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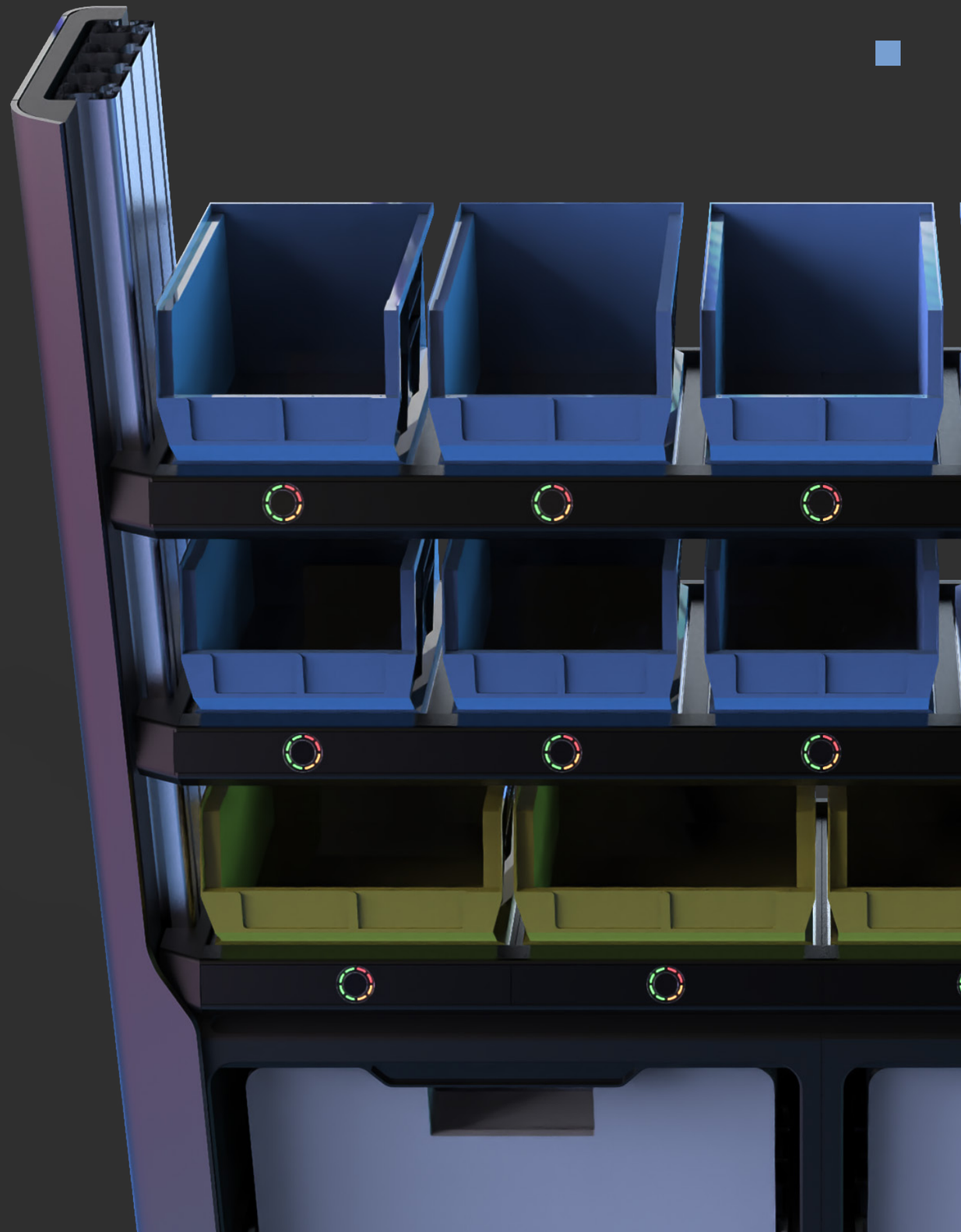
COGNIZANT
Automated Inventory Control

Barkin Alaybeyoglu
IPD / 4989449

MSc. Graduation Thesis



FORDCOGNIZANT
GRADUATIONTHESIS FINALREPORT
BA / 4989449

Delft University of Technology
Faculty of Industrial Design Engineering

Langbergstraat 15, 2628 CE Delft
The Netherlands
tudelft.nl

Hoog+Diep

Vijverhofstraat 47, 3032 SB Rotterdam
The Netherlands
hoogendiep.nl

Ford Motor Company
Research & Innovation Center

Süsterfeldstraße 200, 52072 Aachen
Germany
ford.de

Project Chair
Evangelos Niforatos

Project Mentor
Andre Valkenhoff

Company Mentor
Wouter van der Hoog

Client Mentors
Marcel Grein
mgrein@ford.com

Nicole Eikelenberg

FORD COGNIZANT

GRADUATION **THESIS** FINAL **REPORT**

BA / 4989449

Author

Barkin Alaybeyoglu

Master of Science
Integrated Product Design

Acknowledgement

I would like to say a big thank you and express my sincere gratitude to every person who was involved and contributed in this project and supported me throughout this graduation thesis. First and foremest, to my chair Evangelos and to my mentor Andre for being great advisors with their help, trust, knowledge and experience. To Wouter for his continuous involvement, always helping me to think from a different perpsective and contribution for making me feel ready for the professional life.

Client mentors from Ford RIC Aachen, Marcel Grein and Nicole Eikelenberg, thank you for your trust and contribution by regular meetings, guidance and encouraging me once again to be a part of this dynamic team. Also Walter Pijls, Jeroen Lem and Christian Kirchhof thank you for providing valuable feedbacks and helping me with additional digital meetings.

To all craftsmen who continuosly involved to the process that guided me to develop my project. To my colleagues for participating in user tests and providing great feedbacks. Last but not least, my family and my friends for always being there for the support.

Craftsman's right hand.

Ford Cognizant is a smart inventory control unit dedicated for the consumables carried in craftsmen's light commercial vehicles. Screws, elbows, fasteners or any type of small material with a high usage frequency is hard to manage. This difficulty increases incrementally considering major nuisances that craftsmen face with in the trunk area.

The concept levels up the impractical ways of inventory management in the trunk. Accessible technologies are utilised to improve craftsmen's inventory awareness and work efficiency by being their reliable assistant.

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SECTION I:
INTRODUCTION

In Section I, role of the project partners and vision of Ford Motor Company were explained. Later on detailed design assignment and approach including the scope of the work and methodologies that has been utilised were shown. This section ends with stakeholder analysis and defined research questions with project goals.

Introduction

The term commercial vehicle is used to identify a vehicle which main purpose is to transport goods or materials. The light commercial vehicle market, comprising vans and trucks, in Europe is growing rapidly every year. Such that, they account for over 80 percent of total commercial vehicle sales in European markets (Wagner, 2021). According to Statista Research Department, Ford Motor Company sold 124.571 vehicles between January and April 2021, which makes them the leader of the market with their signature model, the Ford Transit.

Craftsmen are one of the important customers of light commercial vehicles. They see their vans as trustworthy colleagues that help them to bring their materials everywhere. However the current state of their vehicles do not contribute for solving the issues that they face during intense work days. Deloitte's consumer research suggests that the drivers of the next generation want their cars to act as smartphones on wheels, like to remain connected and productive while on the go (Ninan et al, 2015). With this vision, Ford RIC Aachen focuses on creating a smart trunk environment for craftsmen and building the future of the Ford Transit.

As the graduation thesis is in collaboration with TU Delft, Hoog+Diep and Ford RIC Aachen, the project's focus is on the smart trunk ecosystem and inventory management in craftsmen's light commercial vehicles. The particular topic was analysed with a user-centric approach to define a use-case and to add a value as a design engineer.

This report will take you through the process of Ford Cognizant, a smart inventory control system, aiming for enhancing craftsmen's inventory awareness.

The Role of TU Delft, Hoog+Diep and Ford Motor Company

This graduation thesis project has been done with multiple partners; **TU Delft, Hoog+Diep and Ford Motor Company.** During the project, it was taken into consideration to fulfil each partner's expectations and wishes. TU Delft represents the explorative and scientific part of the graduation thesis, on the other hand, Ford Motor Company provides the potential use-cases and business-cases as a client and Hoog+Diep meanwhile covers both ends of the project. The chair of this project, Evangelos Niforatos is an Assistant Professor at the Sustainable Design Engineering department and specialised in Human-AI Interaction. The mentor of this project, Andre Valkenhoff is a designer and design coach at the Applied Ergonomics & Design department.

Hoog+Diep is a multidisciplinary design consultancy located in Rotterdam. They are focusing on products and services for various industries, that catalyses new trends in physical and digital product development. Hoog+Diep and Ford RIC Aachen already collaborating on some projects in the same domain such as 'Tool Tracking' with the aim of building a smarter trunk ecosystem with a user-centric approach in order to boost the efficiency of craftsmen at work.The managing director of Hoog+Diep, Wouter van der Hoog is the company mentor of the graduation thesis.

A branch of Ford Motor Company, **Ford Research and Innovation Center (RIC)**, located in Aachen, houses multiple departments including smart mobility department which develops new mobility concepts with a vision and user centric approach by envisioning the future of light commercial vehicles. The smart mobility department has multiple workstreams that focuses on different projects and target users. Craftsman workstream is one of them that particularly focuses on improving the work efficiency of users by developing innovative concepts for the Ford Transit. The team collaborates closely with a community of local craftsmen with different specialisations such as construction workers, plumbers, electricians in Aachen. This graduation thesis is done together with craftsman track team. Marcel Grein and Nicole Eikelenberg are the company mentors of the project.

During my studies I had a chance to work with Ford RIC while completing the course Advanced Concept Design (ACD). Later on had this exclusive opportunity to finalise my master studies with collaborating with them once again for the graduation thesis. I have been provided with potential use-cases that Ford RIC has been working on. My contribution was to approach these use-cases with a user-centric manner in order to explore craftsmen's actual needs, wishes, requirements and restrictive factors. During the entire design continuum, regular bi-weekly meetings, creative sessions and discussions with engineers from Ford RIC were conducted to maximise the richness of collaboration by compounding the explorative approach of TU Delft and Hoog+Diep with the business oriented approach of Ford RIC Aachen.


Ford
TU Delft

Ford Motor Company and the Future of Transit

The Ford Transit, also known as the Ford T-Series in some markets, is a range of light commercial vehicles produced by Ford since 1965. Sold primarily as a cargo van, the Transit is also built as a passenger van, minibus, cutaway van chassis, and as a pickup truck ("Ford Transit," n.d.). The Transit has been the best-selling light commercial vehicle in Europe for forty years, and in some countries the term "Transit" has passed into common usage as a generic trademark applying to any light commercial van in the Transit's size bracket.

As can be seen from Ford's sales channels, the current Transits are promoted for featuring the following characteristics: **Safe, comfortable, functional and tailored.** The characteristics have roughly stayed the same over more than 50 years of sales of the Transit line. It is possible to see the great examples of these values' reflections on the Ford Transit's product range. Available in different sizes, heights and lengths, every profession or specialisation have a version of the Ford Transit tailored for them. Since the International Van of the Year award was founded in 1992, the Transit has scooped the award five times (Moss, 2013). Craftsmen are one of the most popular customer group of light commercial vehicles, in fact, research by the Freight Traffic Control of the city of London showed that **more than 32% of all LCVs in Britain in 2014 were accounted for by craftsmen businesses** (Spierings et. al.).

The Ford Motor Company has a lot of experience in the field of traditional product innovation. The year 2016 was a record year in number of inventions that were disclosed by Ford employees. However, with the transformation from an auto to a mobility company, Ford is looking into opportunities where not only products play an important role but also services (Spierings et. al.). Therefore, recently Ford Motor Company is collaborating institutions such as TU Delft, or design consultancies with user-centric approach. This vision estabilishes a ground for them to fit their smart services for craftsmen's actual needs. This approach guided the company to steer their focus on topics such as 'Smart Trunk' and 'Inventory Management'.

The project 'Smart Rack' and 'Tool Tracking' are some of them which are ultimately accentuating to solve the issues within the vehicle, especially in the trunk area where all the materials, consumables and tools are transported. For instance, 'Smart Rack' is focusing on enhancing the accessibility and usability of the trunk area by proposing an advanced, configurable racking system with dedicated storage solutions through carried materials, which craftsmen can use with reduced amount of required physical effort. On the other hand, 'Tool Tracking' produces a solution towards forgotten or lost tools either in the vehicle or the construction sites during working.

During the developments of each concept, Ford Motor Company conducted extensive target group analysis in order to shape the future of the Transit while taking the real needs of the craftsmen into the consideration.


801 YYY


Ford

Design Vision

Adapting beneficial technologies to craftsmen's light commercial vehicles to ultimately improve their work efficiency.

1.1 Design Assignment

The initial design assignment for the graduation thesis was **'Enhancing the smartness of the trunk of light commercial vehicles by using artificial intelligence with a human-centric approach.'** It was observed in user interviews that, advanced technologies such as artificial intelligence or machine learning triggers the scepticism of craftsmen towards technology which conflicts with the design vision of the graduation thesis. This particular drawback then discussed with the company and client mentors. The re-formulation of the design assignment has been made in a way that would steer the project into enhancing feasibility with accessible technologies and coming up with a solution that coincides with the design vision.

The final outcome of this graduation thesis is **a fusion of a tangible product and a service design, that has been developed around the topic** that the client is focused. The topic is **the inventory management** within the light commercial vehicle of craftsmen. This topic canalised the graduation thesis into questioning how can the inventory management be developed by making the trunk area smarter and providing beneficial services towards enhacing craftsmen's inventory awareness, to ultimately improve their work efficiency.

It was also taken into consideration while concept development, that, benefits should comprise not just from employee craftsmen's perspective but also organisational (small and medium sized craftsmen companies) point of view in order to empower the business. Along the entire design process, craftsmen and craftsmen companies had the main role, thus, there were the stakeholders who had the highest involvement. Their contribution were critical and substantial, especially while decision making in order to be able to tailor the concept for them and for their wishes. Therefore, not just during the field research phase, but also during the concept development, main target group were kept involved as much as possible. This has been done with conducting multiple user tests and evaluations in order to endeavour answering questions such as; what type of information do craftsmen need to see to enhance their efficiency, how can those information be communicated and integrated to the vehicle without manipulating or interrupting their work flow. The re-formulated design assignment stated below, focuses on answering aforementioned questions.

Figure 1.1: Craftsmen van in a construction site

Re-Formulated Design Assignment

Designing a smart trunk ecosystem for craftsmen's light commercial vehicles in order to improve the inventory awareness and work efficiency.

The concept must fit to target user's identity and contextual requirements in order to successfully enhance the function of their vehicles.

1.2 Design Approach

1.2.1 Methodologies

Initially, a stakeholder analysis and mapping has been made to state the level of involvement and find opportunity areas. Following that, literature research was conducted, considering the topic of the project, mainly about inventory management methods, the envisioned future of automotive industry and applications of big data and IoT. To gain greatest insights from user groups, interviews were held and overt shadowing followed through to examine unconscious behaviours of craftsmen. Japanese designer, Naoto Fukasawa emphasises the importance of those unconscious behaviours for design process by developing his own philosophy called 'Without Thought' which is about finding ideas in people's spontaneous behavior and realising these ideas in design. Not having to think more about how to use a product could allow people to achieve their goals unconsciously, which makes the usage of a product easier and smoother (Xu, 2013). The extensive user research followed by a market research, focusing on inventory management methods, technologies and solutions that are preferred in different industries to find some inspirations. The comprehensive field research guided the graduation thesis to define clear and on-point research questions, problem statement, design goal, requirements and deliverables.

The Double Diamond method (Designcouncil, n.d.) was applied to the entire process to explore the issues regarding the topic widely and then to take focused actions (divergent to convergent thinking) to find an innovative solution (Figure 1.2). This method combining with lean project planning (Stepanov, 2018) enabled conducting fruitful iteration cycles in order to identify the customer needs for continuous improvement. While concept development, ideation phase supported with user tests with high fidelity prototypes. The user tests were focusing on the communicational values and overall experience of the service with testing the relevancy and reliability of the chosen technology to implement.

Delft Design Guide was consulted frequently to support the design process. Metholodologies and approaches such as; Service Design, Data-Centric Design, Product Life Cycle and Morphological Chart were applied during the concept development phase of the graduation thesis.

1.2.2 Scope of Work

The scope of this project is focusing on the topic, inventory management within the light commercial vehicles. It is analysed with a user-centric approach and a concept is developed to improve craftsmen's inventory awareness and management. The concept will be finalised until the stage where engineers at Ford can take over and build a prototype from in order to integrate it to the project 'Smart Rack'. The scope includes;

+ Integration of features and functions that are beneficial for craftsmen workflow.

+ Discovering different ways of interactions with a tangible product by utilising technology.

+ Providing the connectedness between the vehicle and craftsmen

+ Developing a concept package to support further developments by the engineers of Ford for product integration.

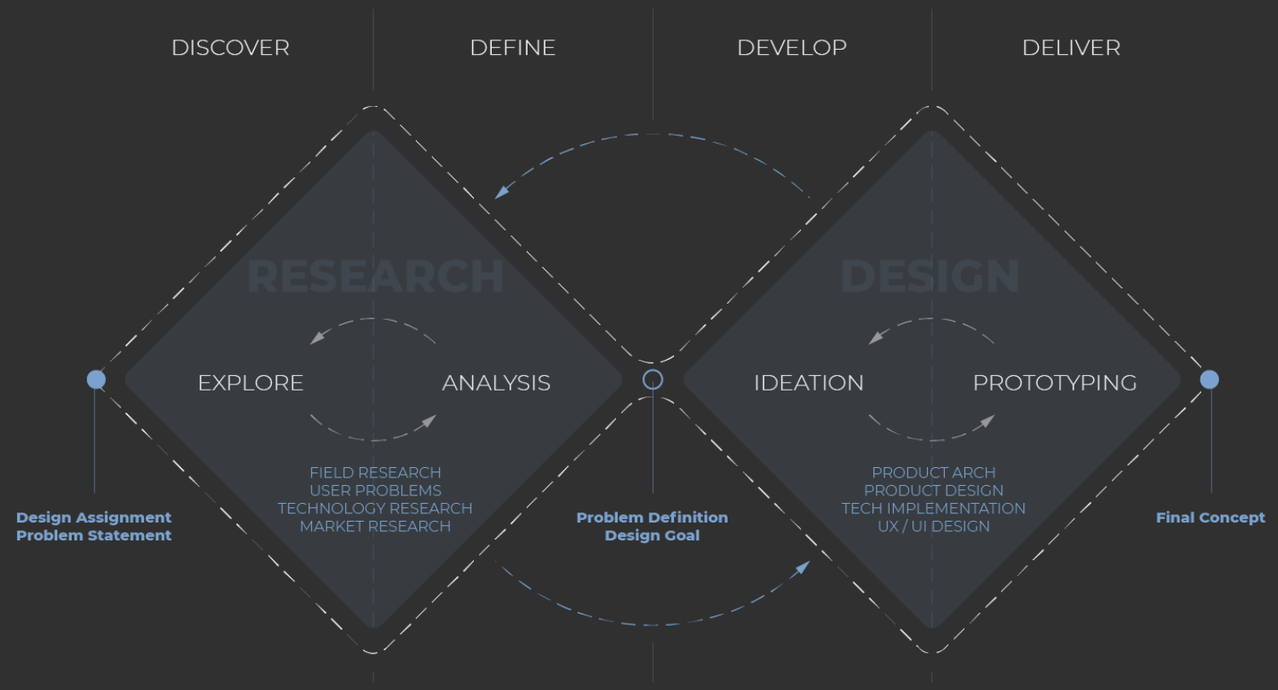


Figure 1.2: Project approach and plan (source: Design Council)

+ Integrating it in the usable space of the Transit Custom van, including doorposts and wheel-arches.

NOT IN SCOPE:

- Structural engineering and vehicle integration in terms of fixation to the vehicles chassis.

- Vehicle integration in terms of power supply.

- Connectivity of the system to the warehouse of craftsman company.

- Cost estimation of non-mandatory or changeable parts.

- Advanced algorithm and coding that might be needed to utilise the system.

1.3 Stakeholder Analysis

Stakeholder analysis has been done for exploring each stakeholders influence and interest level in order to explore the opportunity areas. To achieve that, Mendelow's Matrix has been used for mapping (Figure 1.3). Mendelow's Matrix is a tool that may be used by an organisation to consider the attitude of their stakeholders at the start of a project or when they are setting out strategic objective (Bizzle Dizzle, n.d.). This method is also applicable to design process to define which stakeholder has the most power for interest and influence on the project. Therefore prioritisation regarding the level of involvement for the design process can be conducted.

The key stakeholders were defined as **Ford RIC Aachen, Hoog+Diep and small to medium sized craftsman companies.** Ford RIC Aachen resources the use-case for the graduation thesis project and Hoog+Diep is the main partner. Compared to individual craftsman business, companies which have multiple employees and vehicles have more complex internal organisation, especially for inventory management. Specialised professions such as data managers, IT asset managers or service coordinators are more involved to the inventory management process unlike individual craftsmen who are responsible about every task regarding their work (See Appendix A). On the other hand, considering the overall income and financial status, large sized companies lean towards technological implementations in order to solve complex phases with decreasing human labour and chance of error via automated systems. However, for small and some medium sized companies the situation is a bit different. Because of having less employees and work, even though there are major problems regarding the inventory management, **small to medium companies still prefer to utilise old inventory management methods and do not prefer to be part of digital solutions because of their scepticism which enables a room for improvement for this particular user group.**

Figure 1.3: Stakeholder mapping with Mendelow's Matrix

1.4 Project Goals and Research Questions

The current craftsmen vans are a bus-like vehicles with openings to the trunk as the back and the side-door. The van's interior, mostly compartment racks, is then built into the trunk, using both inner sides of the vehicle and is only accessible from the inside. Those built storage solutions are only focusing on providing space for carried materials and does not contribute to craftsmen's work performance in any way. In fact this approach reveals major user and context related issues that downgrades the productivity due to the lack of practicality. This status quo should be questioned and a smarter solutions with a high potential to improve inventory accessibility and awareness should be developed.

As craftsmen have a certain identity and a work routine, the developed concept should **fit their standards and expectations** in order to give them pride and confidence in their professional usage. At the same time, considering the ultimate design vision, the concept should **familiarise the target group to the world of digitalisation** and help them to realise the potential benefits of technology in the trunk context. The concept should also **empower small and medium sized craftsman company businesses** in order to improve their internal organisation regarding inventory consumption. Therefore, considering the defined use-case, comprehensive field research and it's analysis, challenges and opportunities, the following research and design question had been formulated. In addition, couple of sub-research questions are revealed during the field research phase to be answered with the concept design:

RQ1 **How to design a smart trunk ecosystem that will improve the inventory awareness of craftsmen?**

RQ2.1 How can craftsmen be adapted to the world of digitalisation?

RQ2.2 How can the inventory management be improved in the trunk by utilising technology?

RQ2.3 Can digital solutions spearhead to craftsman business for improving itself?

RQ2.4 How can the physical effort required interactions in the trunk be evolved?

RQ2.5 What type of information do craftsmen need for inventory management?

SECTION II:
FIELD RESEARCH

Section II starts with the definition of craftsmen community and the bound with their vans. Later on this part continues with analysing the inventory of craftsmen observed by exploring vans during user interviews. Focused on each type of materials carried in the trunk in order to define the ones with high potentiality to obstruct inventory management. Later on, determined user problems are explained as a result of conducted interviews. This section finalises with analysing the reflections of user problems to craftsmen's workflow on a regular working day.

During field research multiple steps of interviews has been conducted with eight different craftsmen (Table 2.1). Their vans, especially the trunk area and carried materials were observed in order be able to define a use-case regarding the inventory management. Diversity of the participants was taken into consideration in terms of specialisation, age and experience and the size of their businesses.

List of participans

Craftsmen	Specialisation	Age	Vehicle	Experience	Business
John M.	**Constructor**	31	Renault Master	●●●○○	Medium sized company
Kim v.A	**Constructor**	34	Ford Transit	●●●●○	Medium sized company
Craftsman #3	**Electrician**	47	Mercedes-Benz Vito	●●●●●	Large company
Can T.	**Plumber**	32	Ford Transit	●●●○○	Individual business
Louis B.	**Carpenter**	51	Volkswagen Transporter	●●●●●	Medium sized company
Ethem Y.	**Service Operator**	41	Ford Transit	●●●●●	Medium sized company
Steef C.	**Field Service Engineer**	37	Volkswagen Transporter	●●●●○	Large company
Hakan Ö.	**Gardener**	38	Ford Transit Flatbed	●●●●○	Medium sized company

Table 2.1: Full list of participant craftsmen

2.1 Craftsman

SYNONYM / **HANDYMAN**

a person able or employed to do occasional domestic repairs and minor renovations.

Craftsmen are skilled and adept trade workers that use hand tools, power tools, consumables and automated machinery in their daily work (Figure 2.2). Most of the time they commute with light commercial vehicles from their home or from headquarters to the construction site. Within the vehicle they store and transport their tools/items, materials, goods and loads. They may spend years perfecting their craft and can be a jack-of-all-trades or highly specialised in their knowledge and abilities. A craftsman may produce anything from furniture to bed springs to auto parts depending on their skill set. No formal education aside from a high school diploma is required to be a craftsman, however gaining experience and skill is key to having a successful career (Study.com, 2021).

Craftsmen can either work individually as (jack-of-all-trades) or can be a part of a larger business (with more specialised profession and role). This differentiation influences their income, vehicle specifications and tools that they are using. A craftsman can have a variety of tasks depending on their skill level or area of expertise. Some may focus on making models, die cuts, patterns, designing custom furniture while others might do electrical or construction jobs. Due to the physical and exacting nature of their duties, many craftsmen have a high non-fatal injury rate when compared to other professionals. According to the latest numbers of the ESWC*, 45.5% of the European workers report working in painful or tiring positions while 35% are required to handle heavy loads in their work (Schneider, 2010). Therefore, they work in different environments, where safety is paramount and protection is mandatory. They may wear equipments like eye goggles, gloves and padded clothing to protect themselves.

Craftsmen are undoubtedly connected to modern day society. They are seen in day-by-day traffic or at department stores, seemingly always on the way to a new job. They are also a very common image in pop-culture as they depicted as masculine, do-it-all guys, capable of finishing all kinds of tasks,. Another thing commonly associated with craftsmen is their van, in fact, Ford even called it the ‘Backbone of Britain’ in one of their advertisements (Figure 2.3). It is an indisputable part of handyman culture and the benefits it brings to society. Craftsmen have been portrayed generally positively, as do-gooder helpful types, but not particularly smart or ambitious.

Figure 2.2: Craftsmen

Figure 2.3: Ford's advertisement: Backbone of Britain

2.2 Jack Of All Trades and the Specialist

The term ‘craftsman’ covers a wide range of individuals, differing in age, gender, profession, education, etc. According to the field research, in the Netherlands two main different types of handymen are distinguishable (Table 2.4). Firstly, the “do-it-all” craftsmen, also known as ‘jack of all trades’, who perform various tasks in and around the house. This type of craftsman often works with a lower rate than their specialised counterpart and is recognisable by their informal appearance and improvisational approach. This way of work makes, do-it-all craftsmen or craftsmen companies often take part in short term service jobs. Specialists on the other hand, are more trained professionals. Their repertoire of skills is narrow but profound, as they are trained professionals with the paperwork to prove it.

Depending on the job description, a specialist may come with a team of workers to get the job done. They typically take on bigger projects and may even call on other specialists to help them complete the project. While a craftsman is excellent for helping out around the house with things you could do yourself if you had the time or tools, a specialist is the better choice for more complex, long-term, or large-scale projects (Greaves, 2018).

Short-term service jobs usually consists of couple of job locations per day. Craftsmen apply more improvisational solutions through problems, by making a diagnosis during the initial visit to the job site. However, this impromptu can catch craftsman unawares, for instance with a deficiency of inventory. Therefore, short-term service jobs require to do some additional activities which are results of unforeseen events that make craftsmen lose time. On the other hand, specialised companies who do long-term jobs, often stay at the same construction site for some time which makes them utilise the area as a warehouse. Usually planning has been made resplendently with all the necessary and spare consumables, materials and tools which makes them perfectly prepared for the upcoming task. As a conclusion of aforementioned facts, craftsmen and companies who are doing short-term service jobs were taken as a focus group due to the potentiality of major problems that are mentioned at Part 2.6.

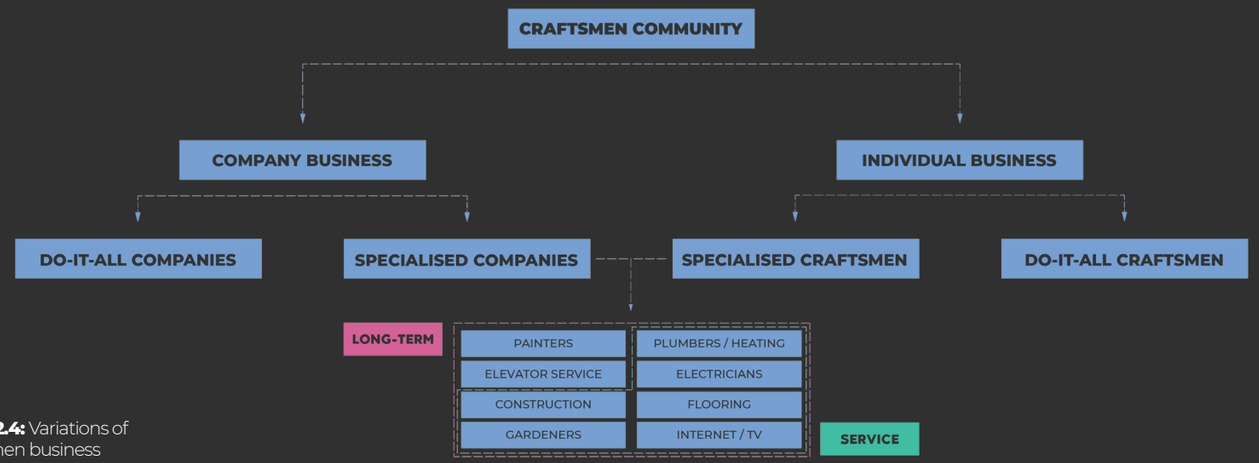


Table 2.4: Variations of craftsmen business


TRANSIT
CUSTOM
NL V-334-VZ
TT AUTOS.NL Steenbergen
Makita
MIXED FINISHER

2.3 The Trustworthy Colleague

Craftsmen of today rely on their trustworthy colleague - their van. A craftsman's van is not only a means to get from A to B; it is also a toolbox, office, lunchroom, stock room, business card and a source of professional pride and corporate identity. In short, craftsmen spend a lot of time in or in close proximity to their vans. Because of this craftsmen often tailor their vehicles to their needs and have a very strong relationship with their vehicle (Spierings et al., 2018).

Craftsmen's vans are utilised with all different kinds of storage facilities, often self-built because of its less cost, and sometimes with equipment catered to them by professional van-interior companies (Figure 2.5). Suitable van racking is essential here in order to turn LCVs into flexible and functional assistants. No matter what size is the vehicle, chances are that it will quickly turn into chaos without an organisation system in place (Rapid Vans, n.d.).

It was observed during user interviews that, current van racking solutions, do not provide any other benefits than **offering an organised configuration with maximising the use of space in order to carry more materials, tools and consumables**. While craftsmen were interacting with the trunk, it was also observed that, **current solutions do not address to actual difficulties that craftsmen face with, such as, inventory management and accessibility.** This influences craftsmen's workflow and the provided organisation within the confined space. With the current solutions for craftsmen's vans, every interaction within the trunk, demands a physical effort such as, searching, controlling or collecting.

Figure 2.5: Different types of craftsmen van setups

2.4 Craftsmen Inventory

When it comes to what craftsmen carry in the back of their vans, there is a huge variety and amount (Figure 2.6). Craftsmen are good at utilising the spacious cargo area that light commercial vehicles provide by building racking solutions in order to carry as much materials and tools as possible. Clearly, a vans strength is in the amount of stuff craftsmen can pack into it. A well stocked van is pretty much a mini hardware store (Perry, 2020). Despite that fact, **having too much materials and tools can reveal some major difficulties** (see Part 2.6). It is compelling to come up with the most relevant solution for every type of materials and tools, especially when contextual nuisances do not provide any convenience.

The tools in the trunk are placed with a priority and requirements such as **frequency of usage, order of usage, the size, the weight, routine check or the maintenance.** Therefore it is hard to keep track of these factors for every single one of them. Craftsmen have to come up with tailored and specific solutions; for instance, the battery powered tools which are considered as valuables are often placed in storage units which cannot be accessed easily except by the craftsman himself. Even though the amount and type of materials can vary depending on the profession or specialisation, it is still possible to cluster them into sub-groups to understand the differentiations between them in terms of their states in the trunk area. It is essential to comprehend the ways of utilisation, storage, restocking and maintenance, along with potential difficulties that they reveal while transporting them. Therefore the observations can be utilised as drivers for the concept generation phase.

Figure 2.6: Craftsmen van inventory

Figure 2.7: Consumables in inventory bins

Figure 2.8: Spare boxes of cosnumables

Figure 2.8: Inventory bins with side door access

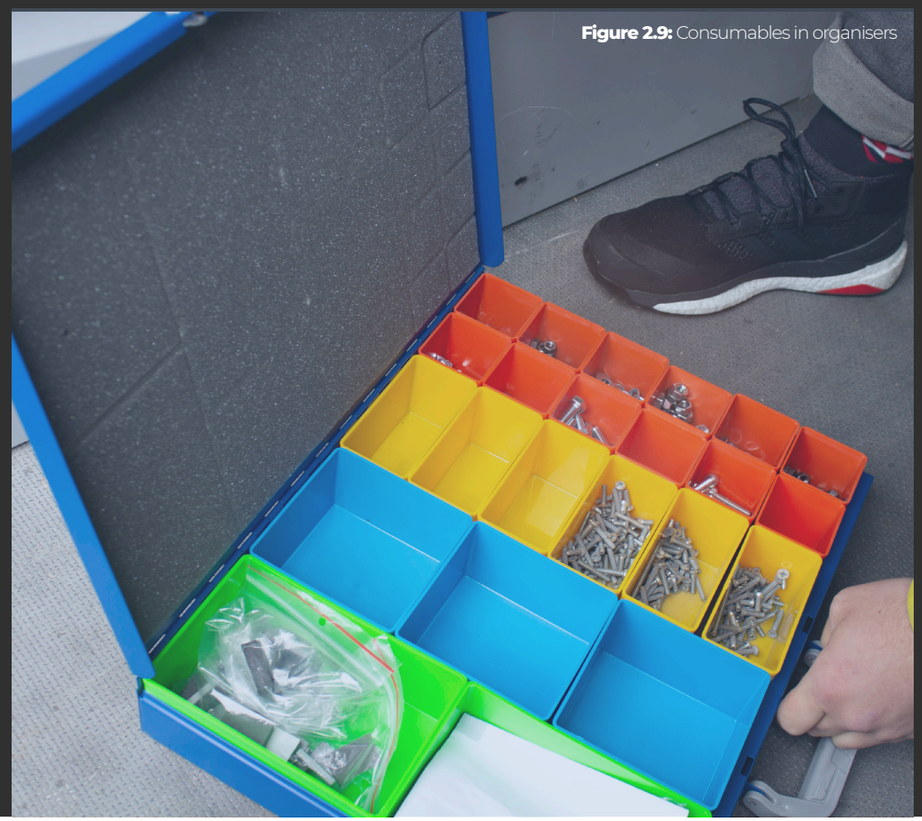


Figure 2.9: Consumables in organisers

2.4.1 Consumables

Consumables are one of the most essential group of materials for a craftsman inventory. This group includes **screws, bolts, fasteners, nails, elbows, switches etc.** which can also differentiate from one specialisation to another. (Figure 2.7) Because of tasks such as drilling, fixing or mounting that are almost always a case for craftsman work, they have a **high frequency of usage and a turnover rate.** This factor, combined with the difficulties experienced in the trunk drives craftsmen to carry high amount and variety of consumables. During interviews it was observed that the main issues regarding consumables are; having **low-stock or over-stock** which are equally substantial, and **getting forgotten or lost** either at the job site or in the trunk.

It is important to manage consumables in order to improve the consumption rate and avoid additional expenses. In craftsmen vans, consumables are often kept in different sized **inventory bins and organisers** to bring to the job site. It is also possible to see spare boxes of those consumables in the van in order to avoid having low stock situation (Figure 2.8). In addition, interviewees mentioned that, consumables are the materials that do not invoiced to the customer, thus, any type of loss and waste is covered by either the employee craftsmen or the manager.

2.4.2 Inventory (Storage) Bins

Inventory bins are used for bin stocking which is an inventory management system that helps track how much of a specific item is available or what products get stocked (Sine-Tific, n.d.). Craftsmen provide these **plastic bins with various sizes in their vans, mainly for consumables,** due to their visibility, durability and longevity because those bins are maintenance free (Figure 2.10). To determine the correct type of storage container, it needs to be known what and how many items need to be placed in the them. Therefore usually small and medium sized industry standardised inventory bins are preferred (see Appendix B). One of the other advantages of these inventory bins is, they are stackable which enables reducement on occupied space. It can be also possible to see different versions of these bins, either as a part of a system or as built-in components.

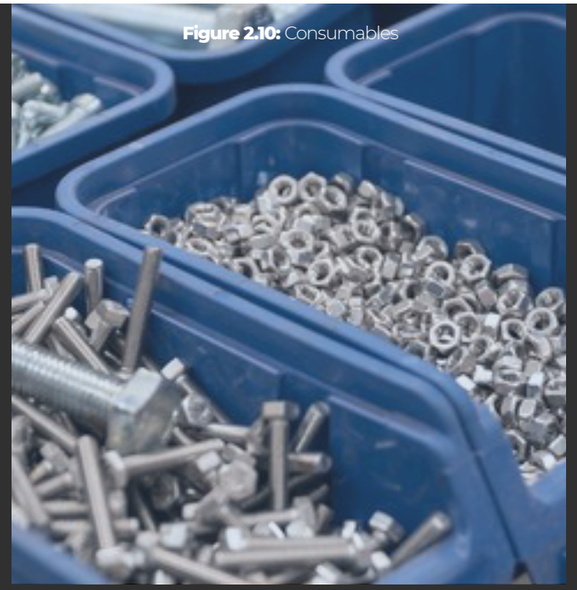


Figure 2.10: Consumables

Figure 2.11: Different sized consumables in inventory bins

2.4.3 Organisers

Organisers are compact and versatile cases with a fusion of toolbox and suitcase look. Even though, there are various types of organisers in the market, often it consists of a **hard plastic body, a transparent cover (for maximising the visibility) and small plastic slots placed inside** (Figure 2.12). Craftsmen prefer to use organisers a lot in order to reduce the interruption of work by going back and forth to the vehicle. It enables to carry every consumable necessary with one go. Even though, inventory bins and organisers have different purposes, two of the interviewees mentioned that they prefer to **keep the stock of consumables in inventory bins and transfer to organisers whenever it is necessary.**

Figure 2.12: Stanley Fatmax Organiser

Figure 2.13: Organisers in storage system

Figure 2.14: Hardly reachable storage for battery powereed tools

Figure 2.15: Battery powered tools

Figure 2.16: Side access power tools cases

2.4.4 Battery Powered Tools

Battery powered tools are one of the most valuable goods for craftsmen inventory. Not just the fact that overall they are expensive, also, maintenance and battery replacement adds more cost. Therefore craftsmen tend to give a good care to battery powered tools. They are always placed in their protective cases in order to avoid any type of damage which can cause a stoppage at job. On the other hand, sometimes incidents such as theft can happen to vans, thus, craftsmen prefer to place battery powered tools in a spot which cannot be reached easily. Some craftsmen place them just behind the side door and in order to reach the tools a special key is needed (Figure 2.14).

Batteries of power tools can get influenced by the temperature. For instance, during winter the back of the van becomes cold and that decreases the life-span of batteries, thus, they have to be kept in HQ or home, preferably with room temperature. Missing out this nuance, can cause craftsmen to buy additional batteries. Considering all of these details which increases the overall cost to obtain battery powered tools, craftsmen prefer leasing rather than buying them since companies provide free maintenance and gives an opportunity to change them with a new set of powertools periodically.

Examples for battery powered tools are; **hand drillers, electric screwdrivers, circular saws, angle drills, sanders, compressors, vacuum cleaners and nailguns** (Figure 2.15).

2.4.5 Everyday Tools

Even if the extent of the craftsman skills boil down to simply tightening some screws or hammering a few nails, they still need some tools to get the job done right (Tirman, 2018). Everyday tools, have one of the highest frequency of use rate, thus, they are always carried from the trunk to the jobsite, often with a toolbox and or a XL sized softbag (Figure 2.17). Examples for everyday tools are screwdrivers, hammers, pliers, wrenches, clamps etc.

Figure 2.17: Toolboxes that include everyday tools

2.4.6 Raw Materials

When the job description is renovating a house or building a roof, then raw materials are needed. Examples of raw materials can be; wood beams, steel, iron and PVC pipes, metal rods, aluminum, copper and metal sheets etc. These raw materials are often bought with large sizes and it is challenging to find a place for them in the vehicle especially when the stowed out context is taken into consideration (Figure 2.18).

Figure 2.18: Raw materials need long spaces

2.4.7 Job Specific Items

Job specific tools can be needed depending on the job description and they do not have to always stored in the trunk. For instance, a ladder or a sink can be needed in some occasions for a plumber or a PVC elbow for a construction worker when a comprehensive job includes plumbing tasks as well (Figure 2.19). It is obvious that carrying a toilet in the trunk regularly is irrelevant due to the space that it occupies . For some scenarios, craftsmen need to go to the supplier to get what is necessary.

Figure 2.19: Ladder as a job-specific item

2.4.8 Specialist's Van Comparison

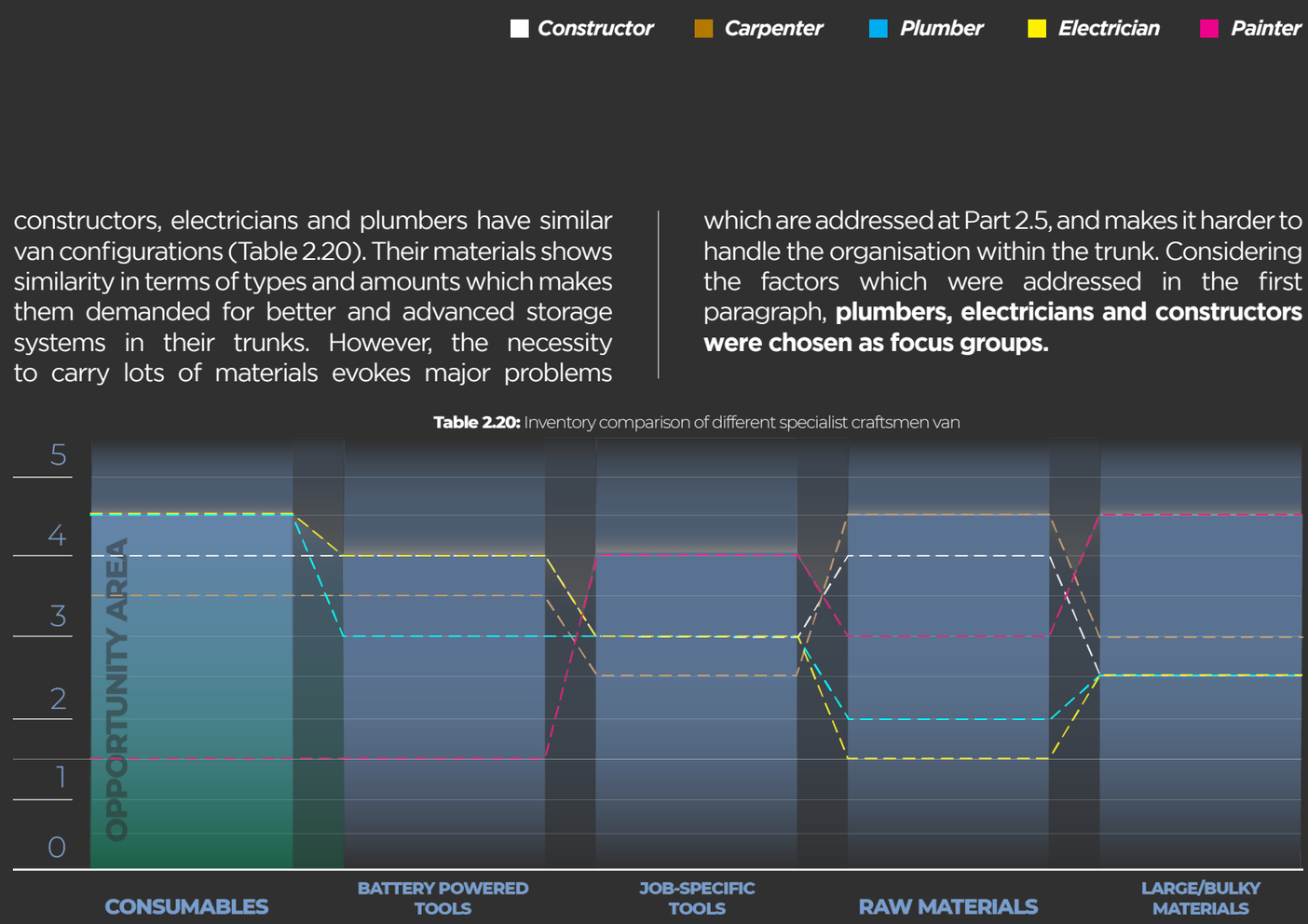
During user interviews, I had a chance to observe different configurations of craftsmen with different specialisations which enabled to make a comparison chart regarding the van setup, priorities and inventory conditions.

This observation guided the graduation thesis to focus on even more specific group of craftsmen who has the most tendency about having difficulties about inventory awareness and management. This decision has been taken by considering couple of aspects such as;

- The amount/variety of materials in the trunk
- The complexity of the confined space
- The frequency of usage of consumables

Some craftsmen need advanced systems due to the amount and variety of tools that they have, such like constructors, electricians or plumbers. On the other hand, painters for instance, need spacious cargo area to transport bulky items such as large paint cans or wall insulation materials. As a result of this comparison constructors, electricians and plumbers have similar van configurations (Table 2.20). Their materials shows similarity in terms of types and amounts which makes them demanded for better and advanced storage systems in their trunks. However, the necessity to carry lots of materials evokes major problems which are addressed at Part 2.5, and makes it harder to handle the organisation within the trunk. Considering the factors which were addressed in the first paragraph, **plumbers, electricians and constructors were chosen as focus groups.**

Table 2.20: Inventory comparison of different specialist craftsmen van



2.5 Defined Problems

During user interviews, it was learned that, there are common problems that most of the participants face with, in fact often they are all because of the major issue, the disorganisation within the confined space. However just like a chain reaction, this chaotic context creates many more problems which can also be considered equally crucial.

Starting from this observation, following difficulties and problems were determined.

- Disorganisation
- Accessibility
- Inventory awareness
- Scepticism
- Unnecessary loads

During interviews it was difficult to understand the perception of craftsmen towards technology, Therefore an iteration has been done on the interview protocol. This enabled to understand the reasons of the sceptical approach that craftsmen have towards digital solutions. Complete interview protocols can be seen on Appendix C.

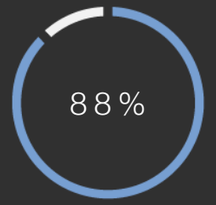
Figure 2.21: Pile of materials in the cargo area

Figure 2.22: Disorganised trunk

2.5.1 Disorganisation

Craftsmen have highly intense work flow. Time is a crucial factor to get everything done as planned and in order to be productive. They also need to travel long distances between job sites. Therefore, most of the time they cannot organise their trunk and it makes the confined space look chaotic (Figure 2.22). The only relevant time to organise the trunk are early mornings and end of days. Because of this inconvenience, finding and gathering desired tools are time consuming and effortful. The disorganisation in the trunk is also linked with if it is an individual or a company business. Large companies with multiple vehicles that are shared amongst craftsmen, care more about the cleanliness of the vehicle as they believe this influences the productivity, organisation and the brand image Disorganisation is also the main reason for the following substantially crucial issues.

n=7/8



of the participants working with disorganised and chaotic trunk.

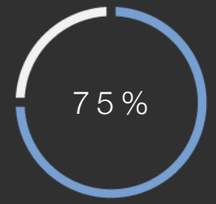
‘Sometimes I spend up to 20 minutes searching for tools that I am looking for.’

LOUIS (51), CARPENTER

2.5.2 Accessibility

The proximity of the storage space and the compartment systems is a major problem that equipments placed in the open space, prevents easy access to storage units (Figure 2.23). This results with either reaching out to drawers and cabinets or getting into the trunk with bad posture which is harmful for physical health often in a longer term (Figure 2.24). According to the latest numbers of the ESWC*, 45.5% of the European workers report working in painful or tiring positions while 35% are required to handle heavy loads in their work (Schneider, 2010). Craftsmen prefer to use the side door to access frequently used materials, on the other hand, back door is often used for loading.

n = 6/8



of the participants have lack of either physical or visual accessibility.

‘It is hard to reach the drawers and toolcases inside the van.’

JAN (49), ELEVATOR SERVICE MECHANIC

Figure 2.23: Hard access to drawers

Figure 2.24: Harmful body postures while reaching

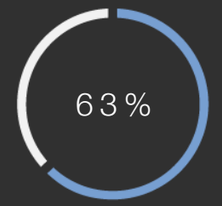
Figure 2.25: Chaotic and messy trunk

Figure 2.26: Drawer with random materials

2.5.3 Inventory Awareness

Accessibility and disorganisation also influences the inventory awareness. Stowed out storage units and obstructive cargo area reduces visual accesibility (Figure 2.25). Craftsmen sometimes realise that there is not enough of specific material which is needed for the next job. Therefore they need to travel to the department store additionally at the middle of the day. This causes them lose time and consume fuel which could be utilised better since time and efficiency is important for craftsmen. On the other hand, overstocking is as bad as having low stock and because of the lack of awareness, this situation also happens time to time.

n=5/8



of the participants have a lack of serious inventory awareness.

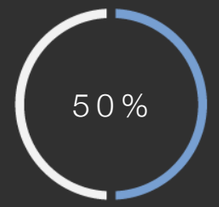
‘I need to travel to the supplier in Utrecht which makes me lose 1-1.5 hours!’

LOUIS (51), CARPENTER

2.5.4 Scepticism

One of the interesting observations made during interviews was craftsmen's sceptical approach towards digital solution. It was known that most of craftsmen are late adopters, however two of the participants were optimistic about the digital solutions as long as they are robust and easy to operate. Because, due to the harsh context, they think solutions containing technology cannot survive perfectly. However as long as the technology provides benefits and assures efficiency, early adopter craftsmen are interested. Which can be supported one of the participants' statement: 'If it is easy to use, saves me time and increases the efficiency of my employers, I would like be a part of it.

n = 4 / 8



of the participants are sceptical about digital solution integrations.

'Advanced configurations can influence my employers for taking good care of tools and materials.'

KIM (34), CONSTRUCTION WORKER

Figure 2.27: Sceptical look of craftsmen for tech related questions

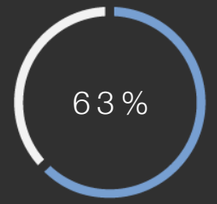
Figure 2.28: Pile of materials dumped to the trunk

Figure 2.29: Unnecessary loads

2.5.5 Unnecessary Loads

As mentioned above, disorganisation within the trunk causes craftsmen to be less aware. They sometimes carry tools which are not needed that day (Figure 2.29). This results as an inefficient use of space and eventually a demand for larger vehicles. Reduced vehicle weights can improve fuel efficiency in volume-limited operations and allow for increased payloads and reduced numbers of journeys to be made in weight limited operations, improving system efficiency (Hill et al., 2015). Increasement of the weight of the vehicle which causes more fuel consumption. However most of the time, it is possible to see piles of tools dumped to the corner of the trunk or not used for a long time. This makes them unnecessarily carried loads.

n=5/8



of the participants carry unnecessary loads in their trunk of the van.

‘I forget the things that I have to do due to the amount of tools and intense work.’

JOHN (31), CONSTRUCTION WORKER

2.6 Day of a Craftsman

A regular day for a craftsman can be really unpredictable considering that they are hired to do more short-term service jobs and emergency tasks. This makes their schedule quite intense and bring time and efficiency into prominence. Consequently, although there are times when a regular day begins at 8 am and ends at 5:00 pm, there will certainly be days when the task starts earlier and extends until midnight (Marie, 2018). Briefly, the day of a craftsman consists of, preparation in the early morning, on-site work at couple of job locations, debriefing at the end of the day and additional activities in between such as travelling between job-sites, lunch breaks and visit to department stores.

This part of the paper will guide you through the reflections of determined user problems on a day of a craftsman. Due to the scope of the project, the focused phases are; **preparation, on-site work, administrative tasks and additional activies** that are done by craftsmen.

The complete chart visualising a day of a craftsmen with detailed information can be seen on Table 2.36.

Figure 2.30: Craftsmen finding materials in his van

Figure 2.31: Craftsmen loading the van

Figure 2.32: Vans at construction site

2.6.1 Preparation

Craftsmen start the day from their home or from the headquarters of the company. The main activities that takes part during this phase are, planning of the day, distribution of work within employees, loading the van and receiving ordered materials, tools or consumables from the supplier (Figure 2.31). Preparation is an important part of the day to have an efficient workflow. Because of the defined user problems there can be deficiencies in preparation ,for instance, **having lack on consumables or on tools for upcoming jobs.** This can be a reason to do **additional activities which results with losing time.**

2.6.2 On-site Work

After arriving to the job-site, craftsmen park their vans and make the initial interaction with the customer about duration of task which then followed by a job diagnosis in order to detect what materials are needed (Figure 2.32). During this phase craftsmen interact with their vehicle most by collecting tools and going back and forth to the trunk. The user and contextual problems influence this most important phase of the day significantly. Since craftsmen do the actual work in the meantime, it is important for them to maximize the efficiency in order to be able to finalise everything on time.

2.6.3 Administrative Tasks

Craftsmen need to do administrative tasks during the day. It can be either with customers and or at the headquarters (Figure 2.34). Throughout the day, they keep track of used materials, current inventory, working hours, driven kilometres and many other things themselves. At the end of the day, most craftsmen end up ordering new materials and stock themselves and spend copious amounts of time doing more bureaucratic tasks and desk work, like making invoices and receipts, and logging working hours (Spierings et al., 2018). Due to the methods that small to medium sized craftsmen companies use for inventory management, **debriefing can take up to 45 minutes with a high tendency for inaccuracy.**

Figure 2.33: Administrative work

Figure 2.34: Craftsmen company office

2.6.4 Additional Activities

A day of a craftsman often does not go how it is actually planned because of mentioned user problems which results with executing additional activities. **Lack of inventory awareness and preparation, results with travelling to a department store after a realisation of a deficiency** (Figure 2.35). On the other hand, due to same reasons, craftsmen often have to go back and forth to the trunk of the van for multiple times during on-site work. This is done to collect needed materials which were not taken to the job site initialy. Those activities are the reasons for losing significant time and interruption on the work flow.

Figure 2.35: Craftsmen in a department store

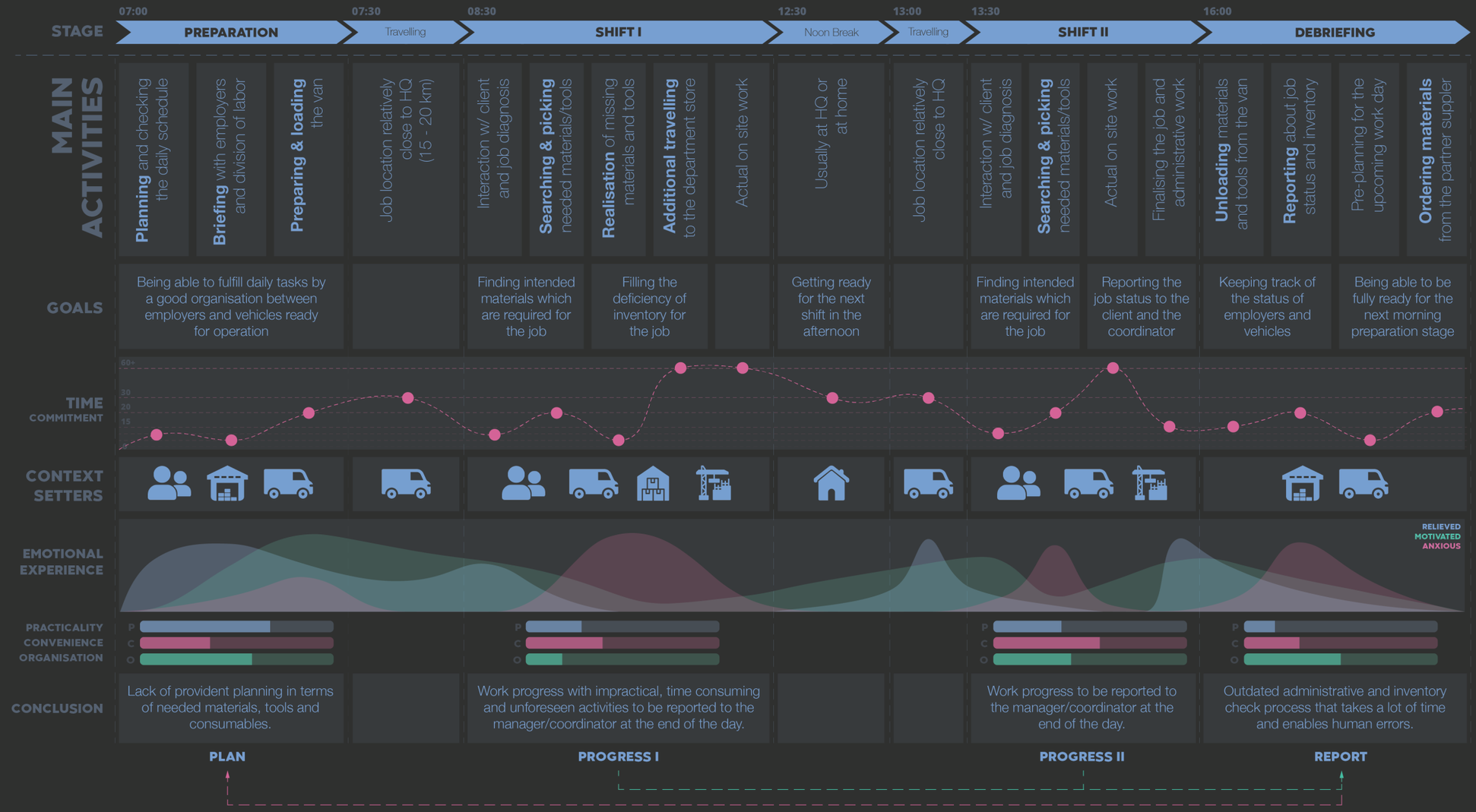


Table 2.36: A complete day of a craftsman

SECTION III:

INVENTORY MANAGEMENT

In this section, inventory management was researched by focusing on different used methods and technologies that are preferred. Later on, sensors and load cells are explained due to the scope of the project. Market research including inspirational solutions for different industries can be seen on Appendix D.

3.1 Methods for Inventory Management

When businesses don't have a handle on the activity of their inventory, or worse, track it with outdated spreadsheets and data entry, the rest of the pieces, like order fulfilment, don't fall into place (Walts, 2020). Also this lack of information can cause a lot of unforeseen events that reduces the efficiency of work . There are many different methods used by organisations to have a better inventory management. Choosing the accurate method is linked with the scale of the business due to their cost, complexity and relevancy. Warehouses, retail stores and health industry some of the industries that gravitate towards advanced inventory management methods. By having an inventory management system in place, the organisation can track, forecast and replenish the inventory in a timely manner. It **provides clear insights of what is happening in the inventory**, enabling to see what products are moving (eSellerHub, 2018).

Still most of the **small and medium sized craftsman companies old and manuel methods** which results with spending long times for inventory check with a high human error tendency and physical effort.

3.1.1 Pen, paper and whiteboards

Paper, pen and whiteboards are the most common method for inventory management, in fact, still most of the small to medium sized craftsmen companies prefer it (Figure 3.1). The age old method of taking care of the inventory included employees individually identifying, counting, and writing down the information about each piece of merchandise in the warehouse. (Element-ID, 2016). It is costless, however demands a **huge human labour and have a high tendency for error** since manuel inputs needs to be done by a personnel.

3.1.2 Inventory spreadsheets

Inventory spreadsheets are relatively easy to use and maintain, as long as there was one person primarily responsible for data input (LinkLabs, 2020). Because of manual inputs which needs to be done by employers, they can also be unreliable considering the probability of human error and inaccurate data.

Also, simple inventory spreadsheets **cannot track inventory in real-time** and data integrity is definitely problematic. Equally significant, it takes a great deal of staff time and physical effort to do various operations on data to make good business decisions

3.1.3 Cloud-based systems

Cloud-based systems harness the power of IoT and moves into the world of real-time tracking, using the right combination of technologies. The IoT solution empowers the organisation to **connect people and inventory, with automated processes.** This increases productivity, mitigates risk, and monitors inventory continuously with a centralized automated system. A interviewee who works in a electrician company mentioned that, their supplier uses RFID scanners to detect what is necessary beforehand. However, despite mentioned benefits, predictive insights and smart decision-making will not be among them. Also, the organisation will still need certain staff to collect and correctly interpret it all before using the information to make business decisions.

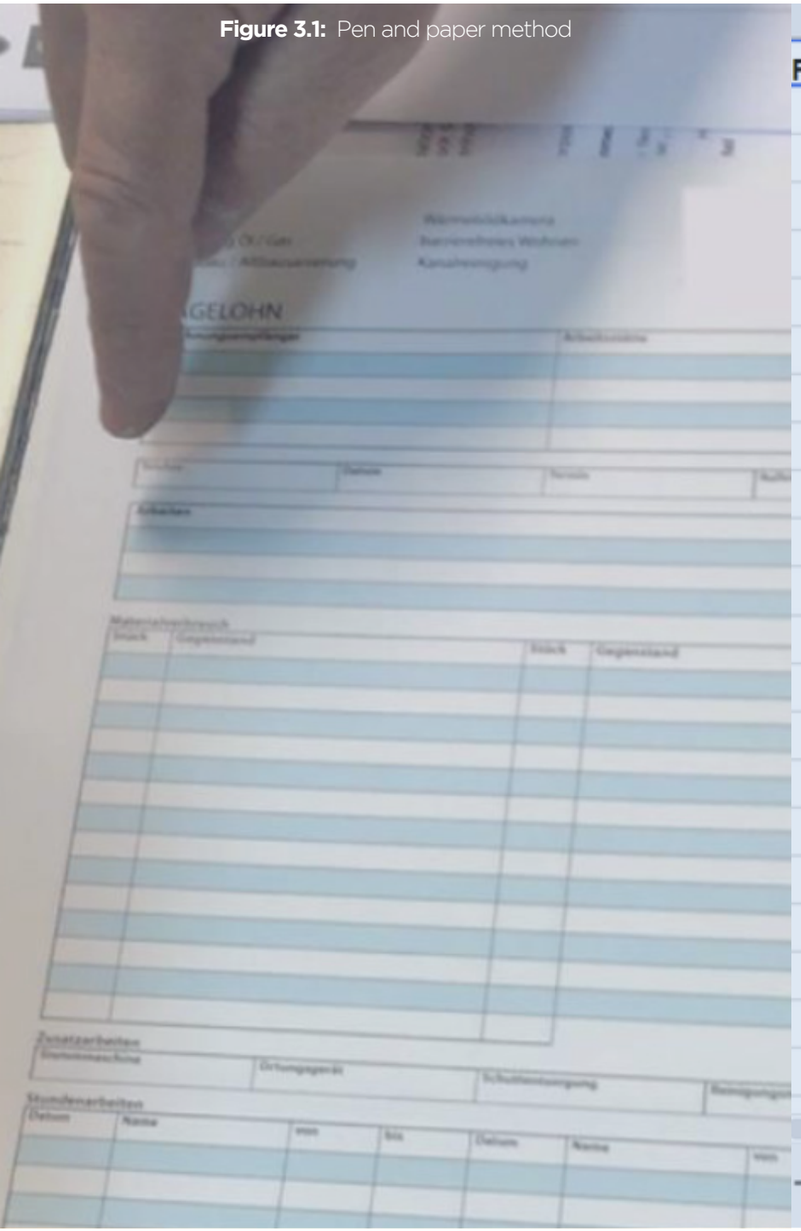


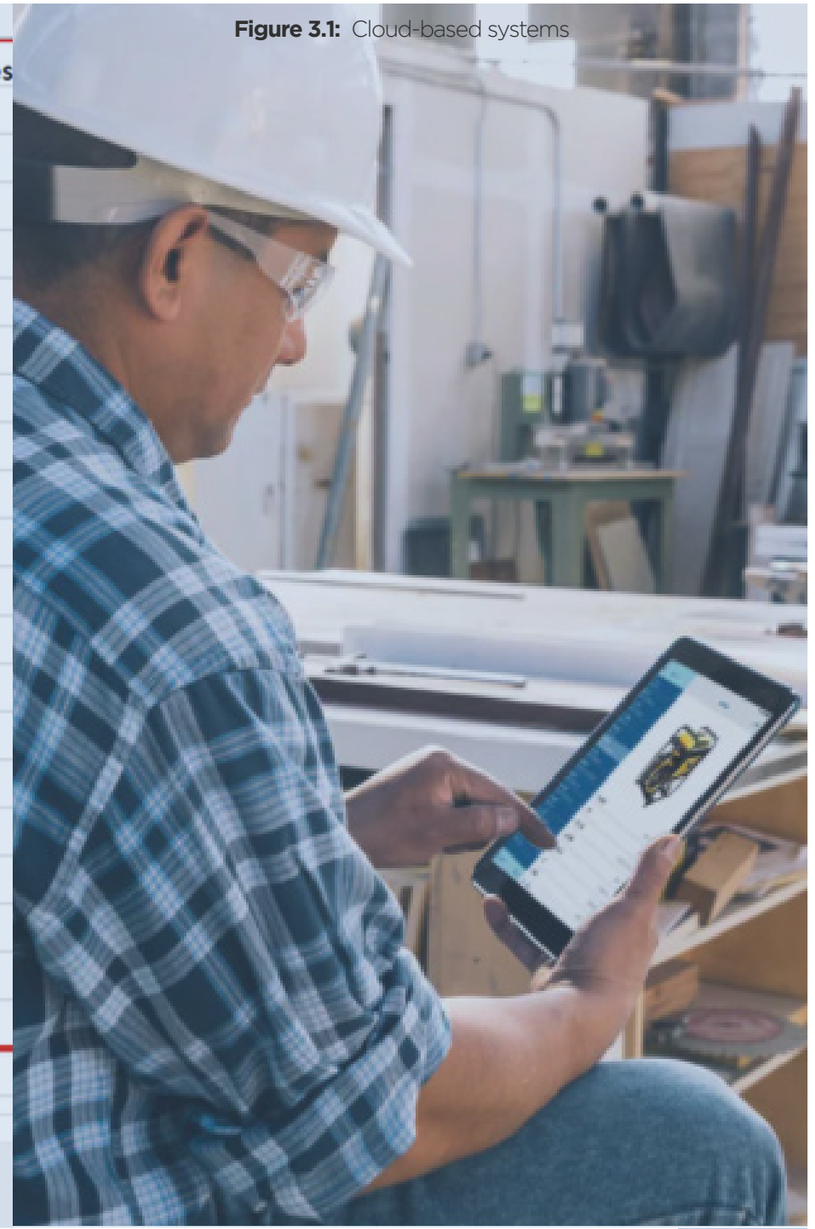
Figure 3.1: Pen and paper method

Figure 3.2: Inventory management spreadsheets

	A	B	E	
	Product Barcode	**Product**	**Initial Stock**	**Res**
1	123	Avocado	50	
2	456	Cantaloupe	60	
3	789	Lotion	20	
4	533799	Pain Reliever	100	
5	825625700049	Fever Reducer	103	
6	9781936093694	Dry Pasta	30	
7	72220099980	Toothbrush	200	
8	612820801035	Halloween Candy	50	
9	29000072800	Mascara	40	
10	884912004710	Dry cereal	50	
11	9781936093695	Blush	35	
12	96619586363	Oatmeal	80	
13	613008737719	Granola Bars	60	
14	72220099981	Potato Chips	60	
15	884912004712	Nail Polish	100	
16	96619783953	Sleep Aid	90	
17	612820801036	Tinted Lights	25	
18	533792	Mouthwash	400	
19	72220099985	Bread	30	
20	9537729	Toothpaste	50	

Product | Sales

Figure 3.1: Cloud-based systems



3.2 Inventory Management Technologies

The technology for inventory management and their applications in industries have rapidly evolved in the past two decades. Many of the challenges that businesses face, **such as running out of stock, having excess stock, obsolete stock or spoilage are as a result of poor inventory management** (Soh Pin Pin, 2019). To overcome this, there are lots of different technologies ready for implementation on a small or a large scale depending on the business needs. A wide range of tracking technologies are available to cater the business needs for inventory management (Table 3.4). Choosing the right technology for the business use case depends on what the aim is, what the business challenges are, and in which environment will it deploy the solution. (Deloitte, n.d.).

There are a few general parameters that can help to make a smart decision. These parameters were taken into consideration and prioritised while choosing a relevant technology for the concept design. Since the aforementioned solutions on the first paragraph already preferred in various industries such as warehouses or retail stores, a contextual comparison has been made in between those contexts and the trunk of the craftsmen van (see Appendix E).

- **The number of materials being managed**
- **Desired granularity / accuracy of data**
- **The value of inventory being manage**
- **The physical environment(s) in which the tracking will be made**
- **Ease of use, including installation and setup**
- **Costs to purchase and maintenance**

	Asset Tracking Technology	Working Principle	Range	Accuracy	Pros	Cons
Short range asset tracking	**Passive RFID**	Calculates proximity to network of RFID antennas and triangulation of input signals	200 m	NA	▪ Many tag types ▪ No battery ▪ Low cost tags	▪ Higher reader costs ▪ High metal and liquid interference
	Bluetooth Low Energy (BLE)	Calculates proximity to network of Wi-Fi access points and triangulation of input signals	100m	1- 2 m	▪ Low power consumption ▪ Easy to deploy	▪ Battery operated tags ▪ High cost per sq. m (tag, reader)
	Wi-Fi	Calculates proximity to network of Wi-Fi access points and triangulation of input signals	200m	15 m	▪ High data throughput ▪ Fairly large range and accessibility	▪ (In)accuracy battery operated tags ▪ High cost per sq. m (tag, access point)
	Ultra-wide band (UWB)	Measures multiple paths – signal time to receiver and angle of arrival to measure bearing	10-20m	Few cm - 3 dm	▪ Resilient to interference ▪ High accuracy	▪ Shorter range ▪ High cost per sq. m (tag, reader)
Long / Wide range asset tracking	**LPWAN (LoRa, LTE-M, NB-IoT)**	Tracks using GPS and transmitted to LoRA gateway, transmitted to back-end using Wi-Fi / cellular	15000m	Few meters	▪ Zero transmission cost ▪ 10 -15 km range with single gateway	▪ Expensive tags ▪ High battery usage
	Cellular: GSM, LTE, 5G	Tracks using GPS and transmitted to back-end using cellular	Limited by coverage	Few meters	▪ Unlimited range ▪ No gateways required	▪ Expensive tags ▪ High battery usage ▪ High transmission cost
	GPS	Tracks using GPS and transmitted to back-end using Wi-Fi	Limited by coverage	Few meters	▪ Zero transmission cost ▪ Low-battery usage	▪ No off-the-shelf system available
	Satellite (LPGAN, etc.)	Tracks using GPS and transmitted direct or via gateway to back-end using satellite	+ / - 10000m gateway range	Few meters	▪ One frequency, modem ▪ Low-battery usage and cost	▪ Requires line of sight to item begin tracked ▪ Small quota of messages / day

Table 3.4: Comparison of inventory management technologies (source: Deloitte)

3.2.1 Sensors

With the advent of computational technology and digitalisation of data, newer methods have been developed for inventory management using computational intelligence. Electronic Sensor based technologies combined with this intelligence can create a remarkable combination of inventory management, which can not only keep a thorough track of the goods required, but the system is also very easy to manage, as a consequence of which these sensors based smart inventory management system become very efficient in terms of preventing any mismanagement of goods (Singh, 2019). Starting with a definition, a sensor is an electronic device that is used to measure some sort of physical parameters (e.g. weight, temperature, pressure, light intensity, etc) (Figure 3.5). Each sensor has a different working principle and the parameter it's measuring but they all convert a physical parameter to an electric signal (Magdy, 2020). A sensor acts like a gateway between the computing world and the real world (Imandi, 2020). Due to the scope of the project this part will proceed with further explanations about one of the most preferred force sensors in various industries; load cells with strain gauges. The complete research on classification of sensors and complete research about force sensors can be found on Appendix F.

Figure 3.5: Examples for sensors

3.2.2 Load cells

A load cell is a device that is used to measure weight or force. When a force is applied to it in a specific manner, a load cell produces an output signal that is proportional to the applied force. Strain gauge load cells are at the heart of the majority of weighing and force measurement devices produced today (Figure 3.6). Load cells can be used individually or in combinations in weighing devices, as dictated by the geometry of the object weighed (Patoray, 2010).

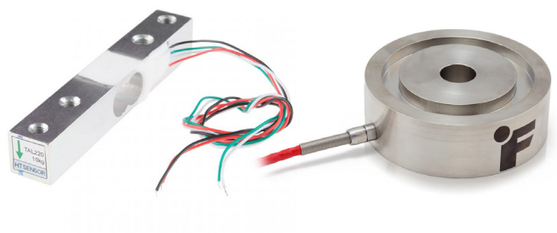


Figure 3.6: Different types of load cells

The most common ones, generally consist of a spring element on which strain gauges have been placed. The spring element is usually made of steel or aluminium. That means it is **very sturdy, but also minimally elastic.** As the name "spring element" suggests, the steel is slightly deformed under load, but then returns to its starting position, responding elastically to every load. These extremely small changes can be acquired with strain gauges (Figure 3.7). Then finally the deformation of the strain gauge is interpreted by analysis electronics to determine the weight (Schmidt, n.d.). Because of **the flexibility of use in different applications, easy accessibility and accuracy** load cells are one of the most preferred force sensors. Main disadvantages for load cells are the bulky size and sometimes it can require expensive electronics. .

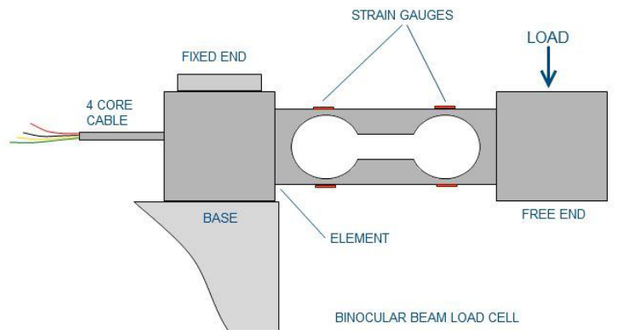


Figure 3.7: Load cell working principle (source: Kobastar)

SECTION IV:
SYNTHESIS

Section IV starts with analysis of the comprehensive field and market research. Later on important Key Findings were shown which will be reflected on the concept design. Analysis of the research and key findings conduce towards defining list of requirements and a persona.

4.1 Analysis

As it can be seen on the extensive field research, there are numerous difficulties and nuisances that craftsmen face with within the trunk of their light commercial vehicles. Even though it was observed that most of these problems influence each other just as a chain reaction, it was important to prioritise them in order to define the problems which will be tackled with the concept design. Therefore, a problem tree analysis has been made with putting the most major and common problem at the center, almost every craftsmen experience; the clutter, chaotic and disorganised trunk (Table 4.1).

Every other difficulties which can be considered as equally substantial placed around that main problem. Problem tree analysis (also called situational analysis) helps to find solutions by mapping out the anatomy of cause and effect around an issue in a similar way to a mind map, but with more structure (Wageningen University & Research, n.d.). Therefore, the problem can be broken down into manageable and definable chunks. This enables a **clearer prioritisation of factors and helps focus objectives.** On the right hand side, focused problems with full opacity boxes are shown.

This method was helpful to specify the focus objectives that compliments with the given use-case by the client, Ford Motor Company. This guided the graduation thesis to **define a concrete design goal and full list of requirements** which are substantial to take into consideration during the concept development phase.

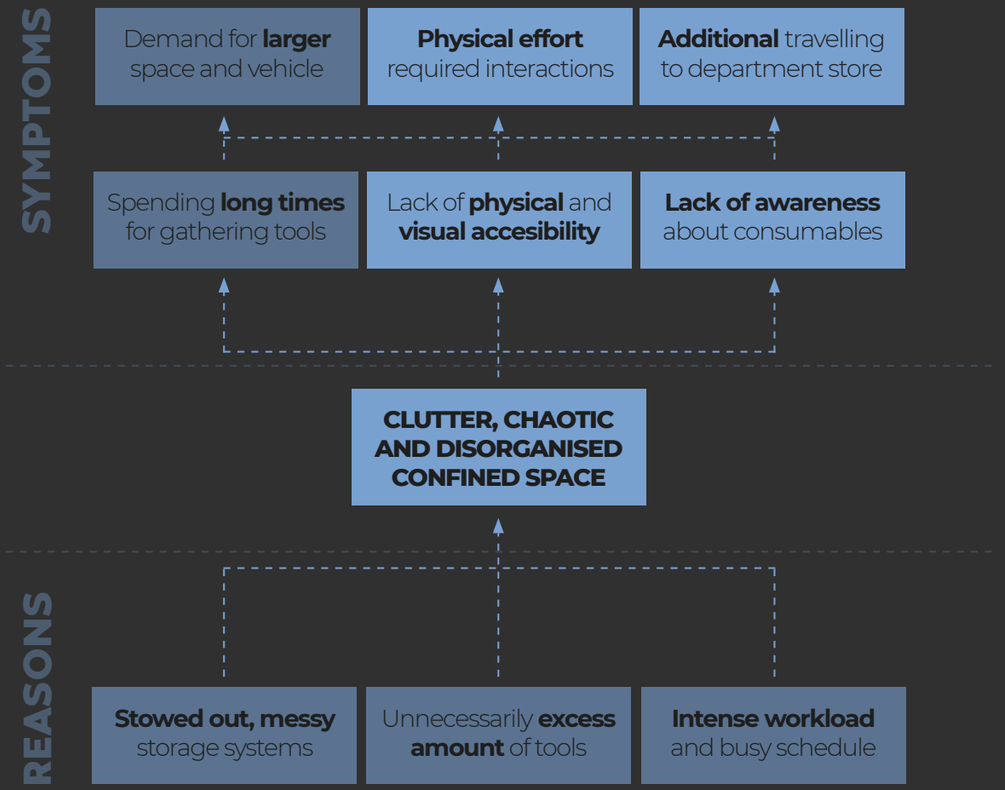


Table 4.1: Problem definition tree

Design Goal

Enhancing accessibility and inventory awareness of craftsmen through offering informative digital services with smart interactions towards carried consumables in their trunk.

4.2 Key Findings

1

Impractical activities and overwhelming interactions, requiring physical effort

RQ1 How to design a smart trunk ecosystem that will improve the inventory awareness of craftsmen?
RQ2.2 How can the physical effort required interactions be evolved?

During the day, craftsmen have to interact with their vehicles multiple times. Some of those interactions are essential to be able to start to work, but some of them are made because of the impracticalities happening in the trunk. Losing time while searching and collecting the necessary tools and materials is one of them. The same situation occurs when an inventory control in the trunk is needed. **Craftsmen need to check every consumable and their holders individually.** This control happens during work and at the end of the day, when the inventory status needs to be reported. Since every operation **requires physical effort** in the vehicle, **routine inventory controls becoming constrained and long-lasting** (Figure 4.2). Craftsmen should avoid getting in and out to the vehicle every time the inventory condition needs to be checked.

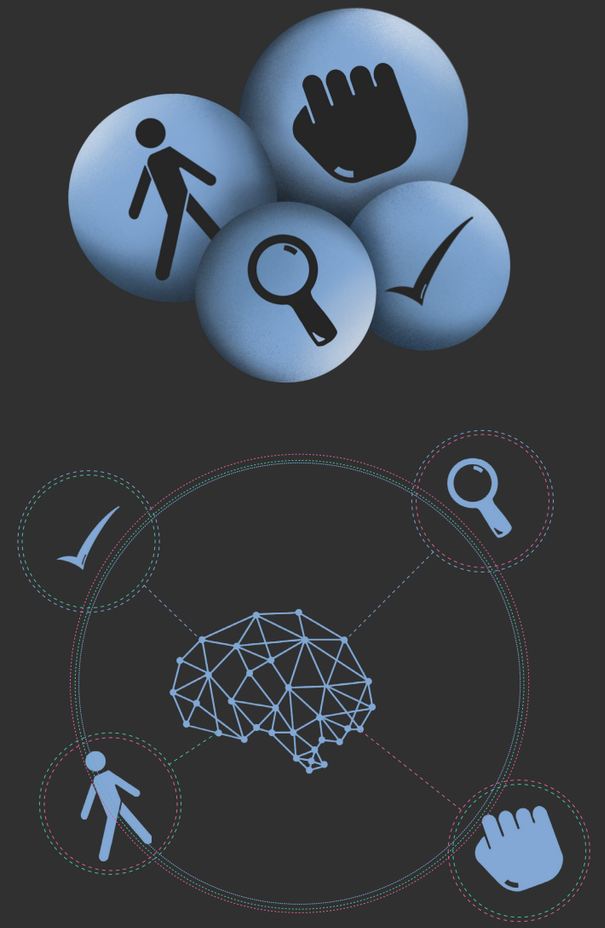


Figure 4.2: Evolving interactions

2

Unnoticable deficiencies on consumables, setbacks in the organisation

RQ2.2 What has the most potential to aggravate the management from the inventory of craftsmen?
RQ2.4 Can digital solutions spearhead to craftsman business for improving itself?

Consumables are one of the goods in the trunk which are not invoiced to the customer unlike raw materials or job specific materials. Considering their frequency of use and turnover rate **consumables are difficult to manage and have a high tendency to get lost or forgotten.** This can result with having low-stock before the work which is a reason for craftsmen to **additionally travel to department stores.** The travelling can take up to 1.5 hours in some occasions which is a crucial time loss for craftsmen. Those problems can create **additional expenses, stoppage in the optimisation of consumption and eventually lack on the orders from suppliers.**

3

Excentricity towards technology can be exceeded by proving benefits

RQ2.1 How can craftsmen be adapted to the world of digitalisation?
RQ2.3 How can the inventory management be improved in the trunk by utilising technology?
RQ2.6 What type of information do craftsmen need for inventory management?

Sceptical approach towards technology drives craftsmen to prefer impractical solutions and methods for inventory management. Despite that scepticism, there is still a group that are **optimistic towards digital solutions and their potential influence for improving the efficiency.** It was concluded during interviews that, the most promising way to familiarise craftsmen to digital solutions is, providing **a solid proof regarding their benefits** for their work flow considering their requirements which are, **robustness, reliability and easiness of operation.** In addition, it was observed that craftsmen do not prefer being supervised and forced while working. **Suggestive informations and reminders,** rather than forcing them to follow certain rules were well-received. It is beneficial to adapt craftsmen towards technology and future of commercial vehicles with small steps.

4

Empower and amplify the business with improving the internal organisation

RQ2.4 Can digital solutions spearhead to craftsman business for improving itself?

It is important to consider both employee craftsman and the company point of view. The methods the small and medium size companies prefer for inventory management, **extends the inventory control phase unnecessarily.** Relying on pen, paper and whiteboards requires long times and human labour, hence, increases the possibility of errors which can result with deficiencies in orders. Accelerating this phase of the day, by taking craftsman companies from Stage I to Stage III of inventory management methods can empower the business and shrink the time that is currently spent. This improvement promises for **improving the internal organisation** within the company and **avoid performing additional activities** such as travelling to department store during work by contributing for accurate orders and consumption optimisation.

5

Contrast in between craftsmen's self confidence and the reality

RQ2.6 What type of information do craftsmen need for inventory management?

Craftsmen, in general, are self-confident professionals about everything related to their work. During interviews, questions which are related about inventory awareness and difficulties about finding materials were responded swiftly, with mentioning having no problems. However, despite this self-confidence, the reality was different which was observed while shadowing when participant craftsmen were asked to find specific materials or consumables. One of them was mentioning how easy it is for him to find everything he is looking for while simultaneously checking five different organisers to get the one which has fasteners in it. It was interesting to observe the fact that even though **craftsmen were aware of the difficulties that they experience in the trunk, they prefer to neglect or ignore them mainly because of their self-confident personalities.**

4.3 List of Requirements

Category	ID	Requirement
Product Features	PF1	The product must contribute for decreasing the physically effortul interactions.
	PF2	Communication with the user should be made with suggestive informations.
	PF3	The product should look of robust, reliable and futuristic.
	PF4	The electronics chosen for the product must be easily operable by craftsmen.
Product Architecture	PA1	The electronics chosen for the product must be highly reliable for precision.
	PA2	Functional part groups such as modules should be dismountable together
	PA3	The product must enable practical assembly to catalyse maintenance
	PA4	Parts of the product must be ergonomically relevant for different craftsmen.
Safety & Durability	SD1	Components must be provident for dirt, dust or spilled liquid in the trunk.
	SD2	The product must resist excrenscence forces can be applied by craftsmen.
	SD3	Safety critical components must (electronics) be reachable and removable.
Product Economics	PE1	The product must be economically accessible considering craftsmen's income.
	PE2	The electronics preferred for the product must be affordable .

Table 4.3: List of requirements

Certain requirements need to met before getting into the concept development. These requirements are defined during the extensive field research and important key findings. To differentiate better, requirements divided into groups which are; Product Features, Product Architecture, Safety & Durability and Product Economics (Table 4.3).

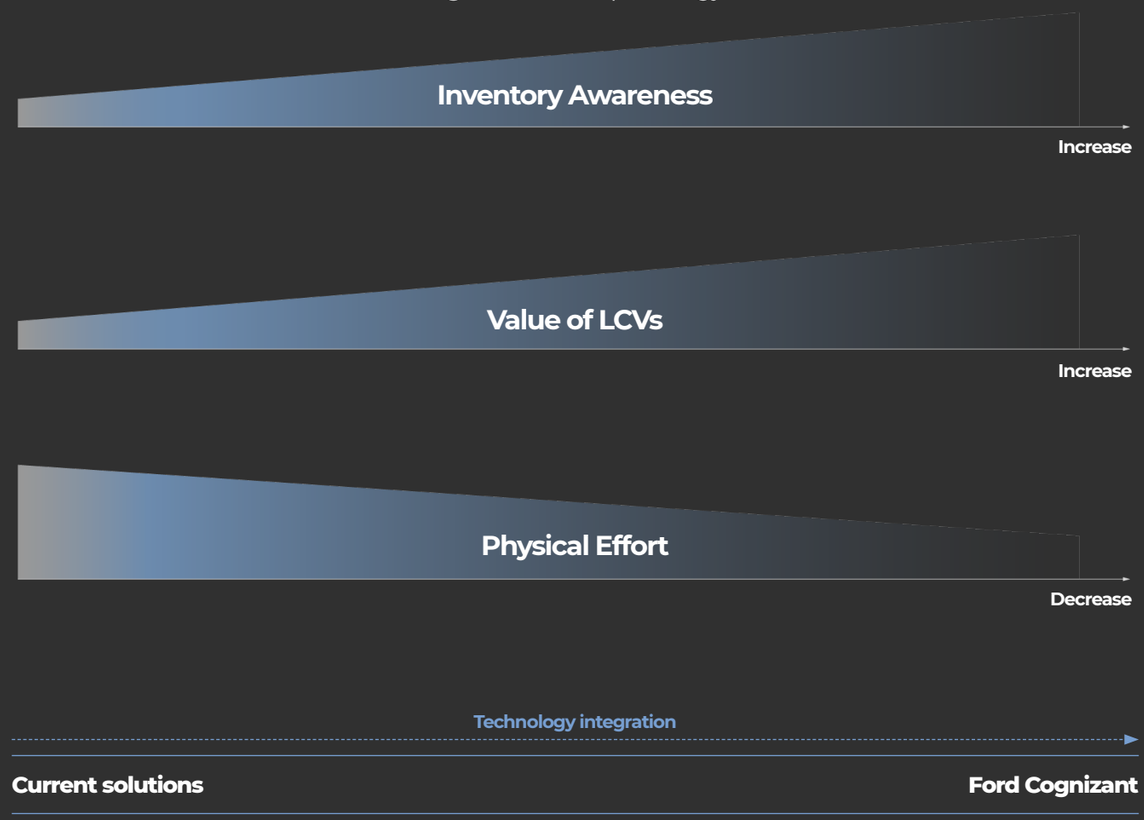
These requirements worked as guidelines for upcoming phases of the design process.

4.4 Concept Strategy

Considering the important key findings, the design vision and the possible future developments, the concept fundamentally focuses on **improving the inventory awareness,** simultaneously **adapting craftsmen to the world of digitalisation** while **building the future of light commercial vehicles.** This is achieved by enhancing the function of the trunk by **making craftsmen and their inventory connected** via smart and accessible technologies integrated to the concept (Figure 4.4). **Reducement in effortful physical interactions** is also a motivation for the concept by taking in mind the current contextual state that craftsmen's trunk have. Therefore, not just the efficiency but also practicality within the confined space can be enhanced in a way that visual accessibility will not an issue anymore for consumables.

Following the proposed topic of Ford RIC Aachen, a direction was taken after comprehensive user-centric analysis towards inventory management. That resulted with defining a use-case which guided the graduation thesis to conduct the concept solution. From different types of materials that they transport, consumables are the ones with high potentiality to disrupt inventory management. This observation combined with defined user problems enabled Ford Cognizant to provide a communicative and informative service for various types of consumables that craftsmen carry. While accomplishing the aimed benefits mentioned on the first paragraph, design iterations have been made in order to improve user experience, user interaction and compatibility of the concept to list of requirements.

Figure 4.4: Concept strategy



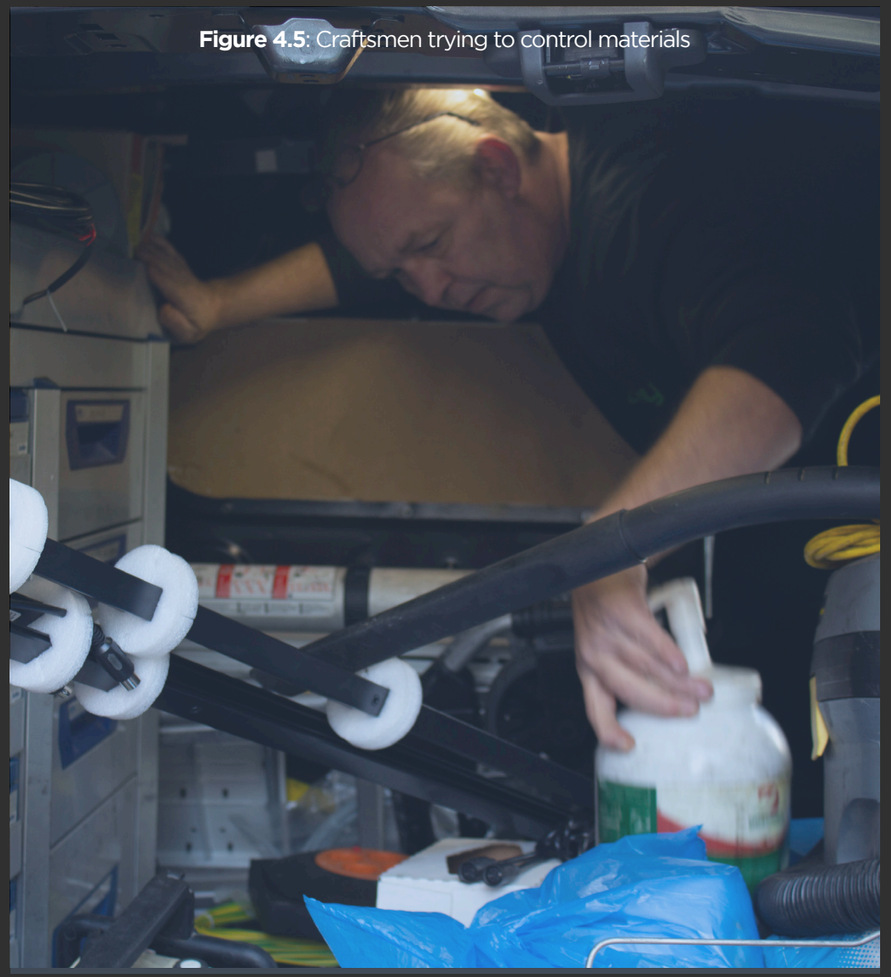


Figure 4.5: Craftsmen trying to control materials

4.4.1 Increasing Inventory Awareness

As it stated on Part 4.1, the design goal of the concept is improving craftsmen's inventory awareness for consumables carried in the trunk. Achieving that will help craftsman and craftsman businesses to overcome situations such as having a low-stock or over-stock which conduce towards minimising inventory costs and maximising efficient consumption. With solid inventory management, you know what's in stock and order only the amount of inventory you need to meet demand (Jenkins, 2020). Enhancing awareness also contributes for having greater insights about the inventory which is important especially from craftsman business point of view. Companies with multiple employees and vehicles can have an idea about the consumption of each craftsman employee in order enable optimisation which results with accurate ordering from suppliers. This will be achieved by enabling connectedness between craftsmen and inventory via enhancing the smartness of the trunk.

4.4.2 Reducing Physical Effort

Research showed that, current solutions that craftsmen implement in their vans require a huge amount of physical effort. Obviously this problem makes operations within the trunk impractical combines with accessibility issues, that ultimately affects the inventory awareness. As it mentioned on Part 2.6, during debriefing session, craftsmen need to report their inventory status. To do that, they have to go back and forth to the trunk to check every single inventory bin in order to have an idea about the consumption. During developing Ford Cognizant, smarter and practical interactions were seeked that will inverse the current impracticalities in the trunk. For consumables, since the frequency of use and turnover rate is high, the concept should offer interactions that will give a quick and clear idea, also should be not tiring and do not take long times.

4.5 Persona

Before concept development, a craftsman and organisation persona has been created in order to address the target group. The craftsman persona is a reflection of interviewees, especially the ones who are optimistic towards digital solutions with similar user problems and demands (Figure 4.6). The same approach has been shown to the organisation persona. A small or medium sized craftsman companies usually have one or two responsible employers for inventory management (Figure 4.7). Defining target craftsman companies is important for the concept development and technology implementation because it enables to think from organisational point of view.

Figure 4.7: Craftsman organisation persona

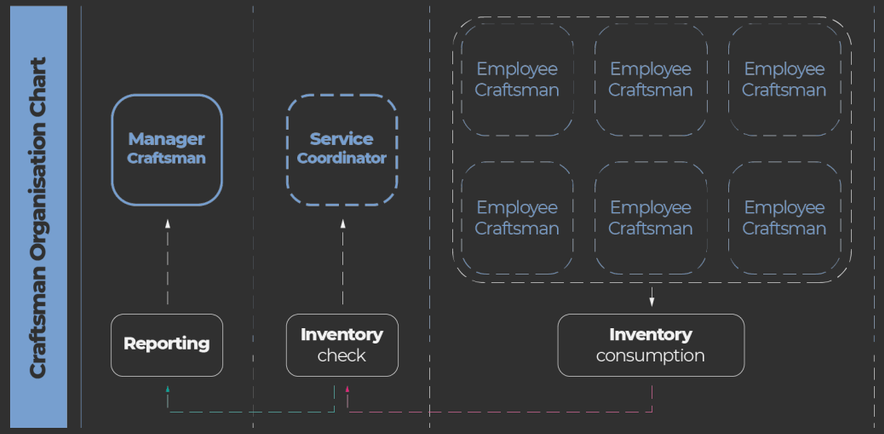
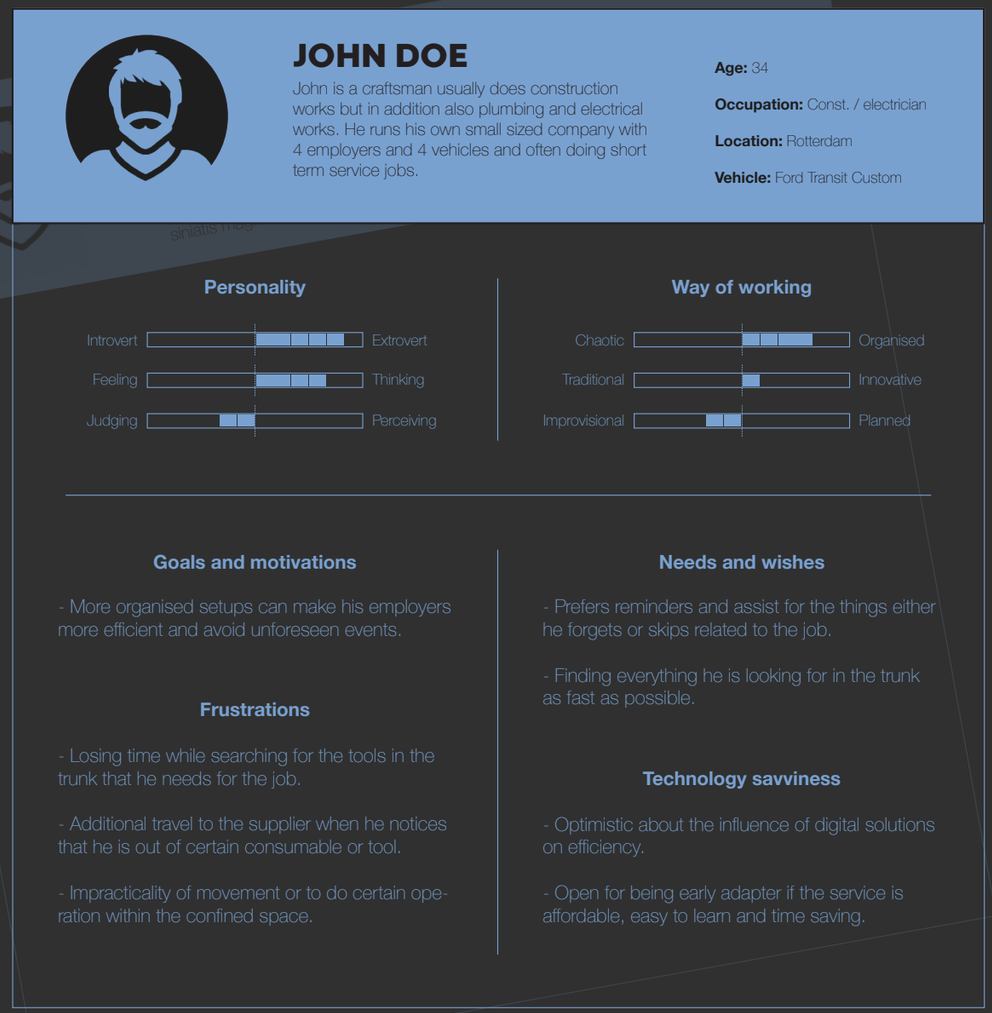


Figure 4.6: Craftsman persona



COGNIZANT

Automated Inventory Control

SECTION V:

CONCEPT DEVELOPMENT

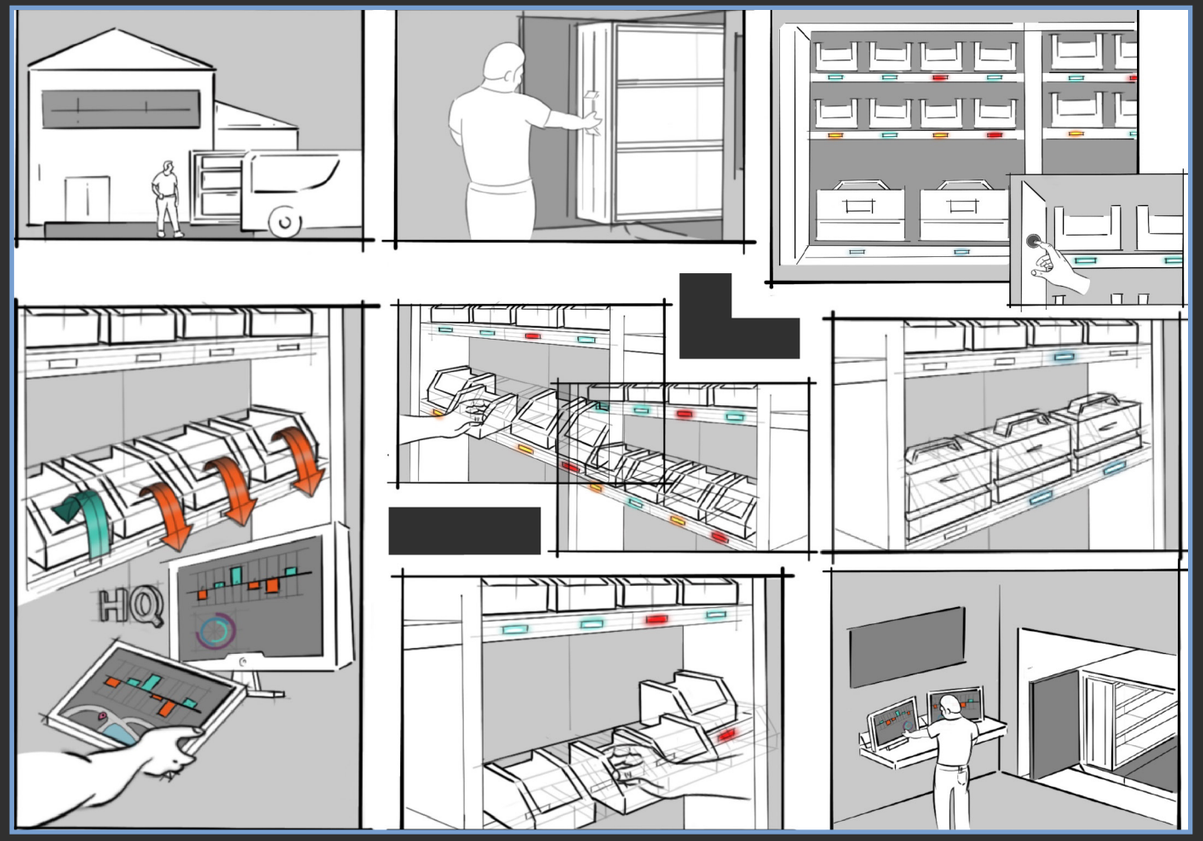
After defining craftsmen's difficulties that they face within the trunk regarding the inventory management, the concept development phase had been started. Defined room for opportunities mentioned as key findings, translated into a beneficial product and service. This section outlines the development of the concept, with it's initial state, followed by user experience tests and further iterations.

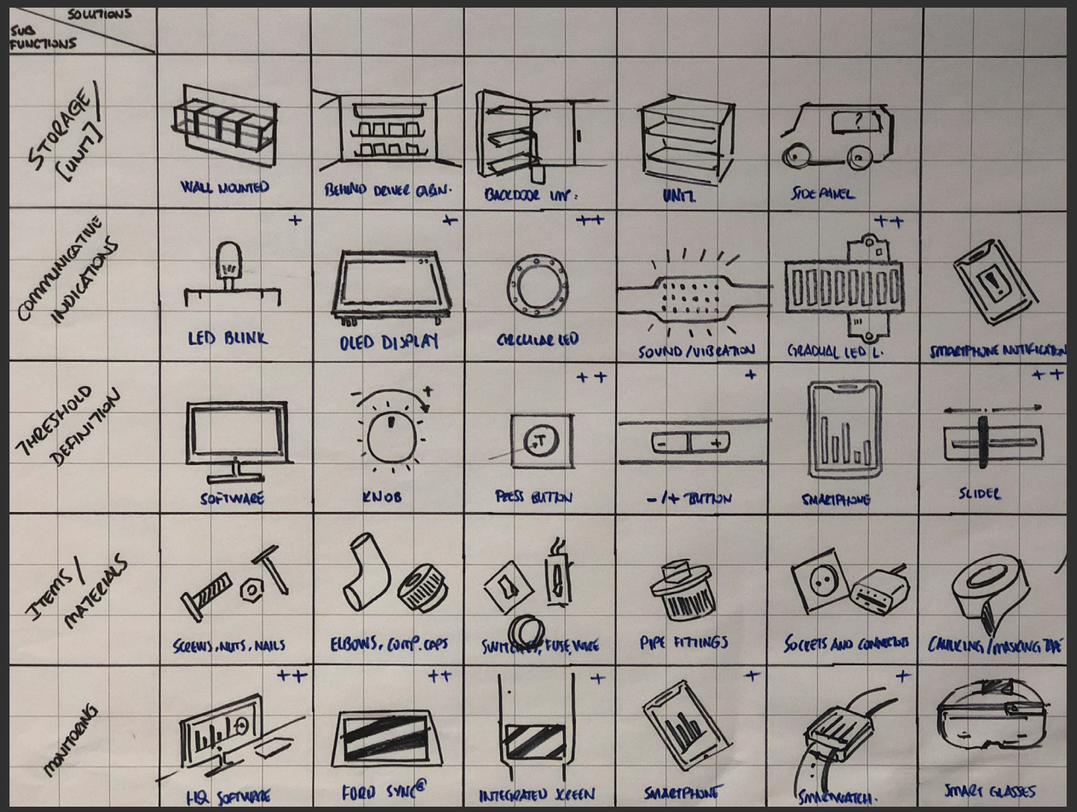
5.1 Initial Concepts

For mid-term evaluation, three very initial concepts were presented focusing on the service design part of the project. It was essential to provide beneficial services, which then be coated with a tangible product around it (see Appendix G). Evaluations resulted with taking the adventageous points of two of the presented concept and fusion them in order to provide a more comprehensive system (Figure 5.1). Technologies which will be implemented were confirmed during the mid-term evaluation as well. Thereafter, the final concept, Ford Cognizant started to get developed from that point. During the concept development, an envisioned scenario has been created, reflecting the user experience aimed to be achieved (Figure 5.2). The main focus of the envisioned scenario is motivating the Key Finding 1, which is transforming physically efforful interactions to more practical and efficient interactions.

Figure 5.1: Initial concepts

Figure 5.2: Envisioned scenario





considered **Product Implementation**

evaluated with **User Experience Tests**

findings from **Research**

Figure 5.3: Morphological chart

Morphological Chart

Extensive concept development phase continued with dismantling the components that will constitute the comprehensive system. This has been done to find possible and potential solutions and exploring the accurate fusions considering the findings of user research and requirements. In this duration, a morphological chart has been created and sub-functions were listed. While functions are abstract, solutions are concrete, but they do not need to have a definite shape or size yet (Boeijen et al., 2020). The morphological chart evolved during the design process, for instance initially there was not a sub-function named 'threshold definition'. Since the concept development phase and user tests went simultaneously, findings of those tests were reflected to the morphological chart. Then another iteration has been done for the improvement of the concept (Figure 5.3).

5.2 User Experience Tests

5.2.1 Test goals and setup

Simultaneously with ideation phase, user tests have been conducted to get beneficial inputs that will ultimately improve the concept. The main goal of the user tests was **to observe and evaluate the overall user experience** during interacting with the product. The term user experience within the conducted user test represents **the service features, operational steps that participants needs to do and communicational values of the system such as different types of indications.**

Deconstructing the comprehensive system of Ford Cognizant to its sub-functions via morphological chart guided me to compare some potential solutions with user tests. At the same time, drawn conclusions upgraded the morphological chart by including additional sub-functions such as, defining individual thresholds which will be mentioned later under this part.

Finally, since one of the requirements for the concept was the reliability and precision of electronic components that are chosen to be implemented, user tests provided a great opportunity to evaluate them. One of the components, single-point load cell can get influenced by external factors such as tilt and drift which can downgrade its precision (Figure 5.4). Tilt is caused by placement of bins and unbalance of goods in it. The drift may be because of sudden change in weight due to external factors such as loading or unloading (Divyasimha et al. 2009).

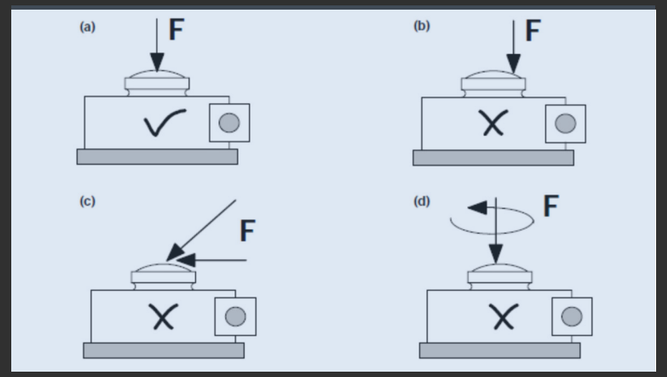


Figure 5.4: Load cell load angles (HBM, 2017)

Therefore, with different tilt scenarios, load cells were tested to see the change of precision of calculation. The reason to conduct those tests was, inventory bins or tool cases in craftsmen trunk are put with an angle in order to make them avoid falling down to the cargo area (Figure 5.5).

Figure 5.5: Angled shelves in a craftsman vehicle

Due to the aforementioned reasons a high-fidelity prototype has been made in order to maximise the realism of the experience. A representative shelf has been made with wood pieces with providing housing for electronics that needs to be placed. Circular laser cut wood parts were used as representative consumables (Figure 5.7). The

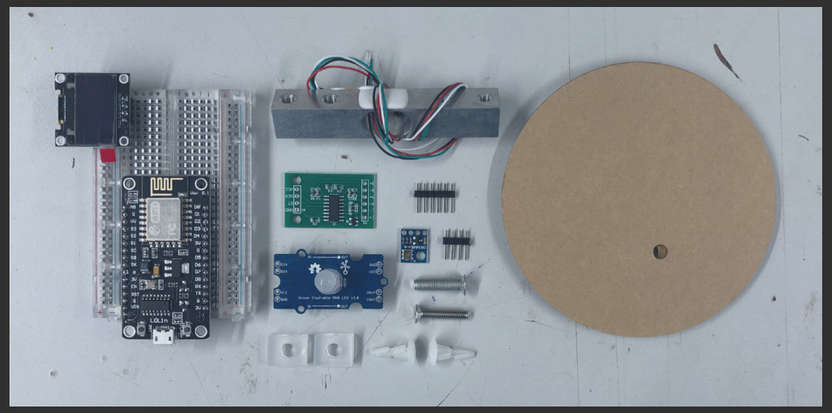


Figure 5.6: Components for tests

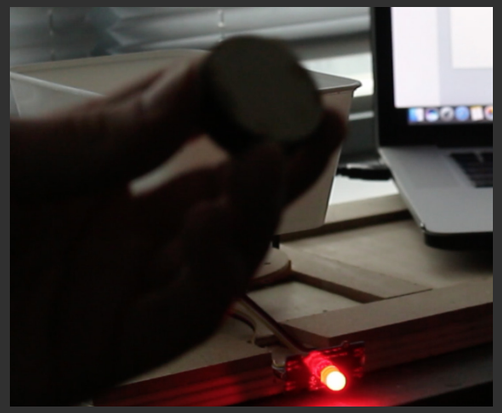


Figure 5.7: Representative consumable

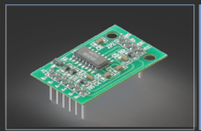
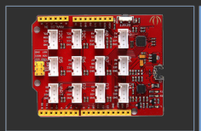
	LED BLINK	Starts blinking once the value is below the defined threshold level.
	CHAINABLED LED	Color of the light changes from green to red once the value is below the threshold.
	BUTTON	Button is used for defining the threshold level for the system by holding it for two seconds.
	LOAD CELL	Weighs the consumables that are placed in the inventory bins.
	HX711	Translates the value to a digital output that can be read by the micro controller.
	SEEEDUINO LOTUS	A microcontroller that every components connects to. Used with Arduino Software.

Table 5.8: Functions of each component

main components that has been used for this prototype was; Seeeduino Lotus, 5kg load cell with HX711 amplifiers, chainable and blink LEDs, button from Grove, a breadboard and a plastic box (Figure 5.6). Each LED light responses differently, thus, it was important to make a comparison in between them within the same task that is given to participants.

In order to give a structure to the user experience test, a simple **task** has been generated and given to each participants to complete. Before explaining the given task, functions and purposes of used components for tests shown at Table 5.8.

The Task

(1) Setting up the system for the first time after for the consumables received from the suppliers.

(2) Mimicking loading/unloading by moving consumables in and out of the bin.

(3) Observing indications and responses of the prototype on each step of the given task.

What the user experience test expects from participants was to imagine themselves in a situation that they are setting up the system for the first time after receiving the ordered consumables (in this case they are the circular wooden parts) from the supplier. Afterwards, they were asked to place the inventory bin on the prototype and define a threshold level by holding the button for two seconds. The amount is up to user's own desire. The threshold level here means, the limit amount of consumables that makes the system indicate the inventory bin either as critical or sufficient (Figure 5.11).

Later on, they were asked to put the rest of the consumables and start taking them out and putting back in. Meanwhile the system's responses and indications via LEDs were observed by participants.

After completing the task, a user test evaluation form was provided for each participant. Questions asked regarding the overall experience, operations and communicational indications under scales such as, **clarity, relevancy, performance, stimuli and easiness.** 10 point scale is used for questions.

Total of 12 participants were attended to the user experience test. The complete user test evaluation form and results of each participant can be seen on Appendix H.

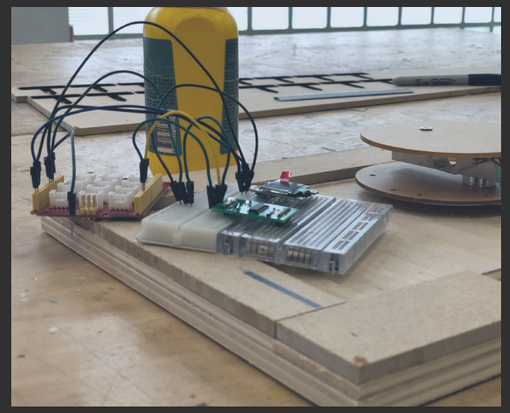


Figure 5.9: Building process

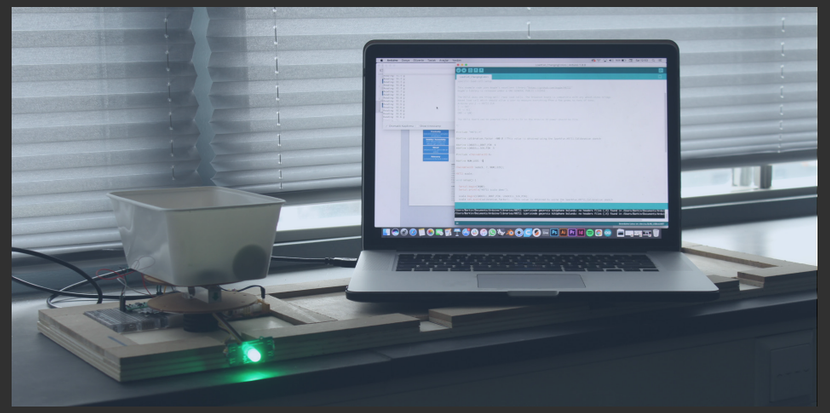
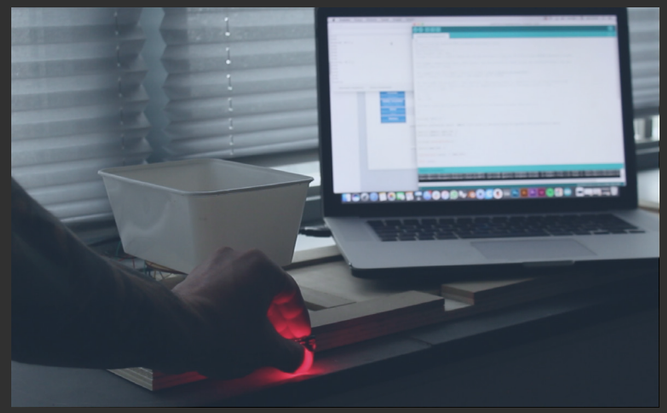


Figure 5.10: Test setup



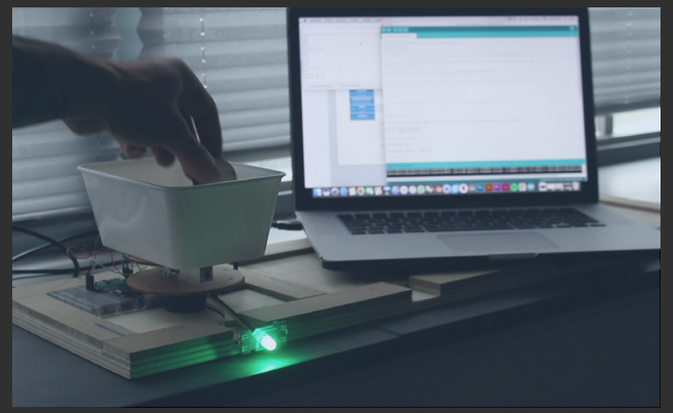


Figure 5.11: Defining the threshold level and the system response

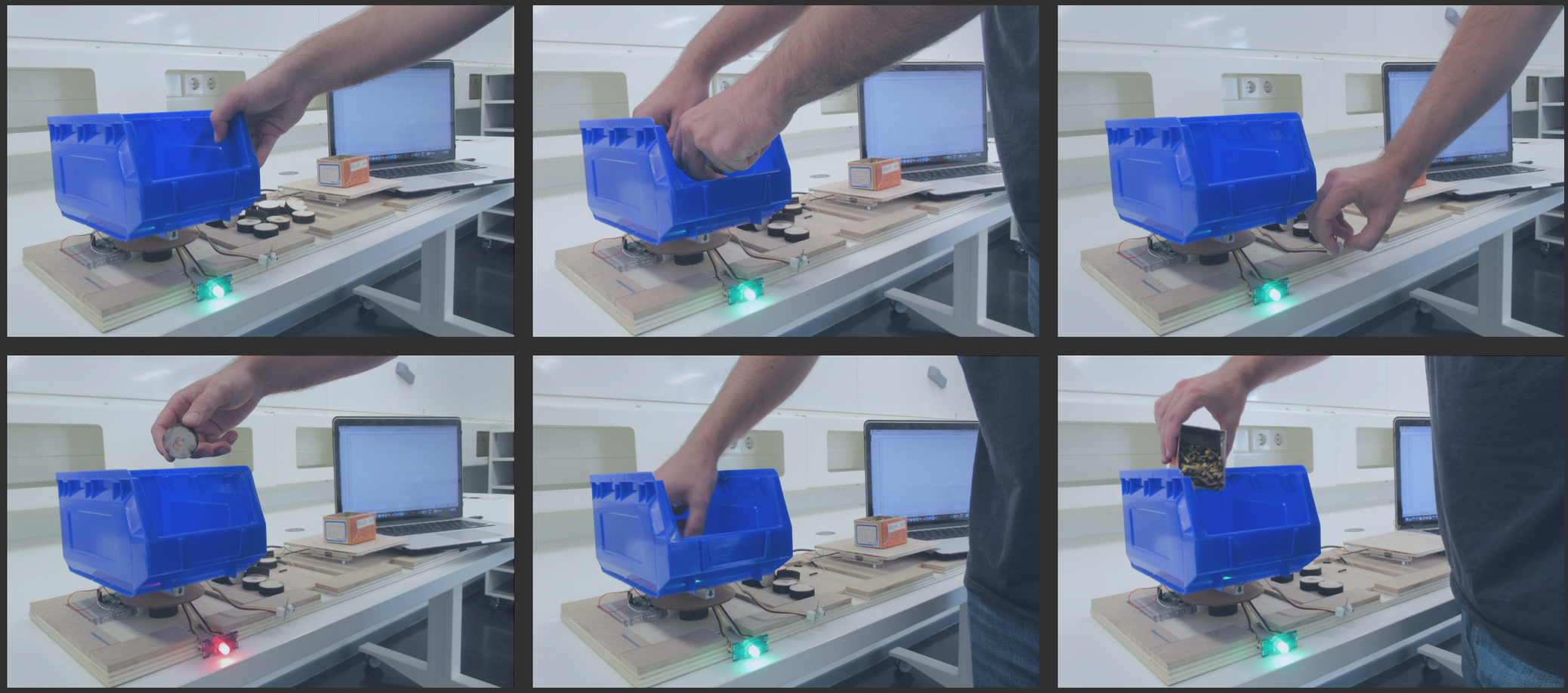


Figure 5.12: Participant #11 working on the given task

5.2.2 Results and outcomes

The full result of user tests are shown on Figure 5.14. Each score were calculated by taking the average out of 12 participants.

While participants completing the task, made observations by watching them already gave some inputs about struggles and difficulties. Especially for indications, sometimes participants looked confused, waiting for some time with an expectation of a response that made them feel unclear about what to do next. This was because of the **lack of indications** which were also emphasised by participants.

Using only green and red LED light limits the given information, not just about the state of the inventory bin but also for other operations such as defining the threshold or having a complete empty bin. **The transition from 'sufficient' to 'critical'** was waquite sharp because of using only two colours. In practical terms this transition is not coherent considering the difference in frequency of use for different types of consumables (Figure 5.13).

Participants were satisfied about the easiness of operations since only one button needed to be utilised. They were **optimistic about the feature; threshold definition,** however it was concluded that, there is lack of indication there as well. Especially when participants wanted to reset or change the threshold level, they expected a confirmation regarding to that. This deficiency was taken into consideration on next iterations due to the fact that, craftsmen's consumption can change from week to week, which means that changing the defined threshold level can occur often. Combining the evaluation forms, inputs and feedbacks from participants and committed observations, the main results were;

(1) Deficiency of indication regarding the level of consumables in the inventory bin.

(2) Lack of feedback for the confirmation of set threshold level.

(3) Unclarity between having low-stock or empty bin.

(4) The indications are unable to guide the user for next steps.

(5) When there are high number of bins, it can be overwhelming to a lot of red lights.

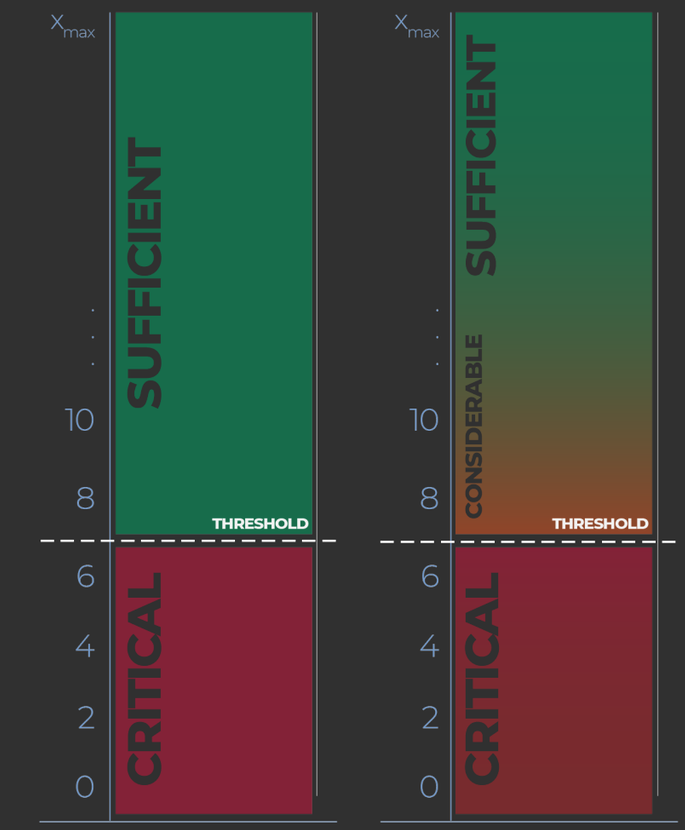


Figure 5.13: Current/improved indications

Figure 5.14: User experience test results

Evaluation scales

As it can be seen on Figure 5.14, participants gave points to each scale after finishing the user experience test. White line indicates scores for each scale and green line indicates the aimed scores with next iterations. Below, explanations for each scale is given.

Clarity
Apprehensibility of indications and their meanings

Relevancy
Satisfactoriness of the informations given by indications

Performance
Proportion of gainings by the shown effort for the given task

Stimuli
Impact on the inventory accesibility and conditional awareness

Easiness
Perceptibility of operational steps of the service

n=12

5.2.3 System bottlenecks

Apart from the results gathered from the user experience test, couple of bottlenecks were determined regarding the system and its components. In order to look for a solution a meeting has been conducted with Christian Kirchhof who is an engineer and sensor expert, working at Ford RIC Aachen. Since Ford is also working on the topic inventory management, we have exchanged ideas in order to come up with logical solutions. Before going into the conclusion of the meeting, determined important bottlenecks are;

(1) External factors like dirt, dust and liquid that can access to electronic components.

(2) Placement of an inventory bin on a different load cell

Considering the trunk context, dirt, dust and liquid are inevitable factors that have a potential to cause malfunction to electronics, thus, they need to be protected very well. On the other hand, defined individual threshold values are assigned to load cells, not to bins. Therefore, once an inventory bin is placed on another load cell, the threshold level changes automatically which can create a confusion for craftsmen.

This can result by providing providing irrelevant informations since the intended level of threshold can be different for a specific inventory bin.

As a result of the meeting with Christian Kirchhof, following solutions were decided to be integrated to the system.

(1) Along with dirt, dust and liquid, due to the characteristics of load cell, the plate which is mounted on has to have a **flexibility to tilt** with a small angle. Through that, the strain gauge inside of the load cell can bend, caused by the weight in the inventory bin. Because of this reasons, the implementation has to have a **perfect insulation and flexibility**, thus, **nitrile rubber** has been decided to placed on the front and back of the plate where the inventory bin sits on.

(2) Forcing craftsmen to put every inventory bin to its original place conflicts with the key findings mentioned at Part 4.2. Craftsmen prefer to have a **flexibility of use** for their configuration. Since each consumable might have different threshold levels, it is important to keep consumable specific information. We have brainstormed with Christian to find a way to **transfer that value from one load cell to another.**

With this way it would be possible to re-assign the value to the correct consumables and inventory bin. At that point, passive RFIDs are relevant solutions due to their relevancy for indoor and short range location finding and affordability. It was concluded that attaching **RFID tags under each inventory bin and RFID readers under each plate** where load cells are mounted, can guide the system to recognise the inventory bin and **swap the threshold level value once it is placed on another load cell** (Figure 5.15).

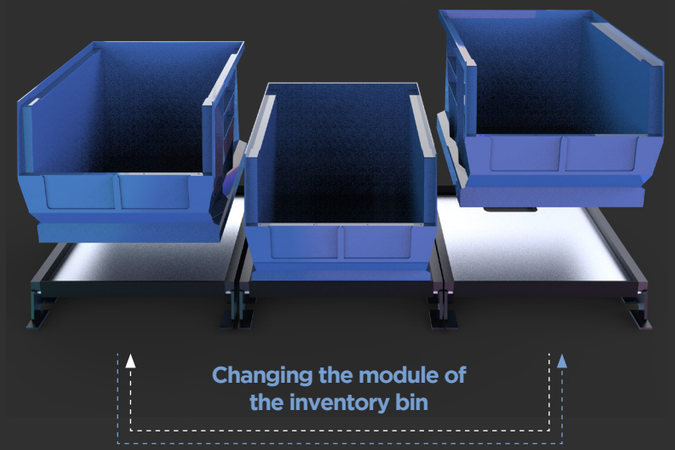


Figure 5.15: Transfering the threshold value

5.2.4 Developments

User experience tests concluded that the information given with indications must be enhanced in order to increase clarity. Current transition from 'critical! to 'sufficient' state is sharp and can be deceptive in some cases. Because having consumables just above the defined threshold is not perceived as different than having the inventory bin full by the system. Therefore, a mediocre colour have been decided to included as 'considerable' state. This alteration led to choose LED bar and eventually circular LED to implement instead of chainable LED (Figure 5.16). LED bars have slots with red orange and green colours, thus, it gives a gradual indication (Figure 5.17). Using a gradual indicator made it possible to add confirmation responses for threshold definition, maximum definition and empty bin state. Being able to add individual responses to each operation enabled adding more function to the button such as 'weight per piece' feature.

Load cells were proven to be accurate and reliable enough by testing them with different weighed consumables (Figure 5.18). On the other hand, tilt test which can be seen on Appendix K showed that even with placing the modules with a small angle, the precision of weighing does not get influenced.

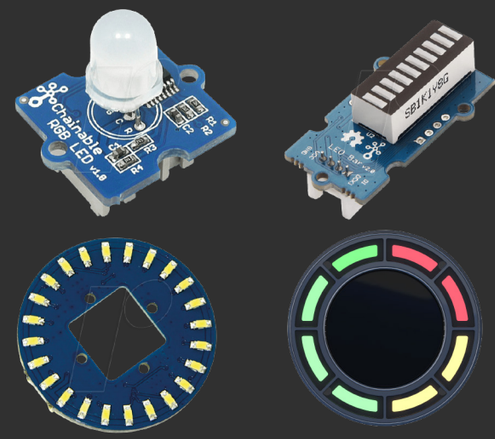


Figure 5.16: Chainable, bar and circular LED

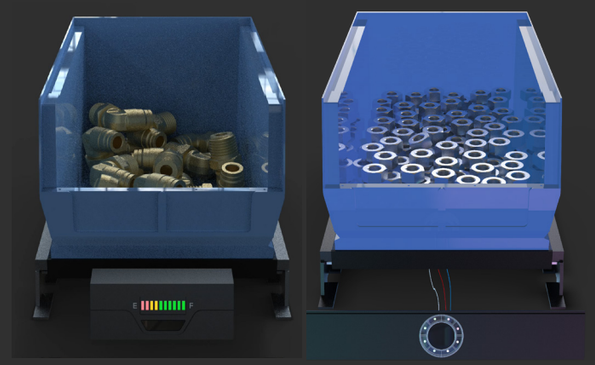


Figure 5.17: Alteration from bar to circular LED

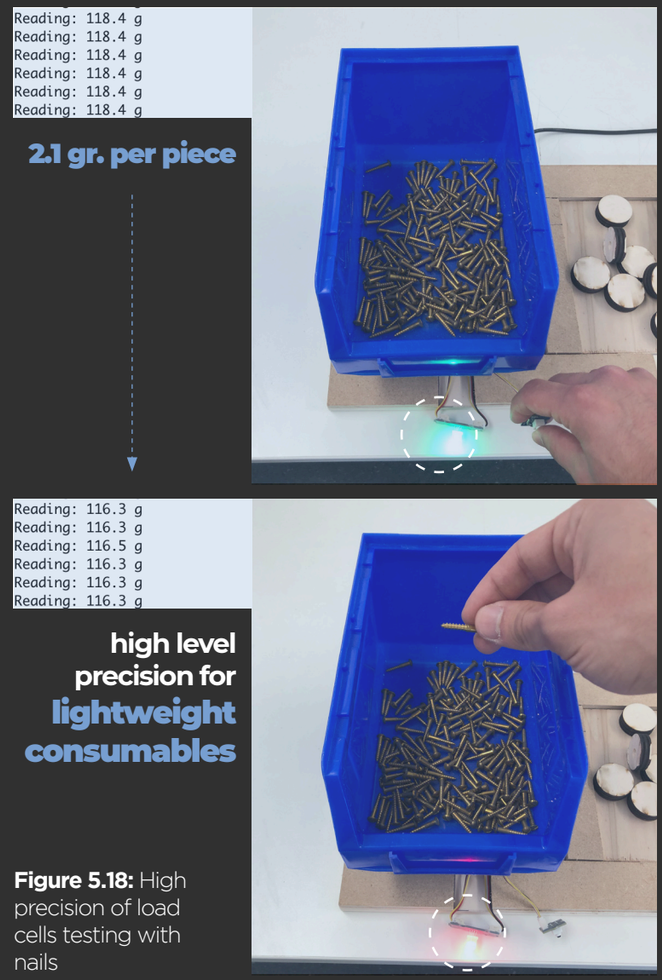


Figure 5.18: High precision of load cells testing with nails

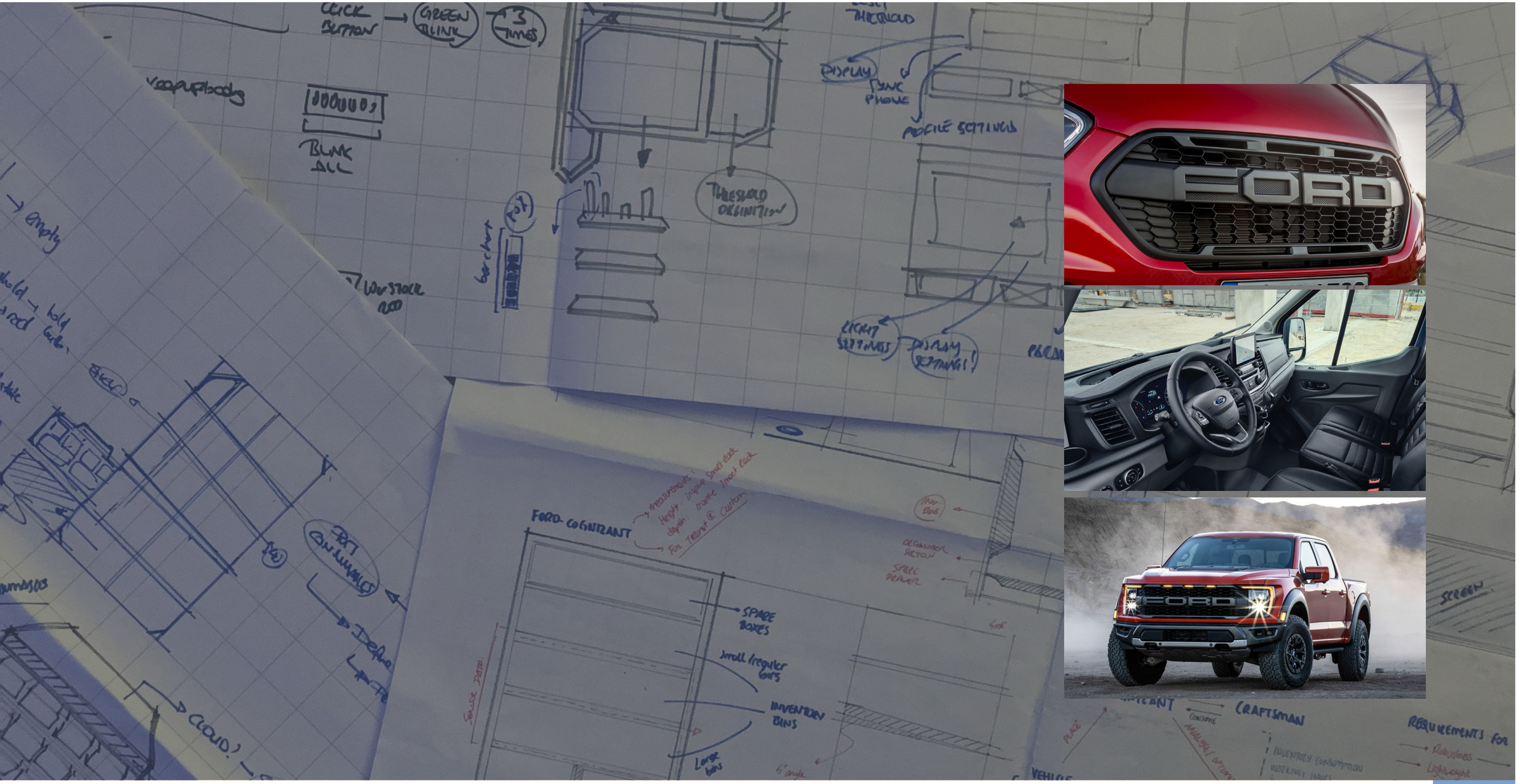
5.3 Ideation

5.3.1 Visual direction

One of the requirements for the concept is, the product must look **robust, reliable and futuristic.** It is also essential for the product to fit Ford's design language and craftsmen personality. According to interviews, craftsmen are tend to prefer solutions which are robust considering the contextual state. Taking into these guidelines in mind, this visual approach can be helpful to fulfill one of the research questions; How can craftsmen be adapted to the world of digitalisation? (RQ2.1).

The unit is the backbone of the system which holds everything together. To define the visual direction for it, a moodboard for inspiration has been made (Figure 5.19). It was taken into consideration that, inspirational products reflect the robust and futuristic look. Then iterations on the unit has been made with using the moodboard as a guideline and in addition to that; dimensions of the trunk area, electronic components, sizes of inventory bins and organisers to place were also kept in mind while designing.

Figure 5.19: Visual direction moodboard

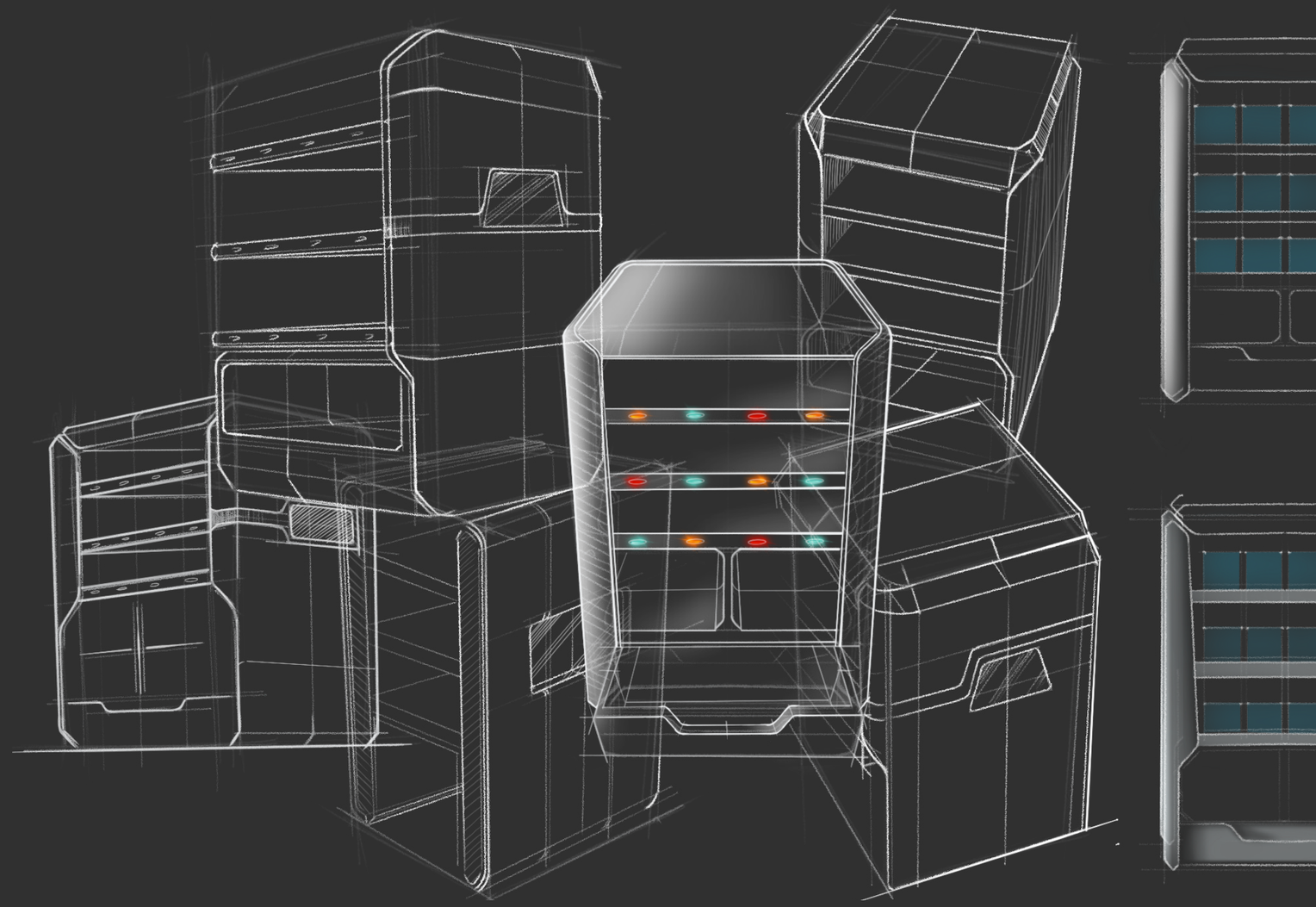

CLICK BUTTON
GREEN BLINK
3 TIMES
BLINK ALL
THRESHOLD DEFINITION
DISPLAY
LINK PHONE
PROFILE SETTINGS
FORD
FORD
FORD COGNIZANT
SPARE BOXES
INVENTORY BINS
CRAFTSMAN
REQUIREMENTS FOR
CLOUD?

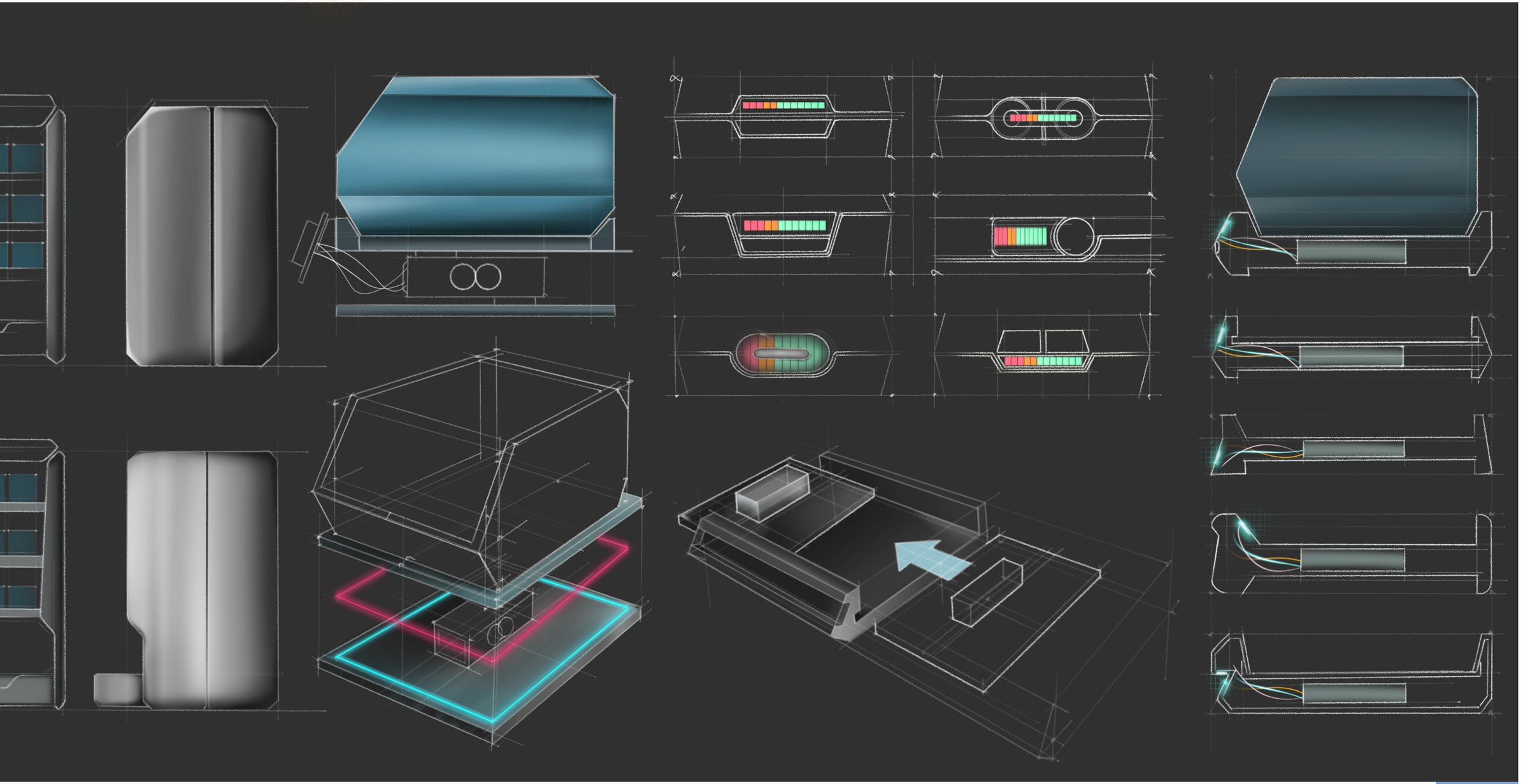
5.3.3 Modularity

Modularity approach has also been taken while developing Ford Cognizant. Considering some of listed requirements (PA2 / PA3), it was essential for the system to be easily dismountable because of malfunction and maintenance purposes. Therefore, instead of offering a built-in shelves with fixed electronics, modules are activated which can be put inside of shelves by craftsmen according to their configuration preference. This approach do not just contribute to fulfill the requirements but also makes the system flexible for different sized inventory bins which enhances the personalisation.

5.3.4 User Interactions

Control panels on shelves helps craftsmen to define certain parameters regarding the inventory bin placed on top of it. While ideating on control panels, clarity and visibility was taken into serious consideration. Those iterations went simultaneously with the user tests done with high-fidelity prototypes. It was important keep the simplicity of operations thus, the intention was to keep the amount of components constituting the control panel as less as possible.





SECTION VI:
CONCEPT DESIGN

This section focuses on the outcome in detail and the development steps which are taken. The outcome includes the product, the service and UI design that comprises the comprehensive system proposed as the solution. User tests and evalutions are also included in this section as motivations of each made decision during the concept development.

6.1 Concept Overview

Ford Cognizant is a **smart storage system dedicated for consumables** in craftsmen's light commercial vehicles. A combination of a product and a service design, it provides **automated inventory control** via accessible technologies, wisely integrated to the hardware. Breaking the walls of stereotypical storage-focused racking solutions, Ford Cognizant **increases the inventory awareness of craftsmen as well as the value and function of their vehicles by enhancing the smartness of the trunk.**

The basis of the concept lies on the vehicle, the Ford Transit Custom. Ford Cognizant has a flexibility of usage and it is up to craftsmen where to place it in the trunk; whether to **the side door or the back door.**

According to the user research, craftsmen prefer to use the side door to **access frequently used materials.** However, one of the possible future developments for Ford Cognizant is the product implementation to the project 'Smart Rack', which is a storage system focusing on accessibility difficulties by enabling to extend the whole rack. Therefore, back door usage of Ford Cognizant is enhanced with 'Smart Rack' implementation which is stated on Part 7.2.

The unit of Ford Cognizant consists of different components like structural elements or electronics that enable service to operate smoothly. Shelves that inventory bins are placed on, contain load cells in order to simply weigh the consumables put in. The physical parameter get converted into an electric signal, then analysed and communicated with the user via control panels located in front of each inventory bin on shelves.

Ford Cognizant adapts itself to its users' preferences and communicates according to that via giving suggestive informations to improve the inventory awareness and management. The dynamic system aims to stimulate craftsmen to take certain actions before facing with unforeseen events by noticeable LED indications. These indications change according to the state of bins and type of consumables put inside. Craftsmen and craftsman businesses can also check the state of the consumables via connected smart devices such as the SYNC display in the cabin of the vehicle, smartphones, tablets and computers. Therefore, not just near the vehicle but also within a distance craftsmen will be aware of the inventory condition in order to be able to act way beforehand the work.


COGNIZANT
Automated Inventory Control


COGNIZANT
Automated Inventory Control

Automated consumabes control | 1

Single point load cells placed underneath each inventory bin, continuously weighs consumables that are placed in to update the inventory condition.

Communicative LED indications | 2

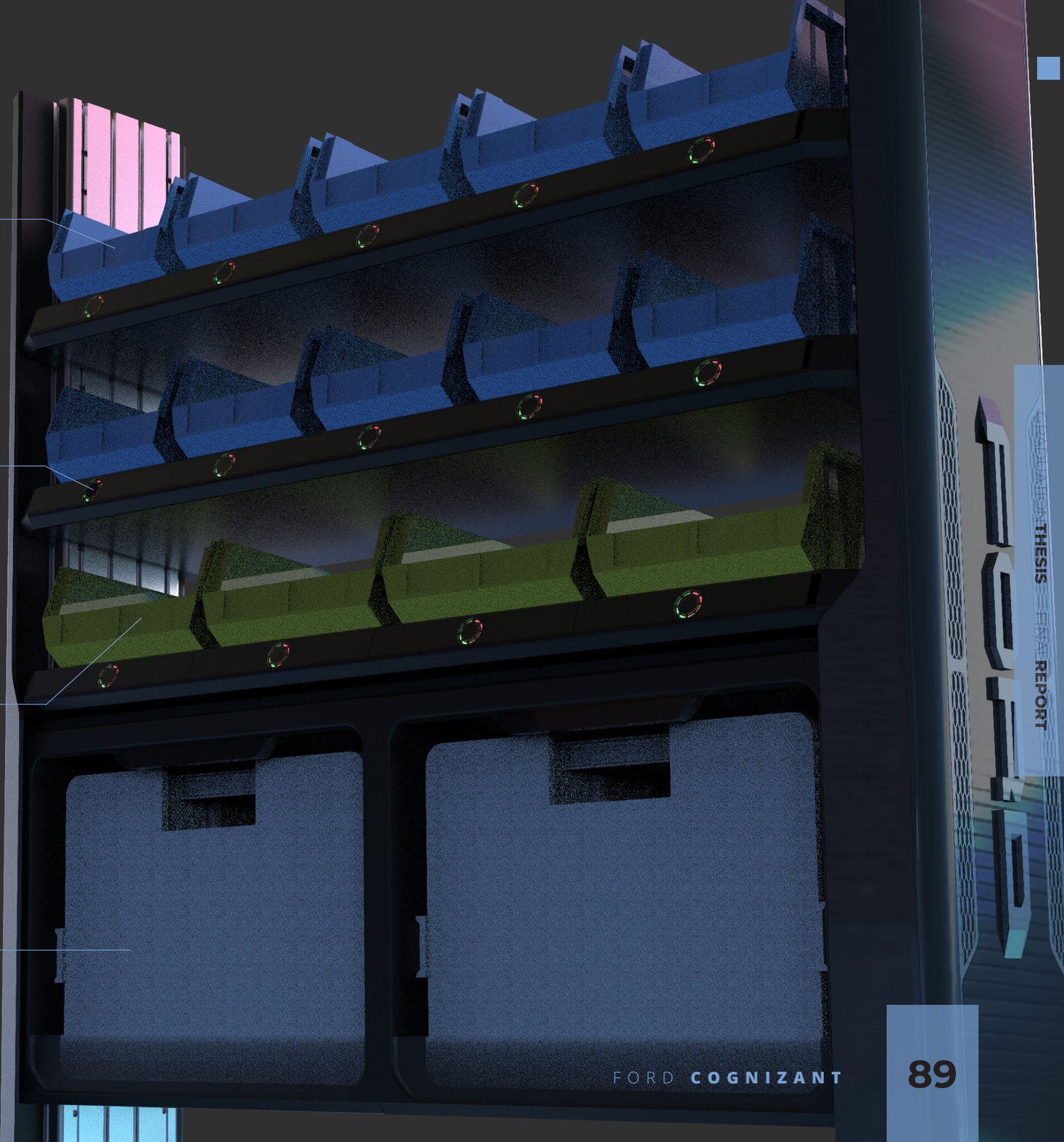
Momentarily reminders are given with gradual led lights regarding the condition of inventory bins.

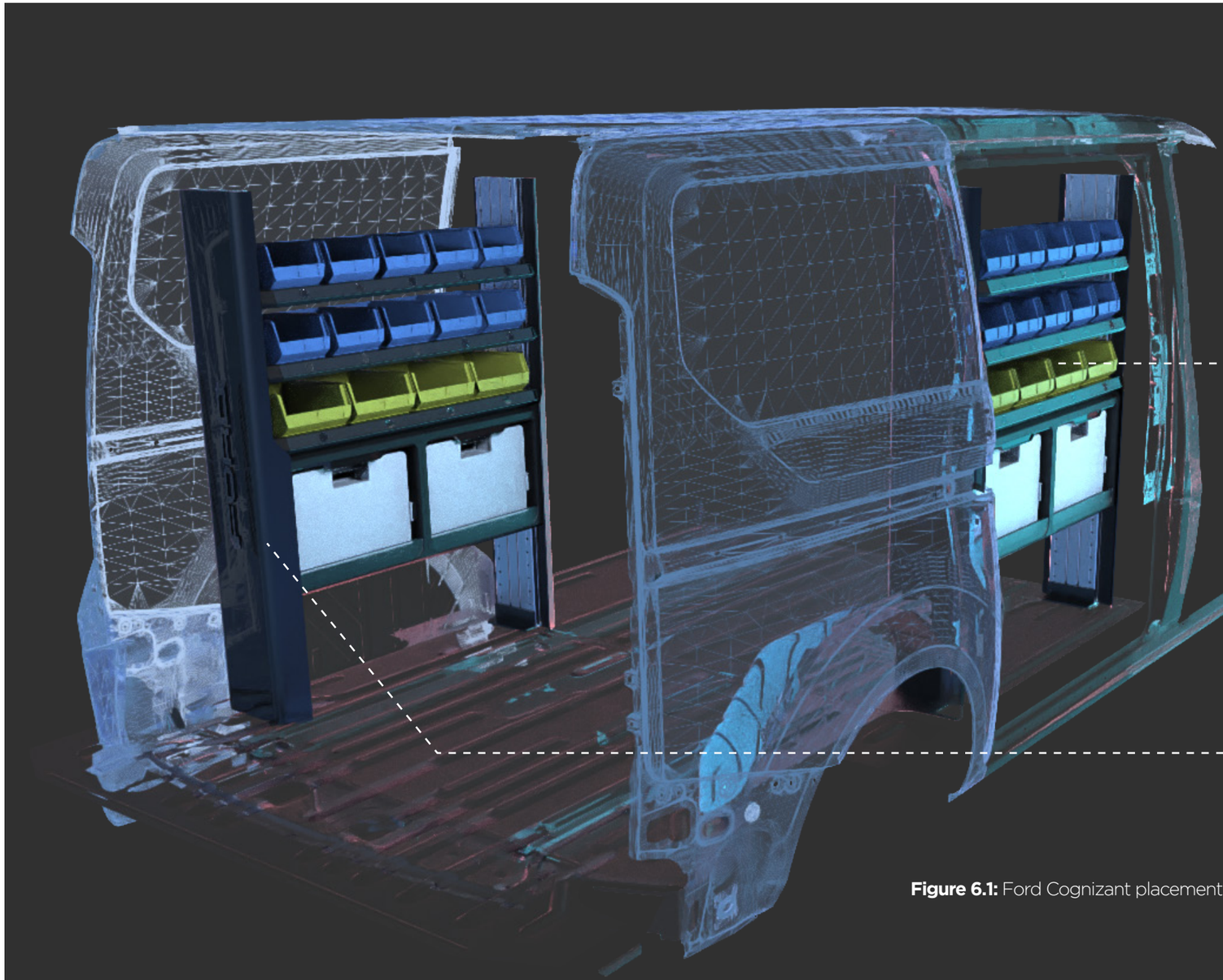
Adaptability for various inventory bins | 3

Modularity approach enables the system to utilise different sized industrial standardized inventory bins.

Storage for organisers | 4

Dedicated slots for organisers that contains consumables ready to go to the jobsite.





1 Side door access

For craftsmen who prefer to gather frequently used materials from side door without getting into the trunk. Access **without showing a physical effort.** LED lights are facing to the operator once the door is opened, thus, the **visibility is enhance**d with this preference. The dimensions of the Unit enables perfect fit to the side door.

2 Back door access

Back door access is an option for craftsmen who prefer to use side door to get into the trunk. The gap at the bottom helps the Unit to **avoid the wheel arch**, thus, the efficient use of space is maximised. Visibility of LED lights are relatively less compared to side door access due to the Unit's perpendicularity to the back door.

Figure 6.1: Ford Cognizant placement options

6.2 Product Architecture

The Unit

The physical backbone of Ford Cognizant is the Unit. It contains the other parts of the system such as **shelves, modules or slots for organisers** but also, **structural components and electronics** (Figure 6.2). Therefore, the Unit can be considered as the complementary piece that makes the system work once every other part has been mounted together. The dimensions of the Unit is 994 x 285 x 1300 mm. These dimensions make the Unit perfectly fit to the side door of the trunk where Ford Cognizant envisioned to be placed.

The side door measurement of Ford Transit Custom 2021 are 1324 (H) x 1030 (W) mm. To make the Unit and its components ergonomically relevant, average Dutch male adult (31 - 60 age) with the stature of 1770mm has been used (DINED, n.d.). Besides that, the loading height of the vehicle has also taken into consideration. Even though, aluminum panels on each side provides flexible configuration, it was still important to set the boundaries of maximum and minimum heights of shelves to maximise reachability (Figure 6.6).

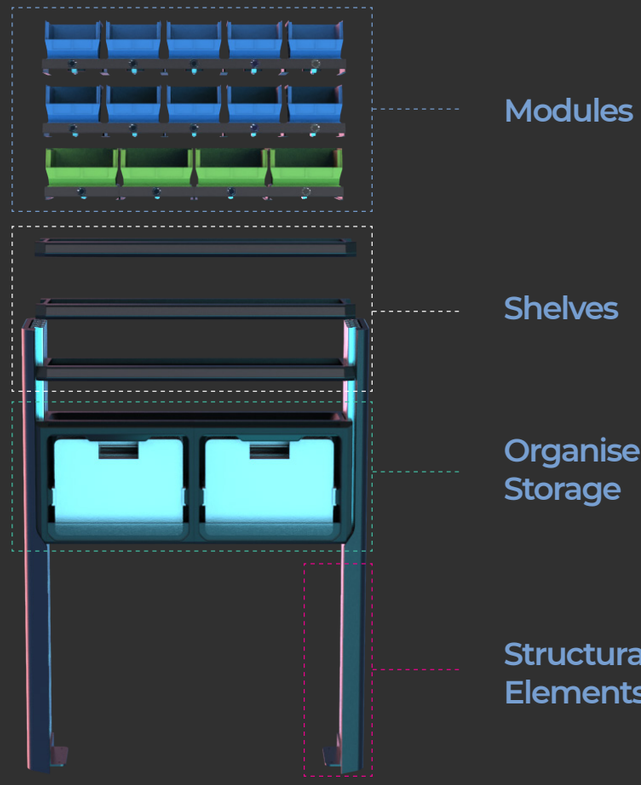


Figure 6.2: Constituent parts of the Unit

Walls located on both ends of the Unit are made from bent aluminum sheets (8mm thickness) that provide housing for aluminum profiles used to fixate shelves (Figure 6.3). The 160x40 mm sized Profile 8 has been chosen as aluminum panels due to its resistance and being able to carry multiple aluminum shelves. The datasheet for the chosen aluminum panel can be seen on Appendix I. The slots on the aluminum profile enable height adjustment for shelves depending on ergonomic relevancy and configuration. This flexibility also enables craftsmen to mount different amounts of shelves, eventually inventory bins depending on the preference and consumption rate.

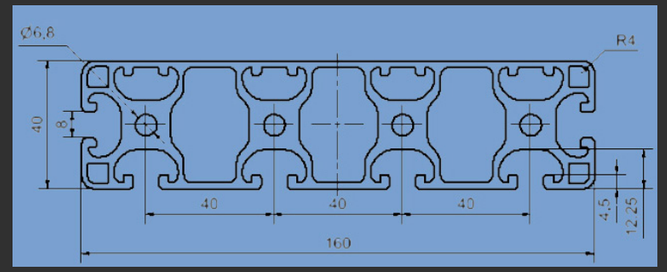


Figure 6.3: Aluminum panel top view

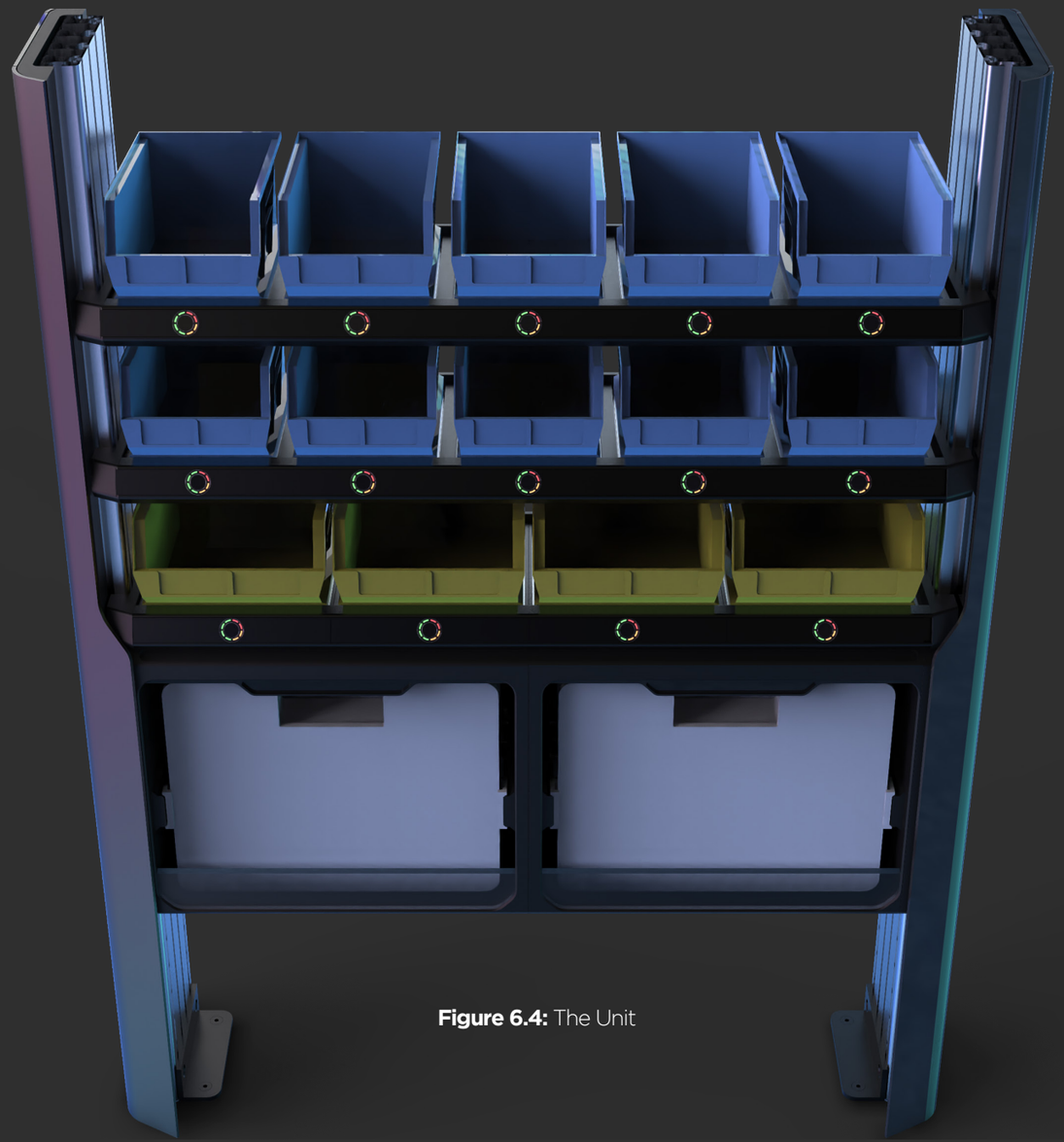


Figure 6.4: The Unit

Monochromic approach was taken on the Unit to maximise the stand out of LED indications (Figure 6.5). That is because the communicational value of the service is fundamental. Black and grey tones were applied to the product to **enhance the visibility and contrast of LED lights but also to give the impression of robustness and strongness.** This approach has been decided after making a moodboard mentioned on Part 5.3.1 and placing inspirational products from the market on it in order to define a visual direction.

Figure 6.5: Colour palette of Ford Cognizant

The lower part of the Unit has a dedicated storage slots for organisers that craftsmen carry their consumables to the jobsite. The storage can hold up to 6 organisers (44.6 x 11.6 x 35.7) is made from polypropylene (PP), which is light and study plastic material, ideal for this application and also very easy to recycle. On the other hand it is a very preferred material in the automotive industry. Used with a variety of vehicle applications such as door panels, console, seatbacks, trunk liners, and much more.

Complete measurements of Ford Transit Custom 2021 can be seen on Appendix J.

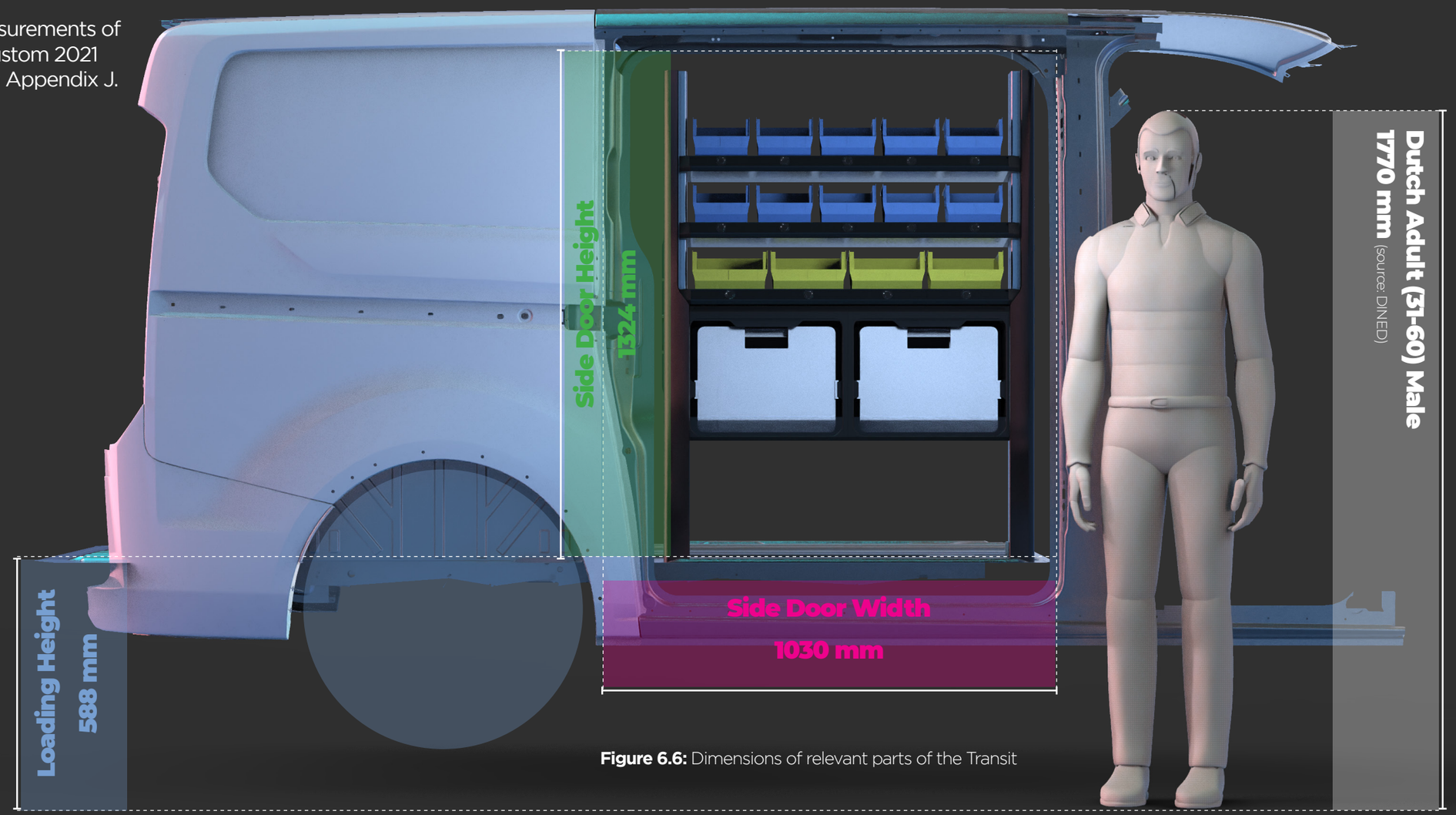


Figure 6.6: Dimensions of relevant parts of the Transit

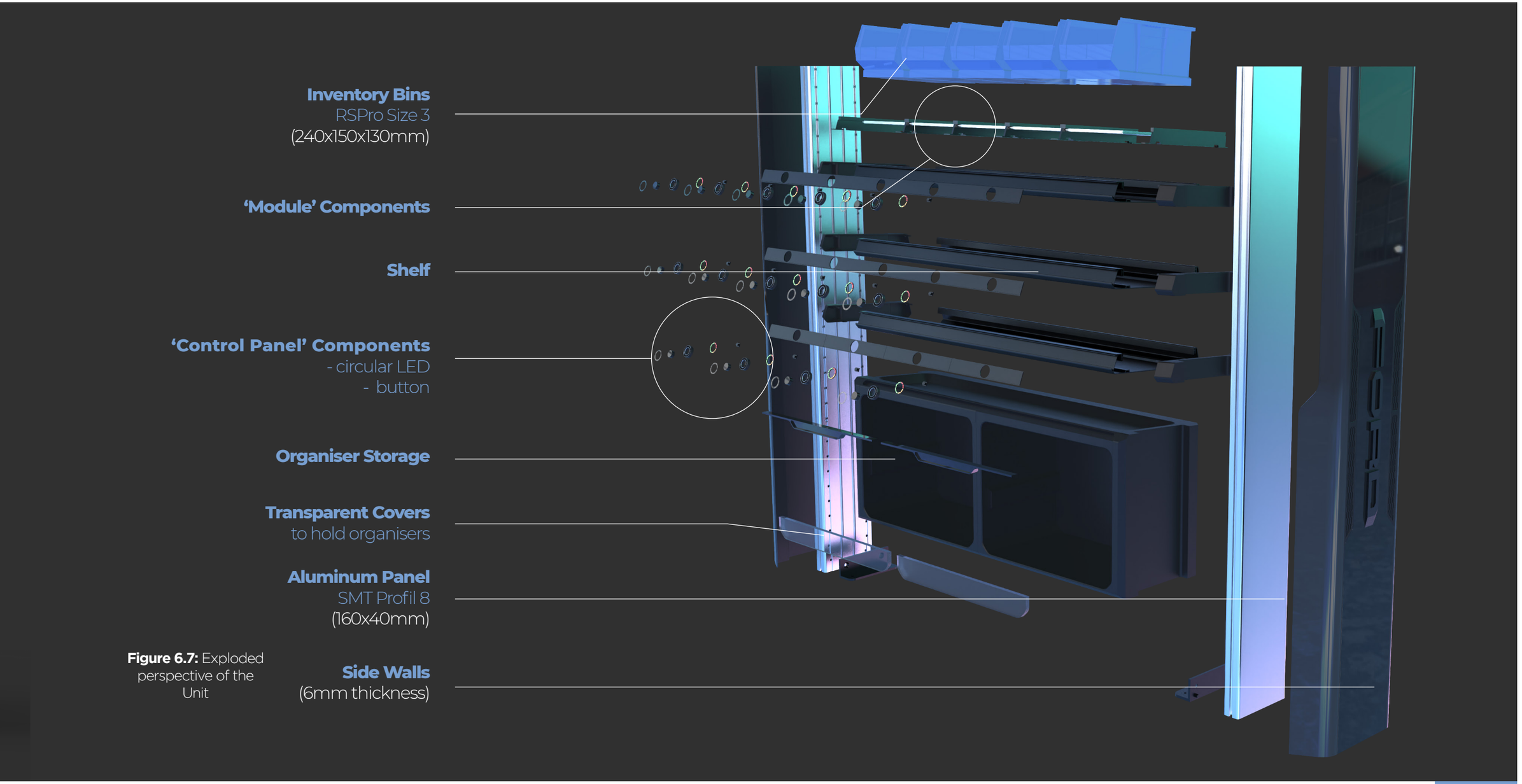


Figure 6.7: Exploded perspective of the Unit

Shelves

Shelves provide housing for most of the components of Ford Cognizant including modules, control panel and separators (Figure 6.10). Manufactured with aluminum extrusion technique, shelves are able to be built with different lengths if necessary depending on the product implementation. On the other hand, length of the shelf was defined in a way that will be relevant to place wider inventory bins for larger consumables. The size of the shelf for the shown version of Ford Cognizant is 900 x 280 x 42 mm. When viewed from the side, the front part of the shelf is for fixating control panels. Bulges located at the bottom long edge of shelves are for sliding the modules to provide perfect alignment with two control points. The side lids of the shelves are dismountable when craftsmen need to take modules out in case of a malfunction or maintenance. Four slots to attach side lids can be seen with the side view of the shelf on Figure 6.9. Side lids also function as a fixator between the shelf body and aluminum panel. Detachable side lids came out from the modularity approach that is taken during the ideation phase.

The sizes of the load cell, components of the control panel which are the button and the LED bar and tolerances were taken into consideration while building the shelf. It was important to provide enough space for every component, however, it was also crucial to avoid designing a bulky shelf in order to reduce the weight of the Unit.

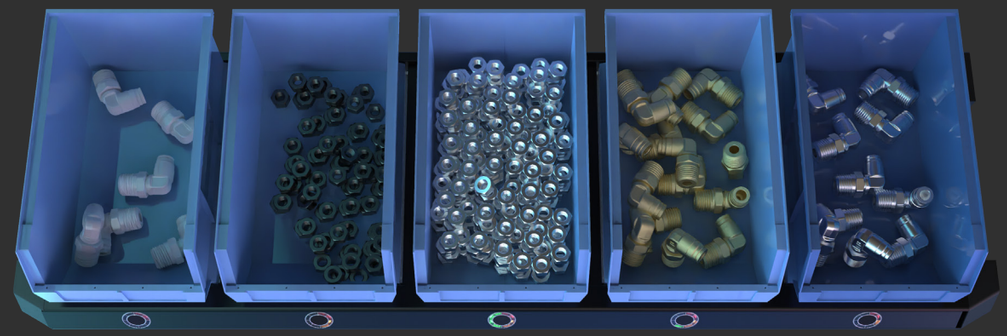
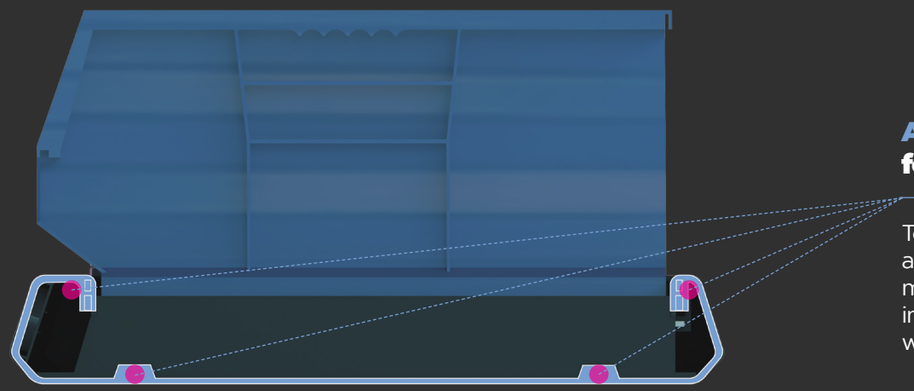


Figure 6.8: Shelf plan



Alignment points for sliding modules

Total four points (2 at bottom and 2 at the top) for aligning modules while sliding them into shelf. 2 mm tolerances were taken into account.

Figure 6.9: Section view of the shelf

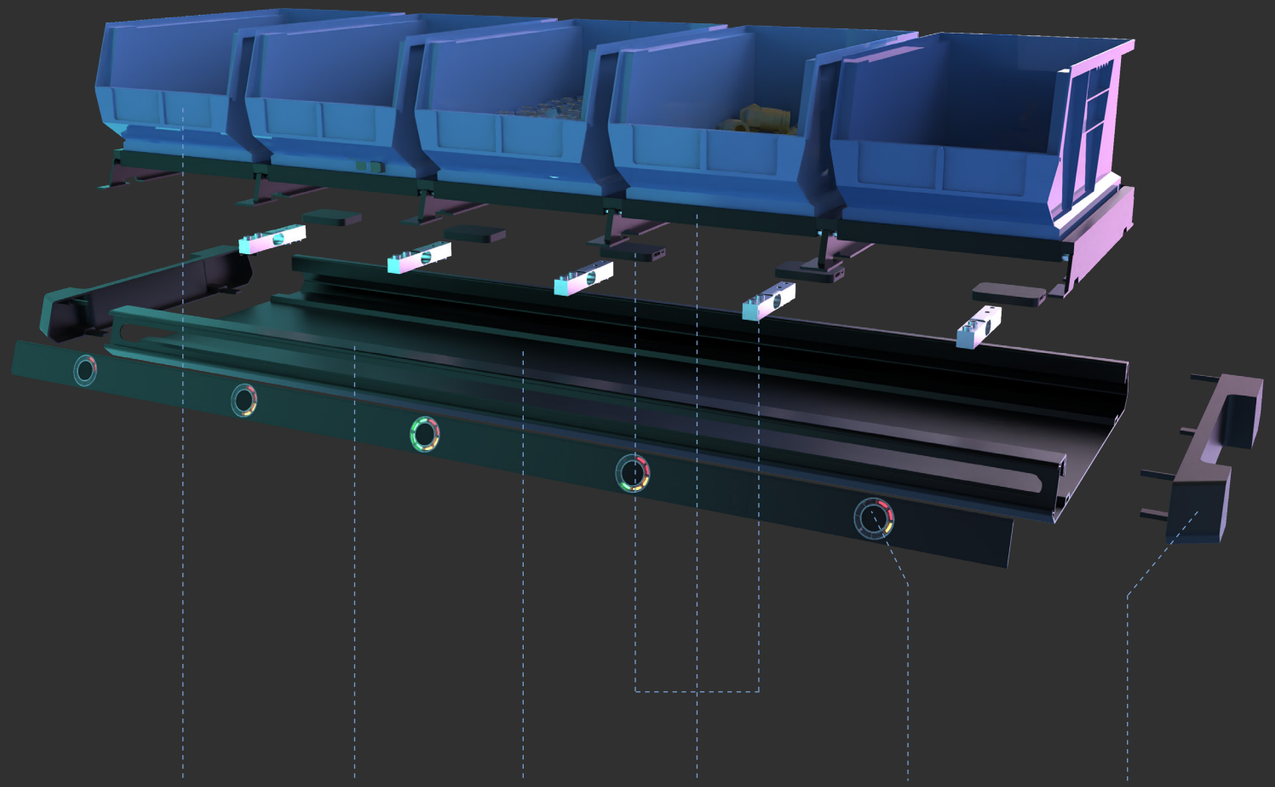


Figure 6.10: Exploded view of a shelf

Setup I - Small modules configuration
screws, nails, nuts, fasteners etc.

Setup II - Medium modules configuration
various sized elbows, sockets, switches etc.

Modules

Modules are one of the most essential components of Ford Cognizant. This is because of the parts they include which makes the entire system function as a whole. With the help of modules, Ford Cognizant can provide its main services which are **automatic inventory control with weighing** and translating that physical parameter into an output to **communicate with regarding the state of the consumables placed in bins**. Based on the field research, craftsmen often prefer Size 3 and sometimes Size 4 industry standardized inventory bins depending on the size of the consumable (Appendix B). Therefore, modules are also coming with two sizes, tailored for Size 3 and Size 4 inventory bins in order to enhance the flexibility of the system. The dimensions of modules are 150 x 240 x 144 mm and 205 x 240 x 144 mm (Figure 6.11).

Modules consist of **aluminum composite plate** where the inventory bin sits on, **load cell and RFID reader** fixed below, **side walls** mounted to the aluminum plate to slide the module into the shelf, **rubber parts** and **control panel pre-wired to the load cell** (Figure 6.14). Therefore, modules act as one piece which fulfills one of the requirements; **PA2.** Once the modules are slid into shelves, the only thing that needs to be done is to fixate load cells from the bottom of shelves via the openings for screws (Figure 6.12).

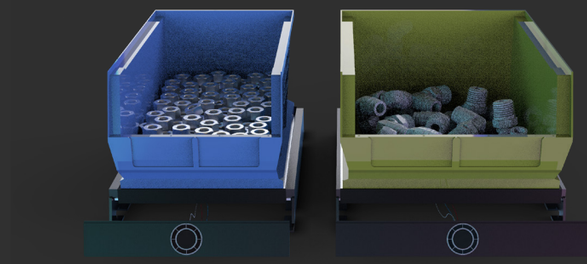


Figure 6.11: Two variations on modules

The aluminum plate has a 6mm thickness and is insulated with rubber on the front and back in order to **provide flexibility for tilting to the plate.** The insulation **helps to avoid dirt and dust to get through inside of the shelf and cause malfunction for electronics (SD1).** Enabling flexibility of tilting was essential due to the requirements of load cells. In order to provide a precise calculation, the plate has to tilt with a little angle caused by the weight of consumables in the inventory bin (Figure 6.13). This weight results with a manipulation on the strain gauge located in the load cell which is the main reason for the tilt of the aluminum plate. The load cells coming with the module are industry standardized, pre-calibrated single point load cells which are accessible and able to show high precision for small weighted items (Appendix L). Because of the pre-calibration, craftsmen can neglect the weight of inventory bins.

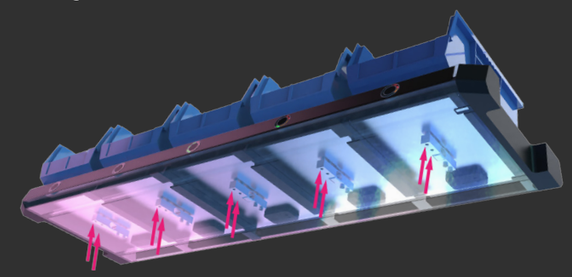


Figure 6.12: Bottom fixation for load cells

Figure 6.13: Module tilting

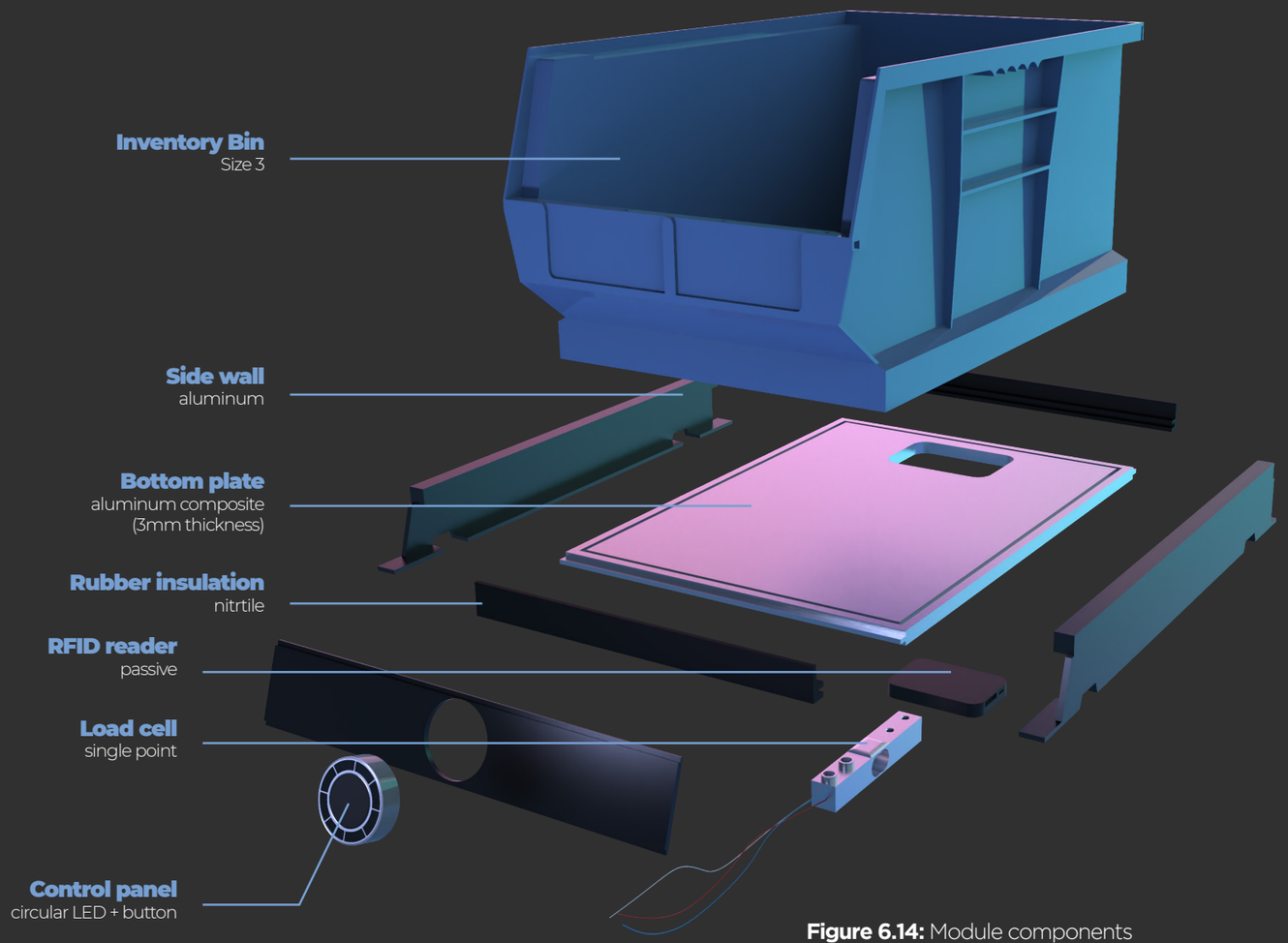


Figure 6.14: Module components

Out of different types of rubbers, Nitrile has been chosen (Figure 6.15). It is the most preferred elastomer in the seal industry and provides perfect compression set, tear, and abrasion resistance (Datwyler, 2018).

Figure 6.15: Nitrile

Passive RFID has been chosen to be implemented on modules because of the intended use-case that is recognising inventory bins in case they are placed on a different slot. Detection will be done within the trunk in a short range. Passive RFID systems use tags with no internal power source and instead are powered by the electromagnetic energy transmitted from an RFID reader. The lower price point per tag makes employing passive RFID systems economical for many industries (Smiley, 2019). RFID solutions in metallic environments are a tricky challenge, as severe interference with the electromagnetic fields may occur (Samson, 2017). Therefore, a cut out was applied on the aluminum plate to enable RFID signals can go through the plate (Figure 6.14).

Control Panel

Even though control panels are part of modules that are mentioned above, it is still better to explain them individually because of their equal importance for the system. Consisting of two main components which are **a custom made circular LED and a button** (Figure 6.16). Control panels enable the user to take benefit from certain features such as; **defining the weight per piece, defining the threshold level and defining the maximum level in the inventory bin.** These features will be addressed with detail, later in this graduation thesis report on Part 6.3. Circular LEDs used on control panels are the elements that communicate with the user about the condition of inventory bins.

Depending on the condition control panels can notify the user whether **the bin is empty, has a critical or a sufficient amount of consumables** indicated with different colors and patterns of lights (Part 6.3.2).

Components are wired to the load cell already, thus, no wiring is required. Transparent covers were applied in front of circular LEDs to avoid any reflection which can be caused by natural or artificial light sources. With this way, it is even possible to see the light indications from a distance.

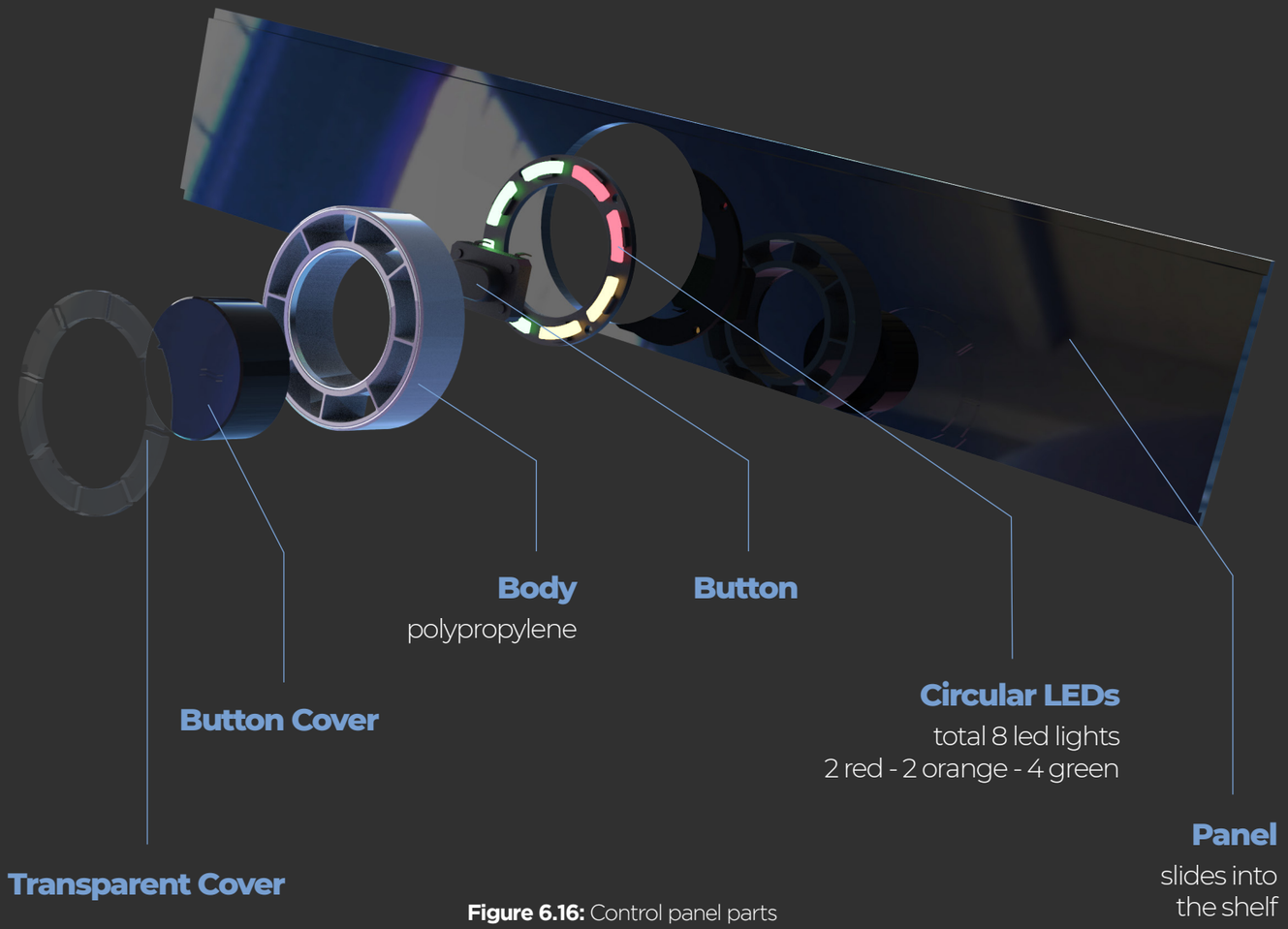
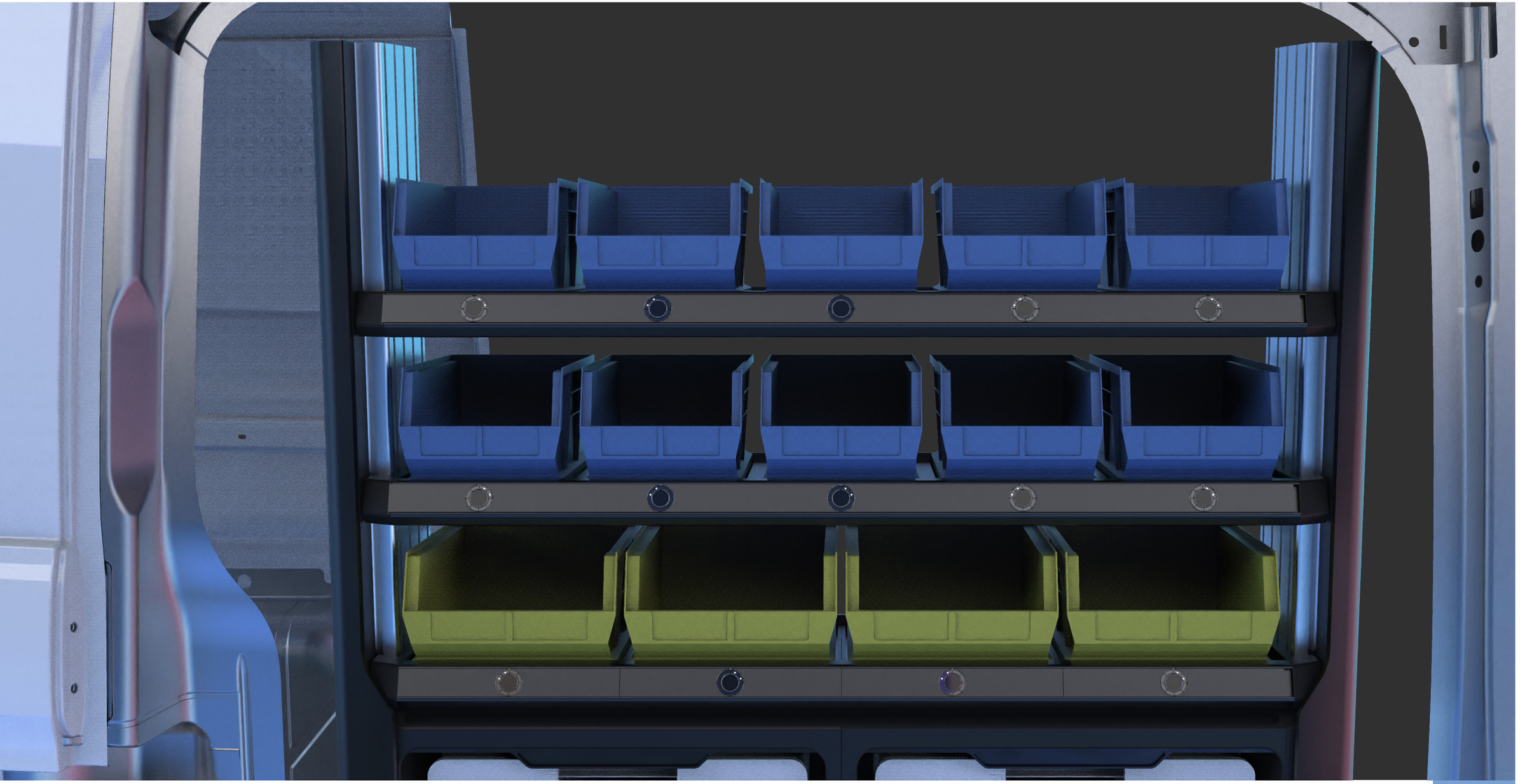


Figure 6.16: Control panel parts



6.3 User Experience

Ford Cognizant enables connectivity between the inventory, vehicle, craftsmen and the organisation (Figure 6.17). This became possible with the integration of technologies that are already proven in various industries. Load cells and RFIDs are two main technologies used for the concept that enables this connectivity by offering various features. The data regarding consumables generated on the Unit, then visualised with the Ford Cognizant application which can be continuously monitored via SYNC display in the cabin, personal smartphones of craftsmen and computer at the headquarters of craftsmen companies.

The main features that Ford Cognizant offers are;

(1) Automated weighing

(2) Individual threshold definition

(3) Maximum level definition

(4) Weight per piece

(5) Recognising inventory bins

(6) Consumption optimisation

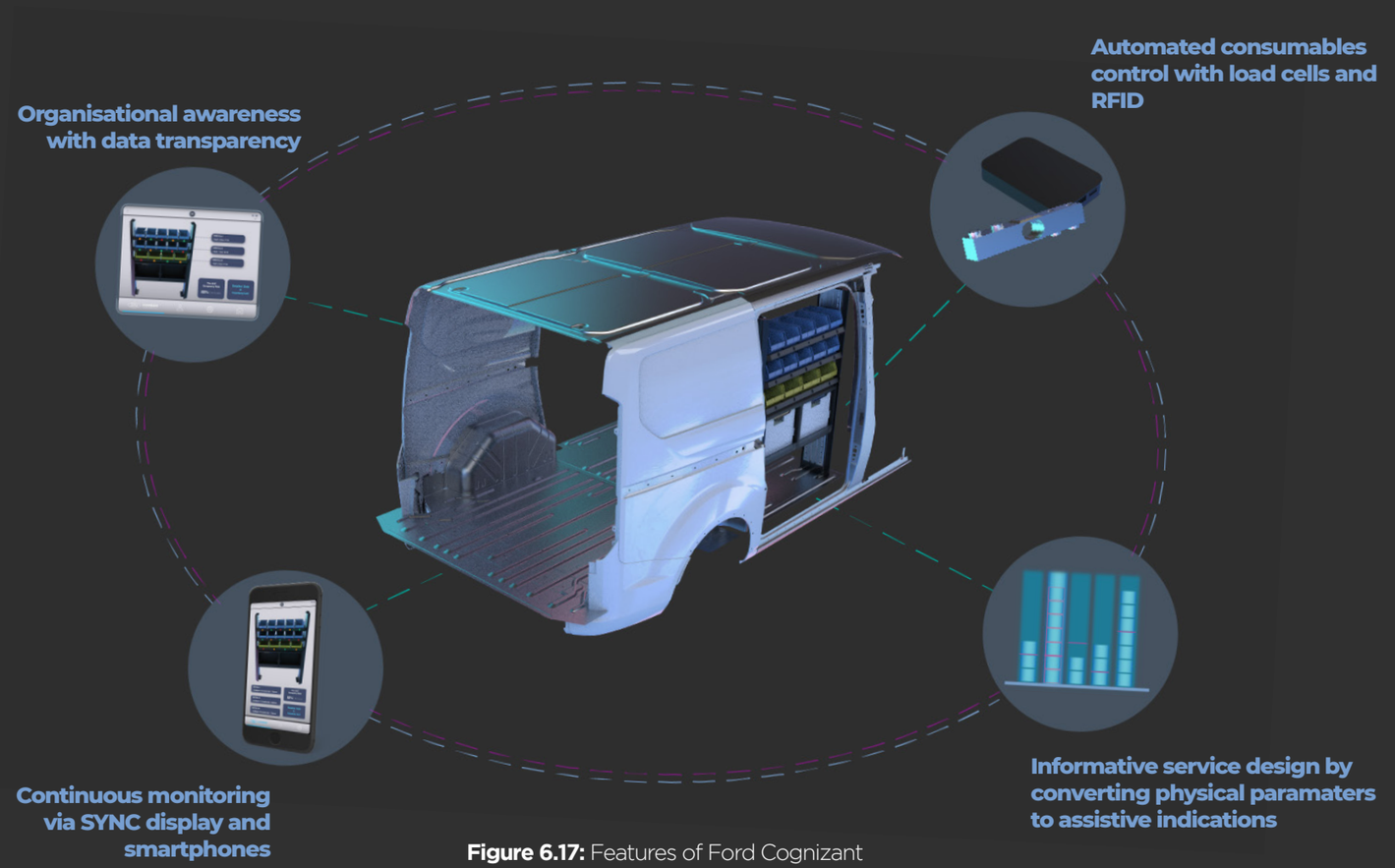


Figure 6.17: Features of Ford Cognizant

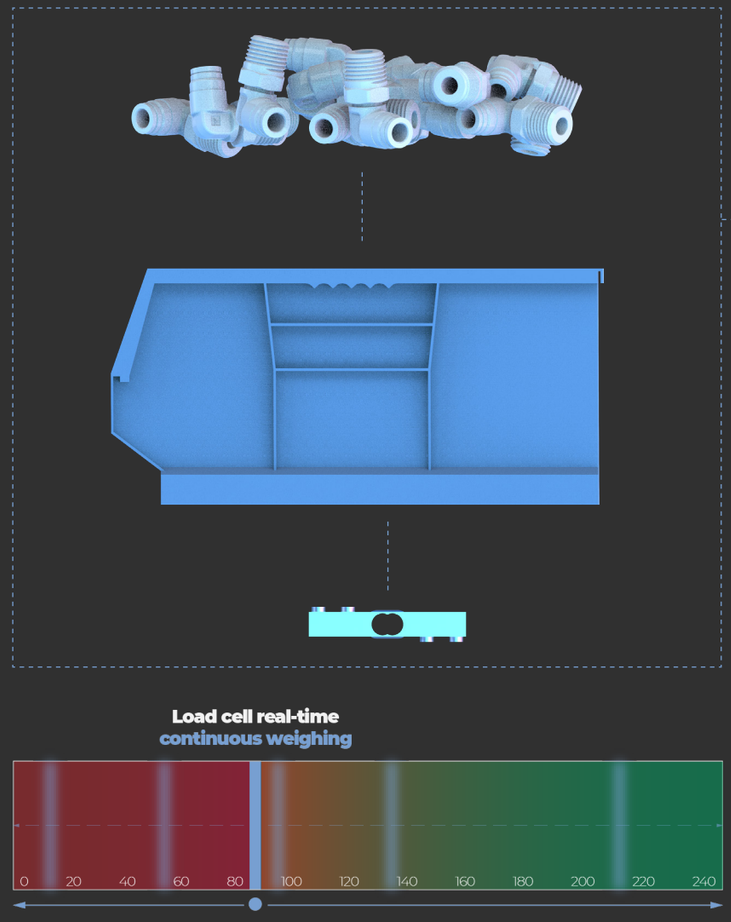


Figure 6.18: Automated weighing working mechanism

6.3.1 System features

Automated weighing

Consumables that are put in inventory bins are weighed continuously via load cells mounted underneath. It was learned during market and technology research that, load cells are relevant solutions for weighing light materials precisely. The physical parameter measured by load cells, gets converted to a digital output by an amplifier which then can be communicated with the user via certain indications (Figure 6.18).

For Ford Cognizant, single point aluminum load cells are preferred since they offer high accuracy and reliability with being affordable and often used in various industries with small to medium-sized scale applications. Single point load cells are unique in that they can accept an off-centre load, this means that they will accurately measure weight if it is placed anywhere on the scale, therefore, allowing them to be highly precise in industrial applications (Variohm, 2018).

Threshold level definition: Since the variety and amount of consumables are very high in craftsmen vehicles especially for specialisations like, constructors, plumbers and electricians, it is essential to get consumable specific information. Therefore, Ford Cognizant offers to its users to define individual threshold levels for each inventory bin according to which consumables are placed in. This feature is included because different consumables can have different weight, frequency of use and size. For instance a fastener can weigh around 1.8 grams, but on the other hand, a 90° brass elbow can weight up to 80 grams (Figure 6.19). It is irrelevant to assign same threshold levels for both of them, since fasteners can be used more often by a constructor or vice versa for a plumber. To explain it more clearly, Figure 6.20 shows envisioned visualisation of threshold levels for different consumables placed on Ford Cognizant.

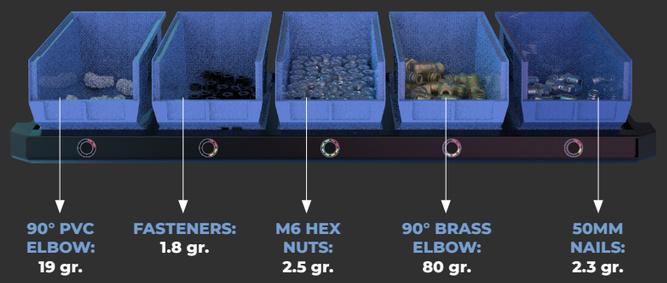


Figure 6.19: Weights of different types of consumables

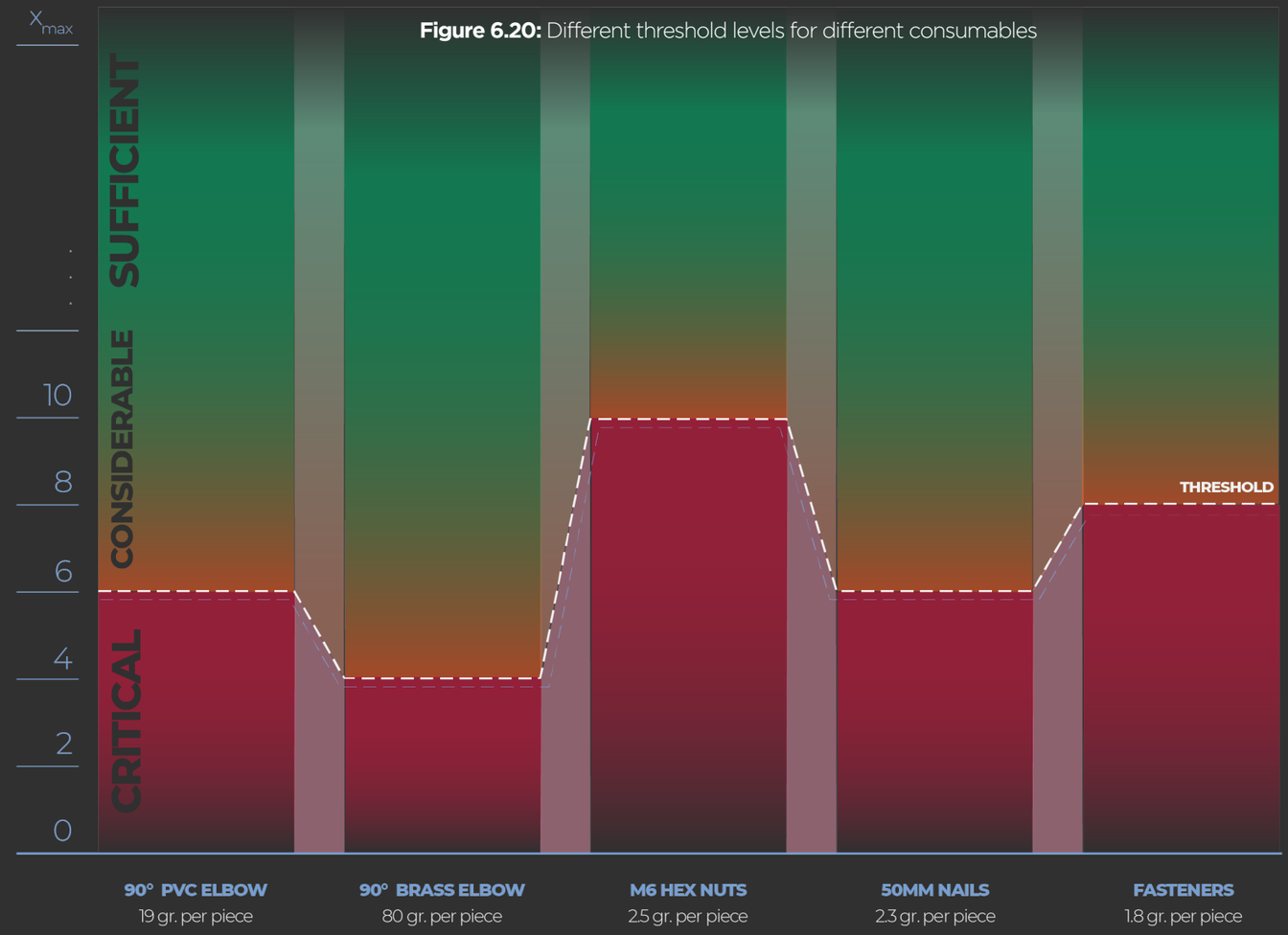


Figure 6.20: Different threshold levels for different consumables

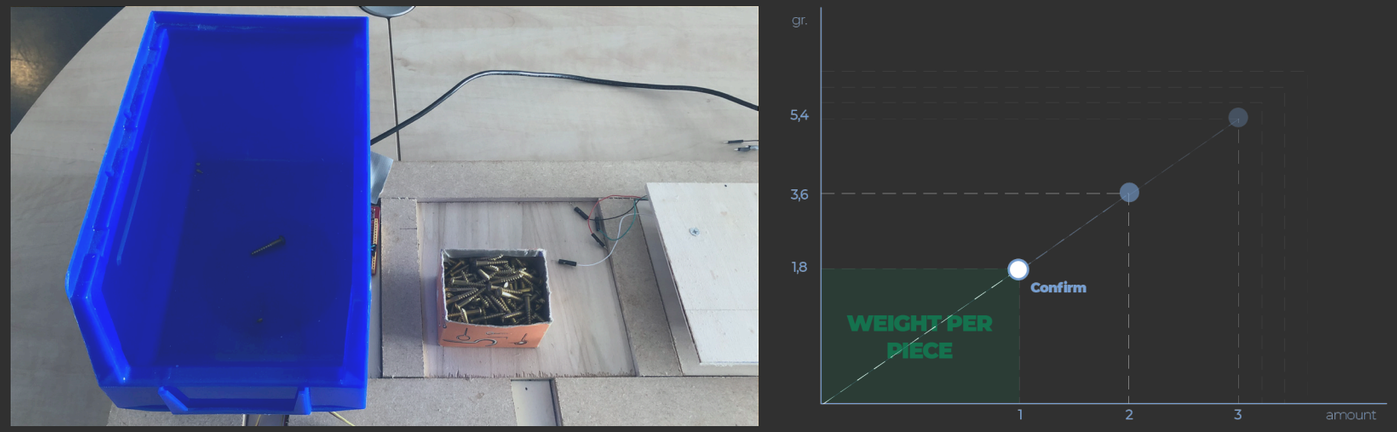


Figure 6.21: Weight per piece definition

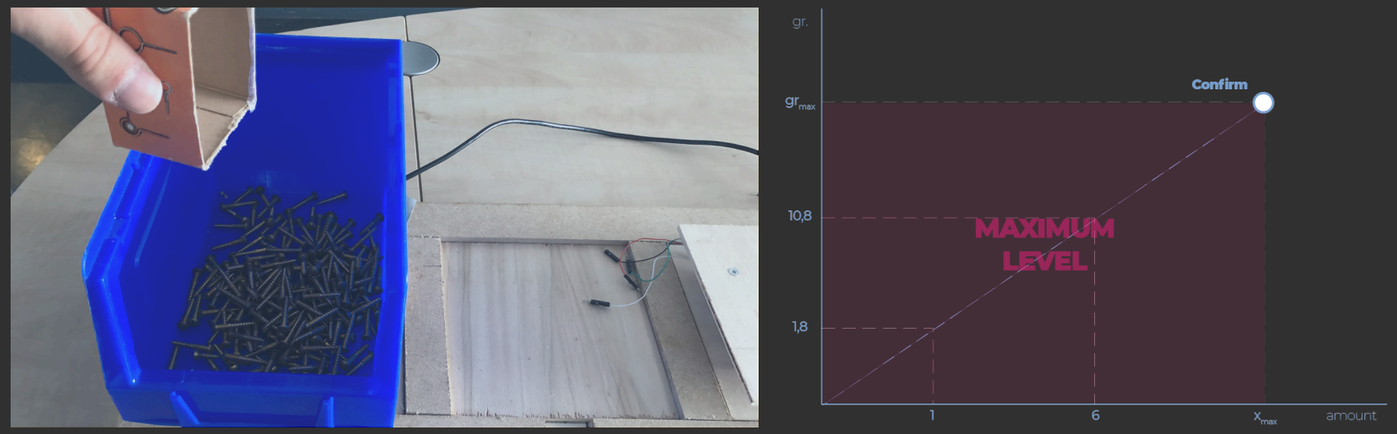


Figure 6.22: Maximum level definition

Weight per piece

Methods for controlling the consumables changes according to the size, amount and the frequency of use. For instance, screws and nuts are checked based on their level in bins (eye-balling). But for the larger sized consumables such as elbows, the amount is counted. The concept offers 'weight-per-piece' optionally for craftsmen. This is done by weighing one (1) consumable in the bin. After defining the maximum level which is the initial total weight in the inventory bin, the system automatically divides the total weight to weight of one piece in order to calculate the amount (Figure 6.21).

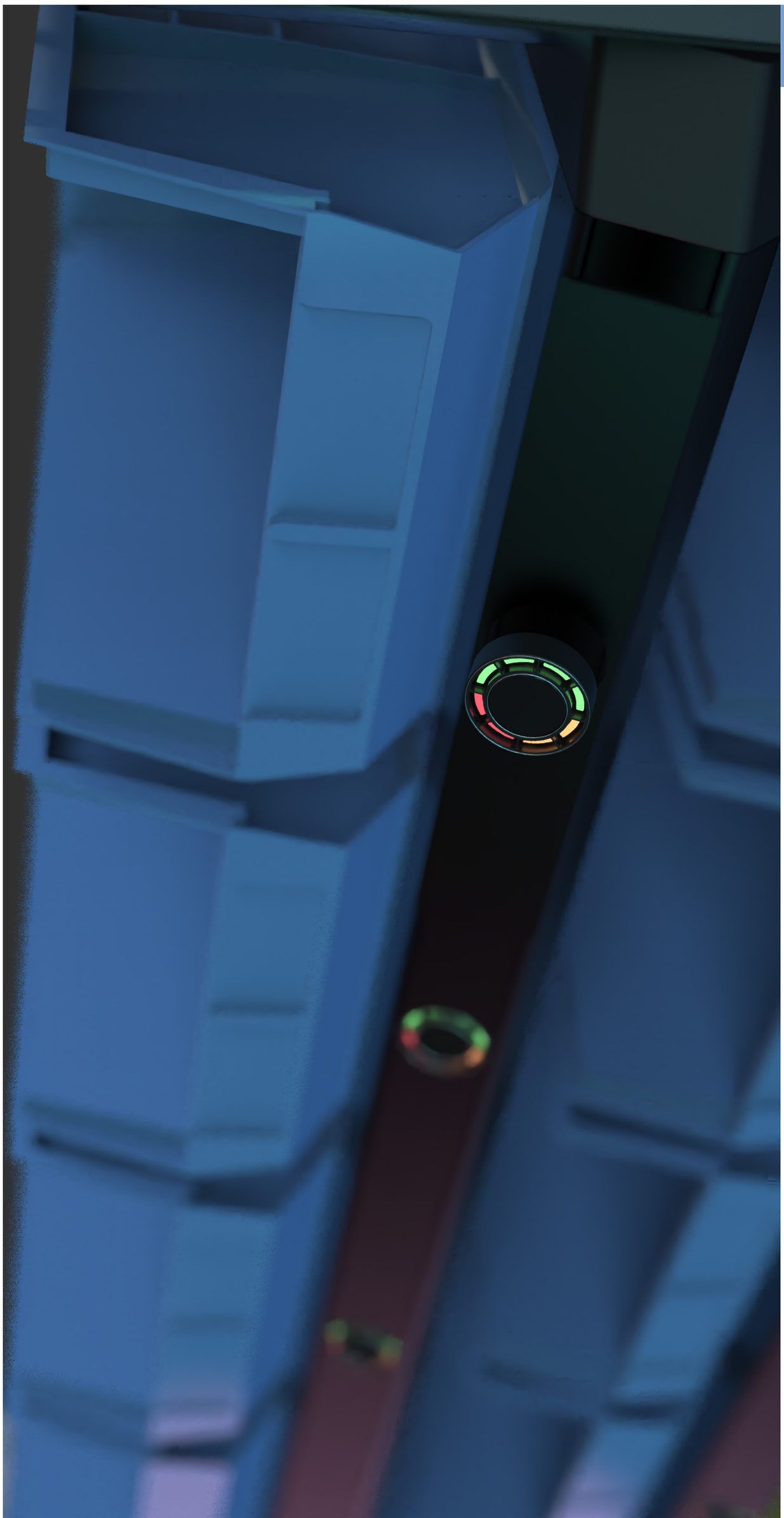
Maximum level definition

Circular LEDs on control panels have 8 slots (2 red-2 orange-4 green). Therefore, it is important to define the maximum level in an inventory bin after confirming the threshold level in order to set the boundaries. Maximum level corresponds to the situation when all LEDs are turned on, on the control panel. The system automatically calculates the difference between the maximum and the threshold level and divides to the amount of slots in order to assign certain numbers (grams) for each slot in between those two variables (Figure 6.22).

Consumption optimisation

It was concluded with the research that, digital solutions can influence and amplify the craftsman business by improving the internal organisation. One of the examples for that is the consumption optimisation that can ultimately enable accurate ordering from suppliers. This can be considered as a substantial improvement since with current inventory management methods, it is often possible to have deficiency of orders that is caused by the lack of inventory awareness which eventually results with going to department store during a work day. Since the service offers continuous monitoring regarding the condition of inventory, it is possible for craftsmen companies to analyse the data gathered from each craftsmen employee vehicle equipped with Ford Cognizant. Therefore, not just the overall (all of the vehicles) consumption but also craftsman specific consumption can be determined (Figure 6.23).

Figure 6.23: Consumption optimisation for craftsman companies



6.3.2 Interactions and responses

Communication on the Unit is made with LED lights on control panels that provide some indications and responses according to the state of inventory bins (Figure 6.24). For each operation made with using the button, there also indications by means of confirmation. Complete list of responses for each of them are shown on Table 6.25 with explanations. They were developed after user tests to improve clarity and relevancy in terms of understandability of indications and value of the given information. Since there is just one circular LED for each inventory bin that gives responses for each features, it was essential to make a good differentiation without causing any confusion while operating the system.

It is possible to redetermine threshold and maximum levels, for each inventory bin via the button. This change of variables can be because of several reasons such as, weekly schedule or job description. The frequency of use for certain consumables can change significantly. In fact, one of the interview participants who is the manager craftsman of small sized constructor company mentioned that, depending on the job, some weeks he consumes a box of screw, but in some occasions that number can go up to five boxes.

Figure 6.24: Control panel main indications

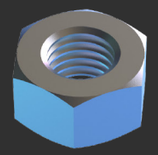
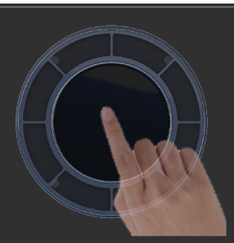
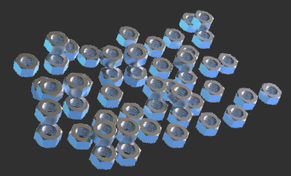
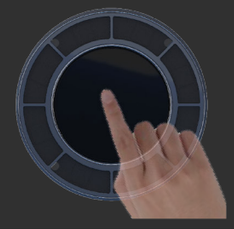
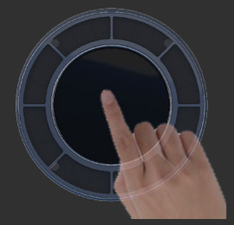
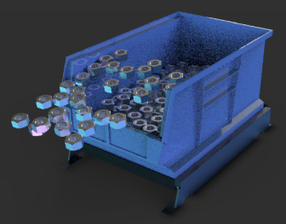
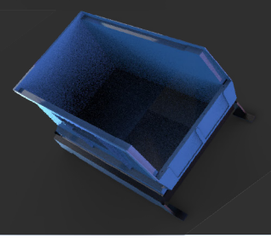
1 **Weight per piece**		One consumable can be weighed in the bin to ultimately communicate with the user regarding the **amount.**	INTERACTION & RESPONSE	**Press the button**		**Full round** **Confirmation**	
2 **Setting the threshold**		Depending on craftsmen's preference, a desired amount of consumables is placed in the bin for **defining the threshold level.**	INTERACTION & RESPONSE	**Hold (2 secs) the button**		**Until 2 red LED** **Confirmation**	
3 **Defining maximum**		To set **the maximum limit** of the inventory bin, rest of consumables (can be a box or more) are placed inside.	INTERACTION & RESPONSE	**Hold (5 secs) the button**		**Full light** **Confirmation**	
4 **Consuming consumables**		Consumption from the inventory bin is communcated with **gradually turning off** LED lights.	RESPONSE	**Consume**			
5 **Empty bin state**		In order to emphasise the stimulation, when the bin is empty, **red LED light start to blink.**	RESPONSE	**Stimuli**			

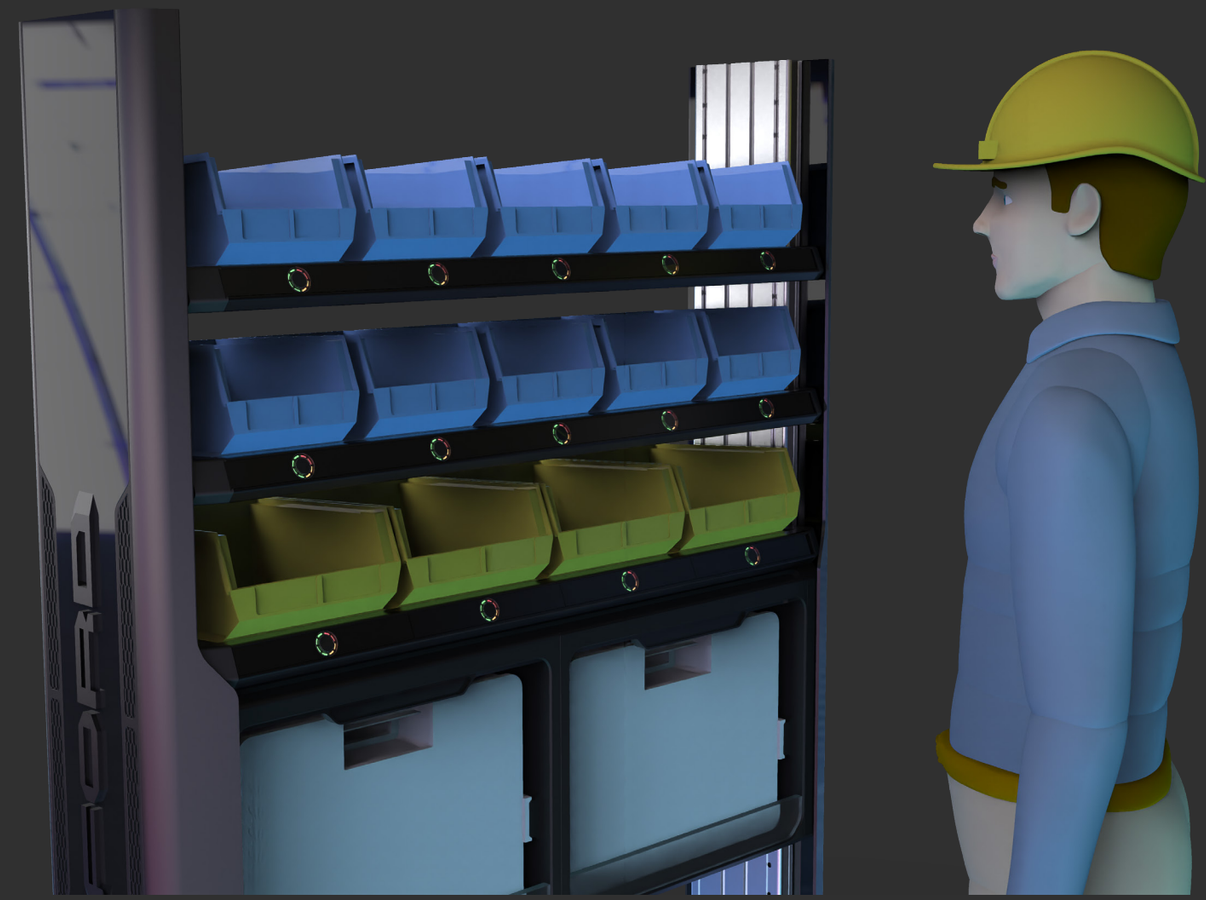
Table 6.25: Interactions and indications list

6.3.3 Use scenario

According to one of the requirements (PF1), Ford Cognizant focuses on improving the inventory awareness simultaneously decreasing the physically effortful interactions. As it mentioned on the Part 4.1, when craftsmen need to control the state of their consumables, they have to check each bin or organiser manually. This operation is exhausting and time consuming considering the fact that it needs to be done multiple times during a work day.

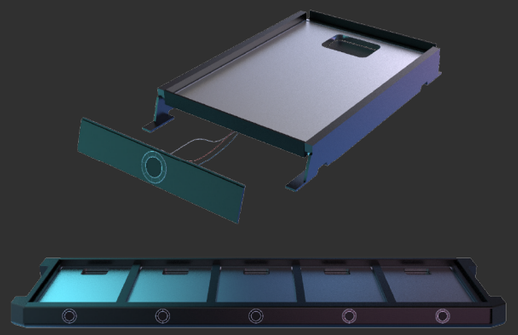
Therefore an envisioned scenario was created that reflects the improvement inventory control with more practical and smarter interactions (Figure 6.26). Table 6.27 shows step-by-step use scenario and operations of Ford Cognizant including the setup, initial configuration, level definitions and settings, consumption, replacement of bins and maintenance.

Figure 6.26: Visual references regarding the state of bins



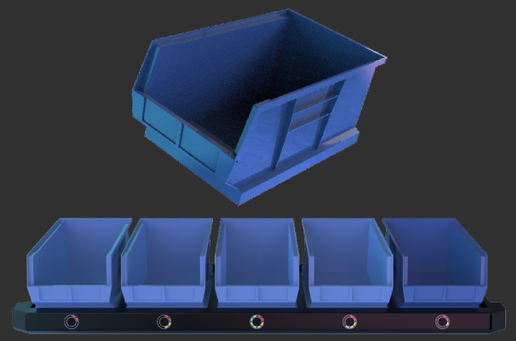
1 Mounting modules

Slide modules (small or medium sized) into shelves to provide the desired configuration on the Unit



2 Placing inventory bins

Place and fixate inventory bins on modules. Make sure to put the relevant sized inventory bin on a module.



3 Turning on the Unit

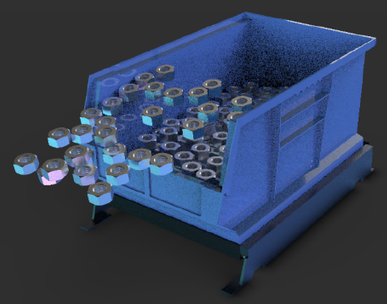
Turn on the Unit when the vehicle is in immobile state due to sensors that need to work precisely without vibrations.

4 Confirming settings

Set threshold and maximum levels with weight per piece to make system ready to operate.

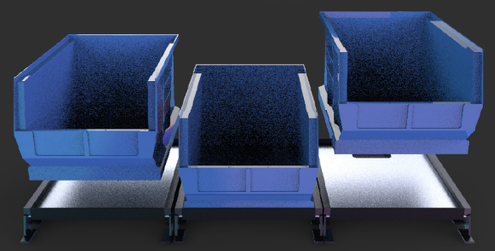
5 Consumption at work

Craftsmen can start consumption during work and receive indications according to states of bins.



6 Replacing bins

Bins do not have intended spots, and craftsmen can place them on different modules without losing the settings.



7 Re-setting levels

Levels for inventoy bins can be reset anytime. Threshold levels can be manipulated via Ford Cognizant application.

8 Modules maintenance

Modules with malfunction can taken out to get fixed by dismounting the side panel of the shelf.

Table 6.27: Use scenario and operations list

6.4 UI Design

6.4.1 Introduction

In order to enhance the awareness and accessibility, Ford Cognizant offers to craftsmen to check the inventory condition not just on the Unit but also from a distance. It is essential to get informed beforehand for better decision making. As it stated on Part 6.2 (Product Architecture), load cells mounted below inventory bins, weigh the consumables and translates the physical parameter to a digital output. This output needs to be communicated to the user to provide the desired service via control panels on shelves and screens, where data visualisation happens.

The fundamental reasons to integrate UI design into Ford Cognizant are, firstly **enable craftsmen to check inventory situation** beforehand, either when they are driving or when they are away from the vehicle. Secondly **enabling continuous monitoring from headquarters or warehouse of a craftsman company** (Figure 6.28). As it mentioned on Key Finding 4 on Part 4.2 it is important to think about craftsman business point of view and provide a room for empowering the business via smart services.

Therefore craftsman companies with multiple vehicles can be able to monitor each employee craftsmen's consumables consumption and eventually **provide optimisation in order to have more accurate orders from suppliers.**

Figure 6.28: Vehicle, craftman, HQ connection

Integration of screens and continuous monitoring will provide momentarily inputs about the inventory in order to improve the awareness. With the current solutions that craftsmen prefer for inventory management, they only become aware about the situation when they go into the trunk and check each bin manually.

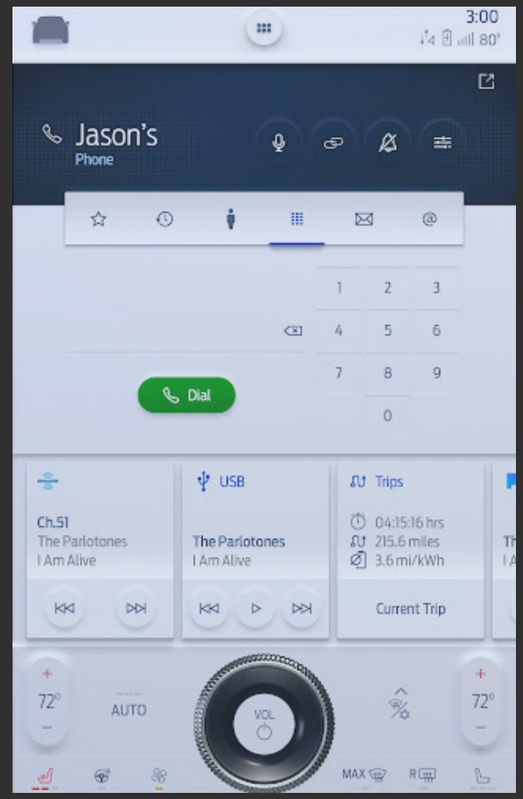


Figure 6.29: SYNC 4 interface

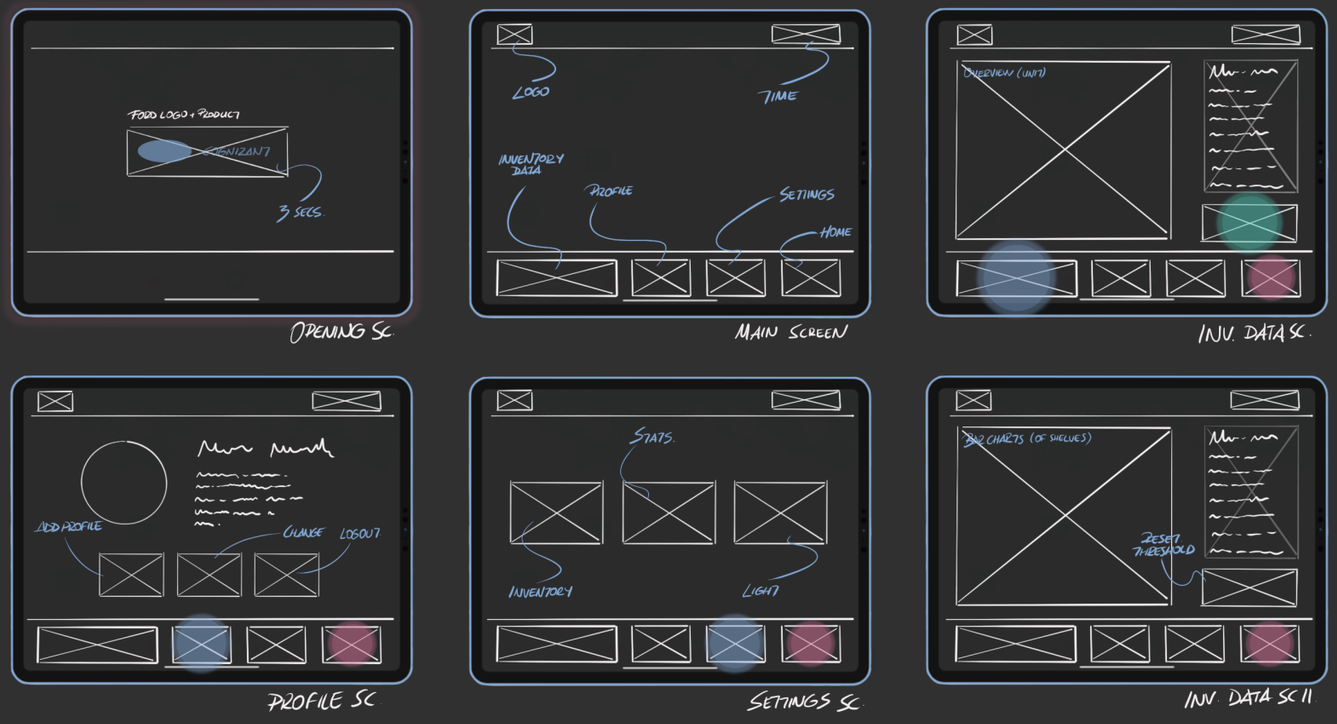


Figure 6.30: Ideation for screens

6.4.2 Approach

While designing the UI, Ford's latest infotainment system, SYNC 4 was preferred as an inspiration. Models such as Mustang Mach-E and F-150 already have SYNC 4 on their dashboards, thus, the same visual approach has been applied for designing screens (Figure 6.31). This has been done by thinking about the next generation of the Ford Transit. Now that every new Ford vehicle comes with optional FordPass Connect™1 with a 4G LTE Wi-Fi Hotspot, cloud connectivity comes standard to SYNC4 (Ford Media Center, 2019). That is why, screens for smartphones are also designed, in case the craftsman wants to synchronise his device to Ford Cognizant.

Figure 6.31: SYNC 4 in Mustang Mach-E

Figure 6.31: Ford Transit Custom 2021 - SYNC3 Display

COGNIZANT
Automated Inventory Control

1. SYNC4 Homepage
2. Loading Screen
3. Unit Overview
4. Inventory Data
5. Settings

MONITORING VIA SMARTPHONES

Figure 6.32: UI Design

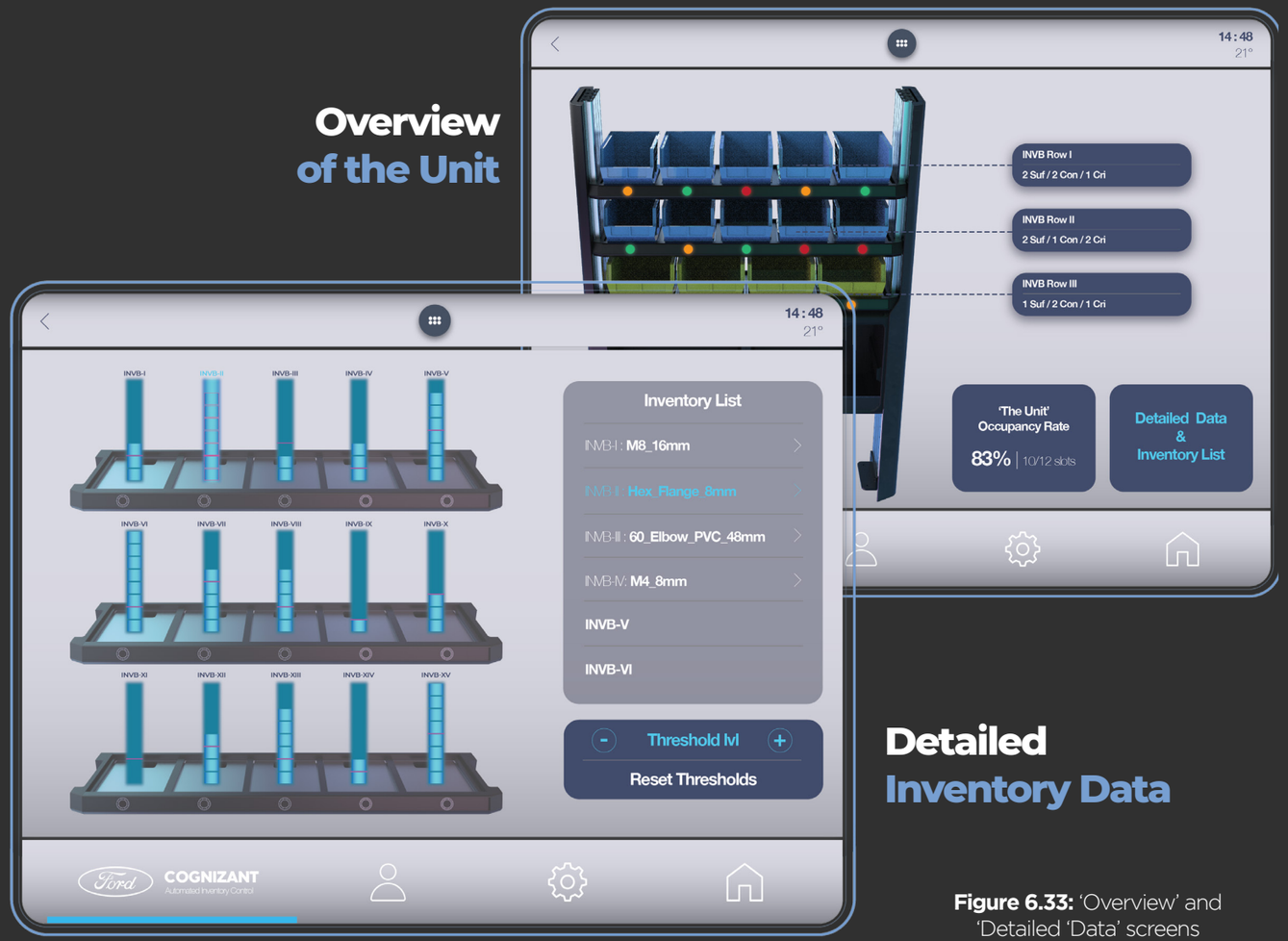


Figure 6.33: 'Overview' and 'Detailed 'Data' screens

6.4.3 Final design

The most important sections of the UI design are the **'Overview'** and **'Detailed Data'** screens, where craftsmen can access either overall view of the Unit and in depth information regarding the consumables (Figure 6.33). On 'Overview' screen, the Unit has been placed with LEDs on it, to give an idea about that levels of each bin indicating them as critical, considerable or sufficient in case craftsmen wants to do a quick check.

On 'Detailed Data' screen, craftsmen can access detailed information per inventory bin shown with bar charts. Bar charts have 8 slots just like the circular LEDs used on control panel. Individual threshold levels are also indicated which can be changed by clicking on '-' and '+' at the bottom right corner. In case the configuration needs to be changed or another craftsman with different inventory setup wants to use the vehicle, all threshold levels of inventory bins can be reset with a simple click. On the other hand, craftsmen can do labelling on this page for each inventory bin in order to avoid forgetting what is placed where.

On the 'Settings' screen craftsmen can synchronise their smartphones, to be able to access informations from their personal devices (Figure 6.32).

SECTION VII:
CONCLUSION

After investigating craftsmen’s difficulties regarding the inventory management, the concept development phase had been started to accomodate the room for oppotrunity. This section outlines the concept, it’s features, it’s envisioned influence on inventory awareness and shows intermediate steps that are taken to reach that point.

7.1 Conclusions

This graduation thesis focused on **improving the inventory awareness of craftsmen within their light commercial vehicles** by providing a smart inventory control concept dedicated for the consumables that are carried in the trunk area.

The topic that Ford Motor Company is working on which is the inventory management in light commercial vehicles, combined with **design thinking methods and user-centric approach.** Relevant use-cases and opportunity areas to improve were defined considering the actual needs of craftsmen to enhance their inventory awareness.

The project included research about inventory management methods in various industries to observe how accessible technologies are utilised to gain benefits and improve organisation. Later on, these findings were used as an inspiration, especially for technology implementation for the concept, but tailored for the target context; the trunk of the van. Contextual factors including materials, configurations, utilisation of the area and nuisances were taken into consideration while choosing right and accurate technologies to be implemented to the concept. Later on these decisions were evaluated by **conducting several user experience tests** with actual users during concept development phase. The results gathered from the tests were **reflected on next iterations** until aimed values are achieved.

Current solutions that craftsmen for their vehicles only provide maximal storage chances to make them able to carry lots of materials with them. However, most of the time craftsmen neglect the fact that having that much materials occur major problems. One of them is **the lack of inventory awareness**, especially for consumables which have the highest frequency of use and turnover rate in the entire inventory. This lack of awareness results having either low-stock or over-stock situations which eventually causes to do time consuming additional activities such as travelling to a department store. Since time, efficiency and money is essential for craftsmen, this time loss can be utilised in a better way, for instance, to work more. Punctual and relevant decisions cannot be taken such as restocking supplies when there is a unknownness about the inventory state.

On the other hand, the deficiency is also substantial from the organisational point of view. Methods that small/medium sized craftsman companies prefer are time consuming, requires human labour and have a high tendency for errors because of manual inputs done by a personnel. During debriefing phase of the day, employee craftsman needs to report the inventory situation to a personnel. Because of relying on pen, paper and whiteboards, the control needs to be done physically by getting in and out to the trunk and checking every inventory bin or organiser one by one. Because of all these impractical activities, debriefing sessions can take long times yet with missing or wrong inputs. This causes having inaccurate orders from suppliers and repeat additional activities which are done while working.

The main research question:

How to design a smart trunk ecosystem that will improve the inventory awareness of craftsmen?

After summarising and synthesising all relevant research findings, the concept, Ford Cognizant was developed with an integration of product and service, in order to address the main research question and sub-research questions.

Craftsman inventory awareness

The final concept, Ford Cognizant, has multiple positive attributes as user benefits. First of all, as it mentioned, consumables are materials which are hardest to keep track because of their variety and amount but also frequency of use. Therefore, gathering or controlling them are effortful and time consuming. With the concept, consumables management is improved to an automated state.

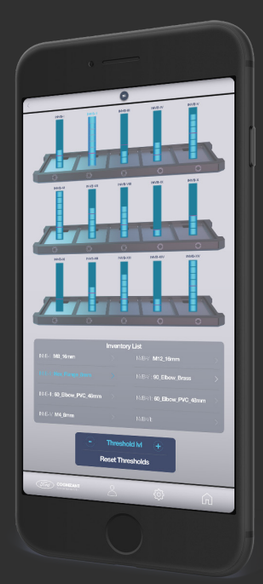
By utilising technology, the concept enables new and practical interactions with consumables in the trunk. This has been done by adapting smart and informative light indications to the unit where consumables are placed on. One of the scales in the user experience evaluation was ‘stimuli’, which is the impact of the system for inventory condition awareness. Participants gave the average score of 7 and this scale is improved with next iterations, for instance, by adding a red blink feature for the empty bin state. Visibility and noticeability of lights are utilised on the concept in order to be able provide immediate informations. Connectivity has been provided in between craftsman and his inventory by enhancing accessibility. Synchronisation of the Unit with SYNC4 infotainment system of Ford and smart devices, enables continuous monitoring even from a distance.

The concept contributes for improving the trunk organisation and inventory management by offering consumable specific information. Considering the reality that each consumable have different weight and frequency of use, thus, the amount, features such as, threshold definition, helps enhancing the relevancy of informations. Those features makes the system adapt to the user which is what craftsmen wish. Rather than forcing them to do certain task, providing reminders and suggestions adapting to their work flow, pave the way for making craftsmen friendlier towards digital solutions.

RQ2.1 **How can craftsmen be adapted to the world of digitalisation?**

RQ2.2 **How can the inventory management be improved in the trunk by utilising technology?**

RQ2.4 **How can the physical effort required interactions in the trunk be evolved?**



Organisational point of view

Enabling automation, makes inventory management much more practical and time-efficient. It was learned with the research that, better and smarter inventory management improves the internal organisation especially companies with high number of assets. As it shown on Part 4.5, the concept focuses on small to medium sized craftsman companies with up to 6 vehicles. Automation for inventory management for each vehicle of the company provides greater and accurate insights regarding the overall consumption. The proposed concept offers continuous and momentarily informations with less error tendency. Since the consumables control is done by Ford Cognizant itself, there is no need for human intervention. This will help for a significant shrinkage in time consuming debriefing sessions that craftsmen need to do at the end of the day. On the other hand, accurate optimisation of the overall consumption will result with absolute orders from suppliers. which are done while working.

RQ2.3 **Can digital solutions spearhead to craftsman business for improving itself?**

RQ2.5 **What type of information do craftsmen need for inventory management?**

Cost Estimation

Two of the key requirements before getting into the concept development was about the product economics (PE1/PE2). Those requirements are quite essential considering the target user that the concept is addressed to. Craftsmen in general do not have high income, that is why it is often possible to see affordable solutions in their vehicles like do-it-yourself rack systems. It was also observed during interview that, the scepticism they have towards digital solution can be avoided only if the technology implementation is affordable and efficient in terms of helping them to gain time or money.

PE1 **The product must be economically accessible considering craftsmen's income.**

PE2 **Electronics preferred for the product must be affordable.**

It was stated at Part 1.2.2 that, cost estimation of non-mandatory or changeable parts are out of the scope. This project takes the next generation of the Ford Transit into consideration, the visual approach that has been taken was vision-centric. In fact, the goal was to achieve the robust, strong and futuristic look which is constituted by visible or shell parts. Designs of shelves, side walls, organiser storage are considered as non-mandatory parts since they can be improved in a way that would reduce the overall cost. However, elements such as, load cells, RFIDs, circular LEDs, buttons, aluminium panels, modules and inventory bins are considered as mandatory in order to enable the system to work (Figure 7.1). Without these elements, it is not possible to achieve what has been aimed with this concept design.

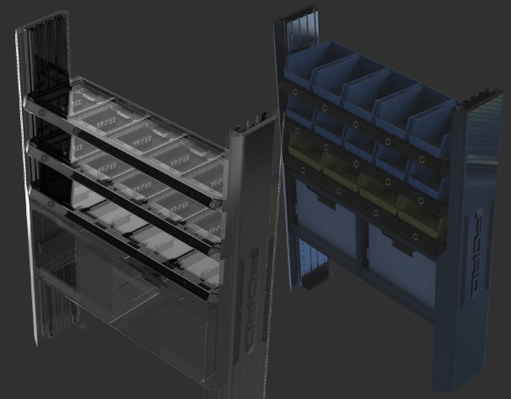


Figure 7.1: Electronic and structural parts are mandatory

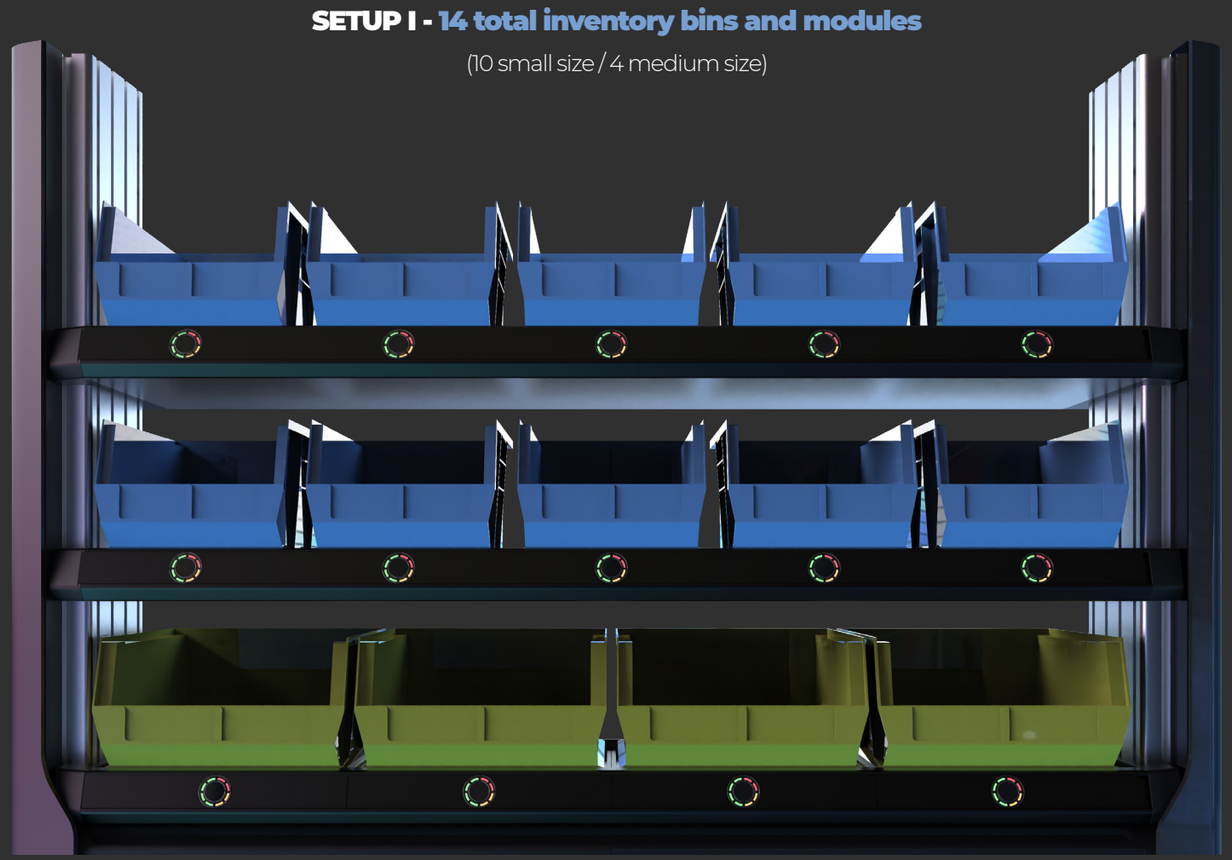
Table 7.2 shows the cost estimation of the concept's mandatory parts. There can be minor changes on the cost depending on the configuration. For instance, placing wide inventory bins mean having less modules, thus, less load cells and RFID. Table 7.2 indicates the cost estimation of the configuration shown at Figure 7.3.

Cost List

Table 7.2: Cost estimation list

Part Name	Price (piece)	Amount	Total
Single point aluminum load cell	5,49 €	14	76,86 €
Custom made circular LED	1,68 €	14	23,52 €
Button	2,03 €	14	28,42 €
Aluminum plate composite 3mm	47,98 € (1000 x 1000 mm)	14	26,48 €
Nitrile rubber insulation parts	87, 92 € (2500 x 500 mm)	28	11, 20 €
HX711 load cell amplifier	1,99 €	14	27,86 €
RFID reader	6,74 €	14	94,36 €
RFID label	0,10 €	14	1,4 €
Aluminum panel 160x40	51.,06 €	2	102,12 €
			392,22 €

Figure 7.3: Example configuration



7.2 Coalesce with ‘Smart Rack’

Introduction

Smart Rack’ is a part of the comprehensive project named ‘Smart Trunk’ that Ford RIC Aachen is working on (Figure 7.4). As it mentioned before, it is focusing on accessibility problems that craftsmen face with by enabling the extension of the complete rack from the back door. It aims to help craftsmen to avoid getting in and out to the trunk while gathering materials. However ‘Smart Rack’ is yet an improved version of hardware storage solutions in the current market. There is still a lack of smartness in it, thus, Ford Cognizant designed and developed in a way that it can be united with ‘Smart Rack’ in order to cover that deficiency.

The product implementation of Ford Cognizant will ultimately increase the product value and fulfil the goal of the comprehensive project ‘Smart Trunk’. This potential implementation was the reason behind the decision of designing a unit that will include components which makes the system work. Preferring identical shelves with identical structural components such as aluminum panels eases the product implementation of Ford Cognizant.

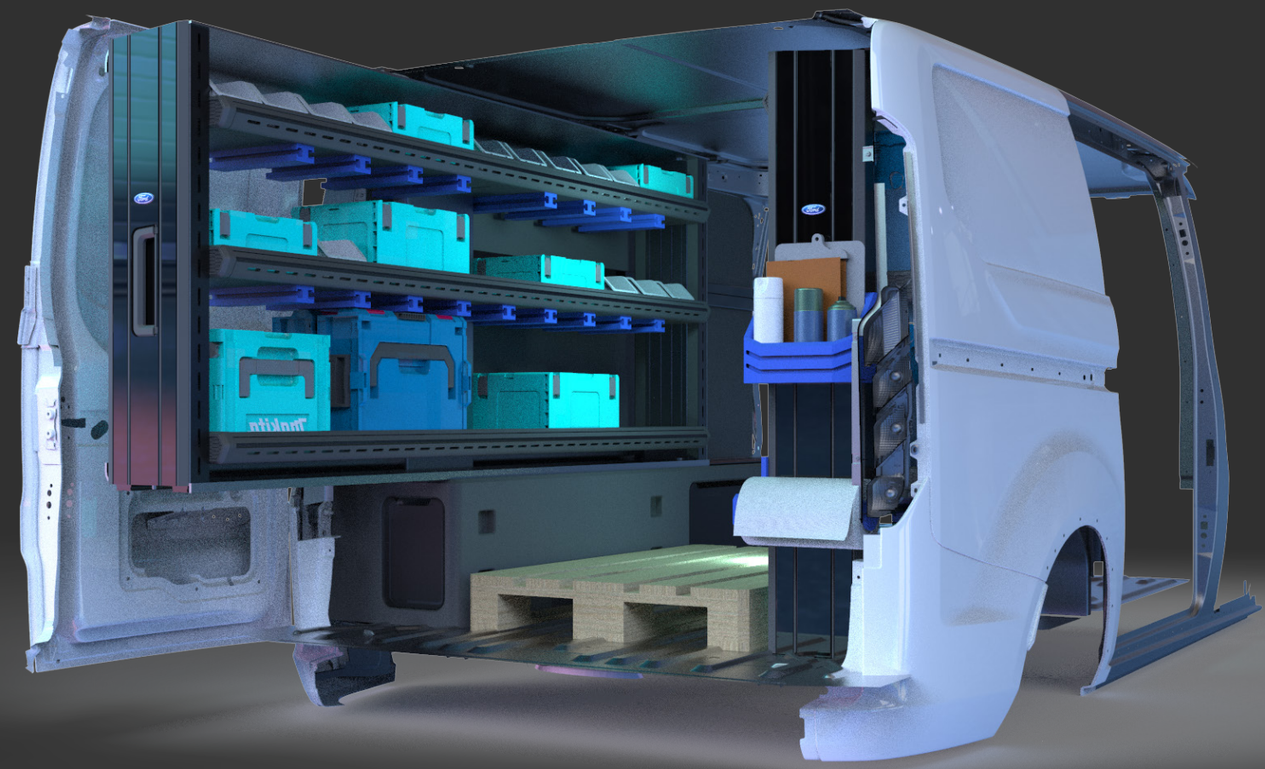


Figure 7.4: ‘Smart Rack’

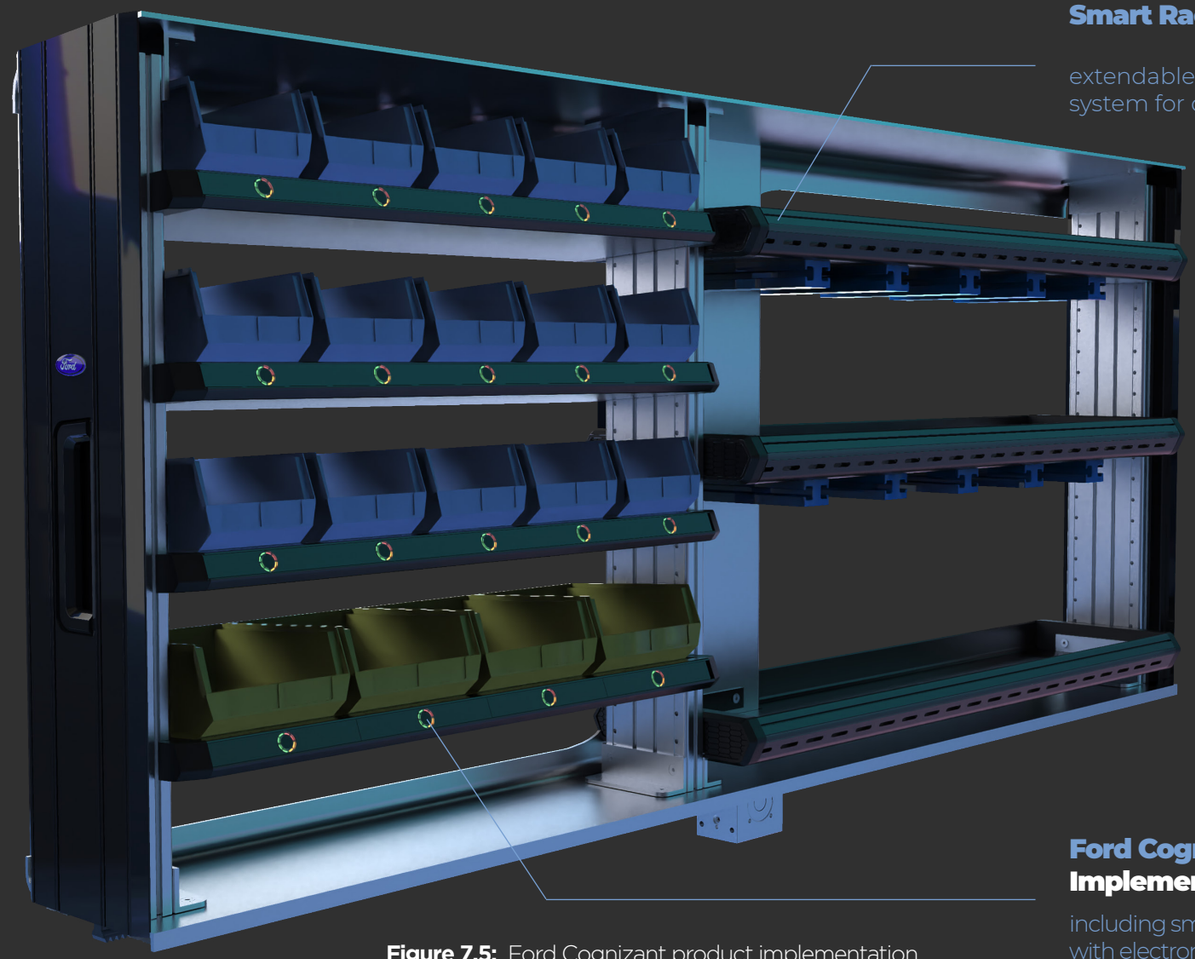


Figure 7.5: Ford Cognizant product implementation

Implementation

The product implementation was the reason behind the decision of designing a unit that will include components thats makes the system to operate. Preferring identical shelves with identical structural components such as aluminium panels eases the product implementation of Ford Cognizant. The envisioned product implementation is shown on Figure 7.5.

Shelves on Ford Cognizant have can be mounted easily to 'Smart Rack'. Using aluminium extrusion method for manufacturing, makes shelves adaptable for different length options. Therefore, craftsmen can even prefer to have a rack long smart Ford Cognizant shelves, or prefer to go with an partial system.

Since the modular approach was only taken for this concept design (shelves do not offer housing for load cells or RFIDs on 'Smart Rack'), a further development is recommended in order to figure out if it is possible to mount one piece shelf with partially electronics in it. Otherwise, additional aluminium panel needs to be added in between the Ford Cognizant shelves and 'Smart Rack' shelves. In practice separate approach can enhance the robustness of the shelves since 'Smart Rack' is a trunk long system.

7.3 Recommendations

AI and ML Implementation

Ford Cognizant helps craftsmen and craftsman companies to be freed of time consuming methods with high error tendency for inventory management. As it mentioned on Part 3.1, even today, majority of small to medium sized craftsman companies prefer pen, paper and whiteboards methods which results with in accurate inventory analysis. Ford Cognizant utilises sensors to provide automation for inventory management within the vehicle in order to give accurate inputs about the condition. Hereby, the concept motivates craftsman companies to initiate stepping into smarter inventory management methods such as cloud-based systems which harness the power of IoT to enable real-time and continuous monitoring.

Beyond cloud-based systems, there is one more advanced stage for inventory management that is machine learning and artificial intelligence which offers features that cloud-based systems are unable to do. This latest stage use predictive analytics to automate business decision-making around cost savings, resource utilization, risk mitigation, dynamic sourcing, and asset maintenance and availability (Link Labs, 2020). Artificial intelligence (AI) makes machines process inputs which subsequently pass through functions to reach a computer-generated decision as an output. These functions can be logical (rules-based), mathematical, or a combination of both. Machine learning (ML) programs learn to perform tasks by finding patterns in large data sets and making inferences instead of following explicit task- specific instructions that have already been programmed (Novick et al., 2019).

Levelling up Ford Cognizant with a potential AI and ML implementation can help for better and smarter decision making regarding the inventory with enhancing the automation of the system. With this way craftsman companies can have solid collaborations with partner suppliers. For instance, in case of a development of Ford Cognizant's data are shared with third party partner supplier, combining with ML, re-stocking consumables can be automated without any human intervention. The system can re-order consumables by communicating with the supplier directly, after learning and adapting itself to the average consumption of the craftsman.

Connectivity between the inventory, craftsman and the HQ

Another further testing is needed in order to ensure the connectivity between Ford Cognizant, inventory, the craftsman and the headquarters (HQ). Especially connectivity of the van to the HQ is important because of the long distance in between during a work. Often LoRa is preferred for long range communication in various industries. LoRa stands for Long Range Radio and it is a wireless protocol specifically designed for long-range, low-power communications. This technology will enable public or multi-tenant networks to connect the number of applications running on the same network (Purbe, n.d.).

However, as it mentioned on Part 6.4.2 bluetooth and cloud connectivity comes standard to new generation infotainment system, SYNC4. The built-in bluetooth system can connect to craftsmen's smartphone after the device is syncronised with Ford Cognizant application. This graduation thesis recommends for a further research about the necessity of an additional mobile application in order to provide the data that

craftsman sees on the smart device to the responsible personnel in the company. Because the data which can be accessed by the employee craftsman needs to be aggregated then relayed to the HQ servers in order to provide continuous information about the state of inventory bins and the consumables.

Tracking consumables in organisers

It was learnt during the field research that, craftsmen put the consumables either in inventory bins or organisers. Organisers are preferred because they are easy to carry and includes numerous slots to put different consumables in. Even though they usually come up with transparent lids to enhance their visibility, sometimes it can be hard to keep track of the consumables that are placed in, considering the amount of organisers that they have.

During the brainstorming session with Christian Kirchhof, he mentioned that he is working on the management of consumables in tool organisers. According to Christian, the most relevant way to observe the state of consumables in organisers is to place them perpendicular.

With a camera placed right across organisers with a linear angle can monitor the levels of consumables in the slots before and after the work to make a comparison and provide information for craftsmen (Figure 7.6). In order to achieve that Ford Cognizant's storage for organisers are designed to place them perpendicular. Organisers like Fatmax series from Stanley would be a relevant choice in order to substantiate mentioned development for Ford Cognizant (Figure 7.7).

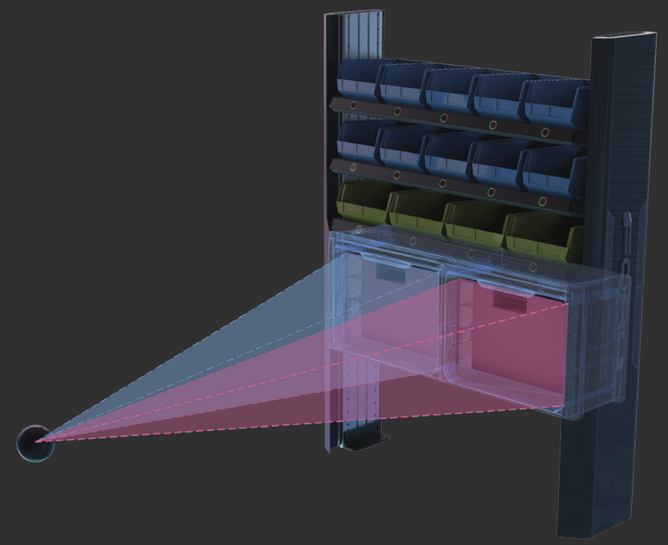


Figure 7.6: Camera positioning to the organiser storage

Figure 7.7: Stanley FatMax organisers

Improvement of UI Design

On the overview screen of Ford Cognizant application, coloured circles were used that provide informations regarding the state of the inventory bins (Figure 7.8). However, this approach is irrelevant for colour blind craftsmen. This particular point is discussed with the client during regular bi-weekly meetings.

Even though, control panels on the Unit also have coloured LED lights, it is relatively easier to learn and

understand the indications since circular LEDs have certain amount of slots for each colour (2 red - 2 orange - 4 green). The overview page of the Ford Cognizant application shows one of those colours to indicate if they are in a critical, considerable or sufficient state. Therefore, further development needs to be made in order to provide the quick information in a convenient way for colour blind craftsmen.

Figure 7.8: Indications on the overview page

Wiring and power supply in the vehicle

As it mentioned at Part 1.2.2, vehicle integration in terms of power supply is out of the scope for this project. However, in order to system to operate perfectly, wiring and power must be provided within the vehicle. Therefore, further steps should focus on providing the connection between the electric infrastructure of the van and the electronic components of Ford Cognizant such as, load cells, RFIDs, amplifiers and lights.

This further development should be done with considering the next generation of the Ford Transit. Overall, Ford expects that two thirds of its commercial vehicle sales will be battery-electric or PHEV by 2030 (Ramey, 2021). With electric infrastructure, the power supply can be easier in terms of providing sufficient electricity.

Batteries used in electric vehicles have more cells due to their unique internal design. As a result, the cells of batteries in electric vehicles tend to resemble one massive battery unlike gas-powered vehicles which uses the standard 12 volt battery made with six cells. The battery of an electric vehicle can be used for an extended period of time (Evolve With Liberty, 2016).

COGNIZANT

Automated Inventory Control

SECTION VIII:
REFERENCES

In this section, inventory management was researched by focusing on different used methods and technologies that are preferred. Later on, sensors and load cells are explained due to the scope of the project. This section finalises with solutions that are used in various industries about inventory management by analysing inspirational examples.

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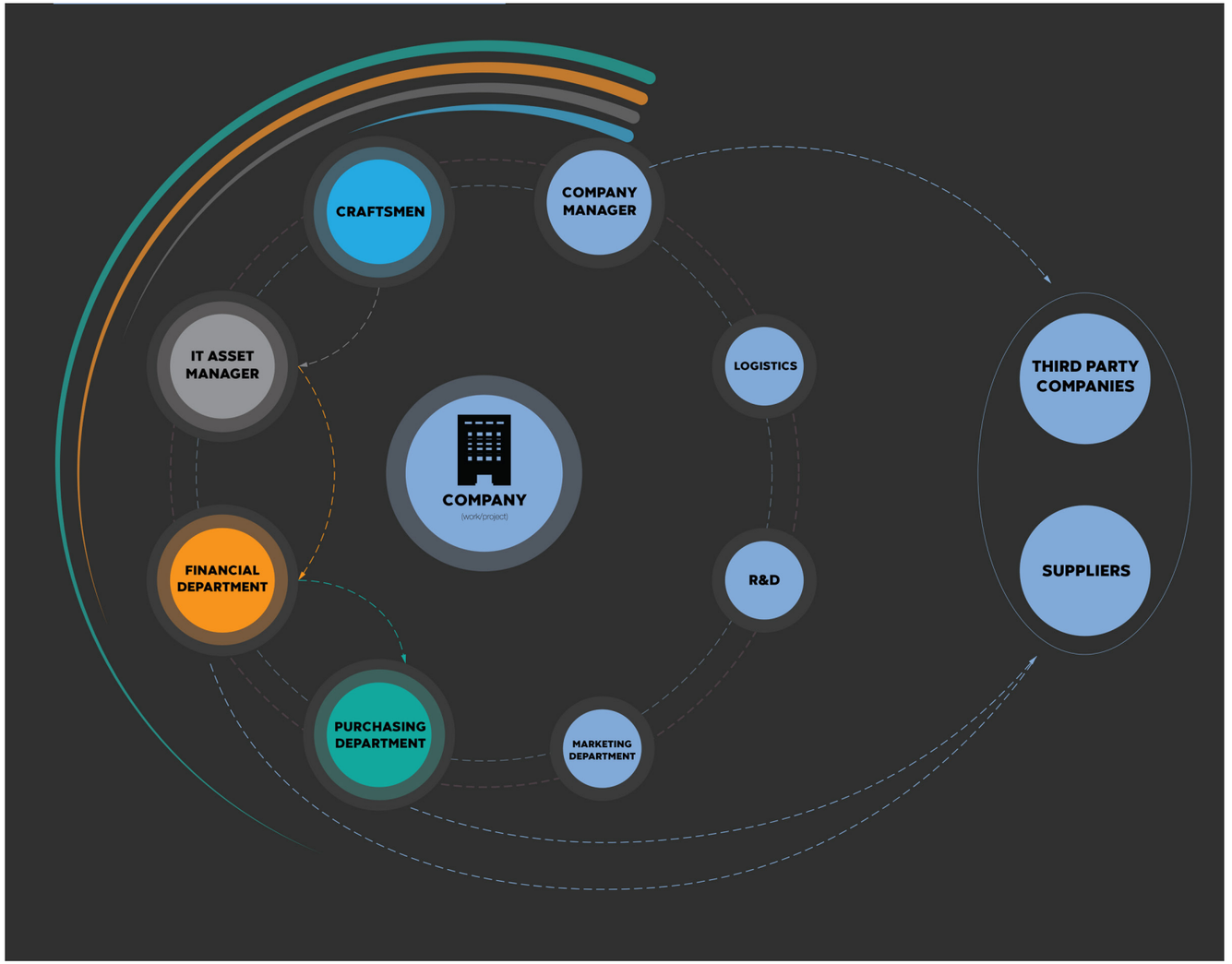
SECTION IX:
APPENDIX

Appendix A
Micro Level Stakeholder Analysis



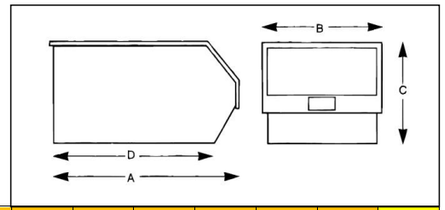
Appendix B
Industry standardized inventory bins

Standard Storage Bins

A simple and effective small parts storage system for a wide range of materials. Space saving, manufactured from Polypropylene, can be stacked or for increased flexibility, used with Louvred Panels, Cabinets and Shelving.

Features:
- Strong, heavy duty with reinforced base, sides and stacking rim
- Durable, resistant to most industrial solvents.
- Material is capable of withstanding a temperature range from -15°c to +50°c, however this may not apply when under load or stress dependent on use or application.
- Hygienic, clean, smooth inside faces guard against build up of grease etc
- Available in 7 sizes and 6 colours as standard
- Moulded in card holder – each pack supplied with sufficient index cards

The Clear Front cover – stock no. 456-3432 fits the **SIZE 7** bin



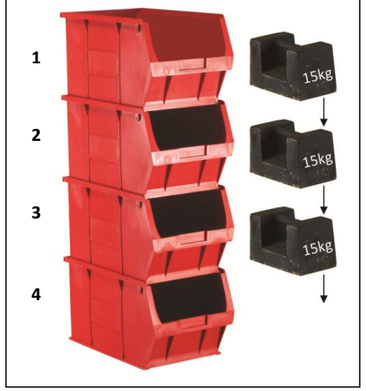
All Dimensions in mm	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 7
(A)Overall Length	90	167	240	350	350	376	510
(B)Overall Width	100	101	150	205	205	419	315
(C)Overall Height	50	76	130	130	181	180	200
(D)Overall Base Length	64	143	200	300	300	310	450
(A) Internal Length	80	154	223	330	330	350	470
(B) Internal Width	88	88	128	179	177	378	270
(C) Internal Height	42	63	120	117	167	164	188
(D) Internal Base Length	65	131	188	287	287	295	435
Volumes (Litres)	0.46	1.27	4.6	9.1	12.8	28.3	31.4
Maximum Container Stack Height – (*See Details Opposite)*	7	5	4	6	4	8	6
Maximum Stack Load Capacity (kg)	12	12	30	36	45	60	42

Container Stacking Loads:

Please note that when stacking containers, the entire stack load is dispersed onto the base container therefore neither the individual load or the total load of the stacked containers (up to the max. stack height) should exceed the max. stack load.

Eg. The diagram below shows **Size 5** containers stacked to their max. of 4 high. As the max. stack load for **Size 5** is 45Kg, if containers 1, 2 & 3 are equally loaded they can each carry 15Kg. If they were stacked 3 high and equally loaded each container could carry 22.5Kg, or 2 high 45Kg.

For all bin capacities see the chart



Appendix C
Interview Protocols

TUDelft Ford

contact:

SAMENVATTING

Dit interview en deze vragenlijst zijn samengesteld met **het doel om de processen van gereedschapsbeheer te onderzoeken, voor vak- en ambachtsondernemingen en aanvullende oplossingen.** Hierbij komt onder andere aan bod, **gereedschap en product beheer in het voertuig,** met name de laadruimte van een licht commercieel voertuig, aangezien goederen worden vervoerd in deze beperkte ruimte. **De communicatie tussen werknemers met betrekking tot de staat van het gereedschap en de distributie van taken en functies van het gehele gereedschapsbeheer.**

Ik, Barkin Alaybeyoglu, studeer industrieel ontwerpen op de Technische Universiteit van Delft en ben momenteel bezig met mijn afstudeerscriptie bij Ford. Ik wil u bedanken voor het accepteren van mijn verzoek voor deelname aan dit interview, doordat uw waardevolle informatie en feedback bijdragen aan belangrijke richtlijnen voor het ontwerpproces.

Geïnterviewde: **Barkin Alaybeyoglu**

Werkomschrijving:

Datum:

OVERZICHT EN OPBOUW:

PI: OPEN QUESTIONS

1.1 Voertuig specificaties
1.2 Gereedschap/goederen die in de laadbak worden vervoerd
1.3 Gereedschap/goederen beheer in het voertuig
1.4 Gereedschap/goederen beheer binnenin de organisatie of het bedrijf
1.5 Algemene vragen

PII: FILL THE CHART

Een cirkelgrafiek met lege vakjes kunnen ingevuld worden in een verklarende manier met ten opzichte van de informatie grafiek over gereedschapsbeheer in het bedrijf. (Een voorbeeld zal worden gegeven ter inspiratie)

PI: OPEN VRAGEN

How would you describe your van? This question can include the built-in shelving system, vehicle configuration, building process, pros and cons etc.

If you had an assistant with you during your shift, what would you have help about?

What are your most preferred and most frequently used tools? Could you elaborate on the reason of preference and frequent usage? Have you faced any difficulties about taking care of tools in the trunk?

How able are you to find tools, consumables or materials you are looking for in the trunk? If yes, how and if no, why?

How often do you get out of consumables/supplies? How do you notice when there is an insufficient amount of consumables/supplies?

How would you describe the communication within your company about tool management in your vehicle? How do you need to report the status to a specific person?

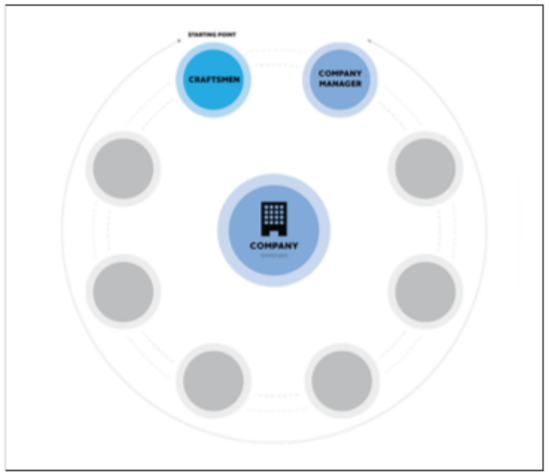
If you had an assistant with you during your shift, what would you have help about?

What is your opinion about digital and technological solutions for your vehicle? Do you have any favorite modern day technology?

How would you describe the communication within the company about tool management in your vehicle? Do you need to report the status and condition to a person?

PII: VUL DE GRAFIEK IN

Hier, een voorbeeld grafiek representeert de stroom en informatiecyclus van gereedschapsbeer in een bedrijf, dat gebaseerd is op een groot bouwbedrijf. Naar aanleiding van observaties tot nu toe, staan vaklieden ofwel in direct contact met een bedrijfsmanager betreffende de condities van het gereedschap, of middels een tussenpersoon. Dit kan bijvoorbeeld een gereedschapsbeheerder zijn, een datamanager, een financiële of inkoopafdeling, afhankelijk van de omvang van het bedrijf en de bedrijfsorganisatie. Vul aub de onderstaande lege grafiek in gezien uw bedrijf en het proces betreft het gereedschapsbeheer.



**** de grafiek hoeft niet volledig ingevuld te worden. Als er minder werknemers verantwoordelijk zijn voor het gereedschapsbeheer, dan kan u sommige velden blanco laten.*

critical level / empty

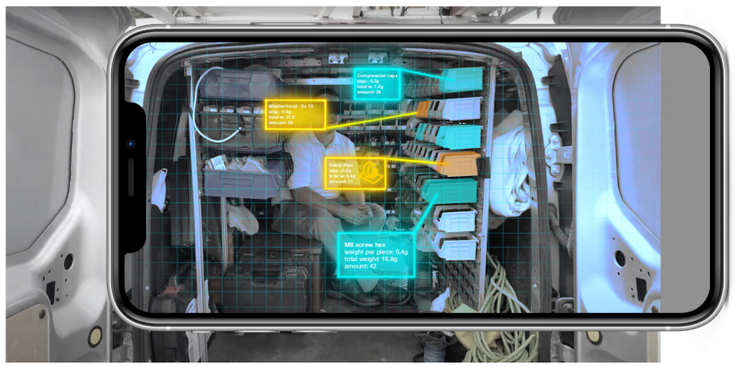
indication for bins with a critical level of inventory

sufficient

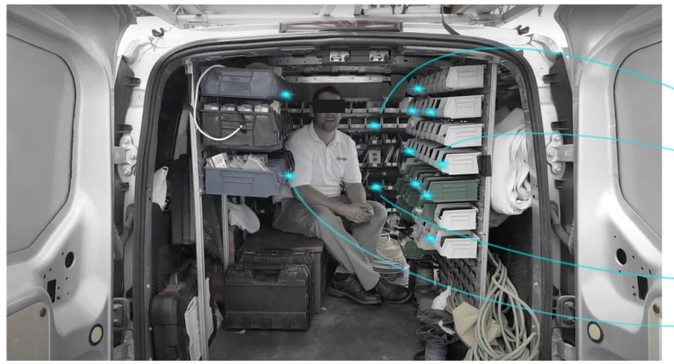
medium / check

critical level / empty

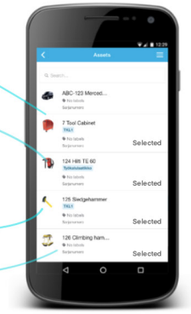
color coded light indication for situations of inventory bins



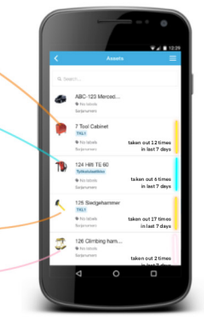
momentarily checking the inventory situation with in depth layer of information



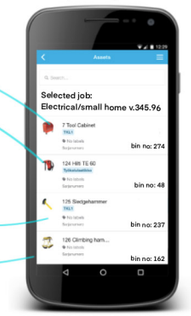
selected tools are indicated



color coded tool suggestions depending on the frequency of use



necessary tools for specific jobs



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Geïnterviewde: Louis
Werkomschrijving: Carpenter
Datum: 16.04.2021

Barkin Alaybeyoglu

PI: OPEN VRAGEN

How would you describe your van? This question can include the built-in shelving system, vehicle configuration, building process, pros and cons etc.

What are your most preferred and most frequently used tools? Could you elaborate on the reason of preference and frequent usage? Have you faced any difficulties about taking care of tools in the trunk?

How able are you to find tools, consumables or materials you are looking for in the trunk? If yes, how and if no, why?

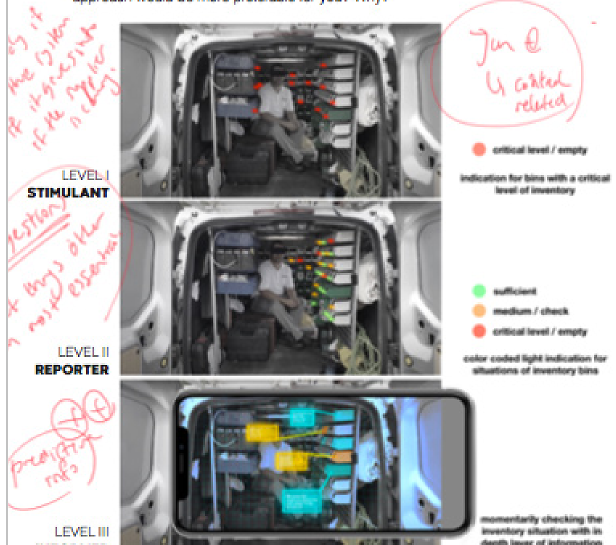
How often do you get out of consumables/supplies? How do you notice when there is an insufficient amount of consumables/supplies?

How would you describe the communication within your company about tool management in your vehicle? How do you need to report the status to a specific person?

If you had an assistant with you during your shift, what would you have help about?

What is your opinion about digital and technological solutions for your vehicle? Do you have any favorite modern day technology?

Scenario II: You have opened the trunk of the van in order to do a check and see if you have enough tools/consumables/materials for the next job. Which approach would be more preferable for you? Why?



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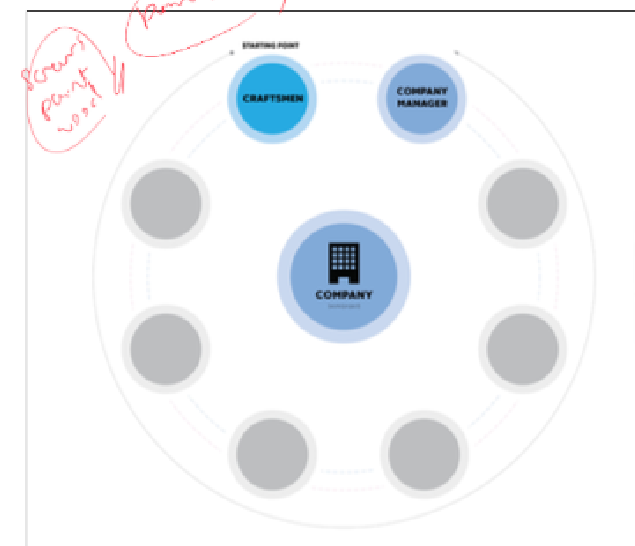


*** de grafiek hoeft niet volledig ingevuld te worden. Als er minder werknemers verantwoordelijk zijn voor het gereedschapsbeheer, dan kan u sommige velden blanco laten.

Appendix D
Industry solutions research

The management of moveable assets is still a major challenge in the industrial environment. Examples for such assets are vehicles, containers, or tools. The goal of moveable asset management is to make assets available when needed and ensure their efficient use. For this reason **inventory management encompasses activities like locating assets, tracking their usage and ensuring their maintenance.** From our daily life we might have experience about the time we are spending on searching for personal belongings. This problem is much more complex for companies that are dependent on many different kinds of assets that are often used on a shared basis (Lampe, 2014). Good inventory management systems should be able to:

- **Manage assets individually,**
- **Allow to locate the right assets**
- **Provide information about the current physical status of an asset**
- **Keep an information history of an asset.**

To fulfill these requirements, there are various solutions in different industries considering the complexity of operations, the amount and variety of assets in the inventory but also the size of the context and requisite information. Shown on the right side at Figure FIXME, some inspirational industry solutions were compared.

Solution Name	Elements	Operation Scheme	Goals
Comarch White Paper	IoT Platform IoT Hubs BLE Bracelets Beacons	Real-time active inventory tracking	Asset tracking Data optimisation Asset location Auto. manufacturing
PAR Excellence PAR Bins	IoT Platform Precision Scales Software	Real-time active inventory tracking	Inventory automation Smart maintenance Automated order Custom value chain
Zemic Easy Shopper	Load cells Barcode scanner Integrated display	Weight sensing based shopping experience	Smart shopping Reduce waiting time Cutting processes

DIGITAL BINS

Managing inventory transaction with precision scales placed under each plastic inventory bin. LED indications are integrated to give certain info.

WAREHOUSES / STORES

GALAXY SMARTTAG+

Compact Bluetooth tracker to find certain objects. The tag can be attached to any object which has a tendency to get lost.

DAILY USE

RFID TOOL CABINET

Drawer and screen integrated mobile cabin for tools that can be tracked with RFIDs for inventory and goods transaction.

RETAIL STORES

PAR EXCELLENCE BINS

Hardware and software merge of an inventory management system works with precision scales and relevant for different sized goods.

COMARCH WHITE PAPER

Cloud baset asset tracking solution that can work with BLE bracelets and beacons or RFID tags and antennas depending on the purpose.

WAREHOUSES

E-TURNS TRACK eVMI

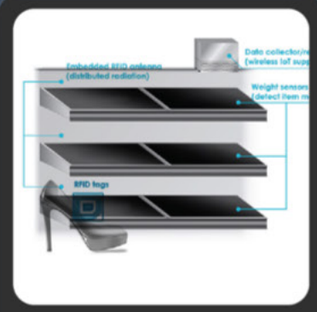
Physical inventory system with weight sensors which does not require any human intervention. Enhances eVMI operations.

WAREHOUSES

ZEMIC - EASY SHOPPER

Weight sensors integrated smart shopping trolley in order to make the shopping experience more practical and time efficient.

SHOPPING / GROECERIES

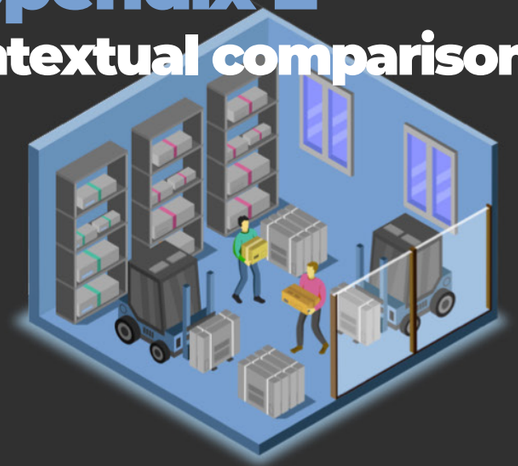


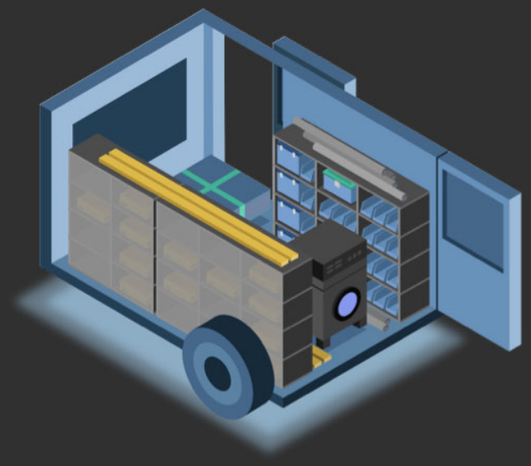
WIIHEY - SMART SHELF

Smart shelf management works with weight sensors and RFID tags in order to observe customer behaviour and inventory condition.

RETAIL STORES

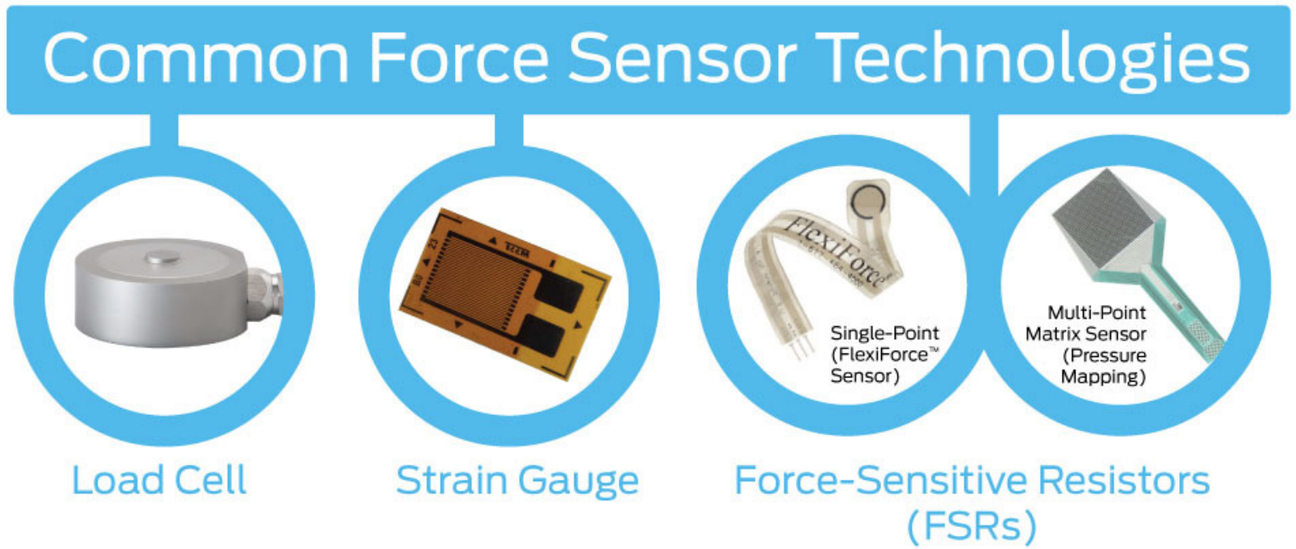
Appendix E
Contextual comparison





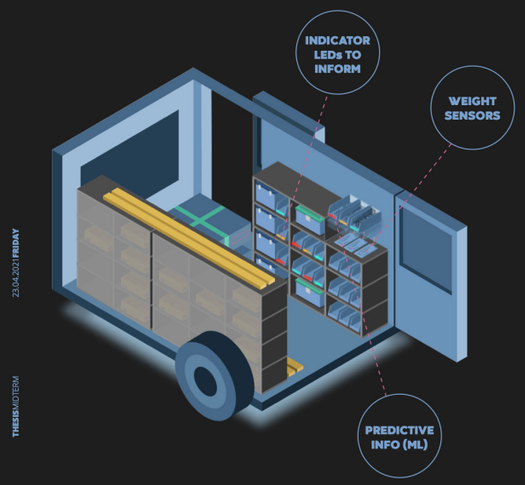
WAREHOUSES	RETAIL STORES	‘THE TRUNK’
scale/size ●●●●○	scale/size ●●●○○	scale/size ●●○○○
amount of assets ●●●●●	amount of assets ●●●○○	amount of assets ●●●●○
variety of assets ●●●●●	variety of assets ●●○○○	variety of assets ●●●●●
complexity ●●●●○	complexity ●●○○○	complexity ●●●○○

Appendix F
Force sensors



Force sensors are electronic devices that measure various parameters related to forces such as weight, torque, load, etc. and provide signals to the inputs of control or display devices. A force sensor typically relies on a load cell, a piezoelectric device whose resistance changes under deforming loads. Other methods exist for measuring torque and strain. Force sensors are used in load measuring applications of all kinds, from truck scales to bolt tensioning devices and used in a wide range of products and applications such as bathroom scales, musical instruments, medical applications, automobiles to detect seat occupancy, and process control in manufacturing facilities, (Thomasnet, 2019). There are different types of force sensors relevant to use for different needs for use cases.

Appendix G
Mid-term concepts



CONCEPT I INSPECTOR

Weight sensor integrated racking system that checks the inventory (consumables) condition when the vehicle is stable in order to prevent out of stock situations and additional travelling with the supplier.

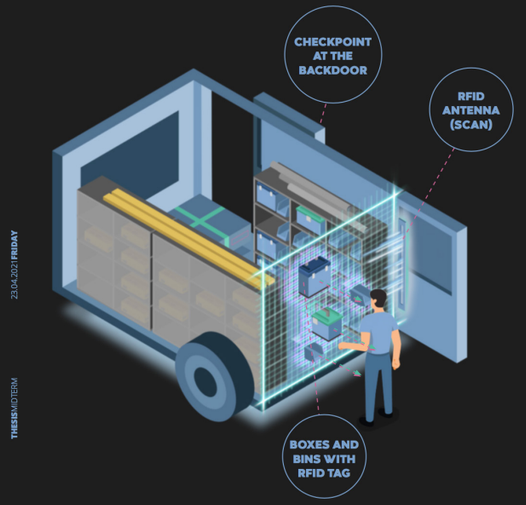
TECH SCHEME

ADVANTAGES

+ Relevancy of weight sensors for small sized goods such as screws, bolts, nuts which are most frequently used consumables.

+ Enhancing the function of the vehicle with an adaptation to user's way of working and consumable consumption.

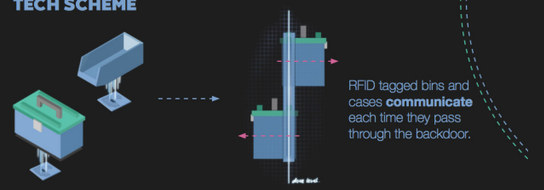
+ Remindful informations that can subliminally stimuli users to take an action.



CONCEPT II SCANNER

RFID tagged inventory bins and toolcases are scanned each time they are taken out and put back in to the trunk in order to provide predictive informations to the user such as frequency of usage.

TECH SCHEME

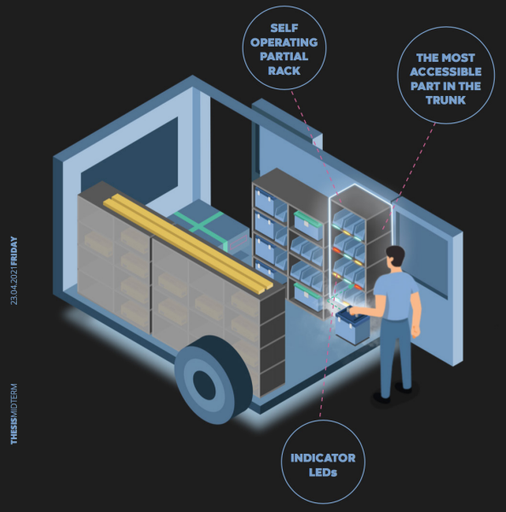


ADVANTAGES

+ Simple and elegant solution with costless implementations.

+ Potential to provide various informations other than frequency of usage such as quantity of boxes and bins or unattended cases.

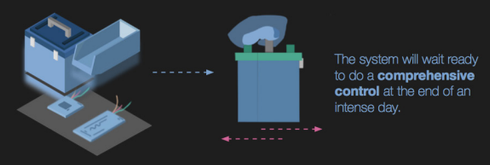
+ Does not require any human intervention. The whole operation is done in an automated way with the help of everyday activities.



CONCEPT III ALFRED

Partial smart shelving system works with weight and pressure sensors to provide informations about the consumption and frequency of use. Tendency of craftsmen to put everything back closest to the backdoor utilized via IoT.

TECH SCHEME



ADVANTAGES

+ Turning the tendency caused by tiredness into a benefit.

+ Using two different sensors can provide more comprehensive information such as 'consumed_amount_per_job / usage_frequency'.

+ To be able to subliminally guide craftsmen for placing bins and cases which needs to be checked to their intended spot.

Appendix H
User experience test evaluations

User Test Evaluation Form

TUDelft

Deze gebruikerstest bij het prototype is vooral gericht op de interactie, communicatieve waarden en bruikbaarheid. Er zijn twee delen, beide met tienpuntsschalen. Het eerste deel van de evaluatie richt zich op de indicatie methoden (aanduidingen) op het prototype en het tweede deel is meer over de algehele ervaring. Van de gebruiker wordt verwacht dat hij een antwoord geeft op de onderstaande vragen na het afronden van de gegeven taak met het prototype.

Naam	Age	Datum	Handtekening
Wim v. Almsick	34	08-06-2021	

Duidelijkheid - Hoe gemakkelijk was het om de aanduiding en de boodschap te begrijpen?

Very hard — Very easy

Stimulis - Hoe effectief zijn de aanduidingen om je ertoe aan te zetten de voorraden aan te vullen?

Low stimuli — High stimuli

Zichtbaarheid - Hoe zichtbaar was elke aanduiding? (rekening houdend met hoek, natuurlijke lichtbronnen enz.)

Not visible — Very visible

Prestaties - Hoe hard moest je nadenken om de taak te voltooien?

Very hard — Very easy

Relevantie - Hoe bruikbaar was de gegeven informatie met aanduidingen?

Not useful — Very useful

Ik vond deze oplossing relevant en nuttig voor mijn bestelwagen.

Strongly disagree — Strongly agree

Ik vond het systeem mogelijk invloedrijk op het voorraad bewustzijn

Strongly disagree — Strongly agree

Ik denk dat er enkele tekortkomingen waren betreffende de aanduidingen

Strongly disagree — Strongly agree

Ik vond de stappen om het systeem te bedienen verwarrend.

Strongly disagree — Strongly agree

Ik denk dat het systeem gemakkelijk te begrijpen is.

Strongly disagree — Strongly agree

Additional notes:

User Test Evaluation Form

TUDelft

This user test provided with the prototype is mainly focusing on the **interaction, communicational values and practicality of operation.** There are two parts for assessments with ten-point scales. The first part of the evaluation focuses on the indication methods on the prototype and second part is more about the overall experience. The user is expected to give points to mentioned questions below after finalising the given task on the prototype.

Name	Age	Date	Signature
John Mostaert	31	14.06.21	

Clarity - How easy was to understand the indications and their messages?

Very hard — Very easy

Stimuli - How effective are the indications to trigger you to restock supplies?

Low stimuli — High stimuli

Visibility - How visible were each indications? (considering angle, natural light sources etc.)

Not visible — Very visible

Performance: How hard did you need to think to complete the task?

Very hard — Very easy

Relevancy: How useful was the given information with indications?

Not useful — Very useful

I found this solution relevant and beneficial for my van.

Strongly disagree — Strongly agree

I found the system potentially influential for inventory awareness.

Strongly disagree — Strongly agree

I think there were some deficiencies on indications.

Strongly disagree — Strongly agree

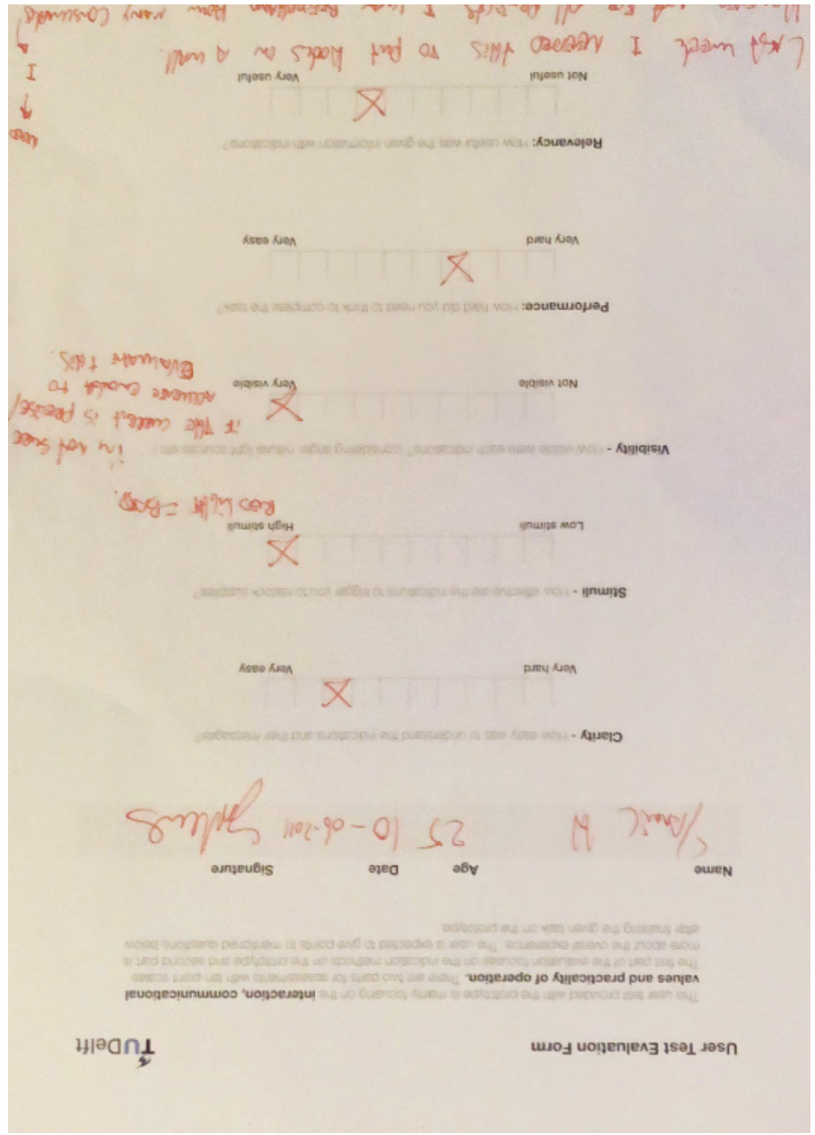
I found the steps to operate the system confusing.

Strongly disagree — Strongly agree

I think the system is easy to digest and understand.

Strongly disagree — Strongly agree

Additional notes:



I found this solution relevant and beneficial for my van.

Strongly disagree — Strongly agree

I found the system ~~potentially~~ influential for inventory awareness.

Strongly disagree — Strongly agree

I think there were some deficiencies on indications.

Strongly disagree — Strongly agree

LAG! i
LACK OF FEEDBACK FOR SOMMB FEEDBACK. NO INDICATION IF EXACT / APPROXIMATE AMOUNT.

I found the steps to operate the system confusing.

Strongly disagree — Strongly agree

SEE ABOVE

I think the system is easy to digest and understand.

Strongly disagree — Strongly agree

Additional notes:
1 WHAT ABOUT PACKAGE WEIGHT?
2 WHAT IF YOU THROW THE WRONG OBJECT IN A BOX?
3 IS VISUAL FEEDBACK OF STOCK INSUFFICIENT? (DO WE REALLY NEED SCALES FOR EVERYTHING)

User Test Evaluation Form

TUDelft

The user test consist with the prototype is mainly focusing on the **interaction, communicational values and practicality of operation.** There are two parts for assessments with ten point scales. The first part of the evaluation focuses on the indicator methods on the prototype and second part is more about the overall experience. The use is expected to give points to mentioned questions below after finishing the given task on the prototype.

Name — Age — Date — Signature

Clarity - How easy was to understand the indicators and their messages?

Very hard — Very easy

Stimuli - How obvious are the indicators to trigger you to notice surprise?

Low stimuli — High stimuli

Visibility - How visible were each indicators? (considering angle, natural light sources etc.)

Not visible — Very visible

Performance: How hard did you need to think to complete the task?

Very hard — Very easy

Relevancy: How useful was the given information with indications?

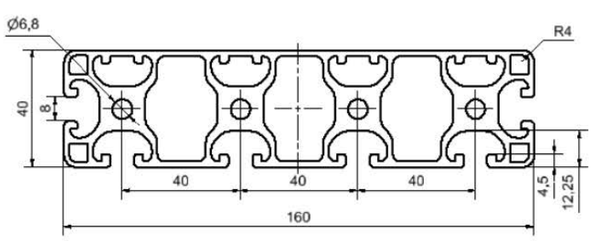
Not useful — Very useful

Datenblatt
S10816040L4N

Profil 8 160x40 leicht 4N

Technische Daten
Werkstoff: AlMgSi0,5F25 natur eloxiert
Trägheitsmoment Ix: 35,09
Trägheitsmoment Iy: 521,68
Widerstandsmoment Wx: 17,04
Widerstandsmoment Wy: 65,21
Gewicht/m: 5,880 kg

Artikel
Bezeichnung: Profil 8 160x40 leicht 4N
Artikel.-Nr.: S10816040L4N



SMT GmbH
Aspenhaustr. 17
72770 Reutlingen

Appendix I
Aluminum panel
160x40

Appendix J

Ford Transit Custom trunk dimensions

VANGUIDE.co.uk

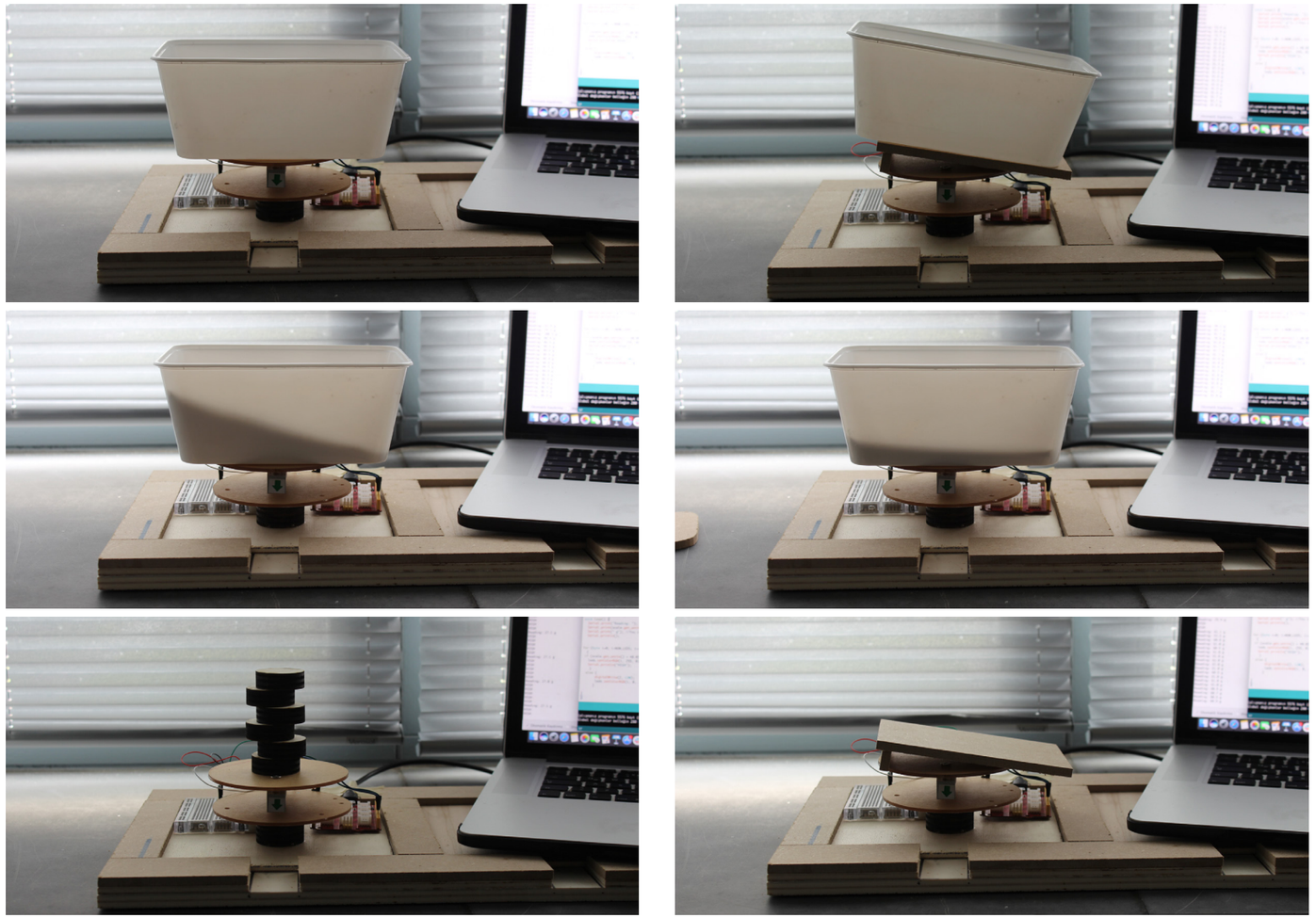
NEWS REVIEWS POPULAR VANS VAN SEARCH ADVICE CONTACT US

Overall Length	4972	4972	5339	5339
Overall Width with mirrors	2272	2272	2272	2272
Overall Height	2020	2389	2020	2389
Wheelbase	2933	2933	3300	3300
Turning Circle (k to k)	10.9	10.9	12.2	12.2
Rear door width	1404	1404	1404	1404
Rear door height	1347	1706	1347	1706
Side door width	1030	1030	1030	1030
Side door height	1324	1324	1324	1324
Loading height (sill height)	588	588	588	588
Loadspace length	2555	2555	2922	2922
Loadspace width	1775	1775	1775	1775
Between wheelarches	1390	1390	1390	1390
Loadspace height	1406	1778	1406	1778

Technical Data

Ford Transit Custom dimensions

Appendix K
Load cell tilt test setup



VPG Transducers
Celtron • Revere • Sensortronics • Tedea-Huntleigh

Model 1002
Tedea-Huntleigh

Aluminum Single-Point Load Cell

FEATURES

- Capacities 0.5–20 kg for 350 ohm
- Capacities 5–30 kg for 1000 ohm
- Aluminum construction
- Single-point 200 x 200 mm platform
- IP66 protection

APPLICATIONS

- Small scales
- Grocery scales

DESCRIPTION

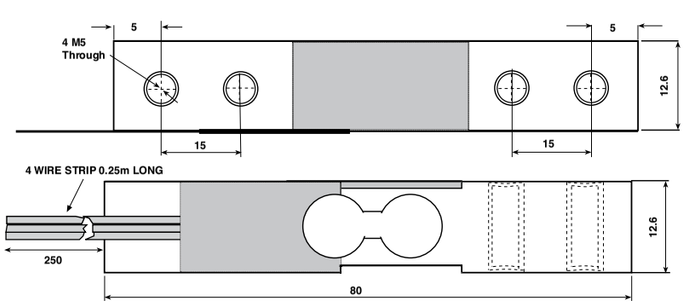
Model 1002 is a very small, low capacity, aluminum single-point load cell, equally suitable for simple weighing scales or for industrial measurement and medical applications.

The Model 1002 has the advantage of very small size. It is, therefore, both versatile and easy to use in a wide variety of industrial measurement applications.

Optional 1000-ohm strain gages are particularly suitable for connection to battery-powered equipment (designated Model 1002-K).

Typical applications include packing machines, filling machines, weaving machines, industrial process control, and low-force medical applications, as well as small-platform weighing.

OUTLINE DIMENSIONS in millimeters



Appendix L
Single point load cell

ENGLISH

Datasheet

Black Nitrile Rubber Tank Insulation

RS Stock number 486047

Description

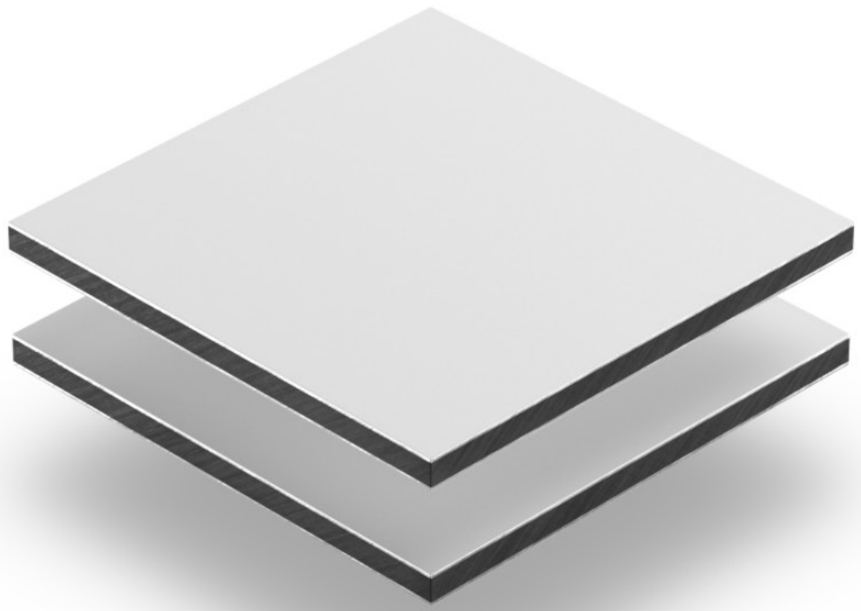
- Ideal for cutting as needed when used for insulation of large pipes, flanges, containers and similar objects.
- The low thermal conductivity capacity assures a sufficient surface area temperature and avoids the accumulation of condensation
- High water vapour permeability
- Foam product with sound absorbing properties, reducing pop and flow noises in pipes.
- Temperature range is -30°C to 95°C (when adhered to a flat surface, operating temperature should not exceed 85°C)
- Compliant with Part L of the April 2006 Building Regulations

Specification

• Colour	Black
• Dimensions	2000 x 500mm
• Length	2000mm
• Material	Nitrile Rubber
• Thermal Conductivity	0.034 W/mK, 0.036 W/mK, 0.038 W/mK, 0.04 W/mK
• Thickness	25mm
• Width	500mm

Appendix M
Nitrile rubber material

Appendix O
Aluminum sheet data



Alupanel wit 3 mm op maat RAL 9003 mat

€ 39,65 / m² Excl. BTW | **€ 47,98** / m² Incl. BTW

Kies vorm en afmeting

Rechthoek | Vormen | Tekst | Uploaden

Lengte max 305 cm — cm

Breedte max 150 cm — cm

Rechthoek

Op voorraad

Verwachte levertijd: **10 - 13 augustus**

1 + -

In winkelwagen

COGNIZANT

Automated Inventory Control

Barkin Alaybeyoglu

Master of Science
Integrated Product Design