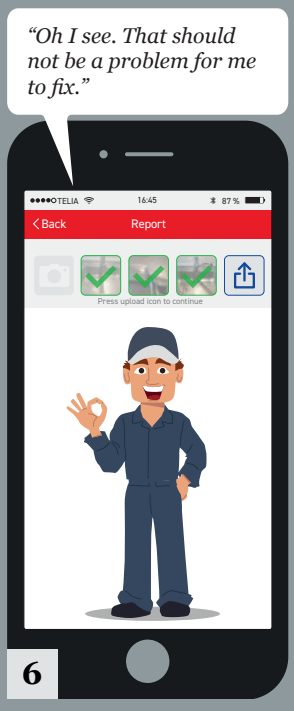
A microphone icon shows when Phillip can speak .



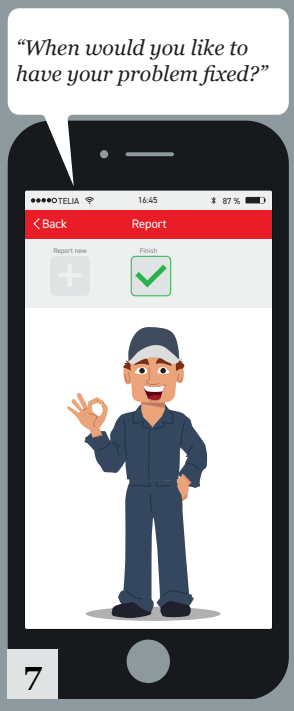
The application automatically skips to next subject.



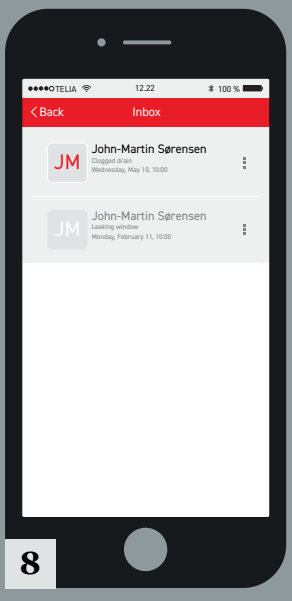
Phillip can upload up to three photos.



The photos are accepted and can be uploaded.



Free spots to choose from are highlighted.

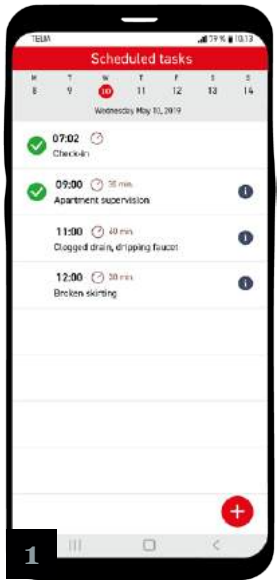


The problem is reported and Phillip has an appointment.

PMTs recieving reports

When Philip has reported the task, the PM at the HQ will receive it and schedule it. Then, the updated application for the PMTs will inform the PMT of the reported task - what the problem is, pictures of it and suggest tools to solve the problem. Depending on the quality of the AI, the task should be reported as if the PMT have talked with the resident themselves and then the risk of faulty reports should be decreased.

The team have decided to concentrate on the physical product development of this project and the communication part of the project will not be detailed further.



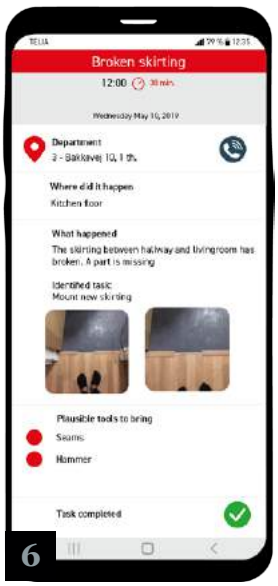
John wants information and taps the respective information mark.

John is provided with comprehensive information and details.

John checks of the suggested tools for fixing this task.

The exclamation mark gives information of the vaguely described issue.

John packs his tools, checks them off and he is ready to go.

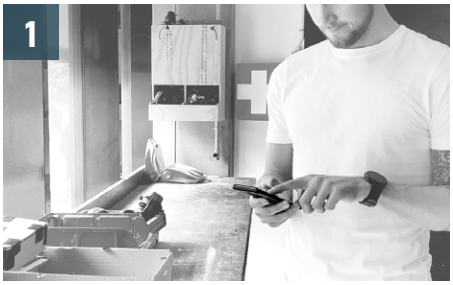


When John is finished with his task he tabs the accept icon.

John now has a full overview of all of his finished tasks.

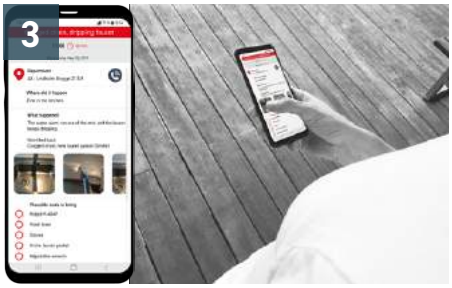
03.5 | **Scenario - a typical residential task**

From the ideation and mock-ups of the storage possibilities, the team found that they lacked an overview of how the PMTs new workday should look like with the add-on concept. The team mapped a new user scenario starting from when the PMT views the tasks for the day, packs his toolboxes, brings the toolboxes to the bike and transports on the bike to apartments and back again.



The PMT starts by checking the tasks for the day in the app for SBH.

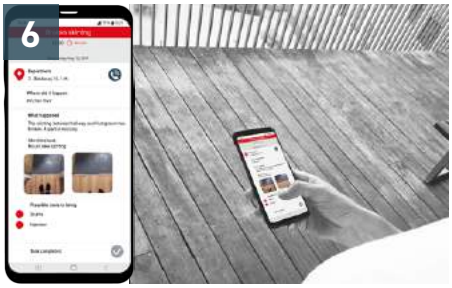
Finishing the apartment supervision, the next task is to fix a clogged drain.



From the app the PMT can see information regarding the task. Here, pictures of the problem and plausible tools to bring are shown.

Identifying the tasks for the day, the PMT are ready to pack his "extended basic toolbox" and "special toolbox" in the workshop.

The app suggested that the PMT packs the Ridgid (drain cleaner tool) as this is the most frequent used tool to fix a clogged drain.



The PMT looks at the information for the following task; a broken skirting.

The PMT packs the suggested tools "extended basic toolbox"; a hammer and seams to fix the broken skirting.

Closes and brings "extended basic toolbox" and "special toolbox" to his bicycle.

Slides/clicks and locks the toolboxes on to bicycle and rides to his first task at Lindholm Brygge.

The PMT rides his bike to the task at Lindholm Brygge.

The PMT parks his bicycle and unlocks cases using his RFID-tag in a 'bracelet', a chip in his keychain or in his staff card.

The PMT only needs to bring the "special toolbox" for the task at Lindholm Brygge.

The PMT lifts the "special toolbox" to the ground, standing on its wheels and deploys retractable handle.

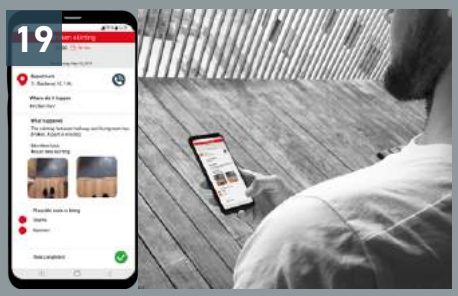
Should the PMT need both the "special toolbox" and the "extended basic toolbox", he lifts the "extended toolbox" of the bicycle and attaches it on top of the "special toolbox" and roll them collectively.

When the PMT gets to the stairs, he detaches the "extended basic toolbox", takes it into one hand and uses a strap to sling the "special toolbox" around his shoulder.

The PMT carries the "special toolbox" around his shoulder and the "extended basic toolbox" in his hand.

When the PMT arrives in the apartment, he opens "extended basic toolbox" and "special toolbox" on the floor in the apartment - ready to work on drain.

When the PMT is finished with fixing the drain, he closes the toolboxes and grabs module.



When the PMT finishes a task, he marks it as completed under information for the reported task in the app.

The PMT walks down the stairs with "extended basic toolbox" in one hand and "special toolbox" across the shoulder.

The PMT puts the toolboxes on his bicycle.

The toolboxes locks automatically when replaced back onto the bike.

The PMT rides to next task or back to the workshop for lunch break.

The PMT has completed the scheduled tasks for the day and has time for outdoor tasks and plausible acute tasks.

Outcome

From the user scenario, the team encountered several challenges which needed to be elaborated further. The size of the wheels had to be bigger to ease the transportation of the toolbox. The team found that transporting the rear toolbox in a upright position on wheels causes all the tools to tumble around inside the toolbox. The dimensions of the toolbox also had to be investigated to ensure that they were able to carry both the basic, the extended basic and special toolset. Lastly, if a shoulder strap is the most appropriate solution to carry the toolboxes upstairs or another solution is possiblem.

- *The dimensions of toolboxes; how many tools are able to be stored in the toolboxes?*
- *What is the most comfortable way to carry the toolboxes when walking on stairs?*
- *How big should the wheels be in order to manoeuvre the toolbox around without causing resistance?*

03.6 | Dimension test

The user scenario led to further investigation of the toolbox dimensions. They should be able to hold the necessary tools while still not interfering with the mobility by adding to the size of the bike. A simple mock-up of a toolbox to contain the common tools of the PMTs were made to test in the context.

Testing dimensions of mock-up

The mock-up was presented to the PMTs for them to provide feedback on the concept as well as testing the size of the toolbox. The team utilized the time with the PMTs by borrowing their tools and see if they fit into the toolbox (fig. 1-5, pp. 68). It was confirmed that the toolbox had space for the basic tools, extended basic tools and some of the smaller special toolsets, but not the Ridgid drain cleaning machine.

Open lid on the special toolbox

The toolbox lid was not able to be closed as the team intended (fig. 6). Peter, PMT, argued that it would not be necessary for the Ridgid to be in a closed container, as the PMTs would only bring it if they knew they needed it. He elaborated that if they were able to bring the "special toolbox" with them easily, it would not cause problems if the toolbox was open.

If the "special toolbox" was open, the basic and extended basic toolbox could not be stored on top. To solve this issue, the team decided that the basic and extended basic toolsets should have wheels as well as the "special toolbox" could be placed on top, and the PMT would be able to stack them either way around and bring both along.

Figure 03.8. *Testing if the basic tools are able to fit into the "basic toolbox". The handle in the middle works as a smaller divider of the tools. Underneath the "basic toolbox", the "extended basic toolbox" is placed. This should be able to store some of the larger tools the PMTs use. The two toolboxes with different tools. Having two toolboxes in one provides a better overview of the tools the PMT brings. The "extended basic toolbox" has a divider which can be used to separate the tools. The divider can be placed as the PMT prefers.*

Figure 03.9. *The "basic- and extended basic toolbox" is now placed on the front of the bike.*

Figure 03.10 *The PMT are able to go through the railway crossing with the toolboxes placed in the front.*

Weight of stored toolbox

While fitting the tools into the toolbox and placing it on the bike, the team encountered another challenge. The weight of the toolbox when stored with tools could be troublesome to ride with, but also when walking up stairs to apartments. The team decided that the PMTs should be able to carry a maximum weight of 20 kg in each toolbox. This was based on the heaviest tools the PMTs have in their possession - a Ridgid of 17 kg (app. 24).

Crossing railway

The team tested if it as possible to go across the railways with the mock-up strapped to the front of the bike. The team learned that the size of the toolbox would not cause a problem to cross the railways, though the toolboxes were empty and did not cause any unbalance which could be a problem with packed toolboxes. The team decided to do a test with 20 kg in both the front and back of the bike to create a more realistic test setting.

With the dimensions confirmed to be appropriate to store the PMTs tools, the balancing of the bicycle with these toolboxes through the narrow spaces often encountered in the housing departments should be investigated. How difficult is it to handle the bike through narrow spaces? The railway crossing often mentioned as an obstacle should be the test setting for this investigation.

The size of the mock-up of the toolboxes are large enough to carry the necessary tools.

3.10 The solution can withstand toolboxes at 20 kg in daily use

3.11 The solution makes it possible to stack the toolboxes and bring along

03.7 | Test: carrying toolboxes on stairs

Based on prior research, the team found that they needed to look into how the toolboxes would be transported up stairs to the apartments as this is a frequent situation. Looking into different possibilities of carrying the toolboxes, the team had three possible solutions in mind; a shoulder strap, carrying it by hand and finally having two straps as on a backpack. To figure out which solution would be appropriate, the team constructed a test of how it feels to carry approximately 17 kg - equal to the heaviest tools. The team put bricks weighing 20 kg. into bags and walked up and down two floors while carrying the bag in the three different positions to simulate the scenario.

Carry by hand

The team found it rather difficult and hard to carry the toolbox by hand with an amount of 17 kg. for two floors. The team members had to shift hands two times when walking up and down the stairs. Balance was an issue as one side of the body is heavily loaded.

Shoulder straps

When carrying the bag using a shoulder strap, the team found it easier to carry the weight compared to when carrying by hand. The weight were split a bit more across the body compared to having all weight in one hand.

Backpack straps

The last option was backpack straps. The team agreed that this was the most comfortable way to carry the weight, although it was difficult to lift the bag from the floor and swing it across to the back and get the arms through the straps.

The result of the test was to carry the toolboxes using a shoulder strap since this was the least difficult scenario and did not cause discomfort when walking up stairs.

With this, the team decided to look into the labor inspectorate regulations of how much a person is allowed to carry manually up a stairway.

How much weight is a person allowed to carry according to the regulations from the labor inspectorate?

3.12 The solution should be possible to be carried using a shoulder strap

3.13 The solution should comply with the rules and regulations from the labor inspectorate in regards to carrying weight

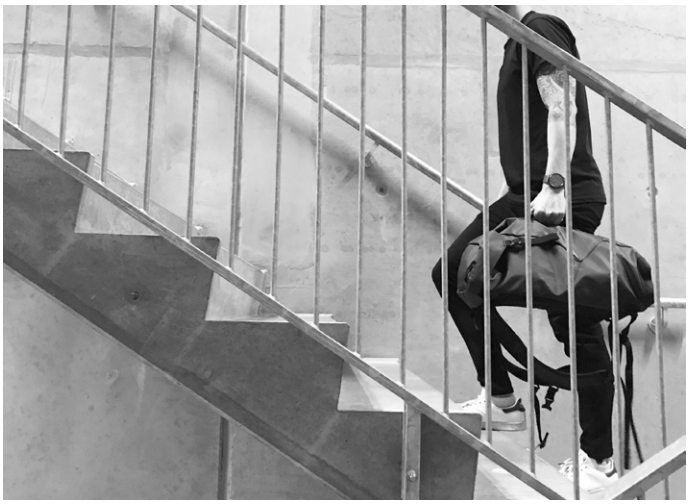


Figure 03.11. *While carrying the weight by hand, the carrying hand had to be switched on the way to shift pressure on the body.*

Figure 03.12. *Carrying the toolboxes using a shoulder strap was more comfortable than carrying by hand, although the balance still was troublesome.*

Figure 03.13. *To carry the toolboxes on the back was the most comfortable way to carry the tools, but swinging the bag around to the back was uncomfortable.*

Figure 03.14. *Simulation of the settings from the railway crossing on a bike with 20 kg. loaded on both the front and rear.*

03.8 | Test: Railway crossing with maximum load

The team creates the opportunity for the PMTs to carry a lot of tools with them with a weight of up to 20 kg. in each toolbox. The toolboxes are placed above the center of gravity on the bike. The team tested how it would be to ride like this, with maximum load on the front and rear of the bike. The team also created a simulation with the dimensions of the railways crossing the PMTs have to cross and often describe as a problematic place to pass through. The PMTs have argued that the reason for them not having a cargo bike in the Lindholm department is due to the fact that they can not pass the railway crossing with it. The team therefore saw it as a demand that they should be able to cross it with both toolboxes on and with the maximum amount of weight.

The team started by placing nine bricks, approximately 20 kg., in the rear basket and afterwards placed same ammount in the front basket. Initially, the bike were driven around the yard to get a feeling of the handling and balance. The team members had different experiences when riding with that amount of weight. One team member found it difficult to maneuver the bike with only the heavy load in the back. Two other team members found it easier to maneuver the bike with load in both the front and the rear since it created som balance on the bike. They all agreed that it was a bit difficult to take a sharp turns.

Afterwards the team mapped the railway crossing on the pavement to see how difficult it would be to ride that path with the maximum amount of weight. Two team members were trying out. One rather easily crossed the 'railway' without difficulties, while the other had one leg down to support and maintain control of the bike.

The team agreed that it would be possible to cross the railway crossing with both toolboxes and the maximum amount of weight on the bike without compromising handling and balance too much. Further, it was argued that the probability of the PMTs carrying that amount of weight on a daily basis would be rare and then the PMTs would rather easily be able to cross the railway.

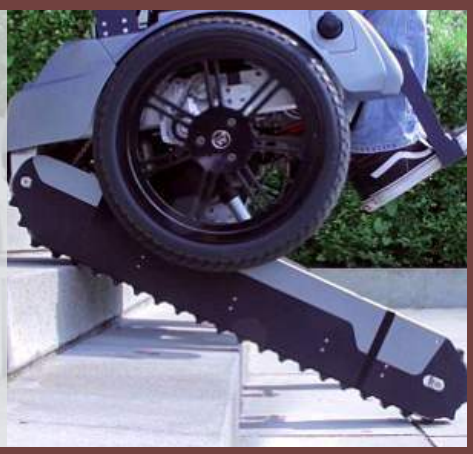
Crossing the railway with the maximum amount of weight - 20 kg. in front and rear - is possible.

03.9 | Market screening on wheels

Looking into the labor inspectorate regulations of how much a person is allowed to carry manually up a stairway, the team found that a person is only allowed to carry 7 kg. within a distance of 30 cm from the body (Arbejdstilsynet, 2015). With this information, the team looked at other possibilities of carrying the toolboxes on stairs and still comply with the regulations. They found that the PMT could potentially drag the toolboxes up the stairs, since it is allowed to carry a maximum of 40 kg uphill (Arbejdstilsynet, 2015). To ease this task, the team looked into different sets of wheels to help climbing stairs.

Scalevo

- *Technical solution*
- *Demand great engine*
- *Demand great power*
- *Takes up a lot of space*



Scalevo, is a swizz wheelchair manufacturer that has rethought the transportation on wheelchairs. When the wheelchair is to climb up stairs, a track of rubber, powered by wheels, unfolds from underneath and transports the user backwards upstairs. (dailymail, 2015). It is a very technical solution that for the sake of powering motor and wheels hence the rubber track would require a great amount of power and take up unwanted space.

Soft wheel

- *Inbuilt suspension in the rims.*
- *Does not take up extra space.*
- *Integrated solution.*

Soft Wheel, is a wheel, initially made for wheelchairs, that has an inbuilt suspension in the rims of the wheels. The suspension-system replaces the traditional rims. The suspension of 'Soft Wheel' provides softness and comfort for the rider when running over a curbstone or down steps (softwheel, 2018)
The inbuilt suspension does not take up extra space, an integrated solution as this would be ideal for shock absorbing when transporting heavy equipment up stairs.

G-Ro

- *No shaft between wheels*
- *No friction*
- *Less space consuming*
- *Less absorbent to shock*

G-Ro wheels are made for luggage carriers. The wheels have incorporated ball bearings between the tire and inner circle, instead of a rim or shaft between them. The 'G-ro'-wheel is less space consuming, has no friction and, due to their size, provide a better weight distribution compared to other luggage carrier tires. Decreasing the dimensions and the density of the tires they become less absorbent to shock which reduces the convenience of transporting heavy equipment. (g-ro, 2019)

Stair climbing wheels

- *Roller bearing centered in wheel-set*
- *No friction*

Stair climbing wheels, can be seen implemented in products such as hand trucks or shopping carts for when transporting heavy goods. Due to the roller bearings centered in the wheelset the user will experience no friction hence only the weight of the packed goods when transporting. (bilcastor.co.uk, 2019)

Outcome

From this market screening of wheels, the team decided to take inspiration from the G-Ro wheels when designing the wheels for the toolbox. The team found them more appealing in the visual expression as they seem a more integrated part of the luggade carrier instead of an add-on. Furthermore, their physical size is small and will take up minimal space to integrate into the solution.

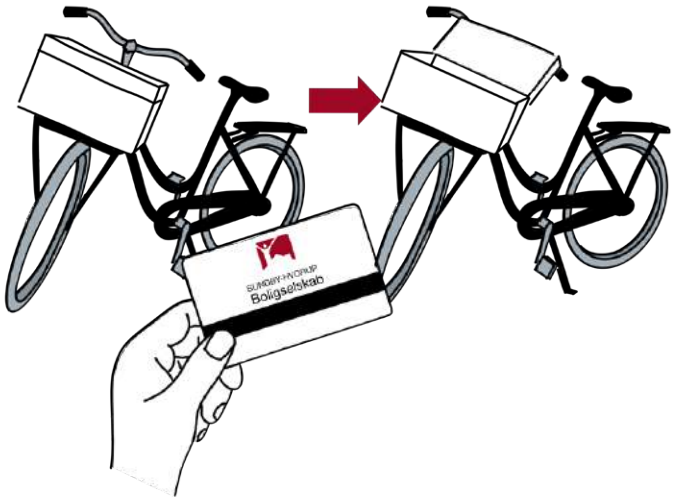
03.10 | Locking system interaction

From the ideation on the bike rack, the team uncovered design demands to secure the toolboxes from theft. Below is a description of three selected possibilities of locking and securing the bike

Concept 1 - RFID reader

The first system the team worked with initially started when the team visited Kent Jørgensen, the PMT at Lejerbo Housing Association. He used a bracelet with an RFID reader to unlock doors in his department (app. 45). The team had observed that the PMTs at SBH had staff cards with RFID readers as well. Exploiting this, the toolboxes could be equipped with RFID as well for unlocking. With this system the locking interaction would be easy to implement and quick to use. The only downside is that it needs electricity to be operable.

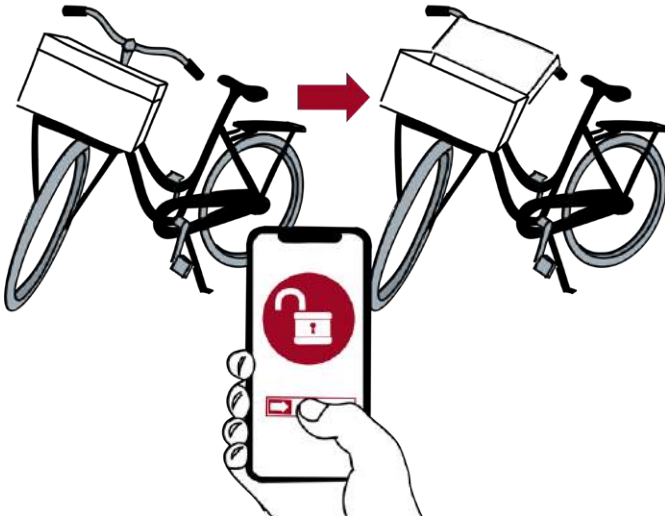
- \+ *Quick to use*
- \+ *Easy to implement*
- \+ *Automatic locking possible*
- \- *Needs electricity to operate*



Concept 2 - Smartphone

The second concept is utilizing the smartphones the PMTs already carry around and could be implemented as a part of the new application introduced at p. 63. As with the RFID reader, it is easy to implement and quick to use. The downsides is, as the RFID, that it needs power and the smartphone has to be charged to work with the lock. A design demand is for the lock to be approved by insurance companies and these have not yet approved only having a smartphone locking system as this is easily hackable. (Computerworld, 2013)

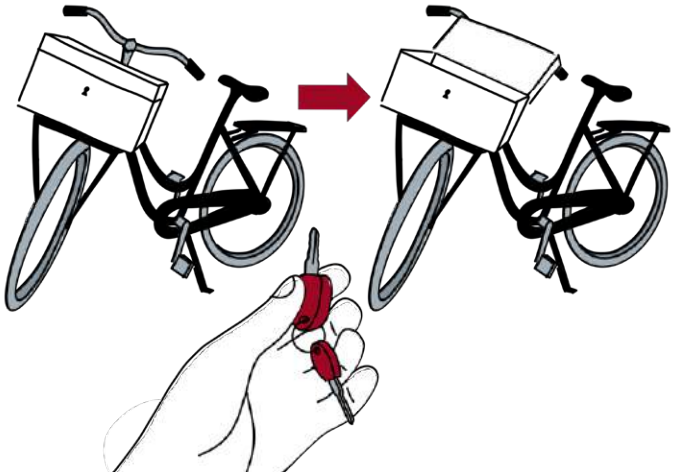
- \+ *Quick to use*
- \+ *Easy to implement*
- \+ *Locks automatically*
- \- *Needs power*
- \- *Dependent on phone Insurance companies dont approve only smartphone locks*



Concept 3 - Mechanical lock

The third and last concept is to have a traditional mechanical lock with keys. Compared to the other concepts, this cannot be hacked and it does not need any power. The downsides of having a mechanic lock is that it takes longer time to use and if one key is lost, all locks have to be replaced potentially. Furthermore, the team had learned from their visits that not all PMTs lock their bikes when leaving for residential tasks - so why should they lock their toolboxes?

- \+ *Does not need power*
- \+ *Can not be hacked*
- \- *Takes longer time to use*
- \- *Lose one, every lock should be replaced potentially.*
- \- *The PMTs do not lock their bikes - why use time on locking the toolbox.*



Outcome

The team outweighed the concepts and chose the RFID system as the best solution. This could easily be implemented and the interaction is quick.

3.14 *The solution should have locks using RFID to ease interaction*

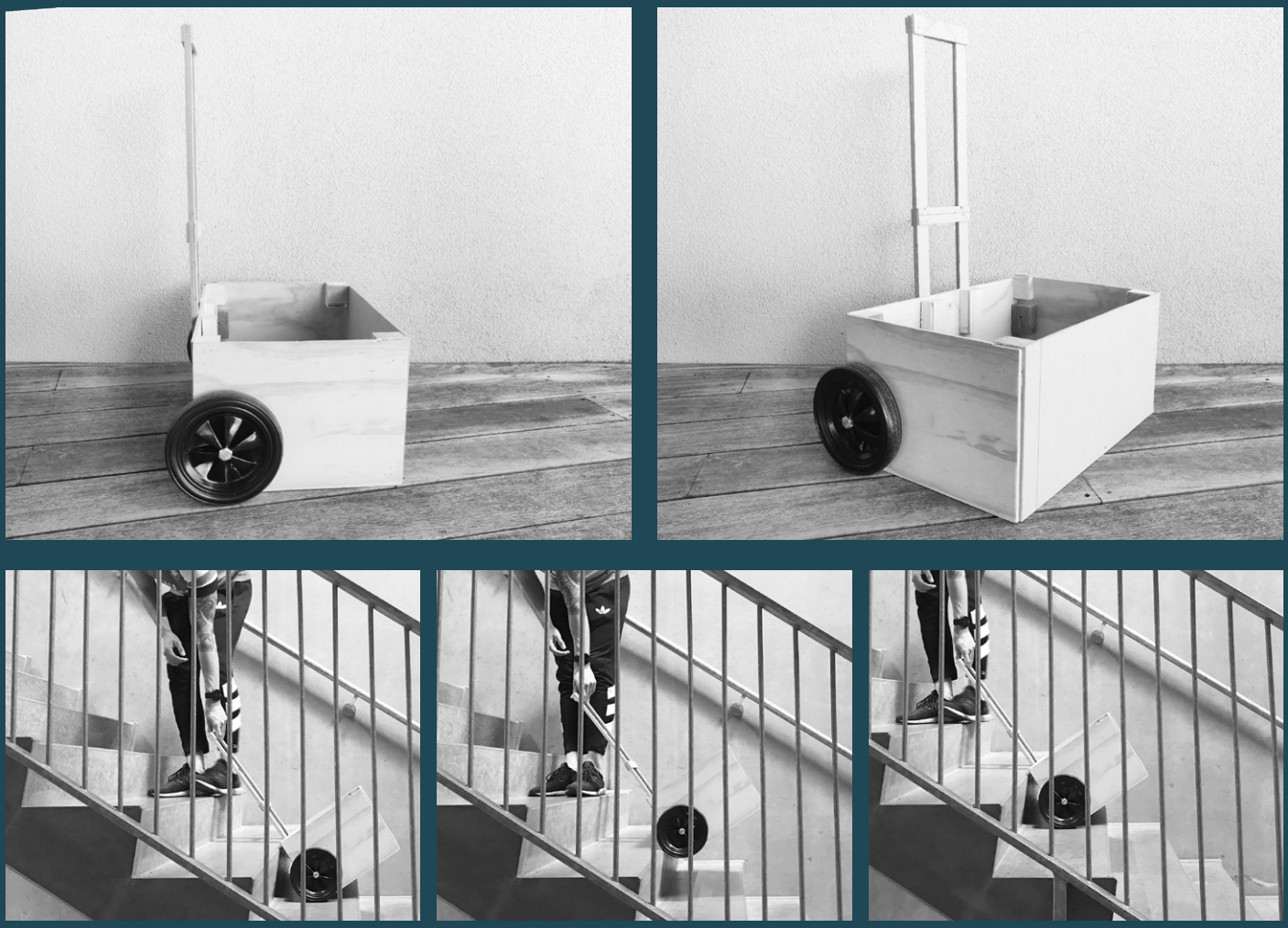


Figure 03.15. *Testing a functional model using the same principle as the G-Ro (p. 71). In this test, it becomes clear that the wheels need to be bigger to more easily travel between the steps.*

03.11 | Wheel test

Previously, it was discussed to use different solutions of carrying the toolboxes on the body (p. 69). Even though a solution by carrying using a shoulder strap was identified, it still had its limitations and still put a lot of strain on the user.

The team discovered that according to the labor inspectorate regulations, a person may only carry a weight of 7 kg. if the toolbox is within a distance of 30 cm from the body (Arbejdstilsynet, 2005). The team looked into existing solutions of how other products solved this problem (p. 71) and started investigating how the toolbox could be carried using the wheels as a slide from stair to stair and thereby avoid the need to carry the toolboxes, but roll them along instead. According to the labor inspectorate regulations, a person is allowed to drag up to 40 kg uphill (Arbejdstilsynet, 2005).

The team then scaled the wheels on the already existing model and made a mock-up in order to test if it was possible and how it felt to drag the toolboxes up stairways. The test was not only intended to the wheels but also the length of the handle. From the test, the team found three main points;

The length of the handle

The handle should have an extra joint in order for the PMT to carry the toolboxes from a comfortable and safe position. The mock-up handle had a length of 600 mm and by adding an extra joint, the length becomes 900 mm.

The size of the wheels

The wheels on the mock-up did not correspond exactly with the teams 3D model, being 20 mm smaller in diameter. The size of the wheels should be further increased beyond that. The team came to the conclusion that they should exceed the average height of a step on a staircase (150-180 mm)(hfb, 2017) and decided in order to comply with the aesthetics of the toolbox, the diameter of the wheels should be close to equal to the height of the toolbox at 250 mm.

The bottom angle of the toolbox

When dragging or pushing the toolbox down the stairs, the bottom of the toolbox scratched the steps and caused some resistance. The team decided to move the wheels further out to ensure that this wouldn not occur.

3.15 The solution should have a handle with the length at least 900 mm

3.16 The solution should have wheels with a diameter of at least 250 mm

Figure 03.16. *Peter testing the functional model to see if it fits his tools (left). On the right, he simulates how he would roll the toolboxes up stairs.*

03.12 | User test

Prior to starting detailing on the concept, the team presented the concept for one of the PMTs, Peter. From the analysis and tests done throughout the conceptual phase, the team made a mock-up of the preliminary design concept. The intention of presenting the concept was to get feedback on the features, principles and aesthetics of the concept and test how Peter interacted with the concept.

Fitting tools into toolboxes

Peter was generally fond of the concept. He tried to put his basic tools and some of the extended and special tools in the respective toolboxes to test if they fit. He commented that the toolbox was missing handles on the sides for him to be able to lift the toolbox down from the bike using both his hands and avoid heavy lifting with only one hand.

Transportation on stairs

Peter was a supporter of the large wheels and the idea of utilizing them for transportation of larger equipment like the ‘drain cleaning equipment’ (app. 26) when climbing stairs. Peter demonstrated how he is currently transporting the 'drain cleaning equipment' where he primarily walks to the department or ocassionally uses his lady bike, even though it is difficult to store on the bike.

Stacking of toolboxes

Peter was in doubt of how he could stack the toolboxes on top of each other, and whether they would be fixed and stable while transporting them.

- *How should the PMT lift the toolboxes down from the bike and where should the handles be placed?*
- *How should the toolboxes be fixed on top of each other to ensure stability while transporting them?*

Figure 03.17 *Top: Peter standing with the concept, where the 'drain cleaning equipment' is placed into the "special toolbox" Left: Close-up of the 'Drain cleaning equipment' in the new concept. Peter commented that he wouldnt bring the bucket using the new concept, as this only was brough to store the equipment within the bucket. Right middle: A great assortment of Peter's 'basic- and extended tools' (app. 22-23) in the front of bike. Right down: The team showing the concept to Peter.*

03.13 | Additions to requirements

Additions to final requirements

After building mock-ups and functional models to mirror the intended features and interactions of the concepts, additional requirements were identified. These requirements are listed below and are an addition to the final list of requirements from p. 55-56.

Metric no.	Need no.	Metric	Imp.	Units	Marginal value	Ideal value
34	Design demand	**Support when transporting toolboxes off of bicycle** *The bicycle only goes as far as the doors of the departments. From that point, there might still be some distance to go and with potentially heavy toolboxes, some kind of support to unburden the heavy load should be possible.*	***	Binary	Yes	Yes
35	p. 69	**"Bulk toolbox" able to be carried on shoulder** *Weight tests showed that the possibility of carrying the "bulk toolbox" with a strap over the shoulder was preferable to carrying by hand at heavy loads. However, loads above 15 kg gave too much unbalance and was not comfortable. See p. 69 for further weight test details.*	**	Binary	No	Yes
36	p. 69	**Toolboxes carried by hand** The toolboxes should be carried by hand as this is the fastest way to carry them. At weights below 7 kg, they are comfortable enough to carry in both hands. See p. 69 for further weight test details.	***	Binary	Yes	Yes
37	Design demand	**Battery powered by solar cells** In order to power a automatically locking lock, a power source must be available. By using a solar powered battery, the need to replace or recharge batteries regularly by the user is eliminated.	***	Binary	Yes	Yes
38	Design demand	**Maximum load on bicycle per rack** The maximum load per rack is based on the Danish industrial safety regulations regarding lift, push and pull. To increase the factor of safety, the values are increased.	****	kg	80	100
39	Design demand	**Factor of safety of rack at 50 kg** The rack must have a safety factor of at least 10 at 50 kg force to withstand impacts and weight.	****	Unit	<10	<15
40	app. 42	**Cost price** *With the statements from the PM regarding purchasing of equipment to the PMTs combined with price comparison of similar products, the target cost price has been set. To see further details on target cost price, see app. 42.*	****	DKK	< 10.000	< 8.000
41	Design demand	**Time from stopping bicycle to "front toolbox" and "rear toolbox" unloaded** *The time factor is critical to convince the PMTs to adapt the product. If the process is too tedious, they are unlikely to adapt it.*	***	sec.	20	15
42	3.03	**Bike rack mounted between head tube and fork** *To ensure the rack can not be easily dismounted from the bike and stolen, it needs to be attached into a more integrated part of the bike. This makes it increasingly difficult to steal the rack.*	***	Binary	Yes	Yes
43	3.04	**Toolboxes installed above wheels** *From the weight distribution test on p. 59, it became clear that placing the toolboxes above the wheels is the most appropriate in regards to handling and balance.*	***	Binary	Yes	Yes
44	3.10	**Maximal load on rack before failure** The advised maximum load to carry according to the labor inspectorate regulations is 20 kg. To create a high safety factor, this weight is multiplied by 3 and 5 for the marginal and ideal values.	****	kg.	< 60	< 100
45	3.15	**Retractable handle length** The handle should be long enough to comfortably roll the toolboxes behind the user.	****	mm.	850	950
46	3.16	**Wheel diameter** In the wheel test on p. 73 it was decided that the wheel should be around the same size as the height of the toolbox to comfortably roll up stairs.	****	Binary	225	250

04/

DETAIL

In the following phase, the concept developed in the conceptualization chapter will be detailed. The detailing will concern the specification of parts and components that are used, materials and production. Also, the principles and interactions of the concept will be detailed along with aesthetical considerations.

04.1 | Aesthetics

The aesthetics of SEKUR has been inspired from existing brands and competitors on the market such as Stanley, Bosch and DeWalt. The team had from their observations at SBH wanted to contribute to the feeling of being a professional craftsman by eliminate either the green milk crates or provide them with a solution which would reflect the PMT identity more accurate than a lady bike with a green milk crate.

SEKUR

The team were aiming for a concept with a identity that could be defined as robust, proud and professional, as the PMTs desired (p. 43). SEKUR is a voluminous toolbox which stores many tools and secures that the PMTs always have the right and enough tools and equipment with them and that they are secure at all times - even when left on the bike unattended - which is why it was named SEKUR. SEKUR also ensures the PMTs that if they by accident drop the toolbox, it would could still secure the contents inside.

Visibility

The team wanted SEKUR to stand out in the context, be visible and attract attention. The team chose to design SEKUR in two main colors; blue and red. Many housing associations use these colors for their identity and by integrating the colors in the toolboxes, they almost become an integral part of the department. The toolboxes of SEKUR should create awareness for the residents so the residents recognize the toolboxes and know that a PMT is nearby.

From the identity parameters (p. 43), the team learned that the PMTs would like to be seen and recognized and would like to be visible when riding on their bikes in fall and winter when it becomes darker. Therefore the team implemented reflective illuminated material on the bumpers and the wheels to signal their presence and be visible in traffic (fig. 04.1.)

Details

Many of the details on SEKUR are oversized intentionally, i.e. the swivel which connect the lid and the toolbox and the handle to carry SEKUR have been over dimensioned to signal robustness. (fig. 04.1.) The brand logo, SEKUR, has also been scaled to create attention. The oversized details are also considered more masculine and rough compared to smaller details and handles.

Figure 04.1 *Left: The oversized, robust swivel connects the lid and the toolbox. Mid: The handles which were added based on the user test (p. 74-75). Right: The reflective material creates awareness and attention from the surroundings.*

04.2 | Interaction details

From the user test, the team found that they had to detail how to stabilize the toolboxes during transport. Peter, PMT, had previously showed the team some of his existing toolboxes and how they were able to be stacked together (app. 46). Inspired from this, the team detailed the interaction of how to stack the toolboxes.

Stackable toolboxes

To secure the toolboxes when placed on top of each other, the team designed a slot on top of each SEKUR. The slot is similar to the one at the bike rack, so the PMT easily can place the toolboxes on the rack as well as on top of each other. Placing the toolboxes in these slots secures the toolboxes in the horizontal direction. To secure the toolboxes in the vertical direction when crossing roadbumps or uneven terrain for instance, the toolboxes are attached together using four hinges placed on the longsides of SEKUR (fig. 04.4). When on the bike, the lock on the rack will keep the toolboxes in place.

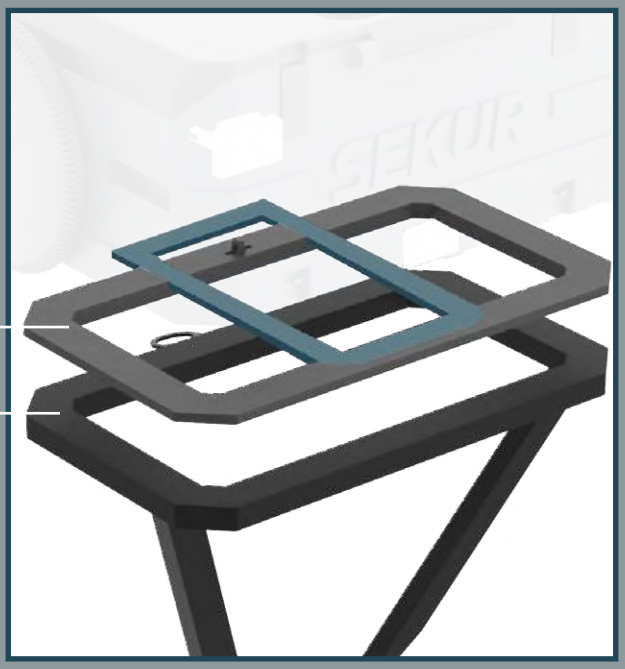


Figure 04.02. *Docking of the toolbox into the top rack and rack. The blue area marks the bottom of the toolbox and fits into the dock area of the top part. The top part of the rack (light grey part) is assembled into the rack (dark grey part).*

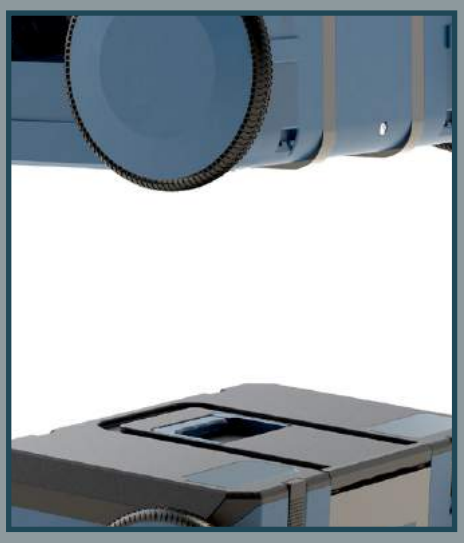


Figure 04.3. *Placing the toolboxes on top of each other using the slots to fixate.*

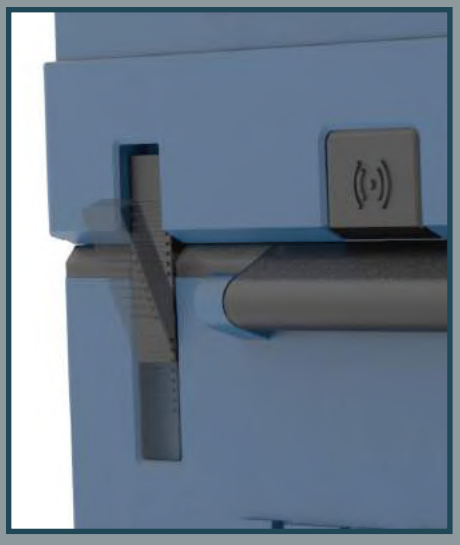
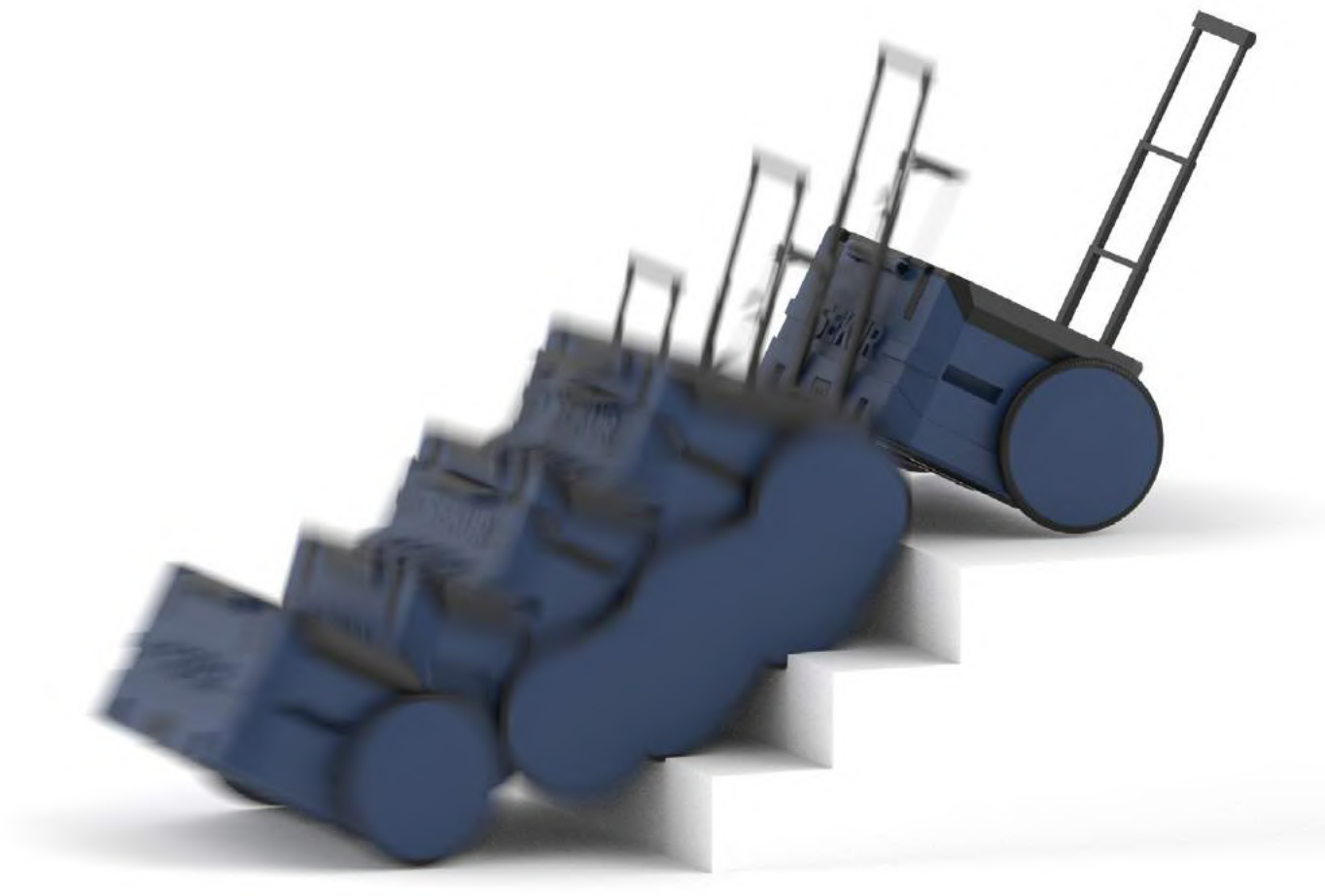


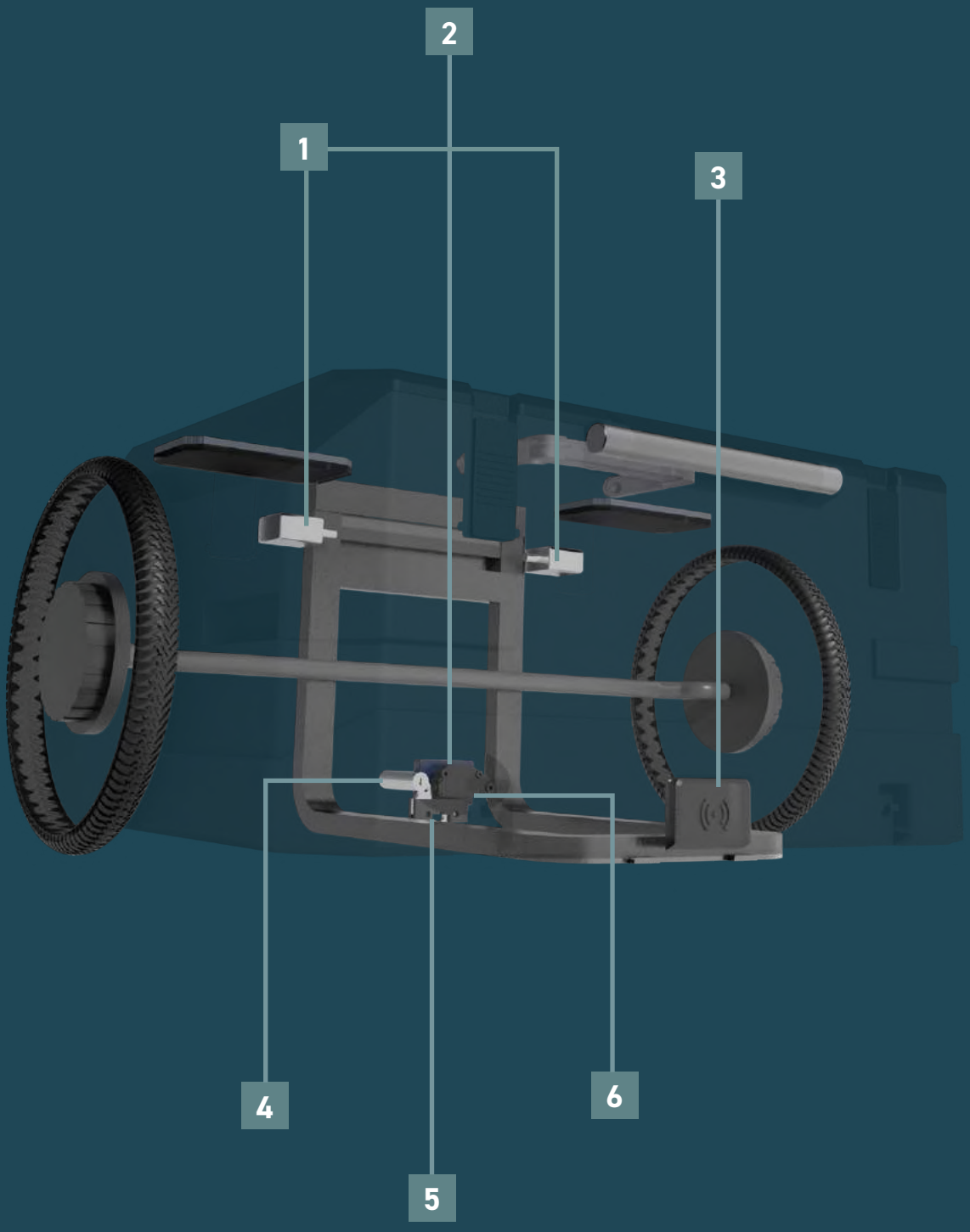
Figure 04.4. *Hinges attach the toolboxes together for transport.*

Stair climbing wheels

The team looked closely into how the toolboxes should be brought on stairways as this was one of the main challenges for the team to solve. When the PMT only brings one toolbox, the adjustable handle should be long enough for the PMT to drag the toolbox in a comfortable and upright position. When carrying two toolboxes, the PMT uses the handle on the top toolbox.



04.3 | Construction and components

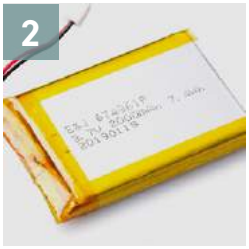


1

Solenoid bolt lock

Two bolt locks placed in the opening of the toolbox make sure the lid can not be opened when the toolbox is locked. The bolt locks are connected to a micro processor control unit that controls the full locking mechanism. When a positive RFID tag is registered, the bolt locks will actuate and retract themselves to allow opening of the lid.

2



Lithium polymer batterym

The electronic parts of SEKUR need power and this power i distributed by lithium polymer batteries. This type of battery is a lightweight, rechargeable battery that is also used in other products where weight weight is a factor such as smartphones and other mobile devices. A power consumption calculation will define the mAh size of the battery to be implemented.

3

RFID reader module

The RFID sensor is responsible for granting and denying access to the toolboxes. In order to be granted access, each user has an RFID tag that is registered to the system. When an approved tag is registered, the RFID tag will send the data to a micro processor control unit and the locks will be unlocked
(app. 44 - flowchart of the system)

4

Keylock

The electronic parts of the toolboxes make for a great, easy-to-use product that require little interaction, although solely basing the interaction of a product on electronics may however come with risks of failure or decharged batteries. Each toolbox is therefore equipped with a traditional, mechanical key lock that with only the turn of a master key will lock or unlock the entire locking system manually.

5

Rotary latch

When the toolbox is placed on either the front or the rear bicycle rack, it is important that it is kept in place both during transport and standstill. For this, a rotary latch is placed in the docking part of the rack. Here, the rotary latch locks around the toolbox when placed onto it. The electronic actuator will pull the latch to unlock it when a positive RFID tag is presented.

6

Electronic actuator

The electronic actuator pushes and pulls the rotary latch to lock and unlock. It is controlled by the control unit. This actuator is rated to operate at -20 to 60 degrees celcius and is thus a good choice for a product that will be used outside for all seasons.

04.4 | Materials

Rack

The rack is made in aluminium, a light and strong material good for keeping total weight down as the tools will add a lot of weight. Three types of aluminium have been considered; 6061-T6, 7020 and 7005. The 6061-T6 is typically used for high profiled bikes and is more expensive than the 7000-alloys. Since the rack is to be welded together, the 6061 will need a heat treating from using this production method. The 7020 and 7005 aluminium alloys do not need a heat treating as it hardens naturally and has excellent properties for welding (aircraftmaterials.com, 2013). To ensure a competitive price and thereby keeping the material and production costs low, the 6061 is not suitable. The choice between the 7000-alloys was determined by the structural calculations (p. 86) where the 7005 would not be sufficient in order to comply with the design demand of being able to withstand at least 60 kg. (p. 76).

Toolboxes

The considerations regarding material for the toolboxes were focusing on a low production and material cost but still being resistant to different weather conditions and great strength properties. Four different types of plastic have been taking into consideration; PE, PVC, PC/ABS and PP.

Polyethylen (PE)

Polyethylen (PE) has great resistance against water, moisture, solvents and chemicals, which is appropriate considering the en- vironment the toolboxes would be situated in. PE is an inexpensive material (plast.dk, n.d.) (Thompson and Thompson, 2017)

Polyvinylchlorid (PVC)

Polyvinylchlorid (PVC) is a strong, hard and stiff type of material. PVC has low heat and weather resistance and it will be necessary to add additives as compensation. For the toolboxes, the hard type of PVC would be to prefer as an advantage about this is that it is recyclable. (plast.dk, n.d.) (Thompson and Thomp- son, 2017)

Polypropylene (PP)

Polypropylene (PP) has a low total cost as a result of a low material price and ease of manufacture. PP is available as a copolymer (PPC) and are created with an addition of ethylene. The PPC is used for a high-end luggage cases from the brand Pelican who produces protective cases for tools, camera and other expensive equipment. The PPC provides a lightweight impact protection combined with resistance against chemicals and water. Besides the low total cost, the PPC is easily recyclable. (Thompson and Thompson, 2017)

Polycarbonate (PC)

Polycarbonate (PC) is a strong and shockproof type of plastic. It is not resistant to scratches and will need a coating. PC is able to be extruded as sheets and further processed as laser cutting, bending, thermoforming, and can also be injection moulded. Compared to ABS, PP is a more expensive material, though its strength properties make up for it. PC can be blended with ABS and to combine the mechanical advantages of PC with the low cost and molding advantages of the ABS. (plast.dk, n.d.) (Thompson and Thompson, 2017)

From the research on mentioned materials, the team decided to use PPC as it has a low total cost and is able to protect the contents of the toolboxes as well as withstand chemicals and water. The PC/ABS could as easily have been the choice of ma- terial, but the PPC provides better opportunities for recycling and the PC/ABS is difficult to disassemble and reuse. Based on this and the PMs noting that they want to contribute to being environmentally friendly, the material of the toolboxes will be PPC. (Thompson and Thompson, 2017)

Figure 04.5. *The toolbox is manufactured using a polypropylene copolymer.*

Figure 04.6. *The rack is manufactured in aluminium 7020.*

04.5 | Production

The design solution will be produced using different production methods. In this section, the production methods of the three main parts; the rack, the top rack and the toolboxes will be exemplified.

Rack

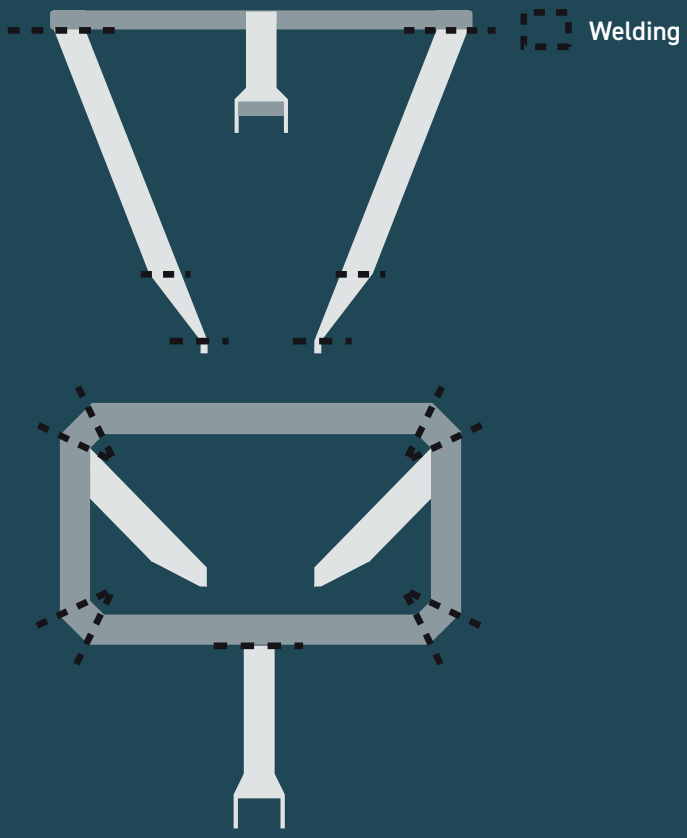
The frame will be produced using the aluminium alloy 7020 in square tube profiles. The profiles have initially been extruded and afterwards cut to the exact length and lastly welded together to create the frame. In order to avoid the aluminium frame having holes cut out for docking and thereby weakening the strength of the frame, a top frame of plastic will be added. This will make room for the docking and the holes for stabilizing the toolboxes when riding the bike and leave the structure of the aluminium untouched.

Top rack

The top frame will be vacuum formed, hence the shape of the top frame does not have a complex shape.

Toolbox

The top and bottom part of the two toolboxes will be injection moulded and afterwards joined together at the hinge. The basic toolbox inside the extended toolbox will also be injection moulded. Below the basic toolbox is a big room with space for the extended tools the PMTs are in need of. In order to keep the tools organized, the bottom of the extended toolbox has grooves to place plastic partition walls. These will be cut out from a plastic sheet using a laser cutter.

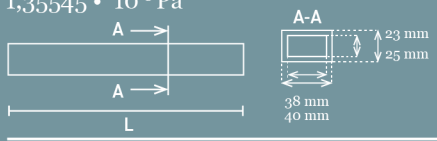


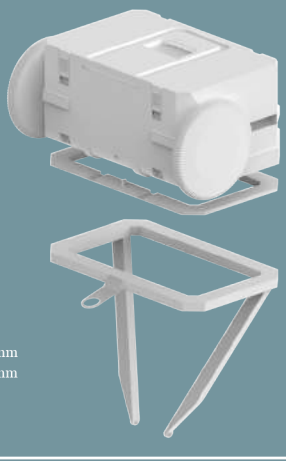
04.6 | Strength calculations

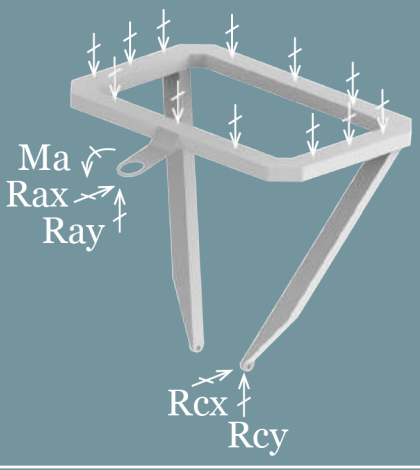
Max. weight of toolbox (q)
25 kg = 363,2 N/m

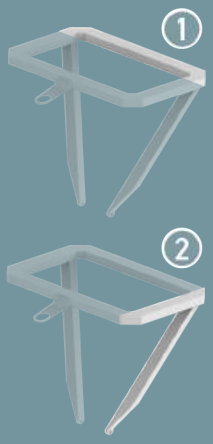
Material:
Aluminium 7020
Youngs module (E): 70 GPa
Possion's ratio (v) : 0,33
Yield strength: 260 MPa

Moment of inertia
1,35545 • 10^{-8} Pa



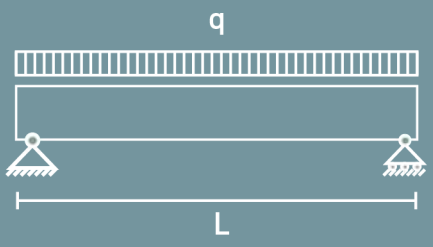




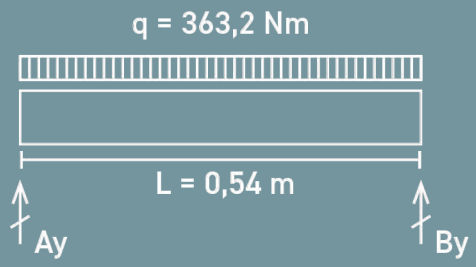


① Type of support

The team have chosen to calculate on one of the aluminium beams in the front racket. The beam is supported as a mix of a pinned and fixed support. The team have decided to calculate on the construction if it has a pinned support, as this is will provide the most conservative result.



FBD

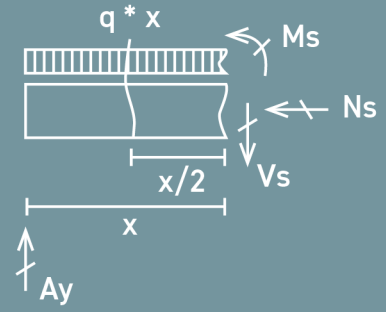


$\Sigma Fy = 0 \rightarrow \quad Ay + By - q \cdot L = 0$

$$Ay = By = \frac{363{,}2\ \text{N/m} \cdot 0{,}54\ \text{m}}{2} = 98{,}07\ \text{N}$$

Section cut

Due to the supports as being pinned with a uniform load the bending moment is biggest in the middle, why the section cut is made when x = L/2.



$\Sigma Ns = 0$

$Vs = 0 \rightarrow \quad Ay - Vs - q \cdot x = 0$

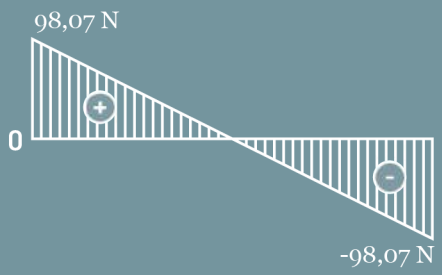
$$Vs = \frac{363{,}2\ \text{N/m} \cdot 0{,}54\ \text{m}}{2} - 363{,}2\ \text{N/m} \cdot \frac{0{,}54\ \text{m}}{2}$$

$Vs = 0\ N$

$\Sigma Ms = 0 \rightarrow \quad Ms = 1/8 \cdot q \cdot L^2$

$Ms = 1/8 \cdot 363{,}2\ \text{N/m} \cdot (0{,}54\text{m})^2 = 13{,}24\ \text{Nm}$

Shear-force diagram



Bending-moment diagram

Maximum bending moment

$$\upsilon_{max} = \frac{5 \cdot 363{,}2\ \text{N/m} \cdot (0{,}54\text{m})^4}{348 \cdot 70 \cdot 10^9\ \text{Pa} \cdot 1{,}35545 \cdot 10^{-8}\ \text{m}^4} = 0,\ 46\ \text{mm}$$

Normal stress

$A = 0{,}126\ m^2$
$y = 0{,}0125\ m$

$$\sigma_y = -\frac{0}{0{,}126\ \text{m}^2} - \frac{13{,}24\ \text{Nm} \cdot 0{,}0125\ \text{m}}{1{,}35545 \cdot 10^{-8}\ \text{m}^4} = -12{,}2\ \text{MPa}$$

The shear strain does not cause a tension and therefore
$\sigma_x = 0$ MPa

Shear stress

Calculating the shear stress requires the combined area. To calculate upon this the team have simplified the cross section to an I-profile (app. xx).

Combined area:

$$Q = \frac{40\ \text{mm}}{8}\left((25\ \text{mm})^2 - (23\ \text{mm})^2\right) + \frac{2\ \text{mm}}{8}\left((23\ \text{mm})^2 - 4(5{,}8\ \text{mm})^2\right)$$

$Q = 579{,}19\ mm^3$

Shear stress:

$$\tau_{xy} = \frac{0 \cdot 579{,}19\ \text{mm}^3}{40\ \text{mm} \cdot 13554{,}5\ \text{mm}^4} = 0\ \text{MPa}$$

Von Mises

$$\sigma_{VM} = \sqrt{(0\ MPa)^2 + (12{,}2\ MPa)^2 - 0\ MPa \cdot 12{,}2\ MPa + 3 \cdot (0\ MPa)^2}$$

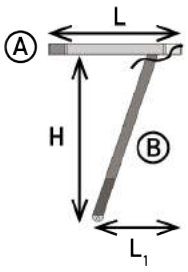
$$\sigma_{VM} = 12{,}21\ MPa$$

Factor of safety

$$N_{SAFE} = \frac{260\ MPa}{12{,}21\ MPa} = 21{,}3$$

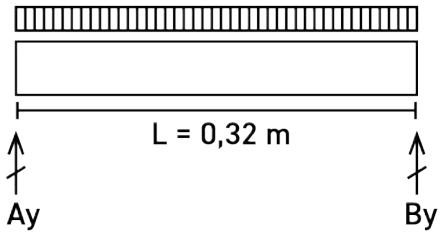
---

② Type of support



The team have simplified the model in order to calculate on the construction, hence it will be satistically indefinite. The calculations for section A can be found in app. 53, and only the results necessary for section B will be presented.

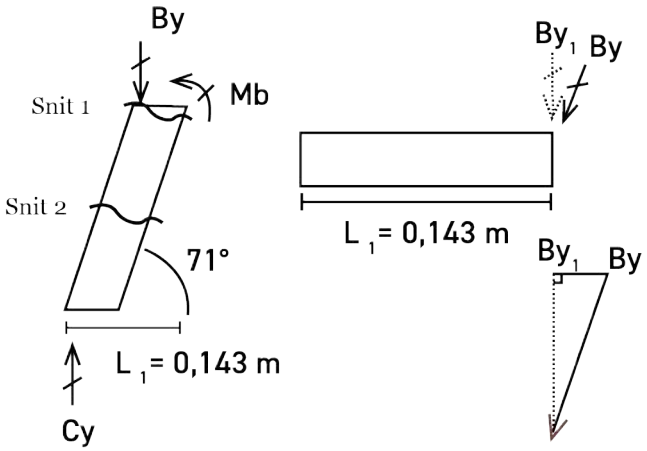
Ⓐ FBD



$$Ay = By = \frac{363{,}2\ N/m \cdot 0{,}32\ m}{2} = 58{,}11\ N$$

Ⓑ FBD

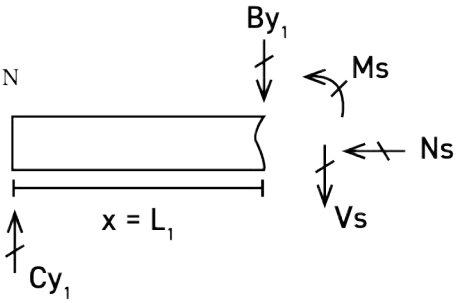
In order to calculate stress and strain for the two sections, the angled beam needs to be placed horizontally. To do this the reactions needs to be rotated acordingly as the beam. An online triangle calculator is being used to calculate By_1.



$$\sum Fy = 0 \rightarrow Cy - By = 0 \rightarrow Cy = By = 58{,}11\ N$$

$$\sum Mb = 0 \rightarrow -Cy \cdot L_1 + Mb = 0 \rightarrow 58{,}11\ N \cdot 0{,}143\ m = 8{,}29\ Nm$$

Section cut 1



$By_1 = Cy_1 = 54,94\ N$

$$\sum Ns = 0$$

$$\sum Vs = 0 \rightarrow Vs - Cy_1 + By_1 = 0$$
$$Vs = -54{,}94\ N + 54{,}94\ N = 0\ N$$

$$\sum Ms = 0 \rightarrow Cy \cdot L - Ms = 0$$
$$Ms = 54{,}94\ N \cdot 0{,}143\ m = 7{,}86\ Nm$$

Maximum bending moment

$$\upsilon_{max} = \frac{54{,}94\ N \cdot (0{,}143\ m)^3}{48 \cdot 70 \cdot 10^9\ Pa \cdot 1{,}35545 \cdot 10^{-8}\ m^4} = 0{,}004\ mm$$

Normal stress

$$\sigma_y = -\frac{0}{0{,}126\ m^2} - \frac{7{,}86\ Nm \cdot 0{,}0125\ m}{1{,}35545 \cdot 10^{-8}\ m^4} = -7{,}25\ MPa$$

$$\varepsilon_x = \frac{7{,}25\ MPa}{70.000\ MPa} = 0{,}000104$$

$$\varepsilon_y = 0{,}33 \cdot 0{,}000104 = 0{,}000034$$

$$\sigma_x = solve((x/70.000\ MPa) = 0{,}000034, x) = 2{,}38\ MPa$$

Shear stress:

$$\tau_{xy} = \frac{0 \cdot 579{,}19\ mm^3}{40\ mm \cdot 13554{,}5\ mm^4} = 0\ MPa$$

Von Mises

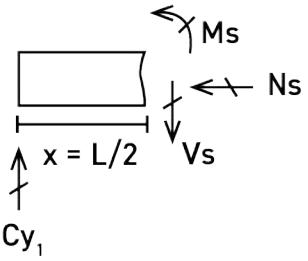
$$\sigma_{VM} = \sqrt{(2{,}38\ MPa)^2 + (7{,}25\ MPa)^2 - 2{,}38\ MPa \cdot 7{,}25\ MPa + 3 \cdot (0\ MPa)^2}$$

$$\sigma_{VM} = 6{,}4\ MPa$$

Factor of safety

$$N_{SAFE} = \frac{260\ MPa}{6{,}4\ MPa} = 40{,}6$$

Section cut 2



$$\sum Ns = 0$$

$$\sum Vs = 0 \rightarrow Vs - Cy_1 = 0$$
$$Vs = 54{,}94\ N$$

$$\sum Ms = 0 \rightarrow Cy \cdot (L/2) - Ms = 0$$
$$Ms = 54{,}94\ N \cdot (0{,}143\ m\ /2) = 3{,}93\ Nm$$

Maximum bending moment

$$\upsilon_{max} = \frac{54{,}94\ N \cdot (0{,}143m/2)^3}{48 \cdot 70 \cdot 10^9\ Pa \cdot 1{,}35545 \cdot 10^{-8}\ m^4} = 0{,}0004\ mm$$

Normal stress

$$\sigma_y = -\frac{0}{0{,}126\ m^2} - \frac{3{,}93\ Nm \cdot 0{,}0125\ m}{1{,}35545 \cdot 10^{-8}\ m^4} = 3{,}6\ MPa$$

$$\varepsilon_x = \frac{3{,}62\ MPa}{70.000\ MPa} = 0{,}000052$$

$$\varepsilon_y = 0{,}33 \cdot 0{,}000052 = 0{,}000017$$

$$\sigma_x = solve((x/70.000\ MPa) = 0{,}000017, x) = 1{,}2\ MPa$$

Shear stress:

$$\tau_{xy} = \frac{54{,}94\ N \cdot 579{,}19\ mm^3}{40\ mm \cdot 13554{,}5\ mm^4} = 0{,}05\ MPa$$

Von Mises

$$\sigma_{VM} = \sqrt{(1{,}2\ MPa)^2 + (3{,}6\ MPa)^2 - 1{,}2\ MPa \cdot 3{,}6\ MPa + 3 \cdot (0{,}05\ MPa)^2}$$

$$\sigma_{VM} = 3{,}19\ MPa$$

Factor of safety

$$N_{SAFE} = \frac{260\ MPa}{3{,}19\ MPa} = 81{,}5$$

Critical load

The critical load is the amount of weight which the construction can withstand before buckling occurs.

$$P_{cr} = \frac{\pi^2 \cdot 70 \cdot 10^9\ Pa \cdot 1{,}35545 \cdot 10^{-8}\ mm^4}{(0{,}143\ m)^2} = 6120\ kg$$

04.7 | Calculations and FEM

To support the calculations, the team performed FEM analysis of the construction. The team analysed on both the actual 3D model and a simplified model to be able to compare with the results on previous pages as those are simplified calculations as well (app. 54).

Displacement

From the calculations on displacement from the first section, the team calculated a displacement of 0.46 mm. Comparing the result to the FEM analysis, it showed a displacement of 0.125 mm (fig. 04.7) and on the simplified model is 0.35 mm (app. 54). The difference between the calculations and the simplified model is minimal and the displacement is not of any significance.

Von Mises

The team assumes that the largest stresses are in the middle of the uniform load, hence the von Mises stresses are calculated in this point. From calculating the stresses the team determined the factor of safety by examine the relation between the yield strength of aluminium 7020 and the von Mises stress. The resulted in a factor of safety of 21.

Design considerations

The profile chosen is overdimensioned compared to the estimated max. weight the contruction would be exposed to. Despite the fact that the construction is overdimensioned, the team has considered the possibility of one of the PMTs leaning and possible sit on the rack and therefore cause a heavier load than intended for, hence a stronger construction is needed.

The chosen profile has been chosen due to aesthetic and functional considerations. As explained on p. 79, the team aimed for a masculine and robust expression for the toolboxes as well as the rack. The rectangular profiles provide a broader surface to place the toolboxes on as well.

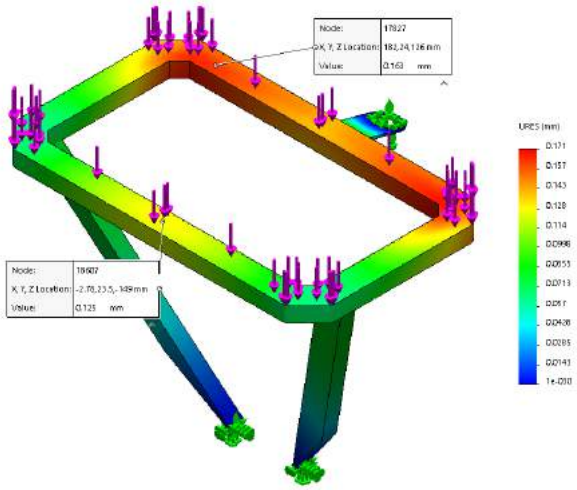


Figure 04.7. *The FEM analysis on displacement on the actual 3D model shows a displacement of 0.125 mm.*

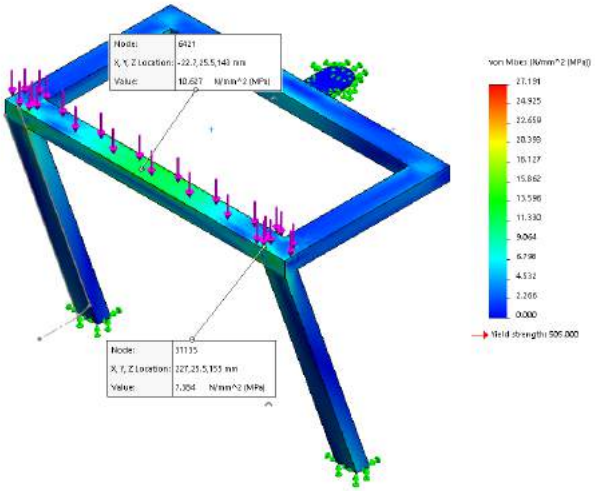


Figure 04.8. *The FEM analysis on von Mises on the actual 3D model showes a maximum of stress on 10.6 MPa compared to the teams calculations on 12.21 MPa.*

04.8 | Power consumption

In the majority of the time, the toolboxes will be in standby mode. In this mode, only the RFID sensor will consume power from the batteries. The most power is consumed when the central locking system 'peaks' - this is when the toolboxes are either being locked or unlocked.

The work of the PMTs is at times hectic, mostly due to the magnitude of work tasks within short periods of time. A new task means a new apartment therefore more transportation and a new task is seldomly the same as the one before it, hence requiring new tools than those used just before. This irregularity means that toolboxes are in use many times during a work day, being opened and detached, locked and attached repeatedly. Therefore, the central locking system of the toolboxes are semi automatic requiring only the registering of the PMTs staff card, RFID bracelet, RFID brick or any other RFID tag. (fig. 04.9)

As mentioned previously, the system is at most times on 'standby' ready to register any presented RFID tag and, if accepted, activate electric actuators i.e. locks. To provide power for the internal electronic components, the toolboxes are equipped with solar panels that provide self-sufficient electronic system with free-of-charge power.

Due to the amount of daily activations that do not reach 'peak current' for much more than two milliseconds, the daily consumption, combined with the 'standby'-consumption of the RFID, only reaches a total of 2,967 W. (app. 49) In order to have the batteries last for approximately one week on a full charge based on normal usage (2,967 W estimated), the battery must be at 2000 mAh at least.

Although being self-sufficient, the components that store the absorbed power from the solar panels, the batteries, will despite being rechargeable not last eternally. The lithium-polymer batteries each have a life cycle of 800 cycles, where one cycle is one full discharge and charge of the battery. With the power consumption of internal functional parts, both in 'standby' and 'peak', the batteries have an combined lifetime of approximately 6 years. (app. 49) These batteries are replaced from the bottom of the toolboxes and are compatible with a standard battery pack.

Figure 04.9. *The RFID tag will lock and unlock the toolboxes. When they being locked or unlocked is also the most power consuming operation and is what drains the battery.*

05/

DELIVER

The following phase is the closing phase of the project and the focus is on the deliverance of the project with emphasis on the practical aspects. A business case and an implementation timeline will argue the relevans and expected value of the project when introduced to the market.

05.1 | Price estimation

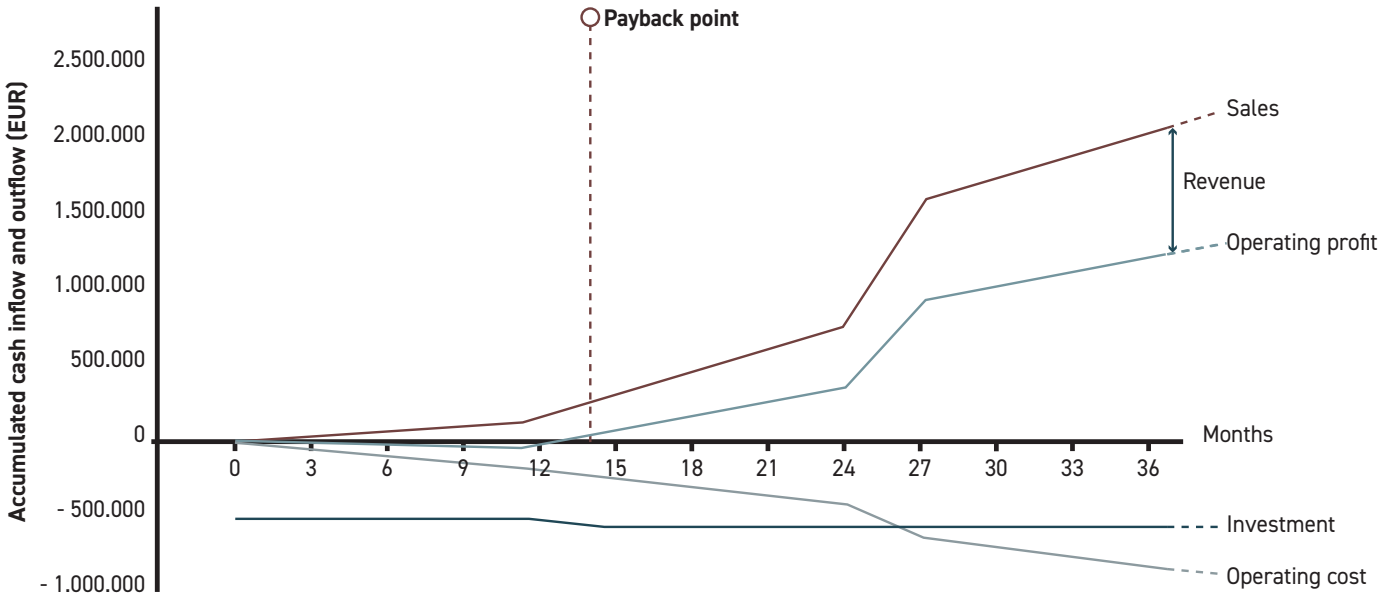


Figure 05.1. *36 months timline of SEKUR's sales, operating profit, investment and operating cost.*

Cost estimation

As an initial comment one must distinguish cost price, the cost to produce a product, and target costing which is suggested retail price. For target costing see app. 42.

When estimating the cost of a product many factors are included and is dependent on aspects such as the price of the materials that make the product, how these materials are processed to accommodate the desired shapes and dimensions and the components that make the finale product function. The toolboxes are made largely from plastic and aluminium, and the cost of purchasing and processing these depends on the amount of weight of the resin or the amount of sheeds bought, respectively, and the machinery and labor that increases as the demand for products likewise inflates. The irregularity of material process prices affects the cost price of the toolboxes from 492 DKK to 338 DKK, within 3 years.

Payback time

After 12 months from launching SEKUR will sell a modest number of 500 units and this will result in a total sales of 133.000 DKK but a negative net income i.e. operating profit, due to initiate start-up expenses, from buying machinery, rent, labor and administration. The product is a success after the first year from launching and the production of SEKUR is ramped up. The production is yet again ramped up after two years of success. This increase in both sales and operation profit can be seen as the graph increases after the 12, 24 and 27 months mark (fig. 05.1). The payback time which is the time, it will take before the income evens up the expenses, appears already after 14 months and from hereon the sales only provide revenue. The revenue is the money to spare when subtracting the operating profit from the total sales of unit and after 36 months or two years and ramping up production yet again twice, well beyond payback time the revenue, the money earned, is 852.941,33. For more information and further calculations see app. 52.

05.2 | Business case

For Sundby-Hvorup Housing Association to justify the expenses of 7.000 kroner per unit with the purchase of SEKUR the product should as a minimum reduce the PMTs daily transportation time by 9 minutes, the equivalent of a decrease of 13,6 percent in transportation time. With the implementation of SEKUR in the daily routine the time saved for a single PMT will exceed far beyond the point of breakeven with a reduction of 32 minutes daily or 144 hours annually. While the daily transportation time almost halves from 69 minutes to 37 minutes of transportation the net profit from investing in SEKUR is more than two times higher than the investment and the return on investment more than triples to approximately 24.000 kroner anually. (fig. xx)

The return on investment for Sundby-Hvorup Housing Association with the implementation of SEKUR shows in many ways, yet one significant advancement is the improvement of efficiency. Time can be administered to other tasks in the department, that previously would have been of extra expenses.

"We want internally (Red. labor) and save money externally." - Ole Faurholt, property manager, Aalborg (app. 04)

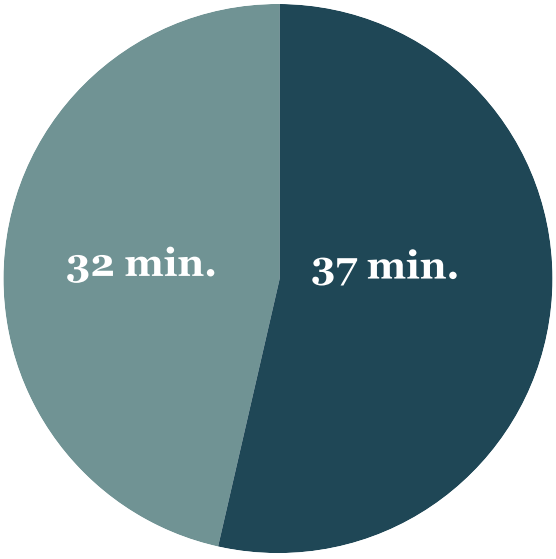
"We're 10 men in 'Vangen' and we take in substitutes." - Henrik Lykholt, property manager, Aalborg (app. 04)

Instead of the administration either having the additional expenses of outsourcing labor that because of fully occupied internal workforce could not be administered internally or postponing tasks such as residentially reported issues the savings frees approximately 150.000 kroner, the equivalent to the cost of half a PMT, the first year at the department's disposal or an additional 12 hours more a month per PMT. This provides unoccupied time to the PMTs daily calendar for more residential tasks, outdoor maintenance or tasks that have been down prioritised for years such as preserving the personal relationships to the residents, both appealing to PMTs and residents.

"The employees would like to have more contact to the residents. It's a very social and personal need." - Henrik Lykholt, property manager, Aalborg (app. 04)

"Back in the days they (PMT red.) would come if you needed your TV fixed, they don't have time for that anymore." (app. 08)

This research is not the result of a large investigation, but not only does it indicate great potential for large savings, the results of this investigation compared to the point of break even also gives enough room for insecurities, caused by unforeseen factors, that may not have been taken in to account. This means that even though other observations where to be made the magnitude of the savings both the financial and temporal of the above investigation provides enough incentive for the implementation of SEKUR in Sundby-Hvorup Housing Association or any other housing association.



	Now	SEKUR	Saving
Transport time (per employee)			
Day (minutes)	*69*	*37*	*32*
Transport time (per employee)	*25*	*13*	*12*
Salary (kroner, per employee)			
**Month*	*27.600*		
Year	*331.200*		
Hour	*171,07*		
Annual transport expenses (kroner)			
Per employee	*51.570*	*27.600*	*23.870*
Sundby-Hvorup, Lindholm dept.	*436.232*	*248.400*	*214.832*
Sundby-Hvorup, all dept.	*1.904.400*	*1.021.200*	*883.200*
Investment, year 1			
Per employee		*-7.000*	*-7.000*
Sundby-Hvorup, Lindholm dept.		*-63.000*	*-63.000*
Sundby-Hvorup, all dept.		*-259.000*	*-259.000*
Net profit, year 1			
Per employee			*16.870*
Sundby-Hvorup, Lindholm dept.			*151.832*
Sundby-Hvorup, all dept.			*642.200*

**Monthly Property Maintenance Technician salary (jobindex.dk, n.d.)*

The amount of minutes spent on transportation as of now is an estimate derived from the observations of a work day of PMT John-Martin Sørensen of the Sundby-Hvorup Lindohlm department. Post implementing SEKUR the waste transportation of that same period of time is eliminated causing a drastic decrease in the transporatation time. (app. 50) According to jobindex.dk a service techincian is paid a monthly salary of 27.600 DKK and in an interview the PM of the Lindholm department, Ole Faurholt, said that his department has 9 PMTs with a total of 36 PMT in the whole of Sundby-Hvorup Housing Association (app. 12), hence the calculations for salary and transport expenses. The initial investment is estimated from the target costing that bases on statements from Ole Faurholt who is the immidiate decision taker in regards to finances as well as from screenings of the existing market. All considerations and results are dependent on the aforementioned information and are visible in the table below and in app. 50.

05.3 | Implementation timeline

The below illustration shows the expected timeline for implementing the product, from the start of the project to the distribution of the product. To start the project the team will seek fundings and this way gain capital to finance initial expenses such as machinery for production, materials for the product, rent and labor. In 8 months a functional prototype will be produced and implemented in the context hereby testing the functions. All the while the prototype is tested the functions will be monitored being adjusted maturing the product so that, after 12 months it will be ready for sales. Due to the national effeciency program (p. 14) housing associations will be eager to find a new effective solution of low expenses in order to safe money, therefore it is expected of them to show rather fast interest in purchasing the product. The first units sold within the initial 12 months from introduction will therefore be targetted towards the intented user group, PMTs. After the first year the use of bicycles amongst other craftsmaen in the country's larger cities is expected to have increased (tvostjylland 2019) and this will be utilized by marketting the product further for a wider, less direct target group, although still within the same field of expertise e.g. other craftmanships such as plumbers, carpenter and electricians in larger cities.

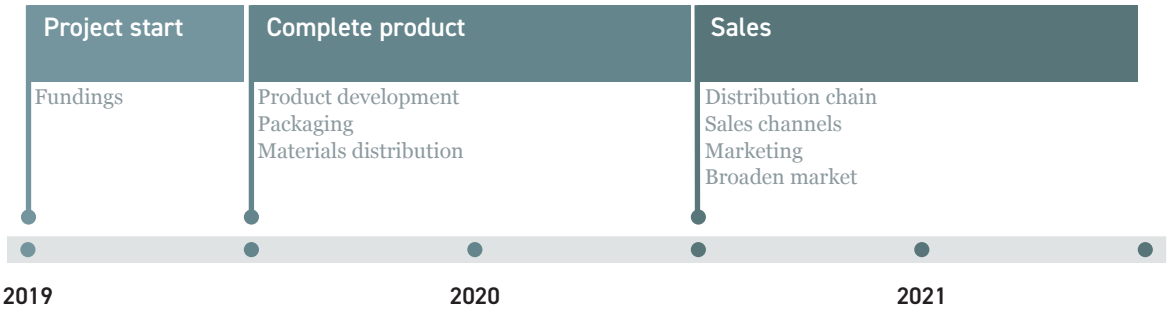


Figure 05.2. *The product's implementation timeline. Sales of SEKUR will start medio-2020*

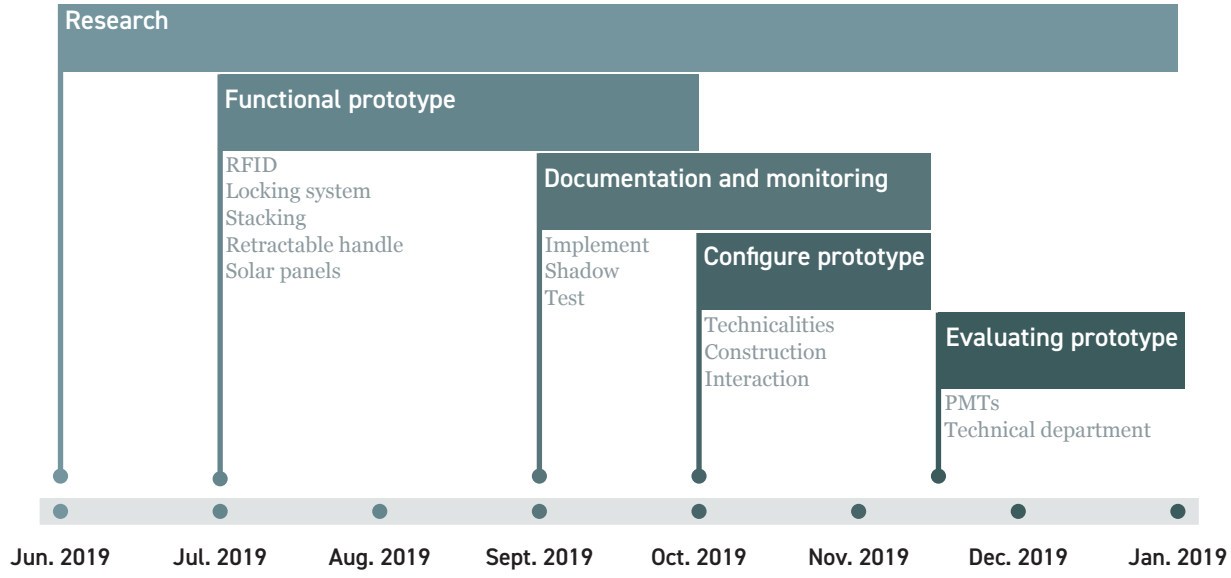


Figure 05.3. *6 months from june 2019 the product will be ready to be sold.*

06/

CLOSING

The following phase is the closing phase of the project and the focus is on the deliverance of the project, hence the execution of practical aspects. A business case and an implementation timeline will argument the relevans and expected value of the project when introducted to the outside world e.g. hardware stores, craftsmen and of course Property Maintenance Technicians.

06.1 | Conclusion

The main goal of this project was to create a new storage solution for the PMTs that streamlines their work by being adaptable to the unpredictable residential tasks, but also assisting them in their routine operational tasks. The final design proposal is SEKUR HIMO 39; a toolbox to support craftsmen that need to be highly mobile in urban areas.

Evaluation of requirements
The final design proposal is evaluated from the requirements specified on page 56-57 and later introduced requirements on page 76. Many of the metrics listed are measured on subjective parameters and thus hard to decide if the solution meets without building a fully functional prototype to test in a real context.

Looking at the metrics that are possible to evaluate if the solution meets, most of these are met at either the marginal or the ideal value. By meeting all these measurable values, the solution should in theory be optimized to satisfy the users and their needs.

By doing functional tests using mock-ups and models, it has also been possible to discover design demands that the users are not able to provide during interviews or observations. These design demands concern primarily around the principles of the solution such as the locking system, wheels that can climb stairs or the stacking of the toolboxes. These are some of the users latent needs, and they were confirmed when presenting them using models and concept visualisations.

06.2 | Reflection

Product

Making a difference
One of the big topics around the housing associations these days are being more effective. This topic has also been very evident when talking to the different stakeholders during the project. The team identified an area with big potential to cut off work hours that were spent on doing work that did not make sense to either employer or worker. However, if the proposed solution to the problem, SEKUR, would make a noticeable difference in the context can be questioned. The tools and possibilities to optimize and plan to save time is provided by the product, but it is possibly also a question of changing the mindsets of the PMTs. When talking to the PMTs, many of them insisted on keeping their motorized vehicle, while others were more open to new ideas. For this group that rejects a solution at early stages, a different approach to convince them of the qualities and gains should be taken.

Other contexts
The SEKUR has been specifically developed to meet the needs of the PMTs, but the need for a mobile but spacious solution expands to many other craftsmen. During the Understand phase, it was revealed that many other groups of craftsmen look to the bicycle to get around in especially urban areas with limited parking and heavy traffic. To extend the SEKUR toolbox to target these other craftsmen, certain alterations to the functionality could be discussed. Also, it would primarily be targeted towards craftsmen that need smaller toolsets for their work as the available space is still limited.

Aesthetics
Working with a group of users that are heavily dependent on the functionality and stability of their tools, the primary focus has been on developing on the important functions and features to support the work. This also meant that the aesthetical considerations were set a bit aside and introduced late in the design process. That meant only few iterations and possible visual expressions were explored.

Changes to the design
After building the final model, some questions and improvements were discussed. To stabilize the wheels on the toolboxes, they have an axle that goes through the box. This axle takes up some space in the box that could be used for tools or materials. By using ball bearings for the wheels, it could be possible to eliminate the axle and improve the design.

Another part of the wheel design that could be improved is the integration into the design of the toolbox. By integrating them better, they would be less noticeable and only apparent when rolling.

Process

Teamwork
The team could have benefitted from a project manager or a team member comfortable with navigating in the fuzzy front end of the design process. The team often experienced reluctancy of trying to move forward without wasting time instead of doing things and possibly learn from mistakes. It was evident that the team members have their strengths in the conceptual and detailing phases where the different competencies within the team were exploited.

Project management
The process has been structured using daily scrum meetings to plan ahead of the day and timeboxing of tasks. Two main milestones with supervisors and fellow students to provide feedback on the project were planned to structure the project periods and targets. The team had planned to use timeboxing effectively due to previous experience of spending valuable time on discussing, but as the project progressed and became more intense, the team forgot to use the tool. This could have been beneficial in order to plan for more iterations on the concepts developed throughout the project.

The topic
The team prefer working in a concrete context where the users are interested and passionate about their work. It was clear for the team that the PMTs of today have other challenges than just a few years back due to economical constraints. The team saw a great potential in not only designing for PMTs but also for craftsmen in urban environments. As the population has been more and more economically friendly and focuses on being green and sustainability, the team would like to contribute by making it possible for craftsmen to carry tools on regular bikes without investing in expensive cargo bikes.

User involvement
The involvement of Sundby-Hvorup Housing Association and its PMTs has been something the team appreciated a lot. The PMTs have gladly provided information regarding their daily work and have been an active part of the development of SEKUR, from the initial observations to final design proposal.

06.3 | References

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UR, would make a noticeable difference in the context can be questioned.

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