GRADUATION

Thomas Hofs

JULY 2020

Master Thesis
Delft, Juli 2020

Author
T.J.B. Hofs (Thomas)
Integrated Product Design (MSc)

Supervisory board
Chair
Prof. dr. Vink, P.
Professor of Environmental Ergonomics
and Head of Sustainable Design Engineering Department
P.Vink@tudelft.nl

Mentor
Ir. Kroon, C.P.J.M.

Delft University of Technology

Faculty of Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands
www.tudelft.nl

Preface

For the last seven months, I have been working on a project with multiple graduates about the new way of flying. Previously I already worked on another project within the aviation industry for KLM. There I was developing a new way of enjoying the time before flying and making the journey a part of the actual holiday. This resulted in the new KLM Crown Lounge at Schiphol Airport, which is currently the biggest lounge in Europe.

In this project, I changed from a solution on land to a solution in the air by designing the new way of stowing hand luggage in the newly designed Flying-V.

To design something for people so that their experience goes from good to very good, I find a great challenge from which I also draw a lot of energy. And hopefully, in the coming years, I may see a design of mine in an airplane or in a subsequent study into a better experience in the air.

I want to express my sincere gratitude to some people and mostly my supervisory board for guiding me through experience.

Thank you, Peter, for your enthusiasm and for opening doors for me through experts and fellow aviation enthusiasts. Special gratitude to Caroline for keeping me on the right track when I was wandering around in the big pile of research and the so many things I would like to change and build for the Flying-V. For honesty and getting me back to earth when I was sorting out and solve things again that were not always relevant to my thesis. And both for the critical look at the wording of my thesis, so that others also understand what I have been doing in the recent months.

Special thanks to Jan Verbeek from ADSE, who made a lot of time to help me understand the importance of good design were thought about the laws and regulations within the aviation industry and helped validate the possibilities of the different concepts during my process.

Also to Thomas Rotte, Mark Broekhans, Roelof Lammers, and everyone from KLM, Safran, and TU Delft that was supporting this project and helped me achieving this final result by offering their time and expertise again and again.

The PMB employees at the faculty who had all the time of the world during COVID-19 and helped me with testing and prototyping. Lies, who had to read my report multiple times and was correcting my English writing.

Not to forget my friends and family who supported me during this project, and were a listing ear to my problems and solutions, and helped me focus on the empty faculty during COVID-19.

Glossary

Fuselage: body of the airplane

PASSME: Personalised Airport Systems for Seamless Mobility and Experience

IDE: Industrial Design Engineering

IPD: Integrated Product Design

IATA: International Air Transport Association

RFID: Radio-frequency identification

AR: Augmented reality

Executive summery

The Flying-V in itself is an excellent project to view in which an extraordinary collaboration between different faculties of Delft University of Technology and companies work closely together.
This project's beauty is that through innovations, we can start a new way of flying with a white canvas.

This project focuses on how passengers, cabin crew and other stakeholders deal with the significant hand luggage problem. Because of the many possibilities due to the Flying-V's new design and because there is nothing fixed within the interior, there are enough possibilities to solve this problem and increase the Flying-V's experience.

This report consists of different phases, from research to a final integrated product. During the process, research was carried out into how hand luggage is currently handled. Researching the market trends and opportunities to improve this part of the journey. This will lead to creative sessions with stakeholders, experts, and interested parties to gain insight into the aviation industry's world. The research phase led to an ideation phase with a lot of ideas to final concept directions. All this weighed up to the best possible solution was decisive for one concept. After testing and further development, this has led to a final product where 'fast and comfortable hand luggage stowage unites'.

CONTENT

PREFACE PAGE 05

EXECUTIVE SUMMARY PAGE 07

PROJECT INTRODUCTION PAGE 11

1.1 Flying-V introduction
1.2 Assignment
1.3 Approach

RESEARCH & ANALYSIS PAGE 19

2.1 Flying-V
2.2 PASSME
2.3 Journey map
2.4 Literature
2.5 Concluding research

FOCUS PAGE 31

3.1 Questionnaire
3.2 Vision
3.3 Design goal

DEVELOPMENT PAGE 39

4.1 Approach
4.2 Creative session
4.3 Concept directions
4.4 Synthesis
4.5 Concept evaluation

FINAL DESIGN PAGE 49

5.1 Overall design
5.2 Odd-sized luggage
5.3 The use
5.4 Mechanisms
5.5 Ergonomics and dimensions
5.6 Materials

EVALUATION PAGE 67

6.1 Evaluation

CONCLUSION PAGE 71

7.1 Conclusion
7.2 Recommendations & Limitations
7.3 Reflection

REFERENCES PAGE 79

APPENDIX PAGE 83

01. PROJECT INTRODUCTION

This graduation assignment leads to a comfortable hand luggage storage system, which increases efficiency in boarding in the Flying V.

The Flying-V is a new airplane where the TU Delft and other companies are working together to create the airplane of the future. It will use 20% less fuel by its form than the current most efficient airplane through its design. Because of this design, the interior is changing as well, which creates new problems and ideas for the new future.

1.1 Flying-V introduction

Together, the faculties of Industrial Design Engineering and Aerospace of the Delft University of Technology, KLM, and Airbus are working on a new long-haul aircraft: the Flying-V (TU Delft, 2020). The Flying-V is a new energy-efficient concept aircraft for long-haul flights. Currently, air transport accounts for around 2% of the 36 billion tonnes of carbon dioxide emissions annually produced by us human beings, so this asks for a new efficient solution. Originally the Flying-V is an idea of TU Berlin student Justus Benad during his thesis project at Airbus Hamburg in 2014; the Flying-V is now further developed at Delft University of Technology and Airbus, in cooperation with KLM.

The aircraft's design integrates the passenger cabin, the cargo hold, and the fuel tanks in its wing structure, resulting in a distinctive v-shape (TU Delft, 2020). The Flying-V is designed as an oval pressurized cabin that allows for efficient structural design, with sufficient design freedom to allow for proper aerodynamic shaping. The preliminary calculations have shown that the aircraft has significantly less drag than a modern widebody aircraft, such as the Airbus A350 or the Boeing 787. Structural calculations have shown that also the structural weight is considerably lower. Based on those studies, the estimation is that the Flying-V consumes 20% less fuel than an Airbus A350 for the same flight."

With approximately the same wingspan as the Airbus A350 - which is 65 meters - the aircraft can use the present-day infrastructure and its gates and runways, increasing the viability by reducing required investments.

The other measurements of the Flying-V are similar to a conventional airplane as an A350. It can hold the same amount of passengers, cargo, and kerosine. Although the Flying-V metrics are identified as a traditional airplane, through aerodynamics advantage, it consumes 20% less fuel.

Next to the development of the Flying-V using traditional kerosene engines, alternative ways of propulsion will be studied in the future like hydrogen or e-kerosene (Vink et al., 2020).

Aircraft interior

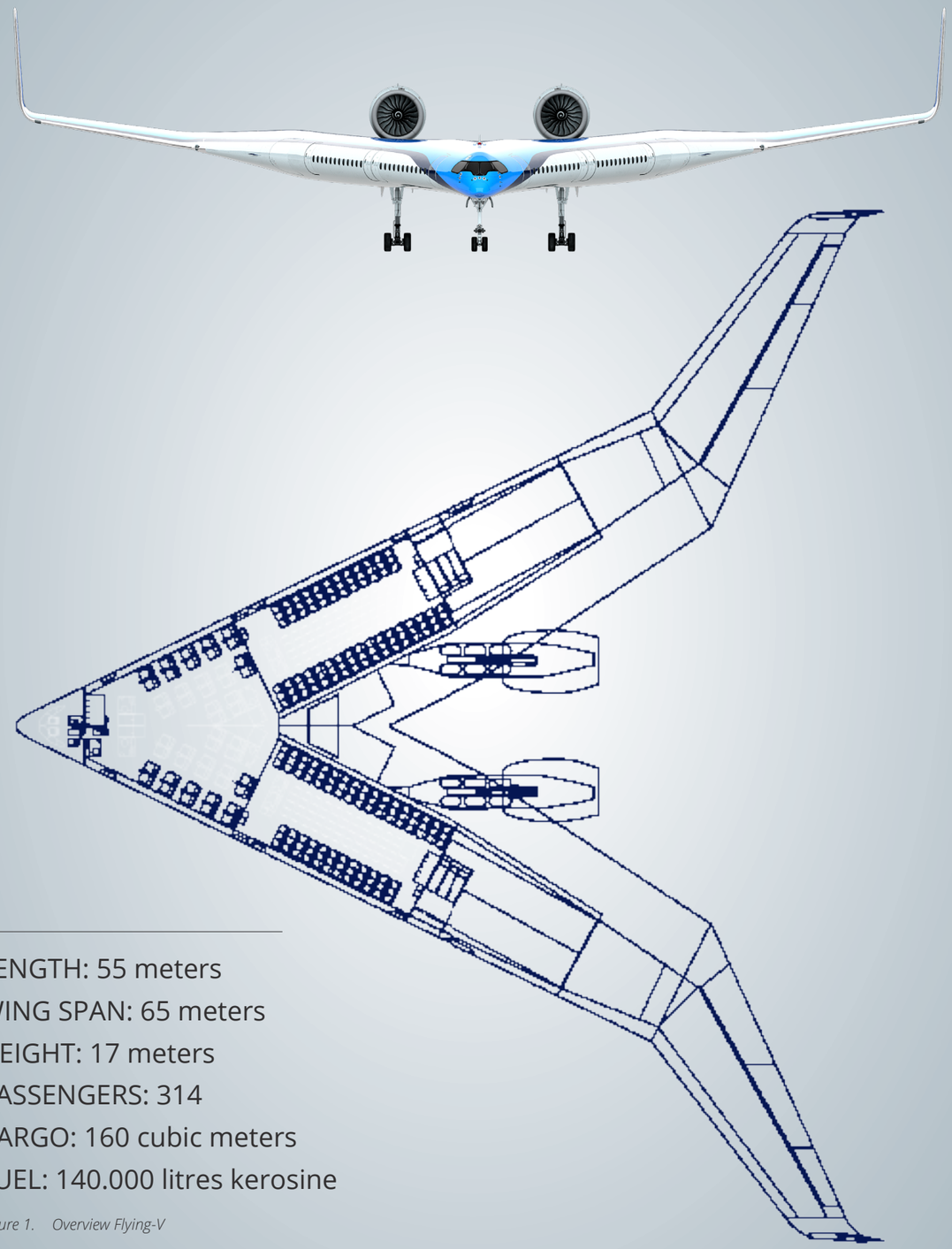
The interior of Flying-V has been fully adapted to sitting inside the wings of this radical new airplane design. It boasts the latest insights into passenger comfort and lightweight material use. The goal of the Flying-V interior concept is to improve passenger experience and at a lower weight. This means that the capacity is still comparable to a current Airbus A350.

Its unique V-shape opens up new possibilities for the aircraft interior. The cabin has an oval-shaped cross-section. This shape would actually deform to a circle when pressurized at high altitudes. In order to prevent this, there will be a frame inside the oval cabin.

Due to this rectangle, it is providing the Flying-V with a width of 6.00 meters and a cabin height of 2.15 meters to design a new interior.

The exterior of Flying-V ensures less fuel consumption by aircraft design. The lightweight construction of the interior will contribute to this as well. For example, the 'normal' seats used in the new model are 4 kg lighter than the typical seats that are currently used on long-haul flights.

The interior concept development is driven by passenger comfort. A new interior has been designed with various seating concepts for different traveling styles in economy class (TU Delft, 2020).



LENGTH: 55 meters
WING SPAN: 65 meters
HEIGHT: 17 meters
PASSENGERS: 314
CARGO: 160 cubic meters
FUEL: 140.000 litres kerosine

Figure 1. Overview Flying-V

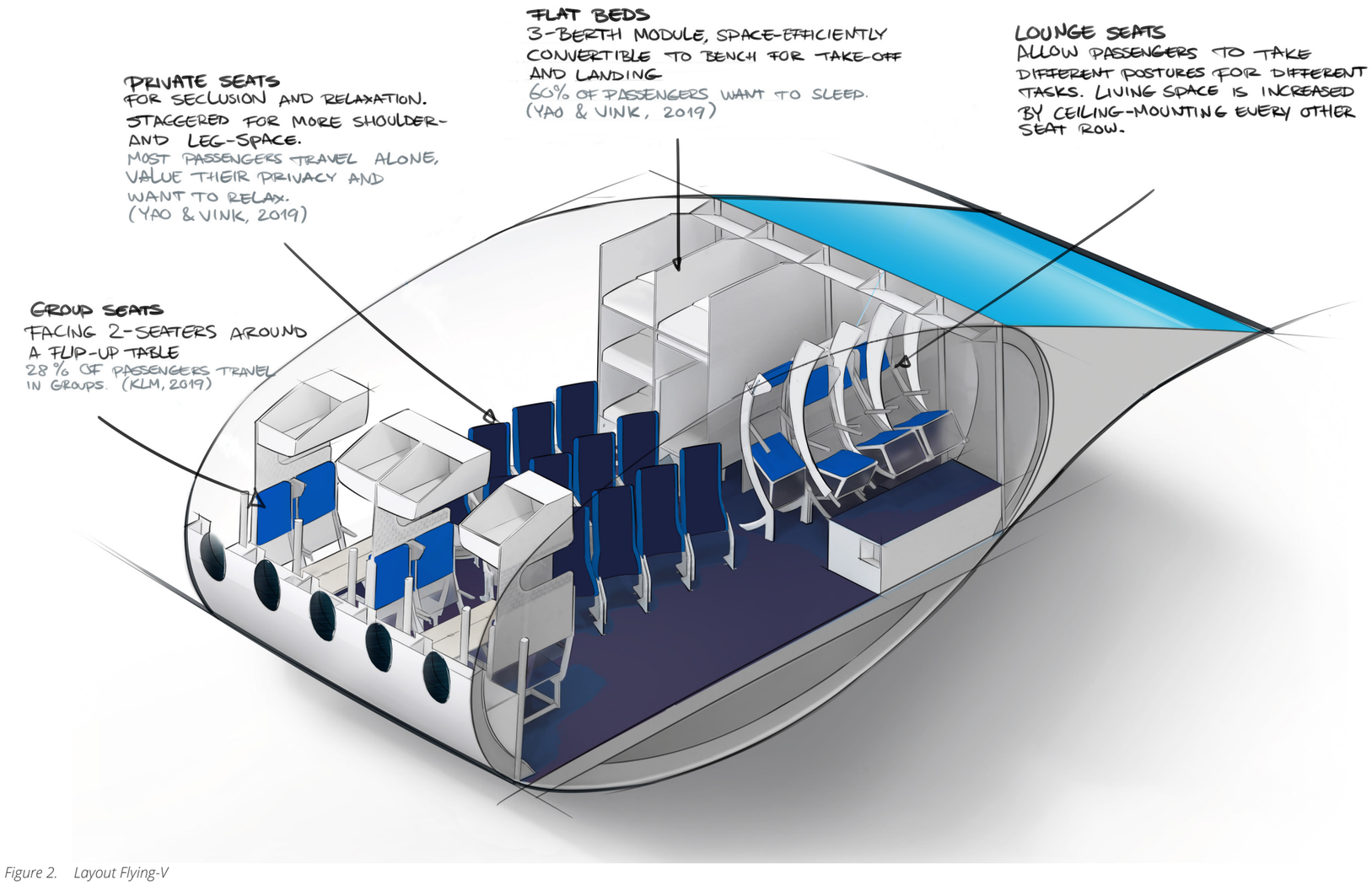


Figure 2. Layout Flying-V

There are currently four different seating options, shown in the figure 2 on this page.

Group seats

Booths of two two-seaters face each other with a table in the middle, so passengers traveling together can sit opposite each other, have conversations, and dine together with a view. Each passenger can also work on his/her own laptop.

Private seats

Rows of staggered seats accommodate passengers traveling alone by increasing the living space, namely shoulder- and leg-space, and sense of seclusion. Due to the cabin's angle to the direction of flight, a fundamental result of the unconventional v-shaped aircraft design, staggering is done by placing each seat in the direction of flight, while keeping seat rows perpendicular to the cabin.

Flatbeds

Research also shows that 60% of passengers want to sleep on long-haul flights - however, they do not want to sleep all 12 flying hours. Therefore, Flying-V's bed concept consists of a three-berth module that can be converted into a three-seater bench for secure upright seating during take-off and landing. A patent is currently pending for this principle.

Lounge seats

In this layout, every other seat row is ceiling-mounted; this does not use up additional space. This type of seat allows passengers to take different postures within the same seat. People can sit upright, for example, for using a laptop, or alternatively use the space of two-seat pitches for lounging or reading.

The seating position that will be the most interesting for this thesis will be the private seating or the staggered seats.

1.1 Assignment

This project aims to improve the way hand luggage will be transported in the new plane. Current solutions may not be ideal for the Flying-V, mainly because of its shape, since all the chairs need to be rotated (staggered) for safety reasons. At the same time, the new shape of the plane creates a lot of possibilities to store the hand luggage and at the same time increase comfort.

The current floorplan of the plane has multiple seating possibilities. The staggered middle section, four-seaters next to the window, sleeping beds, and group areas. So, there is not 1 solution for all the seating positions. And at the same time, the plane will not be on the market before 2040, and a lot of alterations will be done on the structure of the plane. This will have an impact on the interior and therefore the hand luggage positions.

The main goal of this project is to design a new place for the hand luggage of the customer. In a way, it could improves the passenger's comfort but is at the same time the question is whether it is technically feasible and also easy to use for other users within the plane.

I assume the staggered middle section will be in place as it has the highest chance of being realized into the new design of the Flying-V. The possibilities in this section are already endless and need to be reviewed on their feasibility. The design brief can be found in Appendix A1

1.2 Approach

Every design project can be approached differently, due to different interest and result outcomes. Since the direction of this project from the beginning can be considered concrete enough, this project allows for a rather pragmatic approach.

Initially, the plan was that research will be done on what the passengers need in their hand luggage in the new situation in 10-15 years. Also, the possible positions for hand luggage will be researched. This includes storage solutions on current luggage bins and the use of it.

The research phase is quite short because much of the research appeared to be already done in previous studies. My major efforts will focus on user research because I see them as one of the most important stakeholders in this project. There are three stakeholders the passenger, cabin crew, and the aircraft manufacturers. Also, consulting experts, for example, interior builders and trend watchers are important in this process .

In the concept phase, I will explore many hand luggage storage possibilities within the Flying-V. I created a creative session to gain more insights. This could result in building a functional prototype to validate and explore how the user experiences the new design.

In the end, I expect to deliver a complete design that fulfills the passenger's needs and the technical aspects for the use in a plane. This means the design will be tested to see if it fulfills the needs, based on these outcomes the design will be reassessed and, if needed, adjusted. Also, the embodiment of the new design will be worked out, so it fits in the current design of the plane, accompanied by a production plan. An overview of the design plan can be found in figure 3.

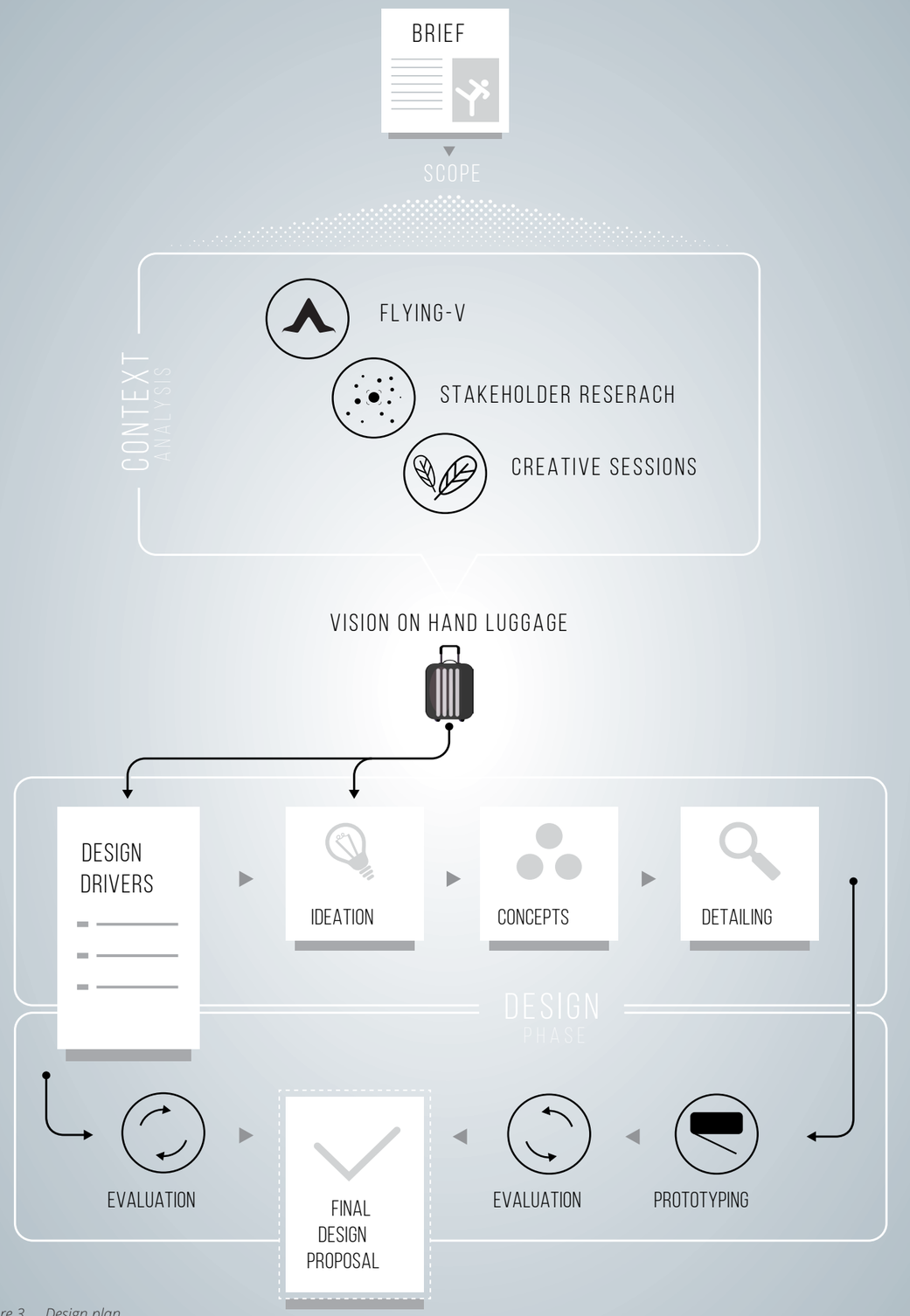


Figure 3. Design plan

02. RESEARCH & ANALYSIS

This chapter provides background information about the Flying-V project and sheds light on another big project that is working on improving the hand luggage problem of today.
Secondly research around the passengers, crew, and previous research performed internally and externally with (potential) clients and other designers.
The findings of this research is synthesized into a framework of all topics in this chapter, which can be used to validate the concept and the final design.

The research and analysis phase aims to get a better understanding of the use of overhead bins and research the possibilities for new solutions for now and in the future. Several research methods have been used in order to obtain the necessary information.

It started with interviews at Schiphol and the TU Delft on the use of hand luggage and current irritations. Which led to a co-creation with different customers and KLM cabin crew.

Finally, trend research on potential blockers and interesting findings has been done. This has been done through literature research and questionnaires

2.1 Flying-V

In October 2019 the first 1:1 scale model of the new Flying-V was introduced. The Flying-V is a design for a highly energy-efficient long-distance airplane. The aircraft's design integrates the passenger cabin, the cargo hold, and the fuel tanks in the wings, creating a its characteristic V-shape. Its improved aerodynamic shape and reduced weight will mean it uses 20% less fuel than the Airbus A350, today's most advanced aircraft with the current propulsion systems.(TU Delft, 2020)

Together with the faculty Aerospace Engineering at TU Delft, KLM, Airbus, and this faculty (Industrial Design Engineering) we are working on this new long haul aircraft. This new interior creates a design challenge. This V-shaped airplane has some difficulties when looking at the seating arrangement and storage of hand luggage. Luggage storage has not yet been designed, but there are multiple possibilities: under the seat of the passenger, above the passenger (overhead bins), in front of the passenger, in the wall, or even at complete other locations in the plane.

2.2 PASSME

People traffic through European airports is rising year-on-year. PASSME aims to reduce door-to-door airport travel time by one hour and improve the travel experience for passengers despite busy airport environments. The project's researchers investigate critical bottlenecks in the airport experience - including luggage, security, boarding, and passenger flow - to develop time-saving solutions that suit passengers' needs.

Some of the project's time-cutting innovations will include improving luggage drop-off and collection; reducing queues at key airport locations; improving communications between airports/airlines and passengers, and developing a PASSME app to make passengers' airport experience seamless and less stressful. The airport environment will also improve for passengers through modern interior design.

The PASSME consortium is composed of partners from seven European countries across the fields of aviation, transport, academia, design, technology, and communications. The project's coordinator is the Department of Industrial Design at the Delft University of Technology.

The overall objective is to reduce travel time by at least 60 minutes by integrating information between all stakeholders and transforming airport and aircraft operations and interiors to make the passenger journey time efficient, seamless, robust and accessible. Reduce stress of passengers by providing personalised information, thereby increasing the quality of the overall experience.

It consists of optimising the flows of hand luggage and goods. They are redesigning elements in the built environment in order to reduce travel time and improve passenger well-being in three airport experiences: Check-in, Security and Boarding. This concerns areas in the airport (e.g. environments around check-in, security, boarding) as well as in the aircraft (e.g. lay-out, luggage bin size and reachability, and seats that facilitate easy ingress/egress) and agents (e.g. check-in booths, boarding desks). (TU Delft, 2020). See figure 4.

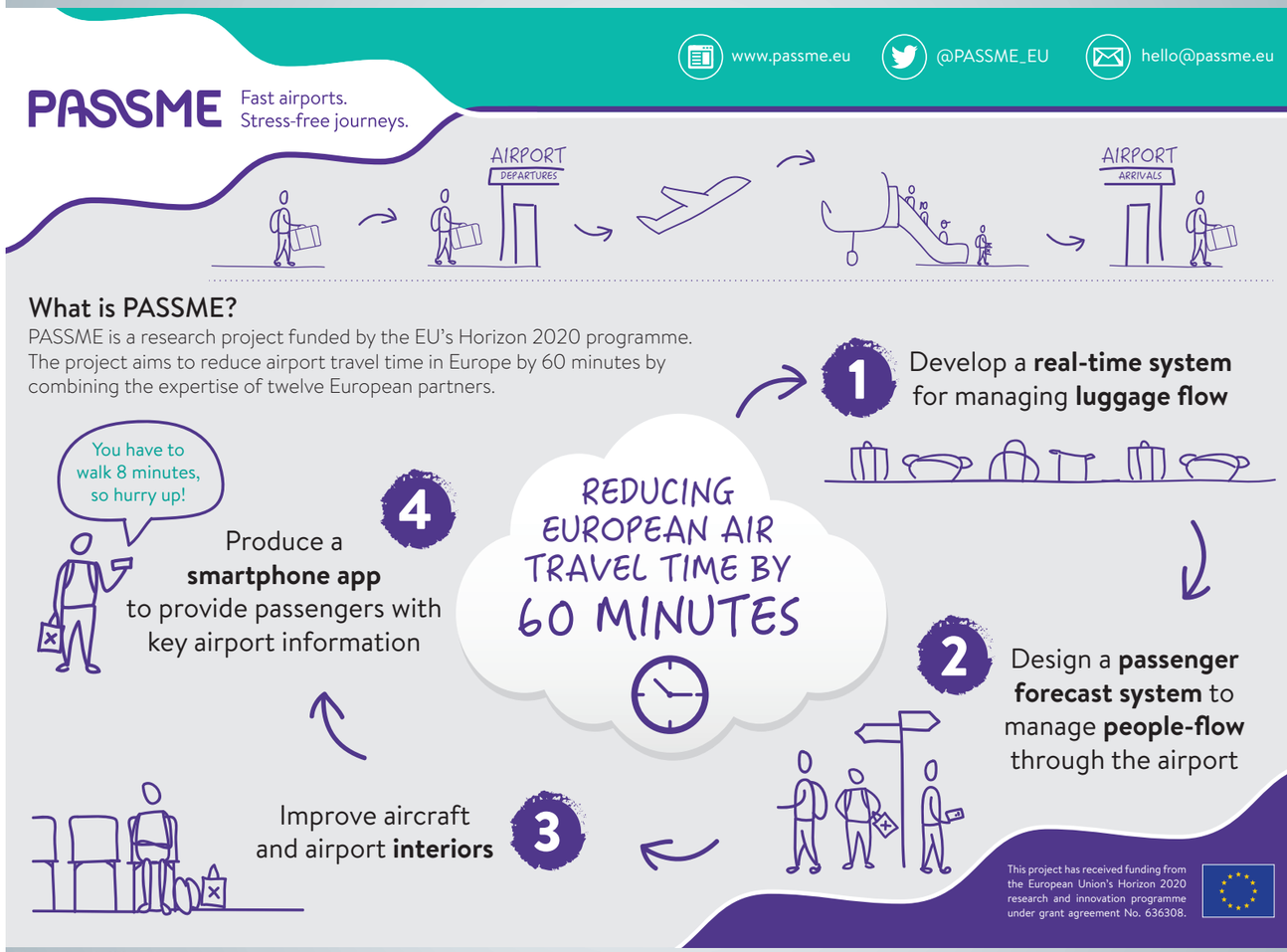


Figure 4. PASSME journey

2.4 Literature

This part gives an overview of relevant existing literature and studies that have to do with hand luggage in an airplane or at an airport. This part is divided into two different parts, literature of previous master theses on topics that are connected to this topic. And on trends that happen within aviation, and trends that have effects on my topic.

Previous Master theses

Before I started on this project there were already multiple other IDE students that wrote their master theses about hand luggage and already came with some solutions. It should be taken into account that these are solutions that can already be implemented in current airplane models. But it creates insights on the behavior of passengers and what the impact is on different alterations of the current situation.

Not all outcomes were relevant. Those that can be applied in the Flying V model will be discussed. Either way, some of it is very useful for the implementation in the Flying-V. These will be discussed hereafter.

Currently, there is not enough overhead bin space in every airplane for all the passengers to stow their hand luggage which they are eligible to bring on board. Xander van der Broek (2015) proposed some recommendations to solve some hand luggage issues and the impact on the passengers.

1. Decrease the amount of hand luggage per passenger, paid options for more hand luggage.

2. Increase voluntarily checked-in hand luggage, so they can check in more bags for free. In exchange, passengers will receive a bag for their personal small items they can keep on them during the flight.

3. Increase involuntarily checked hand luggage, by changing the restrictions for maximum size and amount of bags.

4. Increasing the size of the hand luggage bins so more bags can be stowed.

5. Increase the efficiency of hand luggage stowage through the implementation of new technologies.

These are all ideas to make it al more efficient and lower the delay time for each flight, at the same time it also gives direction for the effects of a new design for hand luggage stowing.

Elise de Kok (2015), studied multiple ideas to decrease the size of the hand luggage in her thesis. Here the final conclusion was a bag scanner that would scan all the hand luggage and would show if the suitcase was too big or not for the specific flight. And if there was still enough space left in the overhead bins. When your suitcase did not have a label for approval to go onboard as hand luggage it still had to be checked-in.

Amandine Marié (2016), studied if it was possible to arrange door to door delivery of your suitcases. This does not really have to do anything with the amount of hand luggage but shows the possibilities and technology-driven solutions for the hand luggage problem. This study concluded that the amount of hand luggage could actually increase since the check-in baggage would be picked-up several days in advance. But since the Flying-V will be expected in 15 to 20 years, technology could be way ahead so this could make sense to implement in the new airplane.

Jeppe Dijker (2016), studied a more passenger-centric solution for the hand luggage problem. Mainly it were solutions for more guidance in advance to traveling for the passengers. One of the more technology-driven solutions could be of interest where the passenger could always track its bags. The passengers than are offered both peace of mind and do not need to wait at the baggage reclaim belts.

Coppens (2018) and Vendel (2018), researched the effects of different boarding patterns and improvements on hand luggage stowing in correlation with customer satisfaction. With their research, they wanted to reduce the boarding time. By implementing a Guided Hand Luggage System passengers have their own personal place in the hand luggage compartment in the overhead bins. This reduces the stress levels in the passengers and the cabin crew and the time people need to find their place and stow their hand luggage. Including better guides to their seats, passengers would be blocking the aisle less often. Since they know their assigned seat better and are sure they can stow their hand luggage above their seats. At the same time, it reduced boarding time with a couple of minutes. An additional outcome was that training or preparation had a positive effect on boarding times. This could indicate that making airplanes more uniform and coach passengers before entering the airplane could affect customer satisfaction.

The research had been done with a small group of participants and needs to be repeated on a bigger scale to establish the precise effects.

Trends

In aviation, multiple trends are going on at the moment. The main driver behind these trends is to make it as comfortable as possible for passengers and, airport and airline staff and make it as safe as possible. On the other hand, the process is desired to be sped up using technology, also securing its functionality for the coming 10 to 20 years.

Last year, almost 25 million bags were mislaid by airlines and airports. This is already a reduction of almost 50% since the year before. Airports and airlines want to decrease this even more because this still accounts for 40 missing bags every minute. That is why IATA (International Air Transport Association) rolled out a new regulation last year, whereas airlines are obliged to track all the items on board. IATA proposes airlines and airports should change so they can provide their passengers with the tracking data as well. This gives the passengers a more ensured feeling about their luggage and could decrease the growing amount of hand luggage in the plane.

Hong Kong is one of the airports where the RFID tags in their baggage labels were introduced as first (RFID Journal, 2009). This provides them with a lot of data which helps them in operational analysis and planning including information for passengers. With good results, other airports will follow since it saves them a lot of money. The loss of luggage can be decreased by almost 99,9% according to the Economic Times (2019). Figure 6.

Figure 5. RFID Tag in labels

At the same time, there are multiple companies working on automated baggage sorting and transportation systems. Like the Airports Evolutions: FLEET by Vanderlande(2019), they claim their product is faster and more reliable than current systems at the airport.

So when hold luggage gets reliable in the coming year, hand luggage can be decreased. So that everybody will have room for the personal belongings that they need during the flight. The result of this adjustment will be proportional change to more hold luggage and pressure on that part of the operation.

The research done by Alberda et al (2015), shows that passengers take many different personal belongings on to the plane. A large amount of it will not be used during the flight, only on the destination. However, they also value their leg space and want to have their belongings close by and easy to reach.

The largest item is the laptop and charger, which is not allowed in the hold luggage due to the battery (Figure 7). At the same time, people want to keep other valuable items closeby.

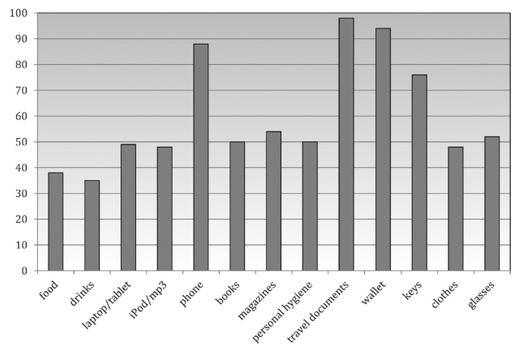


Figure 6. Personal items passengers take with them

In July 2019 Airbus presented their new cabin vision for 2030. They showed their vision on the embodiment of technology in aircrafts. One of the key developments is the seamless integration of the personal cloud of every passenger. All data will be stored in a small wearable device and can be accessed through a screen in the chair. This will eliminate the use of a laptop and other electronic devices during the flight. Which will lead to fewer items needed in the hand luggage of the passengers. (Obsolete by 2030, 2016). This trend can also be deducted by taking a look back in time, where currently the newest smartphones are faster than most of the computers we bought 7 years ago.

Most of the airlines allow every passenger to bring one piece of hand luggage on-board free of charge. In some cases, like at KLM, passengers with a high priority status can bring more than one piece of hand luggage on-board. At the same time, the size of hand luggage that is allowed on-board with different airliners, differ widely.

The policy about the sizes and the number of pieces of hand luggage is changing. At Ryanair, the passenger has to pay for every item they take with them. The hold fee differs when the passenger booked extra luggage online, at the check-in desk, or at the gate, where it gets most expensive.

IATA and some airlines researched and found out that when the hand luggage size will be decreased from 56 x 45 x 25 cm including the wheels and any handles, to the size of 50 x 40 x 20 cm. So that it will be possible for every passenger to bring their hand luggage in almost all the planes and airlines. In figure 8 the percentage of passengers that can bring their hand luggage on board is showed for the fleet of KLM.

IATA assumes that airlines will follow due to the lack of cabin space and delays in flights caused due to the amount of hand luggage people bring. This leads to more checked-in bags at the gate which takes more time than when people do this beforehand at the check-in desks (The Guardian, 2018),(eDreams,2020).

Aircraft type	Number (planned)	Passengers (different classes)	Hand baggage capacity	Percentage	Type code
Boeing 777-300ER	11 (+3)	425 (35C 40Y 350M)	191	45%	77W
Boeing 777-200ER	15	316 (34C 40Y 242M)	142	45%	772
Boeing 747-400	7	408 (35C 36Y 337M)	153	38%	744
Boeing 747-400 Combi	13	268 (35C 36Y 197M)	126	47%	74E
Airbus A350-900	0 (+7)				
Airbus A330-300	5	292 (30C 40Y 222M)	191	65%	333
Airbus A330-200	9	243 (30C 35Y 178M)	155	64%	332
Boeing 787-9	4 (+11)	294 (30C 48Y 216M)	155	53%	789
Boeing 787-10	0 (+6)	338 (38C 36Y 264M)			
Boeing 737-900	5	188 (56C 132M)	102	54%	73J
Boeing 737-800	25	186 (30C 6Y 150M)	70/92/102	55%	73H
Boeing 737-700	18	142 (36C 106M)	70/91/92	65%	73W
Embraer 190	30	100 (100Y)	54	54%	E90
Embraer 175	1 (+16)	88 (88Y)			E75
Fokker 70	15	80 (80Y)	30	38%	F70

Figure 7. Space for each passenger for their hand luggage

Above mentioned hand luggage surplus is already in place with most of the airlines. This means that when airlines are efficiently checking at the check-in desk on the guidelines, the delay will reduce. Mainly because the boarding time is shorter and less hold luggage needs to be moved at the gate.

Transavia announced that if passengers want to be sure that their hand luggage can be stowed in one of the bins they need to pay an extra fee. When they paid this, they get priority boarding and are assured of a spot in one of the overhead bins. They do this is because the overhead bins are overfull. With this measure, they hope to solve this problem and reduce the boarding time and discard delays.

Mobile applications (figure 9) are being developed and applied. The application can inform the user about the rules on the maximum size of the hand luggage, flight information, and directions to their seat in the plane through AR. (KLM AR bagage check, 2020)

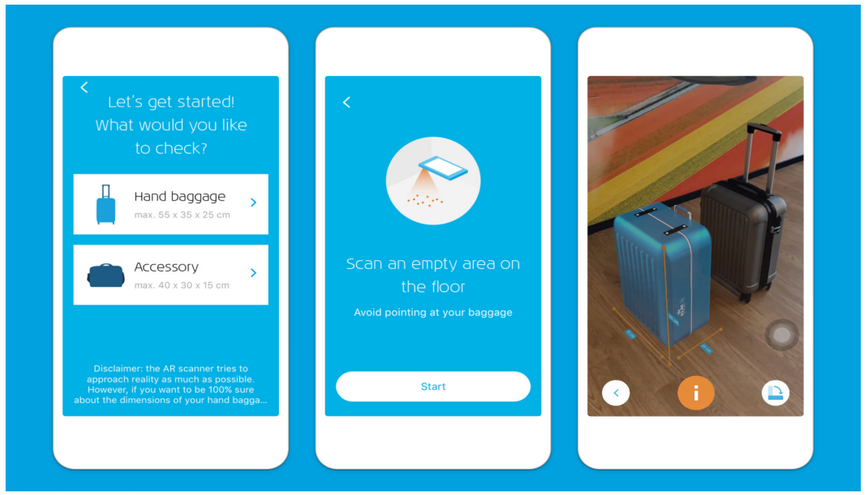


Figure 8. KLM AR solution for hand luggage

2.5 Concluding research

Concluding from the context research and analysis, the following statements have been formed. These statements combine different insights into context factors that give directions on the design of the new solutions for hand luggage stowing.

The above papers, trends, and guidelines make way for finding design directions:

Multiple possibilities for stowing hand luggage in the Flying-V on first sight.

1. Under the seat.
2. Above the seat.
3. In front of the seat.
4. In the wall of the airplane.
5. New places.

PASSME fast airport stress-free journeys to reduce the airport travel time in Europe.

1. Real-time system for luggage flow.
2. Reducing the boarding time.
3. Creating a stress-free journey for the passengers.
4. Improve the interior design of airplanes for passengers through technology.
5. Provide personalized information to the passenger, to create a more positive experience.
6. Redesign of the luggage bin, to create optimized space and reachability

Previous research theses gave directions on how to improve the flight journey for the passengers.

1. Decrease the amount of hand luggage a person.
2. Increase the voluntarily checked-in hand luggage.
3. Change the amount of bags and the maximum size of hand luggage.
4. Increase the size of the hand luggage bins, so all the hand luggage can be bestowed.
5. Use new technologies for efficient hand luggage stowing.

Current trends to improve the hand luggage stowing.

1. RFID techs to decrease anxiety for the passenger, so they can follow their suitcase.
2. Importances of items in the hand luggage of passengers.
3. Luggage size changes so a bigger percentage of hand luggage can be bestowed.
4. Technologies as AR and others to inform the passenger during and before their flight.

The main takeaways are that there will be more technology integrated into planes to make the travel experience more passenger-centric. Passengers get more information on their flight and luggage through technology. Hand luggage size will decrease due to projects like PASSME and door-to-door services, and technological advancement which will replace current devices.

There are a lot of peripheral matters and items that passengers take on board which create design restrictions and challenges.

03. FOCUS

This chapter will be about creating the vision and clear design goal for the ideation phase. All research done throughout the previous phases will be combined to set clear boundaries. Included is a questionaire done with 60 participants. Followed by requirements to create a concept that meets the needs of the stakeholders.

3.1 Questionnaire

In order to gain a renewed insight into the problem from a customer's perspective, a questionnaire and interview were executed. The part was done among students and other relatives between the age of 20-60, and a part was done at Schiphol airport with passengers within the same age group. The total of all the respondents was a group of 60 people. The questionnaire including the result can be found in Appendis A2 & A3.

Multiple questions were asked to indicate what passengers valued the most during a flight and which personal items they wanted to keep close by and the motivation for it. A lot of reasons were given, but three of them stood out. Firstly that 58% of the participants only take hand luggage with them (figure 9). Then 39% of the participants bring both check-in luggage and hand luggage when it is possible. In their hand luggage are mostly convenient items, like travel documents, books, headphones, and valuable items. The main reason for the 58% that travels with only hand luggage is that they want to access their belongings at all times, keep valuable belongings close to them, and don't want to lose their suitcase.

The statements from above contradict the question asked earlier in the questionnaire which stated how often they need to access their hand luggage during the flight (figure 10). 77,7% of the respondents do not need their hand luggage more than twice during the flight. The side note is that the participants which answered twice during the flight also mentioned, that is was to grab their headphones or book and stow it back again during landing. 11% of the participants never needed their hand luggage during the flight.

This is an important insight because it means that in general passengers pack more items in their hand luggage than they might need during the flight. The reason most of the time is that they have room left in the suitcase that is permitted to bring as hand luggage.

When asked if the participants would mind if the hand luggage size would be decreased, or that they could not bring that much onboard anymore. The greater majority of 69% answered that this would not be tolerated (figure 11).

If airlines are minimizing the maximum capacity of allowed hand luggage, passengers firstly will not be happy. In order to reduce the amount of hand luggage, other systems need to be improved. For instance the accessibility of the overhead bins, clear rules that apply to all the airlines, and insight in the checked-in luggage.

An observation from this research was that only 3 out of the 60 participants thought about their jacket and where they want to stow it. All the other participants did not think about their jacket as one of the top 5 items they bring in their hand luggage.

Key takeaways and observations from the questionnaire and the interviews are summarized below.

- Passengers want to be guaranteed of a place for their hand luggage or personal spot in the bin. And closeby their seat so they do not need to disturb other travelers.
- Bigger personal storage space, like pockets in front of the seat or overall bigger storage bins.
- Don't compromise the available leg space over their belongings
- Make the maximum amount of suitcases and the weight becomes less, so everybody can bring their belongings into the plane
- Make the location of the storage facilities more accessible during flights and/or for small people
- Participants want to bring more items or bigger sizes as hand luggage. They don't trust the airports for their luggage handling.
- The majority is overpacking their hand luggage because they still have space left in the suitcase/backpack
- Majority brings extra clothing in their hand luggage
- Only 3 participants thought about bringing jackets as hand luggage and that they need to stow that somewhere as well.

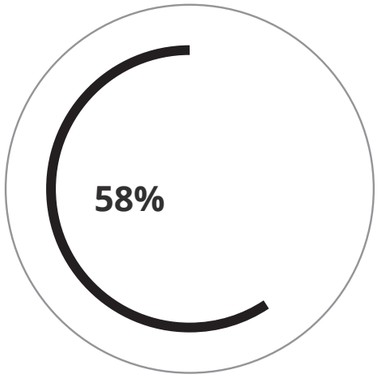


Figure 9. Passenger that only fly with hand luggage

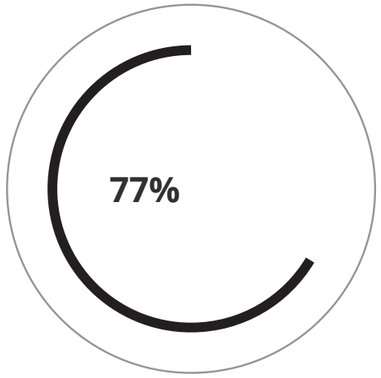


Figure 10. Passenger that only need access to their hand luggage twice during a flight

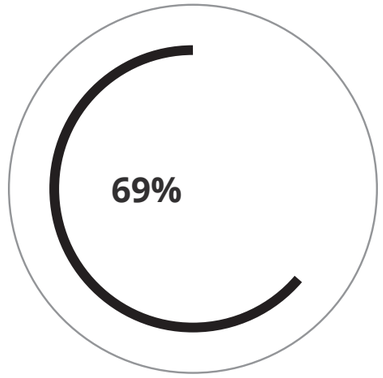


Figure 11. Bin size need to same size or bigger

3.2 Journey map

In order to get a better idea of what the touchpoints are with the hand luggage during the whole journey, a map was made. In the map, all the actions a passenger is going through during its trip are being written. In blue the touchpoints with the hand luggage for the passenger are being indicated. In red is the cabin crew interaction indicated.

As seen in figure 12 below, there are a lot of touchpoints during the whole journey with the hand luggage. Some of them are necessary, but some of them can be simplified since they are now potential blockers during boarding and cruise. Considering the results from the interviews, a lot of the participants preferred to have a personal space for their belongings: closeby, and easy to access.

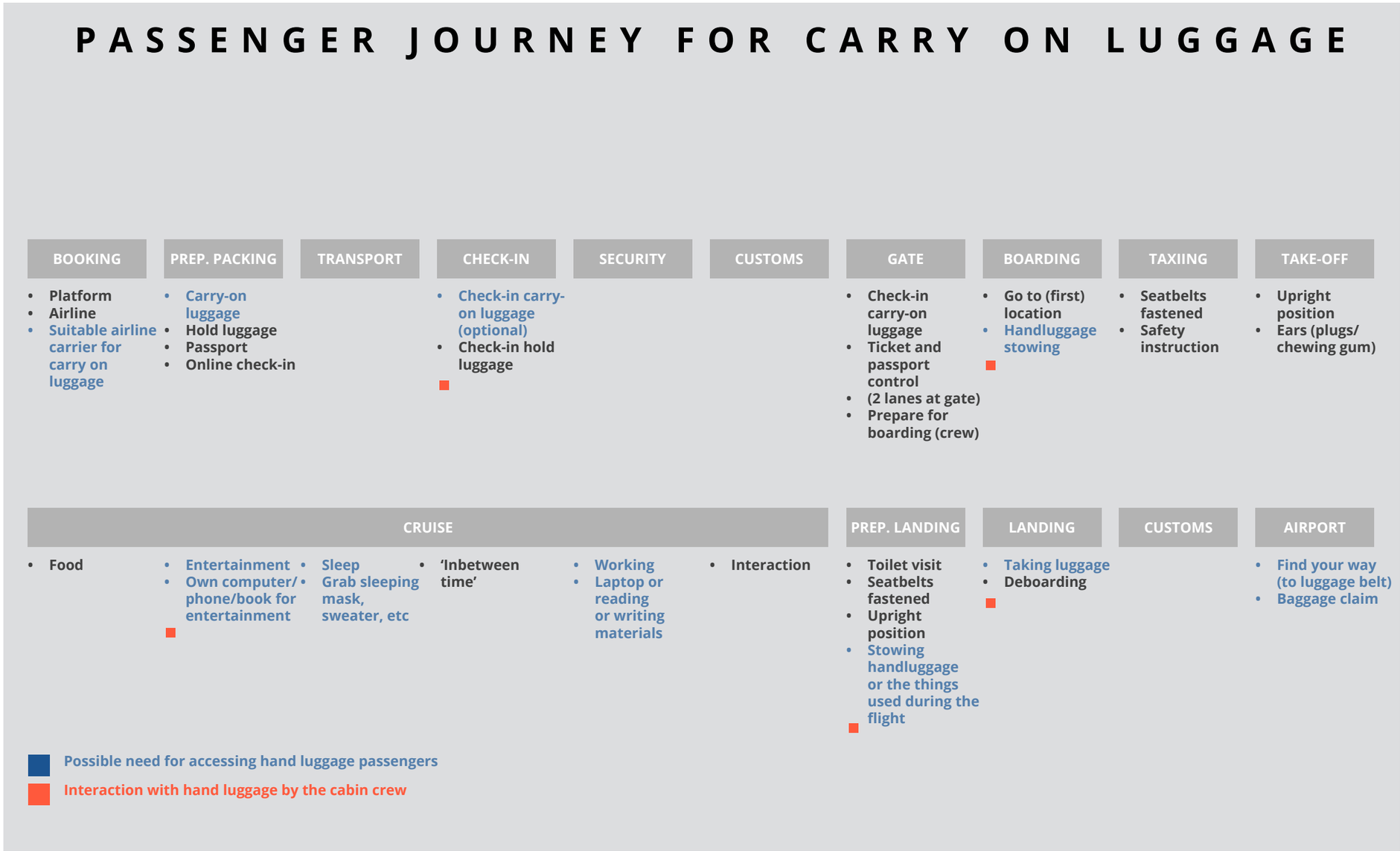


Figure 12. Passenger journey in blue the touch points with hand luggage during a flight

3.3 Vision

Current situation

The current interaction with hand luggage stowing has been analyzed during interviews and the creative session (figure 13). Users of the overhead bins had a lot of comments about the way they function and have been approved over the years. But most comments were negative since that is an overall experience people remember more easily than a normal or good experience.

All interactions were summed up in descriptive adjectives, where some of them are more valuable than others. These adjectives gave insight on how the new interaction should be and contributed to a vision for the hand luggage stowing for the Flying-V.

Desired situation

When looking at the previous undesired proceedings and interactions and at the co-creation sessions and interviews a new desired situation has been created (figure 14). Obtained by these findings the basis for the new design goal was created into a complementary vision.

FULL	TAKES AWAY LEGG SPCE	HANDS FREE
NO PLACE FOR EVERYONE	HEAVY	HARD TO REACH
UNCOMFORTABLE	NOT PERSONAL	INSECURE
WAITING LINES DURING BOARD-ING	SAVELY LOCKED	

Figure 13. Current hand luggage interaction

PERSONAL PLACE	NOT INTERUPT-ING YOUR LEGG SPACE	NOT INTERUPTING OTHERS PEOPLE
ASSURED OF A SPOT FOR YOUR BELONGINGS	GUIDED	SMART TECHNOL-OGY
EXPERIENCE	INTERGRATED WITHIN THE PLANE	EFFICIENT
	TRANSPARENT	

Figure 14. Desired hand luggage interaction

NEW VISION

"THE INTERACTION NEEDS TO GIVE THE USER A FEELING OF SAFETY AND HAVE THEM EXPERIENCE AN IDEA OF FUTURE FLYING. DURING THE JOURNEY, PASSENGERS ARE GIVEN GUIDANCE, ARE BEING INFORMED, AND ASSURED OF THEIR BELONGINGS. THE ACCESSIBILITY SHOULD BE EASY AND AT ANY TIME WITHOUT BOTHERING OTHERS TOO MUCH. "

3.4 Design goal

Concluding from the new vision stated in the previous part, the following principles emerged to create a framework for the design goal for the new solution on stowing hand luggage.

Based on the above-mentioned conclusions, the following design principles emerge. In Appendix A4 is a full list of requirements that support these principles.

Easy & labor-light

For all the stakeholders the ease of use and accessibility are of big importance, so the solution needs to resonate with the passengers, cabin crew, and the builders.

Constructive

To make sure the usage is logical and reasoning behind every design decision. These need to come from the restraints, safety regulations, and research.

Reduces anxiety

Through research passengers, and cabin crew stated that there is fear for losing luggage or having no access to it. So the solutions should give them more certainty and deliver to a more relaxed flying experience.

Revolutionary

The current solution to stow the hand luggage is basic and should give the new Flying-V a more revolutionary feeling in which all the stakeholders are involved.

Sustainable

Currently, overhead bins can be repaired and reused. The materials that are used to build the bins are recyclable. In the new design, this need to be a pillar as well.

Involve & align stakeholders

From the start, the goal was to create a solution in which all stakeholders are satisfied. So it is important that the ownership is felt by all three of them: the passenger, cabin crew, and manufacturer.

Personal interaction

Could it be possible to create a positive and personal interaction with the new solution for hand luggage stowing? Create a place where the belongings of the passengers are save and where they can rely on.

DESIGN GOAL

"TO CREATE A SOLUTION FOR THE LONG-EXISTING HAND LUGGAGE STOWING PROBLEM FOR THE NEWLY DESIGNED FLYING-V. PASSENGERS WILL BE GUIDED THROUGH TECHNOLOGY INTEGRATED AIRCRAFT TO ARRIVE AT THEIR PERSONAL PLACE WITH PERSONAL SPACE FOR THEIR BELONGINGS. PASSENGERS AND CREW WILL FEEL COMFORTABLE IN THE REVOLUTIONARY FLYING-V IN 2040."

04. DEVELOPMENT

This chapter provides an overview of all the steps made during the ideation phase leading towards the concept design.
Initially, the creative session that included the different stakeholders was elaborated. From this, design directions were created which developed into multiple promising ideas. These were in turn tested for feasibility, viability, and desirability. Thus evolving in a concept direction.

4.1 Approach

In the timeline in figure 16 is an overview of the design iterations done in chronicle order. Started with the restated design goal and the design principles. These will be used to test the different ideas created in the following phases. Followed by a creative session with students (in the role of a passenger) and cabin crew. Afterward, the ideas were clustered and new directions were explored to create new ideas with these insights. The ideas were provided with drawings and added to the big pile of ideas. From this, several promising ideas were selected. These were further elaborated and tested with small and some bigger prototypes. Finally, this led to a promising concept which then was tested to the aforementioned principles and the design vision, and requirements.

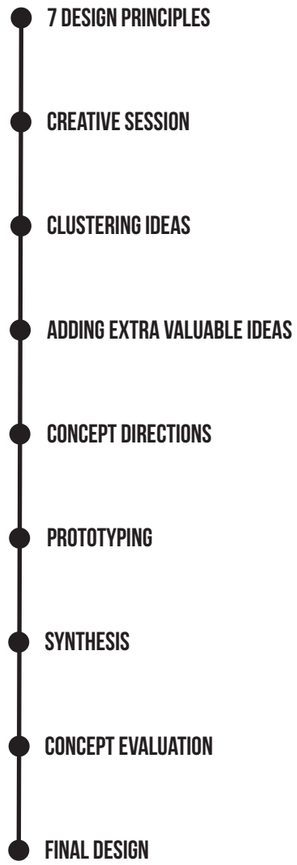


Figure 16. Design timeline

Figure 15. Creative session in the Flying-V mock up

4.2 Creative session

Brainstorm through a co-creation session with users was organize to gain more understanding of the problem and gave me insights. In this case stewardesses (2), students (2), and passengers (2) will be present. During this co-creation with 6 participants, I guided them through a number of design methods. The total creative session lasted 4 hours in which we used methods like how might we (Delft Design Guide, 2020), role-playing, and rapid prototyping. To give the participants the best feeling about the subject I placed them in the model of the Flying-V. In Appendix A5 is the presentation followed by Appendix A6 & A7 with the results and ideas.

It was discussed how hand luggage handling is done at the moment. This is also the reason two stewardesses were invited. They were able to share their perspective on the problems passengers experience. During this discussion, we mainly talked about how we could and should improve the current situation and what bottlenecks are currently present.

When the current obstacles were inventoried, possible solutions were discussed. This created new perspectives on the luggage problem.

The goal was to create ideas on where to place your hand luggage in the new design of the Flying-V. During the session, the design vision, goal, and principles were explained.
DP1: Easy & labor-light
DP2: Constructive
DP3: Reduces anxiety
DP4: Revolutionary
DP5: Sustainable
DP6: Involve & align stakeholders
DP8: Personal interaction

Goal
Generate as many ideas for individual storage solutions for hand luggage as possible.

Method
The session was focused to place everybody in the role of a passenger and secondly as being a cabin crew member. Before the design vision, goals and principles were explained. Then the new idea and design of the Flying-V were explained and they took place in the 1:1 model of the Flying-V. Here, they were asked to come up with as many ideas as possible and combine different ideas in an attempt of creating feasible solutions. This led to a diverging session with a lot of ideas.

I used the planning learned during the course of Creative Facilitation with different techniques provided by the book of Creative Facilitation (Tassoul, 2012).

Key takeaways from this creative session
Cabin crew likes to see that the size and weight of the hand luggage reduced and that there are central regulations for this.

The new idea of a new type of luggage, in-between hand luggage. Personal belongings that we need right before the flight / when landed. But are useless during the flight. Passengers are content with handing this over at the gate or when entering the plane to be stowed away somewhere else. (e.g. a locker or depot at the entrance).

Multiple bottlenecks; e.g. coats, cameras, items passengers want to use directly when arrived at the destination (toothbrush).

When removing the windows there are more possibilities for stowing hand luggage.

Technology can create new possibilities to access the hand luggage.

Odd size items and extra hand luggage (duty-free and children seats) causing irritations with other passengers because they take more space in the overhead bins.

4.3 Concept directions

After the creative session, I continued and added more ideas and tested some of them through rapid prototyping. Thereafter this created four concept directions (figure 17).

After collecting all the different ideas and directions, they were compared with each other and the outlines created in the previous phases. All of them were clustered into five feasible ideas. In order to check if they were feasible five of them were further explored and tested through prototyping. For these concepts directions, some values were leading:

- Q1: Does the concept give the passenger their personal space, and which is the best usable?
- Q2: Does it involve the different stakeholders?
- Q3: Is it easily accessible and labor-light?
- Q4: Is it better than the current solution for hand luggage stowing?

Besides these values, the requirements (Appendix A4) are taken into account as well in order to check if the concepts will pass these as well.

As stated in the beginning the concepts are focused only on the staggered seat in the middle of the Flying-V since this is currently the only configurations that we are sure of that will be realized.

Explanations of the five concept directions follow on the next page. The different concept directions are derived from different ideas during the research and ideation phases. The concepts are designed to make efficient use of the new space created in the Flying-V through the overall shape of the airplane.

In order to evaluate the five directions by these values and requirements, a model has been created. The evaluation can be found in paragraph 4.4.

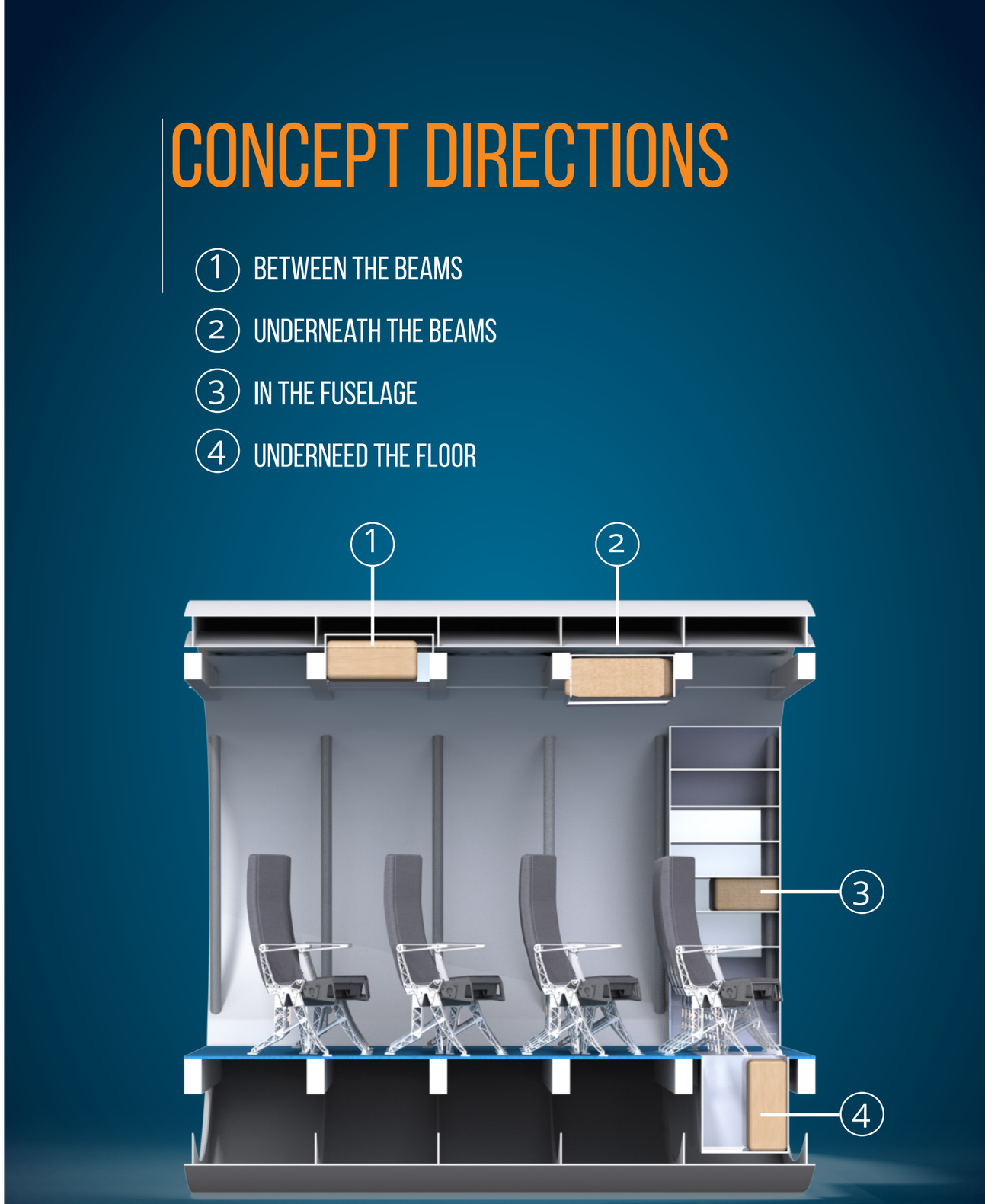


Figure 17. Cross section of the Flying-V with concept directions

Figure 18. Concept 1: hand luggage space underneath the floor

1

In this concept, I made use of the space underneath the floor and the seats, since this space will not be used in the new configuration for stowing luggage as in current airplanes. This way, all passengers have their own space and can access it will be seated.

There is a lot of space so the orientation of the suitcase can be decided by the user. At the same time, there is no consensus on the size of the hand luggage, and the current size can be used.

2

For this design, the same benefits are in place as for the previous concept. Only the seat will be 25 centimeters higher. The advantage of this solution is that there will even be more space underneath the chair, and it can be extended towards the outer rows as well. In this way, it is already possible to implement it in today's aircraft.

Figure 19. Concept 2: hand luggage space underneath the seat

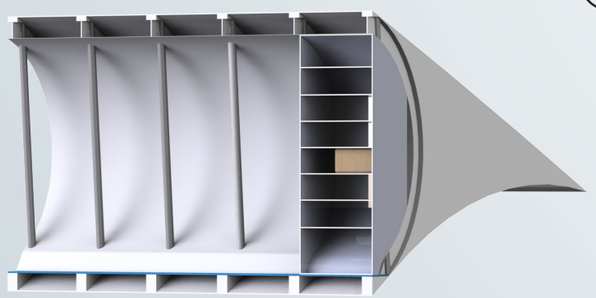


Figure 20. Concept 3: Cabinet within the fuselage

3

This concept uses the space in the areas of the plane where no passengers can be seated. It is in the rounded fuselage, but it can be used as a storage place for six hand luggage suitcases when we place a cabinet in it. It will not hold enough space for all the passengers, so this concept will be better as an addition to another idea.

It might also serve as a place for coats and other odd size items and duty-free shopping.

4

The fourth concept, the storage space, is more in a conventional way above the seat. The difference is that every user has its overhead bin with its own lit. The orientation differs as well. It is in the same direction as the seats instead of the alleys. One of the main advantages is that everybody goes directly to their seat. So the boarding time can be reduced since there is no need anymore for queuing in the alleys.

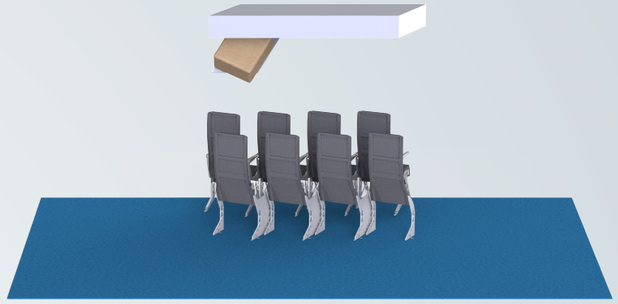


Figure 21. Concept 4: Overhead bin in same direction of the seat

5

This concept is a variation of the previous concept. In this concept, the bins are in the perpendicular to the beams of the structure of the plane. It is a more simplified concept than the previous concept number four since there are no sharp angles. Thus, the space available for the passenger can be used more optimal then with sharp corners. The benefits of the previous concept apply to this concept as well. So the personal space above your own seat is accessible from your seat, which leads to no queues in the alleys.

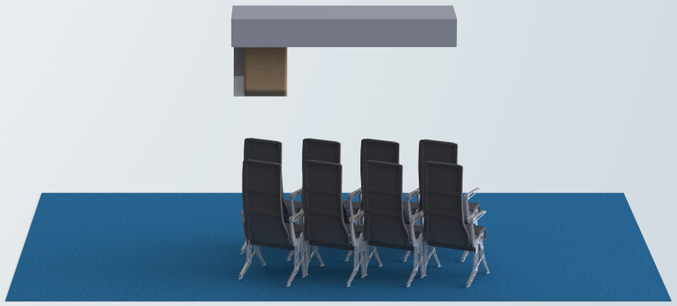


Figure 22. Concept 5: Overhead bin in same direction of the alleys

4.4 Synthesis

The main focus is to create a positive experience for the users and overcome the current problems we have with the current overhead bins.

The concepts were evaluated based on the four values stated earlier. The results are shown in figure 23. It shows the score of each of the concepts on the values that are regarded most important for this phase.

Eventually, a decision had to be made on what concept would be the best feasible and desirable. At the same time through basic testing, one concept was performing better than the others and gave the most opportunities to move forward with. So concept five has been chosen because of the feasibilty of the idea.

This concept has been developt over a period of time to a functional prototype. Further validation and prototype testing can be found in Appendix A8.

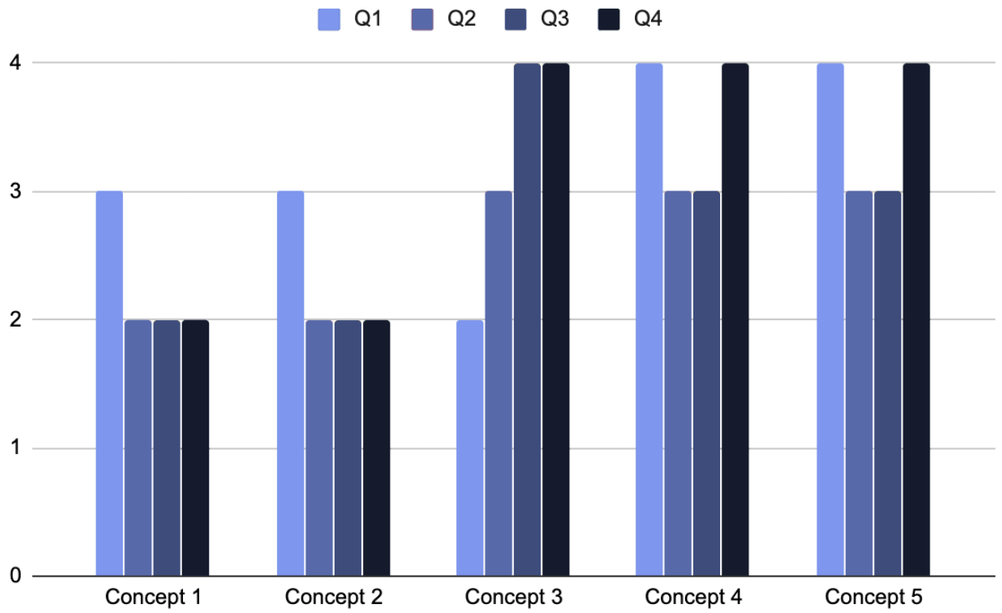


Figure 23. Concept evaluation model

4.5 Concept evaluation

Through some synthesis of the concepts, the lasts steps were taken towards the final concept. This concept was shown to experts in certification, specification, development, and qualification (ADSE). And tested with students at the TU Delft that were available at the university due to the COVID-19 virus.

The design principles stated in paragraph 3.3 were used to evaluate this concept wether to be better than the current solution.

Overall conclusion

Positive remarks were given on the overall design and user centralized solutions. The way in which the cabin has been thought in terms of flexibility and possible adjustments of the seats was also good, which makes this design good to work with for all other stakeholders.

Some concerns were expressed on several safety regulations.

Figure 24. Chosen concept direction

Improvement and added requirements

The following concerns are expressed regarding the design of the bin:

- What will be the weight of all individual bins combined, and is it a possibility to combine personal bins to make it accessible for a whole row?
- The tradeoff between other planes (e.g. A350)
- If the hinges are electric, what will be the extra weight? And what are the benefits
- Small items can fall out when opening, is there another solution for?
- Finger trapping of the user when using.
- Ease of searching the bins (e.g. no possibilities of hiding explosives).
- Air masks need to deploy above the head of the passengers, is it possible to fit this in?

One thing that I personally thought that would be a problem was air ventilation. But this is already better in the new aircraft and it is so small, ADSE saw no problems in this. These can easily be placed somewhere in between since there is still enough space around the bins for this.

These improvement points led to some adjustments and changed calculations on the final design.

05. FINAL DESIGN

The final design is based on a series of iterations, redesigns, details, and research which will be explained in the upcoming chapters.

5.1 Overall design

The position of this hand luggage system is best out a series tested. The different concepts consist of different directions and places throughout the plane. All concepts had different directions and locations which had their upsides and downsides. At a certain point, this design had the best starting position and the most potential. Solving most of the complaints on the current bins and meeting most of the demands and desires stated.

There are many advantages to this new system. The PASSME project showed that boarding is slow because passengers put their hand luggage in the overhead bin while standing in the aisle. In this new system, the hand luggage can be placed in the overhead bin while standing between the seats keeping the aisle free. So this will result in shorter boarding times since the passengers do not need to stand in the aisle to load their suitcase.

From previous research, 90% of the participants during the questionnaire preferred to have access to their hand luggage during the flight without bothering other passengers, and have to pass their neighbors. In the new design, it is possible to stand at your own seat and be able to access your own luggage. The new bins are made for two passengers and open directly above their own seats. The bin is divided into two by lighting and the seat number is placed in the bin in order to guide the passenger to use their dedicated part of the bin.

So the passengers are guaranteed their own dedicated space within the aircraft where they can stow their hand luggage. With the side note that this applies as long as they follow the guidelines. But when they do it will be possible to stow the biggest hand luggage suitcase, which is 56x45x25cm(Samsonite, 2020). On top of that, they can place their jacket in there as well.

During the research, a returning topic was the part of being assured that the passenger was able to bring their personal belongings on board and keep them closeby. Knowing that it is possible for your suitcase to be in the lower luggage compartment last minute due to lack of space. It gave many passengers anxiety, which led to that they could not enjoy their trip as part of their holiday. With this design, every passenger is assured of enough space.

All other luxuries the passengers currently have, are included in the new design. For instance, they have control of their own light and air flow. The safety features that are currently in place are still present. So the emergency masks will come down in the same position that they used to according to known specifications.

The new design and system are ergonomically sound in the sense that the dimensions are based on the sizes of humans and measurement guidelines used by interior manufacturers. Detailing can be found in the upcoming chapter.

Figure 25. Final concept render

EXPLODED VIEW

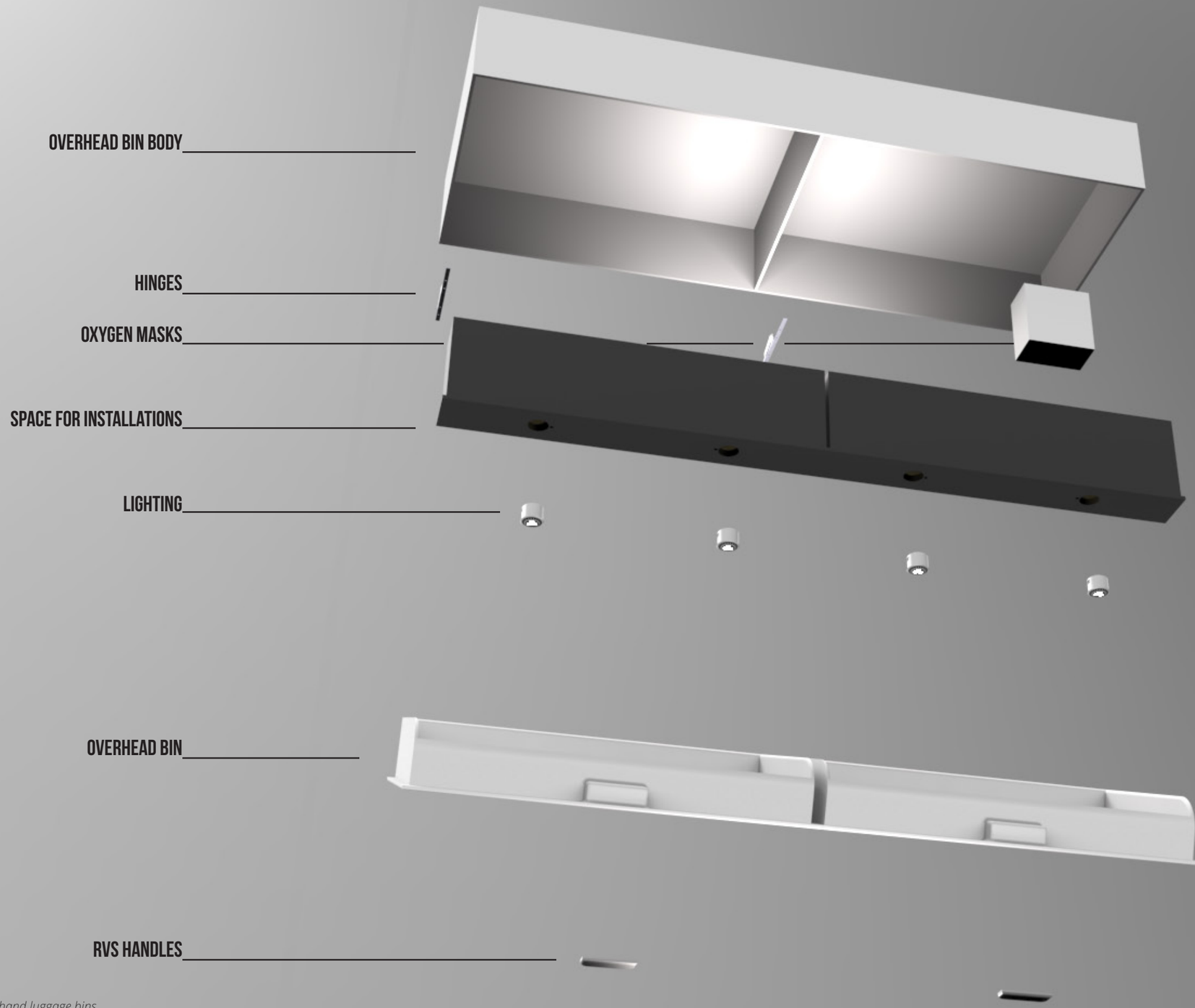


Figure 26. Exploded view hand luggage bins

DETAILS

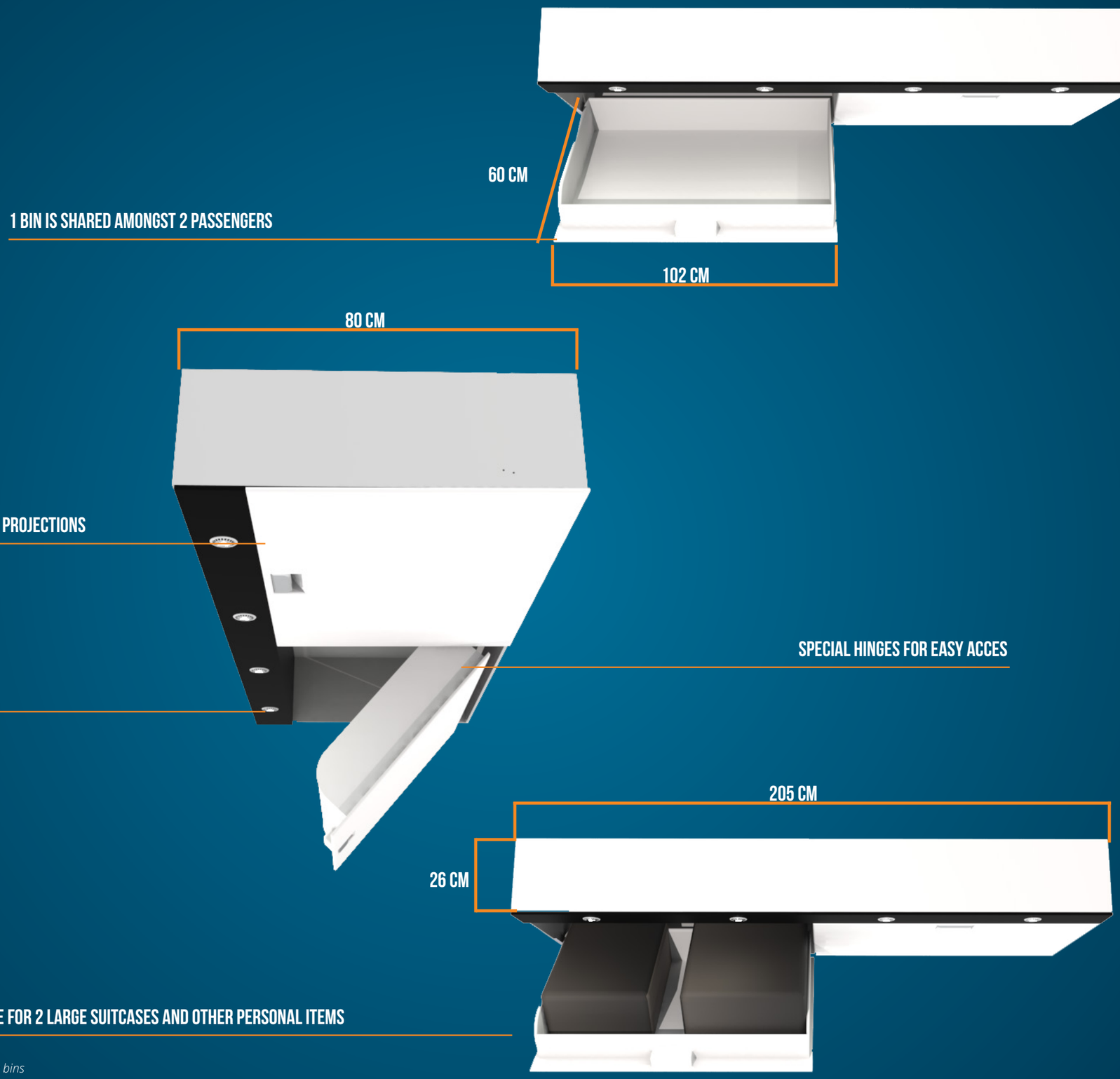


Figure 27. Overall dimensions hand luggage bins

5.2 Odd-sized luggage

During the co-creation session with the cabin crew, an interesting finding was the problem with extreme sized hand luggage or the so-called odd-sized luggage. Think especially of strollers, musical instruments, and duty-free items, these created irritations for passengers and cabin crew. So next to this design, an other idea returned. In the plane, there will be space in closets on the side of the aircraft in unused space currently. It has a multifunctional purpose, on the one hand, for the cabin crew for their hand luggage. On the other hand, for the odd-sized luggage. The idea is that passengers can reserve a spot in one of these closets for an extra amount of money.

Also, for items that may fall out of the overhead bins or are too big, these places will be ideal for this sort of hand luggage.

To create a fitting solution for this, further research needs to be done and see what airlines prefer about the layout of this closet. But it is an excellent addition to the whole design on the current problems cabin crew is facing.

ODD-SIZE

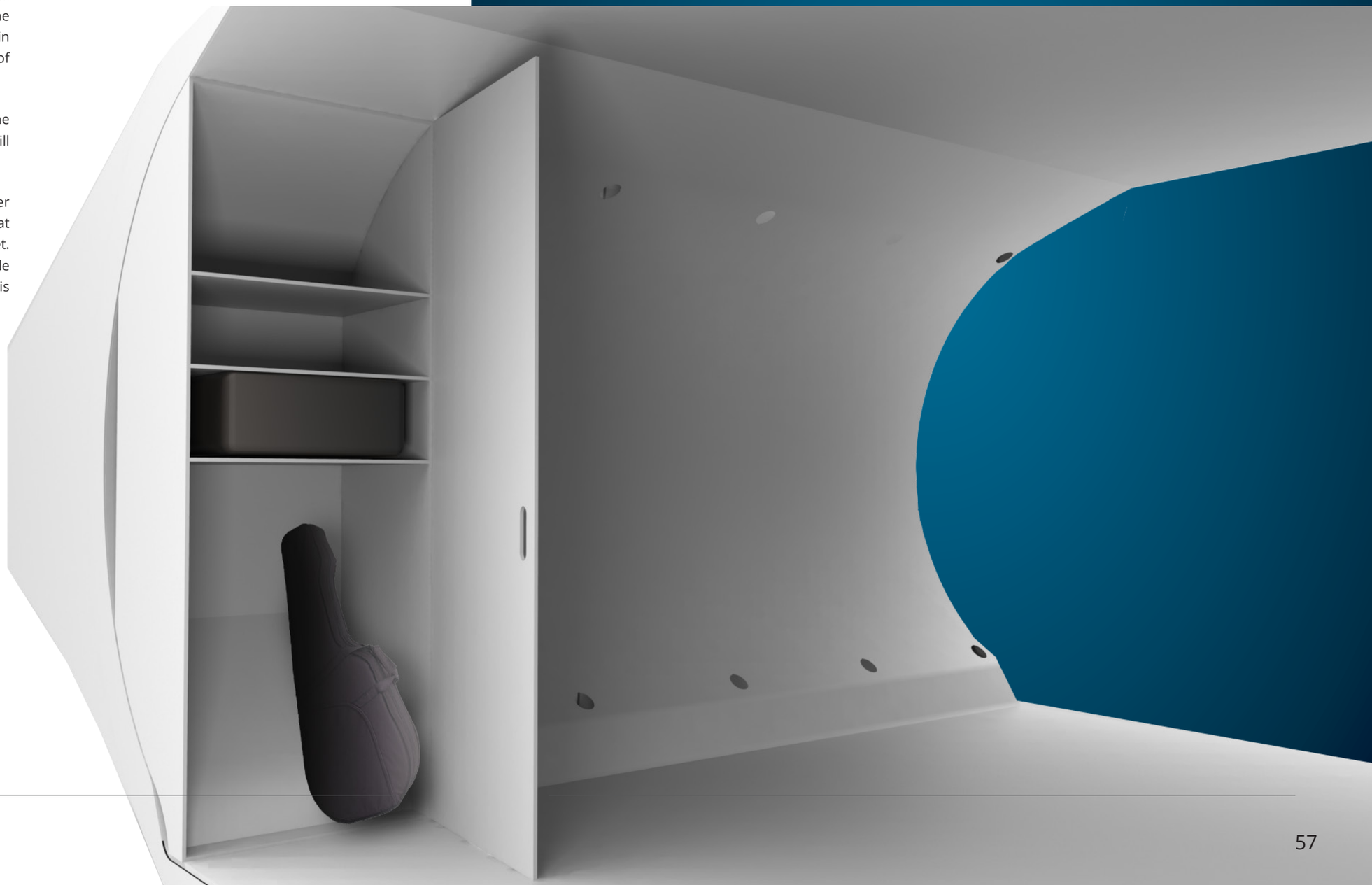


Figure 28. Odd-sized luggage storage solution

5.3 The use

In figure 29 the passenger journey within the Flying-V and the new overhead bins is visualized.

The passenger will walk into the plane as usual and look for his designated spot on his flight ticket.

The passenger will be shown the place in question when entering the aircraft. The place where he can place his hand luggage is indicated by a projection on the luggage bin. Here is the name of the passenger and the seat number projected.

Because the luggage bins are personal, the passenger is assured of a place for their personal belongings. To speed up the flow in the plane, the luggage bins are rotated so that they can easily access them from their own seats. The advantage is that they do not have to stand in the aisle but in front of their own seat and therefore do not hinder other passengers.

The passenger can place his suitcase on his folded seat so that it is easier to lift it in the luggage bin.

The passenger can then easily close it.

The passenger can then sit quietly in place.

If the passenger needs one of his personal items during the flight, he does not have to hinder his immediate passengers or cabin crew because he can simply stand in his own seat and open the luggage bin.

Figure 29. Overall use of the new design within the Flying-V

5.4 Mechanisms

Because the aircraft is currently in a development phase, it may occur that the orientation of the seats could change. In addition, different airlines also have different distances between their seats. Chances are that this will also be the case in the Flying-V. In addition, the clamping distance between the profiles of the ceiling is now placed at 60 centimeters apart. When the aircraft is to be further developed, this distance may change due to material or profile changes. In order to be flexible here, it was decided not to fixate the bins around the profiles, but to mount them on rails. This has the beneficial effect that the bins can be removed more easily during maintenance or other activities.

The rails look-alike the rails used in current aircraft to fix the seats on the floor, but these will be placed on the ceiling.

In the wooden prototype, a normal piano hinge was used. This was used to test the operation of the bins. This will create a different movement for the final design. Different hinges and movements have been investigated. One of the biggest problems that arose was the problem that the case hits the edge of the box when the box is closed, because the turning angle of the case is greater than that of the flap.

Systems that are currently being used in aviation were researched.. However, none solved the problem immediately or gave the desired result. Because of this, other markets were explored for a system that gave the desired movement.

The closest thing to the system is the hinge below that is used to hold books at an angle to the counter.

The hinges that provide the movement of the bin were specially designed for this design. The aim was to create a movement so that the passenger who has to place luggage in the bin could reach it easily. And at the same time that the passenger in the next row of seats had no disturbance when the bin was open. The purpose of this was that the passengers could still move freely when other passengers opened their bin. This required the bin to have a downward and forward motion. This was tested with a wooden system to see if it had the right movement. This was then adapted and incorporated into the final design. Currently they are spring loaded to make it easer to open en close the bin.

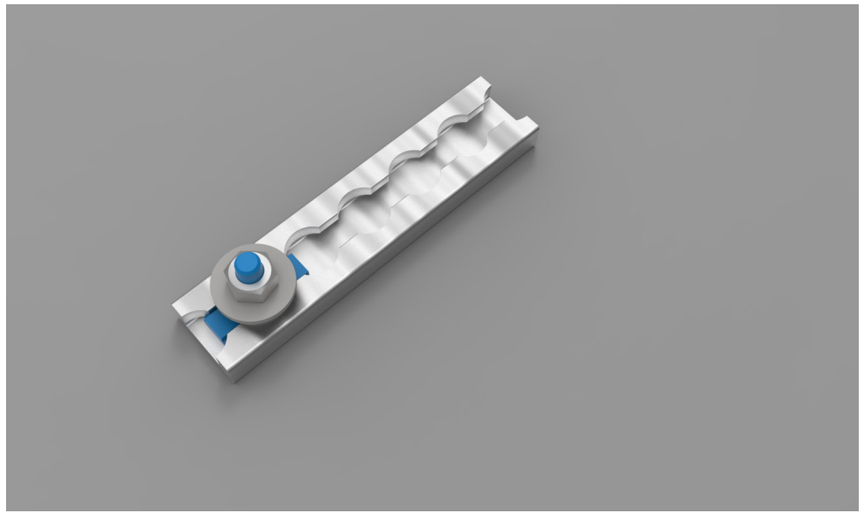


Figure 30. Mounting rails overhead bins to the ceiling

HINGE MOVEMENT

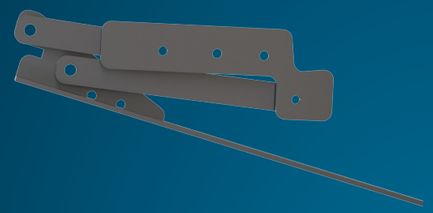


Figure 31. Closed hinge

Figure 32. Open hinge

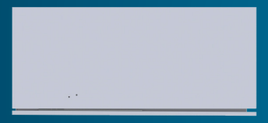


Figure 33. Closed bin

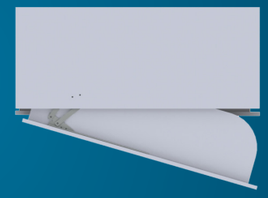


Figure 34. Opening bin

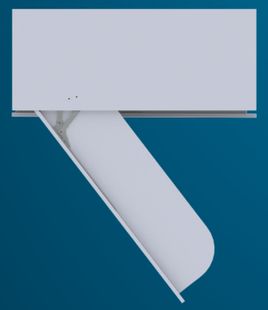


Figure 35. Opened bin

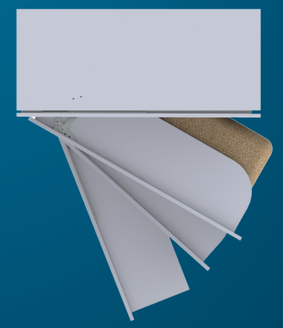


Figure 36. Overview movement opening bin

5.5 Ergonomics & dimensions

Among the new orientation and human measurements in mind, a structural model was designed(Muller, 1997). For the human dimensions, the smallest and largest person in the range should be able to use this design. In other words, the largest (P95) male and smallest (P5) female was used (DINED, 2004). The criteria that matter most are the length when standing so that they can pass underneath when the bins are closed. The passenger's length when they are seated, and the bins are closed so that they have enough headspace during the flight. And the grab height so that they can enter the bins well.

Some dimensions play a critical role in the structural built and are therefore elaborated below and in figure 37.

Other dimensions needed to give the design the best usability are.

- The maximum dimensions of hand luggage
- The maximum space in the plane in the ceiling
- The height of the seat of the chairs
- Installations that are on the plane and also must be built into the ceiling

In the requirements, it was stated that the hand luggage size would decrease to 50 x 40 x 20 cm, due to previous research on the current hand luggage solution. However, there is so much space in this plane and the seats in the current design have a distance between each other 80 cm. Therefore this would mean that there would be a 'gap' between the bins that would be unused, or for installations.

That is why the bin is made as large as possible so that everyone can take their belongings with them. It must fit into the design as a whole and not become too large that usability becomes impossible.

That is why it was decided to use the largest carry-on suitcase on the market with a clearance of 5 centimeter all around. The height of the bin is even 10 centimeters heigher than the suitcase. This has to do with the prefereble ergonomic use of the bin.This allows the passenger to bring normal large carry-on luggage, his jacket, and another carry-on item.

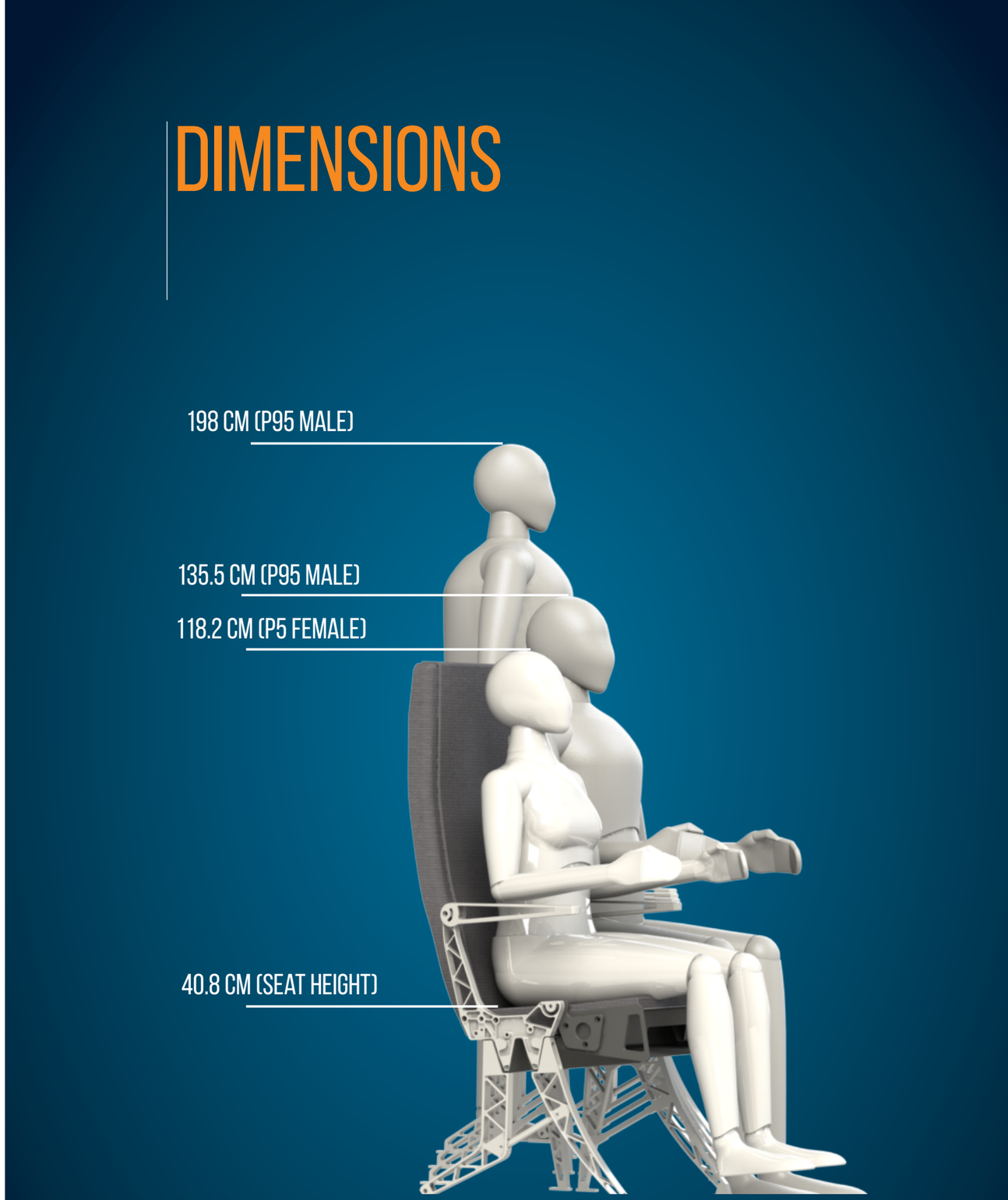


Figure 37. Structural model dimensions P5-P95

5.6 Materials

Weight is significant for building the interior. When a part became heavier, another part needs to be lighter.

The material currently used in the aviation industry is made up of Nomex honeycomb core, of approximately 13mm thick, with a 3 mm cell size structure(figure 38). Usually, the core is faced with one or two skin plies of glass/phenolic prepreg for most ceilings and walls, and glass/epoxy or carbon/epoxy for floor panels, which require higher tensile strength. The complete data-sheet can be found in Appendix A10.

The benefit of this material is that it is easy to produce. More complex shapes, such as luggage bins, can be made from flat pressed panels with simple “cut and fold” methods. A strip of the upper skin is removed to expose the core; the tighter the fold or radius angle, the wider the strip removed. The adhesive is applied to the exposed core, which is not cut, and the panel is simply folded to the desired position and clamped until the adhesive cures. This method is very beneficial because it can be done quickly without complicated tools. The material can be applied with a film of any desired color and texture the airline demands.

Since this is material is specially made for the aviation industry to meet all the demands and requirements of weight, stiffness, and safety regulations. This is, therefore, not interesting for me to search for better material for this concept. So the new concept will be made out of the same Nomex material that they currently do. To check if the design is stiff enough, a FEM analysis has been done (Appendix A11).

To check if the new design is not ten times heavier than the current overhead bins, a comparison has been made between the Flying-V and an Airbus A350 bin. The current bin weights 17,55 kilograms. When applying the NOMEX material on all the bin parts and an aluminum alloy on the hinges, 18,98 kilograms appear. This is a calculated weight through software, but it is a good sign that it does not weight that much more like the current solution.

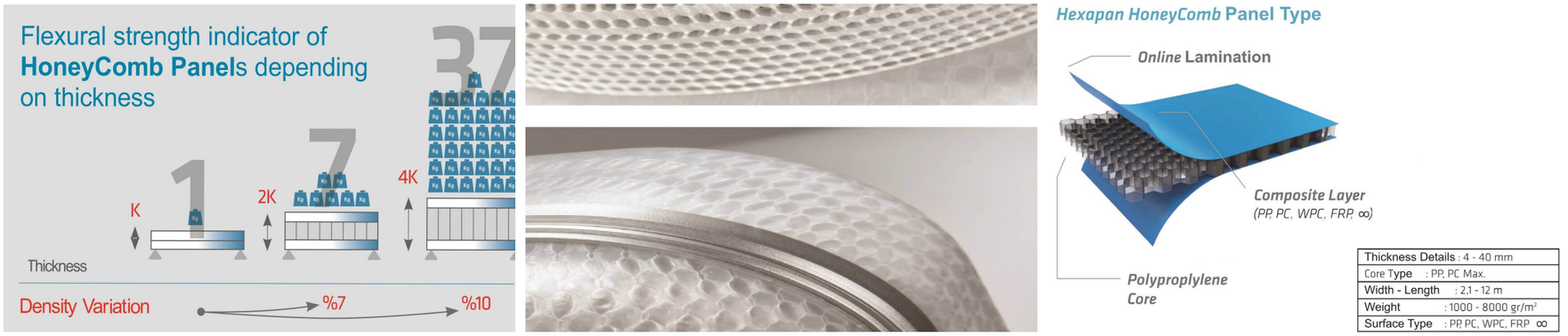


Figure 38. Material aspects NOMEX

The newly designed bins can hold up to four large suitcases. This has been compared with a similar-sized bin which can hold the same amount of hand luggage.

For the smaller parts, like the handles, hinges and the mounting rial are made out of different kinds of aluminum. The choice for these materials has been made because this is what is currently being used. They are light and can hold the forces that are applied during use.

After a FEM analysis on the hinge, it occurred that the displacement with a weight of 50 kilograms would be more than 10 centimeters. A new study was done after adding an extra support strip on the place where the hinge was displacing. This resulted in the maximum displacement of only five millimeters at a weight of 50 kilograms. The results can be found in Appendix A12.

The technology used to project images on the ceiling and the bins is something new, but it is already something some interior manufacturers are using (Collins Aeorspace). It is a nice extra feature to the Flying-V so it stands out. This technology can also help to reduce the stress of the passengers and guide them to their seat.

Figure 39. Overhad bin A350 with a weight of 17,55 kilograms

Figure 40. Overhad bin of the Flying-V with a weight of 18,98 kilograms

Figure 41. Light projections on the ceiling and overhead bins

06. EVALUATION

Evalution on the final design phase, and a check if the design meets the requirements an design principles stated during the project.

6.1 Evaluation

Proof of concept

During the validation and prototype phase, the concept has been proven to achieve a higher level of comfort and solving the design principles stated in paragraph 3.3. Which was also one of the reasons to continue with this concept direction.

Further testing has been done after the detailing phase, in which the concept continued to be further designed. The plan was to build a new full-scale prototype to test with the same group of participants that was used for the creative session. This concluded passengers, students, and cabin crew. Due to the COVID-19 situation, this plan changed a bit and testing of the final design hasn't been done anymore.

Since the main aspects of the concept had already proven to be working as expected. Passengers could access their personal belongings easily and it was their personal storage location.

Further testing was not needed anymore. When the final design is completed, a new testing phase needs to be initiated. But unfortunately, this lays beyond the reach of the project time.

Multiple parts of the design have been tested, which can support the overall working and design of the product.

The hinges

The hinges that provide the movement of the bin were specially designed for this design. The aim was to create a movement so that the passenger who has to place luggage in the bin could reach it easily. And at the same time that the passenger in the next row of seats had no disturbance when the bin was open. The purpose of this was that the passengers could still move freely when other passengers opened their bin. This required the bin to have a downward and forward motion. This was tested with a wooden system to see if it had the right movement. This was then adapted and incorporated into the final design.

The location of the bins relative to the seats.

The rows of chairs are 80 centimeters apart. And a passage of 55 centimeters when the chair is folded up. In the test set-up in the Flying-V, the seats were slid relative to the prototype bin that was attached here. Two subjects of different heights, 187 centimeters, and 165 centimeters, were tested at the circumstances under which the distance between the bin and the chair was best.

The next step to be taken into account was the placement of the oxygen masks. These should fall freely when needed. In addition, the passenger in the position in which he is then seated must be able to easily grab the oxygen mask. This means that he must be able to do this in both the upright sitting position and the reclined position. By simulating this with a rope on the ceiling of the aircraft at the bins, the ideal placement has been found for this.

The easiest is if around the placement of the oxygen masks can also be placed personal lighting and air conditioning. The benefit is that this whole compartment can be built as one integrated installation.

The advantage of these two components is that, as is already happening now, they can be adjusted personally. In addition, in new aircraft, it is almost no longer necessary to provide passengers with personal air conditioning. This has to do with the fact that the cabin temperature control has improved to such an extent that it may expire in the coming years.

In order to check if the new bins are an improvement compared to the currently used bins in an A350, a trade-off has been made. The overall dimensions of the new bins are bigger in volume, so it can contain more personal items per passenger. The new bins are slightly heavier than the current ones. A side note to this part is that there is no locking system in place yet and that the hinges are now spring-loaded. When a full skill test is performed, a decision can be made on if that is sufficient or that the new system is in need of electric hinges, which weight more than spring-loaded ones.

Requirements

Requirements have been set up throughout the process to test the product against these requirements. These consist of the design directions and the overall requirements that the product must meet. In general, the new design meets the requirements set throughout the process. Some requirements have been met, and others are partly or not. Below we will discuss what the requirements were and which therefore need further elaboration and which are not feasible within this design.

Past

- The belongings of the passengers need to be stowed away close by.
- The solution needs to be applicable to the current airplanes as well.
- Accessibility needs to be within reach for the passengers.
- The hand luggage is not allowed to disturb the flight experience for the passengers, it should make their experience better.
- All important belongings need to fit in the new hand luggage solution.
- When changes in regulations are made, it should be easy to adjust the product.
- All different demographic groups and genders should be able to use it.
- Accessible for young and old people (e.g. not heavy or too high), outside of the ergonomic standards.
- Meet the requirements on safety and protocols stated in the aviation industry.
- The solution is designed so it can hold double the weight of the maximum permissible amount.
- Besides the suitcase, it should be able to hold a jacket as well.
- The product needs to be recyclable.
- The product needs to be personalizable for different airlines.
- The product should fit the vision of the new aircraft.

Not tested yet

- Accessibility needs to be better accessible for the cabin crew.
- The new hand luggage bins need to be integrated with smart technology.
- Small items do not fall out when opening.
- The new solution may only be 15% more in weight than the current solution.

07. CONCLUSION

In this chapter the conclusion of the project will be discussed, followed by recommendations and limitations for the project.

7.1 Conclusion

Overall conclusion

The purpose of this project was to explore the new possibilities within the new context of a new layout of a newly designed airplane. At the same time looking into the future since this plane will be finished in 2040 at its first.

The overall project is approached looking at the complete Flying-V not only at the bins itself. This to create a viable, tangible, and feasible vision and mission to create a design that fits the whole picture. Concerning all the different stakeholders within the project, it concluded in an integrated interaction and product.

The main aspect was to reachers the current pain points for the different stakeholders and overcome them in the new design. And at the same time design something that is future proof that meets the vision of the Flying-V.

"To create a solution for the long-existing hand luggage stowing problem for the newly designed Flying-V. Passengers will be guided through technology integrated aircraft to arrive at their personal place with personal space for their belongings. Passengers and crew will feel comfortable in the revolutionary Flying-V in 2040. "

The outcome of the design goal is an integrated product that serves the needs of the stakeholders and fits within the Flying-V. The different elements have been tested with the means at my disposal. Their reactions and feedback were integrated and led to this design for future Flying-V.

Does the new design of the overhead bin pass the three design pillars of Industrial design, Feasibility, desirability, and viability?

Feasibility
Can it be done?

The overall design looks feasible. Some parts need further development and some additional research, for instance, the hinges. But this will be discussed in the recommendation section. The components used to build are similar to the current methods used. The challenging part will be the implementation and integration of technology.

Desirability
Does it address the stakeholders' values and needs?

Passenger: For passengers is this the best solution, they have more space for their personal belongings. They are assured of a place for their belongings closeby and can access it at all times without hindering other passengers or cabin crew.

Cabin crew: For the cabin crew, it is an improvement because the boarding time can be reduced, and passengers are not blocking the alleys anymore when they need to access their hand luggage. A part that is not tested is if they can access the bins easily from the alley.

Manufacturer: For the manufacturer, the changes are doable, if this solution solves the hand luggage problem for the airlines. The bins' connections will be the same for all the different aircraft, so the manufacturing time for the various brackets for the different planes will be decreased.

Viability
Will it survive in a longer-term?

In general, there are not very many changes within aircraft because they often have far-reaching consequences, due to the size of the fleet. So when this design is placed on an airplane, chances are it will stay there for a while. The biggest question is whether it is durable. At first glance, weird materials are not used that are currently not used. The part that may become obsolete over the years is the projection from onto the aircraft's bins and ceilings; this is a new part and has not yet been fully tested within the aircraft industry.

When looking at the desirability of the stakeholders, the viable aspect needs some extra attention, but it will survive.

7.2 Recommendations & Limitations

It is ubiquitous that every project does not go as it should have. And this often has to do with limitations and external influences. Let's start by saying that the aircraft industry is not the most accessible market to design for. This thesis's focus was mainly on the further development of a concept as it stands, and this is also entirely in line with my master's program. Although it would be nice to do the research phase more extensively with a team, a thesis is a project for one person.

The design meets a lot of requirements and wishes that were set during this project. However, several things have not yet been fully worked out. This has to do with several limitations, but this also leads to recommendations for the further and better elaboration of this project.

Limitations

To remove the elephant directly from the room, there have been limitations from the COVID-19 pandemic. This made it impossible to visit companies to see how certain things are produced. As well as having conversations with companies on location, there are technological solutions such as Skype, but these significantly slow down the entire process.

Besides, the possibilities to make prototypes were also limited due to companies' closure and the limited opening of the Technical University. All in all, this has turned out reasonably well after adjustments have been made in the planning.

Unfortunately, testing the final products to arrive at a well-founded conclusion could not be done with the various stakeholders.

Recommendations

There are a number of recommendations to take this project forward

Research

the research part was made concrete too late, so there are several parts within the design that needs more research to complete the whole.

Odd-sized luggage compartment

The storage system for the odd-sized items of luggage has not fully come into its own. This will have to be tested to find out how this should look further and what the cabin crew thinks about this.

Final Prototype testing

The latter concept has not been tested. This has emerged through the validation of the other ideas and testing against the design principles. The latter design can use several iteration steps before it can be put into production. It is, therefore, important that the various stakeholders are involved in this, especially the cabin crew. In addition, no comparison has yet been made between the boarding advantage over an A350. It has been assumed that this will go faster because there is less nuisance in the aisles. The same applies to the usability as it has been tested here with two people of different lengths, and not for a long time with multiple participants.

Hing testing and improving

The hinges developed for this design were created with essential knowledge and rapid testing. They provide the desired effect and are quickly tested for rigidity and other properties they meet. However, the moment a manufacturer can think about this, with more insights into this market. Is there a better product here that also complies with the laws and regulations in this market? They may have already developed a similar product. This part must be further developed before it can be put into production with the knowledge I have. The reason that I did not develop an electrical hinge has to do with the weight of that system. But there might be a solution to make it electric without extra weight incorporation with a locking system and newly designed hinges. But that could be a whole project on its own.

Testing of technology

the idea of the design was to provide it with the necessary technological improvements and applications. However, this has remained a bit in the background because of the completion of the design. Research has been conducted into the possibilities of placing projections on the ceilings to change the overall atmosphere of the aircraft. And personal messages in the bins for the passenger concerned. These are all possibilities that are also possible and feasible within the design. However, its effect is not complete enough.

Passenger and crew testing

I have already mentioned before that testing with the right stakeholders was not possible. This has been the biggest loss, so this should be addressed first.

7.3 Reflection

Introduction

The project had a bit of a slow start. I was still partly working as a manager at a company. Moreover, research is not really my favorite activity within a project. This was also noticeable in the number of studies and papers I read during that period. Therefore, the information I collected during this period was very different and, therefore, did not have a single direction. This was partly due to the fact that I did not have a clear goal in sight.

After a while, a questionnaire and a creative session further, a challenging and clear vision and goal were formulated. This has helped a lot in creating the final end result. And has resulted in a good end product for the new vision that the FLying-V carries.

On personal project principles (Appendix A1)

At the beginning of the project, I formulated some goals for myself that I wanted to work on during this project. Those were about involving the client, including people and stakeholders, in the design using co-creation and testing as much as possible. In the beginning, I think I made a good start in this and showed it during the project. Nevertheless, it did not work out until the end, and I could not continue this until the end of the project. I would have liked to have another creative session with the same composition of participants, and then test the new prototype with them to have a better-substantiated end product.

On learning goals from the project brief

In the project brief, I described some personal goals. Prototyping and user testing is something I like to do. And the plan was also to spend a lot of time on this during this project. However, things have turned out differently due to circumstances. Nevertheless, I am satisfied with how it went in these circumstances. But this remains a point that I want to keep working on in my next projects.

Project planning is something I have had a problem with throughout my studies. However, I can proudly say that things went much better during this project. In the beginning, the planning was global and was not very concrete. But the second part of the project had a clear schedule in which I had weekly goals, which was then neatly divided into days and hours that I could spend on it. When something did not go as planned, this was also adjusted in the planning. This gave me a good overview of the different things that still had to happen and when.

I did work out a design to a viable production plan but could have done better. I think that if I could have made a final prototype, it would probably have come into its own better.

With the visual appeal of the report and design, I am delighted, I once started this stage earlier during a project for a change. This has resulted in a well-kept looking report that is structured. I also owe this partly to Caroline's critical view of legibility.

New challenge

The most significant challenge I have found for myself is to have confidence in my project. I should have closed some things faster and continued with the results I had available at the time. I often spent too long looking for the best solution. This also gave me too little time to develop the final product further and make it appear more convincing.

08. REFERENCES

References

Airbus. (2019, 9 september). Airbus focuses on Connected-Cabin innovations and long-range passenger experience at APEX Expo 2019, Los Angeles USA. https://www.airbus.com/newsroom/press-releases/en/2019/09/airbus-focuses-on-connectedcabin-innovations-and-longrange-passenger-experience-at-apex-expo-2019-los-angeles-usa.html

Alberda, W. (2015, 1 januari). Access improvement to aircraft passengers' hand luggage - IOS Press. Alberda research. https://content.iospress.com/articles/work/wor01829

Bijker, J.. (2016). Hand baggage a passenger-centric approach to decrease the amount of hand baggage | TU Delft Repositories. TU Delft Repository.

Black, S. (2006, 1 november). Advanced materials for aircraft interiors. CompositesWorld. https://www.compositesworld.com/articles/advanced-materials-for-aircraft-interiors

Boeijen, A. van, Daalhuizen, J., Zijlstra, J., Schoor- Rombouts, R. van der., Zijlstra, Y., & Kuntonen, J. (2017). Delft design guide: design methods, Delft University of Technoloy, faculty of industrial design engineering. Amsterdam: BIS Publishers.

Boute, S. (2020, 17 juli). A future baggage reclaim: innovating around the passenger at the A-area | TU Delft Repositories. TU Delft Repository. https://repository.tudelft.nl/islandora/object/uuid%3A5109eeda-ddc6-4fc2-8dca-211a84b9ef34

Broek, v.d. X. (2015). Hand luggage surplus | TU Delft Repositories. TU Delft Repository.

Cabin Interior Monuments - Galleys & Stowages. (2019, 18 juni). AIM Altitude. https://www.aimaltitude.com/products/galleys-and-stowages/stowages-and-partitions/

Coppens, J. (2020, 17 juli). Improving airplane boarding time | TU Delft Repositories. TU Delft Repository. https://repository.tudelft.nl/islandora/object/uuid%3A4effde78-d030-4736-93e5-d4a6096118c3?collection=research

DINED. (2014). DINED. https://dined.io.tudelft.nl/en

Flying-V. (z.d.). TU Delft Flying V. https://www.tudelft.nl/lr/flying-v/

Gedotec Swing Away Springbeslag. (z.d.). Klepbeslag keuken. https://www.amazon.nl/Gedotec-Swing-Away-Springbeslag-opklapbaar-klapbeslag/dp/B00VA6I8GQ/ref=asc_df_B00VA6I8GQ/?tag=nlshogostdde-21&linkCode=df0&hvadid=430549488388&hvpos=&hvnetw=g&hvrand=15189071007187029154&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1010704&hvtargid=pla-699300306150&psc=1

Genter, J. T. (2018, 12 april). Airbus and Lufthansa Have Ideas to Free up Overhead Bins for Passengers. The Points Guy. https://thepointsguy.com/news/airbus-lufthansa-ceiling-stowage-bins/

Harreveld, M. (2019, 3 juni). KLM en TU Delft gaan de Flying-V ontwerpen, een vliegtuig met een opvallende V-vorm. Business Insider Nederland. https://www.businessinsider.nl/klm-tu-delft-flying-v/

Honeycomb Sheet - Bubble Sheet - Polypropylene Panel | Hexapan. (z.d.). Honeycomb NOMEX material. Geraadpleegd 17 juli 2020, van https://www.hexapan.com/?gclid=CjwKCAjwlZf3BRABEiwA8Q0qq-o_3RPkZza3Imhx-NtSc7sJtQ_wJEe_XzAf103ZW2pA44S5rE0JBBoCYOYQAvD_BwE

IATA's Annual Review. (z.d.). IATA Anual report 2019. https://www.iata.org/en/publications/annual-review/

Journal of Air Transport Management | ScienceDirect.com. (z.d.). Journal of air transport management. https://www.sciencedirect.com/journal/journal-of-air-transport-management

Kingsland, P. (2019, 28 mei). Developing autonomous baggage handling tech. Airport Technology. https://www.airport-technology.com/features/autonomous-baggage-handling-vehicles/

KLM. (2018, 6 september). KLM launches Augmented Reality for hand baggage check. KLM launches Augmented Reality for hand baggage check. https://news.klm.com/klm-launches-augmented-reality-for-hand-baggage-check/

Kok, E (2015). Optimisation of KLM's hand luggage checkin process | TU Delft Repositories. TU Delft Repository.

Luggage Bins. (2018, 2 april). General Aerospace. https://www.general-aero.com/en/applications/luggage-bins

Marie, A. (2016). Pickin-up luggage from origin to destination and back | TU Delft Repositories. TU Delft Repository.

P. (2018a, juni 6). New RFID tech could spell end for lost airport baggage. The Economic Times. https://economictimes.indiatimes.com/industry/transportation/airlines-/-aviation/new-rfid-tech-could-spell-end-for-lost-airport-baggage/articleshow/64478553.cms

PASSME. (2018, 19 juli). Innovation and Networks Executive Agency - European Commission. https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/aviation/passme

Pexels pictures. (z.d.). Pexels pictures gallery. https://www.pexels.com

Pull Down Rack Hinges - - Amazon.com. (z.d.). Amazon hinge. https://www.amazon.com/Pull-Down-Rack-Hinges/dp/B00ZGOJJ8E

Samsonite UK address: 1 The Square, Stockley Park, Uxbridge, Middlesex, UB11 1TD. (2020, 17 juli). Samsonite. Samsonite. https://www.samsonite.co.uk/hand-luggage-size-restrictions-dimensions/

Topham, G. (2018, 24 augustus). Ryanair: cabin baggage rule change means small suitcases no longer free. the Guardian. https://www.theguardian.com/business/2018/aug/23/ryanair-introduces-new-restrictions-on-cabin-luggage

Vendel, M. E. (2020, 17 juli). Effects of a hand luggage guiding system on airplane boarding time and passenger experience | TU Delft Repositories. TU Delft Repository. https://repository.tudelft.nl/islandora/object/uuid%3Aa9bf7c35-b0bc-4f2b-9c5b-9f2a3f121994?collection=research

VIU Lighting. (z.d.). Collins Aerospace. https://www.collinsaerospace.com/what-we-do/Commercial-Aviation/Cabin/Lighting/Wash-Lighting/VIU-Lighting

09. APPENDIX

THOMAS HOFS | IPD MSc PROJECT | 4216490