

Appendix

Increasing Perceived Viral Safety in Air Travel

Master thesis

Maciej Zawierucha

Faculty of Industrial Design Engineering

Delft University of Technology

Master Thesis
Delft, April 2021

Maciej Zawierucha
MSc, Integrated Product Design
Delft University of Technology
Faculty of Industrial Design Engineering

Supervisory team

Chair
Prof. Dr. Peter Vink
Department of Environmental Ergonomics
Faculty of Industrial Design Engineering

Mentor
Ir. Wim Schermer
Department of Human-Centered Design
Faculty of Industrial Design Engineering

Company mentor
Luciana Ribeiro Monteiro
Technology Development Analyst
Embraer Netherlands, B.V.

COVR
Increasing Perceived Viral
Safety in Air Travel

Table of contents

Appendix A - Project Brief	6
Appendix B - Data processed from literature research	14
Appendix C - Interview guide	18
Appendix D - Processing interviews - 9 cabin moments	22
Appendix E - Processing interviews - Quirkos analysis report	28
Appendix F - Co-creation session presentation	30
Appendix G - Co-creation session voting sheet	44
Appendix H - Overview of existing concepts	46
Appendix I - Rapid prototyping	54
Appendix J - Harris Profile	58
Appendix K - User test plan	62
Appendix L - Presentation for a product designer	64
Appendix M - Materials and processes inventory	68
Appendix N - Comparison of impacts of iterations 2 and 3	70
Appendix O - EcoAudit report generated with Granta EduPack software	72
Appendix P - EcoDesign strategies for product optimization	84

Appendix A

Project Brief





IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according to the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name	Zawierucha	Your master programme (only select the options that apply to you):
initials	M. given name Maciej	IDE master(s): ☒ IPD ☐ Off ☐ SPD
student number	4859502	2 nd non-IDE master:
street & no.		individual programme: - - (give date of approval)
zipcode & city		honours programme: ☐ Honours Programme Master
country		specialisation / annotation: ☐ Medisign
phone		☐ Tech. in Sustainable Design
email		☐ Entrepreneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	Peter Vink	dept. / section:	HCD/AED
** mentor	Wim Schermer	dept. / section:	HCD/DA
2 nd mentor	Luciana Ribeiro Monteneiro		
	organisation: Embraer Netherlands B.V.		
	city: Amsterdam	country:	The Netherlands

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v.

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

comments (optional)

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30

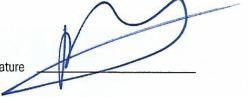
Page 1 of 7



Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Peter Vink date 23-9-2020 signature 

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC ☒ YES all 1st year master courses passed

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC ☐ NO missing 1st year master courses are:

List of electives obtained before the third semester without approval of the BoE

name _____ date - - signature _____

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

Content: ☐ APPROVED ☐ NOT APPROVED

Procedure: ☐ APPROVED ☐ NOT APPROVED

Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?

Is the level of the project challenging enough for a MSc IDE graduating student?

Is the project expected to be doable within 100 working days/20 weeks?

Does the composition of the supervisory team comply with the regulations and fit the assignment?

comments

name _____ date - - signature _____

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30

Initials & Name M. Zawierucha Student number 4859502

Title of Project Increasing passengers' perceived safety in post-pandemic air travel

Page 2 of 7

Appendix A

Project Brief

Personal Project Brief - IDE Master Graduation



Increasing passengers' perceived safety in post-pandemic air travel project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 28 - 09 - 2020 end date 08 - 03 - 2021

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money...), technology, ...).

The COVID-19 pandemic had a huge impact on the aviation industry in 2020. Companies across the entire supply chain faced job cuts and financial difficulties due to a sharp decline in air travel, mainly caused by government restrictions and people being less willing to fly (fig. 1). Air travel facilitates the potential spread of viruses over long distances and should not be encouraged during periods of increased risk of infection. However, as with any mean of mass transport, every effort should be made to reduce these risks when travelling.

This project is in collaboration with Embraer, an international aircraft manufacturer that seeks ways to improve passengers' viral safety in air travel. This is to ensure that its airplane cabins will not only be more resistant to viruses, but also regarded as such by the passengers.

According to the latest knowledge, coronavirus primarily spreads through contact and respiratory droplets (1). This is especially relevant in economy seats class where passengers sit close to each other. A study on COVID-19 concerns shows that the fear of sitting next to an infected person in the plane is the biggest factor discouraging from flying. One-third of the respondents are planning to avoid air travel in the near future as a continued measure (2). This shows that the pandemic is likely to have long-term effects on attitudes towards flying, with an increased need for viral safety measures throughout the journey. By implementing them, aviation companies can ensure better handling of its passengers and make flying more resilient in the future.

Another important aspect is how safe people feel with these measures. Passengers perceive safety differently than aviation specialists, because their decisions are based not only on facts but also on fears (3). Their evaluation is more unpredictable and may differ from what is really effective. This thesis will focus on solutions that will be perceived as safe among passengers, to ensure that a pleasant travel experience is not compromised in the post-pandemic travel.

Embraer is involved in many environmental initiatives such as the DIPAS program, set to reduce fuel consumption, CO2 emissions, the use of harmful materials, etc. in their products (4). To reflect Embraer values, TU Delft's mission, and my personal goals, an important criterion in this project will be the low environmental impact of the chosen concept.

This project will be developed for the Flying V plane concept, which is currently being developed in a collaboration between TU Delft and several aviation-related companies, including Embraer. This new type of plane will use about 20% less fuel than the leading industry plane, Airbus A350, bringing significant cuts in carbon emissions in commercial aviation. The advantage of the V's interior layout is the arrangement of economy seats in diagonal rows, which reduces physical contact of passengers compared to current airplanes (fig.2). This is a good starting point for developing a truly virus-proof plane interior, which will promote Flying V as a resilient and sustainable solution for air travel. For Embraer, the findings from this project may help improving the safety of its current and future products.

To ensure feasibility, the developed concepts will be assessed in terms of the current EASA guidelines for cabin safety and accessibility, as well as ICAO COVID-19 Passenger-Crew and Disinfection guidelines (5).

space available for images / figures on next page

Personal Project Brief - IDE Master Graduation



introduction (continued): space for images

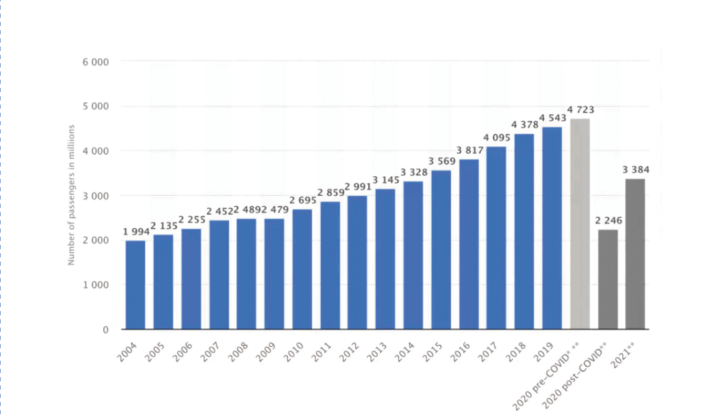


image / figure 1: Number of scheduled passengers boarded by the global airline industry from 2004 to 2021 (6)



image / figure 2: The Staggered Seat in the Flying V interior (7).

Appendix A

Project Brief

Personal Project Brief - IDE Master Graduation



PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

This project focuses on designing aircraft interior element(s) that will reduce the spread of coronavirus and increase the perceived safety among passengers.

The COVID-19 pandemic in 2020 raised many concerns about the viral safety of airplane interiors. People are less willing to fly as they fear sitting next to an infected person. Known issues facilitating the spread of viruses in the cabin is the contact between passengers and the spread of respiratory droplets. Another problem is the sense of safety of passengers, which may differ from what is really effective and can have a big impact on the well-being during the trip.

For this, the perception of safety will be researched. Concepts that minimize the spread of viruses will be generated, tested with users, and evaluated in the scope of ergonomics and their environmental impact. Furthermore, concepts will be assessed against aviation safety and disinfection guidelines to ensure their feasibility in the current context. This project will be developed on the full-scale model of the "Staggered Seat", an economy class seat in the Flying V interior, available at the Industrial Design Engineering faculty building.

In order to make the project manageable within given time, the COVID-19 will be the only type of virus taken into account. The cabin airflow and the airborne transmission (unlikely way of infection), as well as the use of the on-board lavatories will be left out of scope. Nonetheless, these aspects will be considered during consultations with experts.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design aircraft interior element(s) that will increase viral safety by reducing the contact and evoking the sense of safety among passengers. Explore what influences perception of safety, ideate concepts and test with users. Consider the product's environmental impact and aviation industry guidelines.

The project is expected to result in a product/set of products that will improve the viral safety and perceived safety among the passengers of the economy class in the Flying V cabin. The main criteria when choosing the concept will be their COVID-19 safety, perceived safety, environmental impact, and compliance with aviation guidelines. Several aspects will be considered to address the comfort of passengers and flight attendants, such as intuitiveness, accessibility, and easy maintenance.

Research questions:

What interior elements will reduce contact and spread of droplets between passengers?

What are the factors influencing people's perception of viral safety when flying?

How to reduce the passengers' fears of catching a virus in the plane cabin, while not decreasing their sense of responsibility?

Personal Project Brief - IDE Master Graduation



PLANNING AND APPROACH **

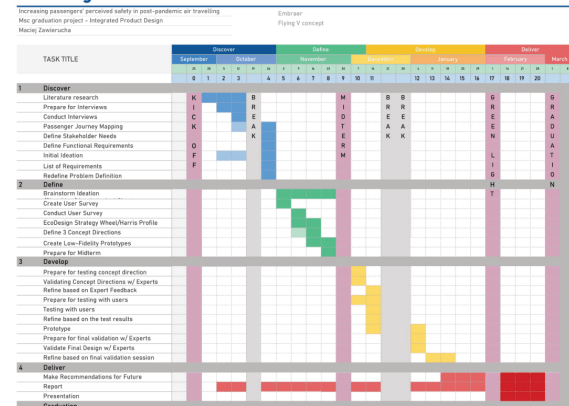
Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 28 - 9 - 2020

8 - 3 - 2021

end date

Planning



The planning of this graduation project follows the Double Diamond method (8), which distinguishes the project into different phases of divergent and convergent thinking approach: Discover, Define, Develop and Deliver.

Discover phase will focus on gathering information, which will mainly involve literature research, conducting interviews, and identifying the needs of stakeholders. These will be followed by the problem definition. Next, in the Define phase, concepts will be generated and tested with users. They will be assessed in the scope of the ergonomics, environmental impact and the aviation industry guidelines. Three to five concepts will be chosen and developed using rapid prototyping. In the Develop phase, chosen concepts will be assessed with experts to ensure feasibility and meeting client's needs. The selected concept will be further developed by a mean of a full-scale prototype. This will be concluded with a final validation of the developed concepts with experts. The last phase, Deliver, will consist of making recommendations, finalizing the report, creating a presentation and developing the concept showcase.

As research on the COVID-19 virus is still ongoing, new discoveries could impact the process at any stage of the project. Adjustments in the planning may be necessary to ensure the relevance of the outcome.

Two trips to Poland (one in October, one in December) regarding family matters and the Christmas/New Year period, will push back the final presentation date by three weeks.

Appendix B

Data processed from literature research, grouped





Interview guide - Flight attendants

Interview guide - FLIGHT ATTENDANTS

Increasing passengers' perceived safety in post-pandemic air travel

This research focuses on investigating how the plane passengers perceive safety in the plane cabin during pandemic and how it influences their behavior. This is with an aim to address their concerns when flying and help them rebuild trust in flying after the pandemic.

INTERVIEW QUESTIONS

1. Introduction questions

- a. What was your last flight destination?
- b. Are you flying less during a pandemic? Why exactly?

2. Perception of safety

- a. Using the scale provided, indicate which setting do you think is safer from catching viruses like COVID-19. Why do you think so?
- b. Do you think the level of safety changes for longer flights such as from the Netherlands to New York, compared to short ones, like the Netherlands to Paris? Why do you think so?
- c. The image provided shows common activities when travelling by plane. Please look at each step of the journey, and think of how safe or unsafe it feels for you in the scope of viral safety from your perspective. Rate it from 1 to 5 using the scale provided, and explain why you gave it such a grade.



1. Entering the plane



2. Walking through the alley
Looking for a seat



3. Storing luggage in the over-
head compartment



4. Taking your seat



5. Sitting in the seat



6. Flight Attendants service



7. After landing - Regressing



8. Any other activities

- d. What was your biggest safety concern when being inside the cabin during a pandemic? Why did you feel it?
- e. Was there something that made you feel safe against viruses in the plane cabin? Why does it make you feel in that way?

- f. What do you think could be improved to make you feel safer against viruses when being inside of the cabin? You can provide ideas for each step of the journey.

3. Passenger behavior

- a. When being inside the cabin, did you observe any behaviors among passengers that negatively impact viral safety? What were these behaviors and why did they make you feel unsafe? Why did they do it?
- b. Are there any measures you wish were executed better by the passengers or other members of the crew? If yes, what are they and why do you think they could be improved?
- c. Can you think of any measures for passengers in the cabin that would increase your feeling of safety?

4. General questions

- a. Do you think the flight attendants are protected well against viruses in the plane cabin?
- b. What would be your main message to passengers when flying during a pandemic?
- c. What do you think should be changed in the aviation industry to convince people to fly in the future?

Interview guide - Passengers

Interview guide - PASSENGERS

Increasing passengers' perceived safety in post-pandemic air travel

This research focuses on investigating how the plane passengers perceive safety in the plane cabin during pandemic and how it influences their behavior. This is with an aim to address their concerns when flying and help them rebuild trust in flying after the pandemic.

INTERVIEW QUESTIONS

1. Introduction questions

- a. What was your last flight destination?
- b. What was your motivation to fly?
- c. Did you travel alone or with someone?
- d. Are you flying less during a pandemic? Why?

SLIDE 1

2. Perception of safety

- a. Using the scale provided, indicate which setting do you think is safer from catching viruses like COVID-19. Why do you think so?
- b. Do you think the level of safety changes for longer flights such as from the Netherlands to New York, compared to short ones, like the Netherlands to Paris? Why do you think so?

SLIDE 2+3

- c. The image provided shows common activities when travelling by plane. Please look at each step of the journey, and think of how safe or unsafe it feels for you in the scope of viral safety. Rate it from 1 to 5 using the scale provided, and explain why you gave it such a grade.



1. Entering the plane



2. Walking through the aisle
Looking for a seat



3. Storing luggage in the over-
head compartment



4. Taking your seat



5. Sitting in the seat



6. Flight Attendants service



7. After landing - Regressing



8. Any other activities

- d. What was your biggest safety concern when being inside the cabin during a pandemic? Why did you feel it?
- e. Do you think you will still have these concerns after the pandemic is gone?
- f. (If a participant flew with someone) Were you concerned about the safety of your co-traveller(s)? If yes, why were you concerned?
- g. Was there something that made you feel safe against viruses in the plane cabin? Why did it make you feel in that way?
- h. What do you think could be improved to make you feel safer against viruses when being inside of the cabin? You can provide ideas for each step of the journey.

3. Passenger behavior

- a. When being inside the cabin, did you observe any behaviors among passengers that made you feel less safe against viruses? What were these behaviors and why did they make you feel unsafe? Why did they do it?
- b. Are there any measures you wish were executed better by the passengers or a crew? If yes, what are they and why do you think they could be improved?
- c. Can you think of any measures for passengers in the cabin that would increase your feeling of safety?

4. General questions

- a. Are you willing to go back to your normal flying patterns right after the pandemic is over? After a year? Would you change them? Please explain.
- b. If the negative things you mentioned before were improved, would you go back to your normal flying patterns faster? If not, what would?
- c. Would you pay more for a ticket if the safety measures you mentioned were implemented? How much more? 30%, 70%, 100% and more?
- a. What do you think should be changed in the aviation industry to convince people to fly in the future?

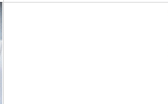
Appendix D

Processing interviews - 9 cabin moments

Activity	Entering the plane	Walking through the alley	Storing luggage in the overhead compartment	Taking your seat	Sitting in the seat	Flight Attendants service	Eating	After landing - disembarking	using toilet
Indicative image									
high concern	2	2,2,3	3,3	2,2,2	1,2,2	1,1	1,1,1,2	1,1,1,3,3,2	1,2
all grades	5,3,5,4,4,5,4,5	4,2,2,3,1,5,4,5,2,2	2,1,5,3,1,5,3,4,3,3	2,1,4,4,2,5,4,3,4,4	2,2,2,4,2,5,3,5,4,5	3,1,3,2,4,5,2,5,2,5	1,1,2,2,2	1,3,1,3,1,5,4,3,	1,2,3,3
average grade	4.4	3	3	3,3	3.4	3.4	1.5	2.7	
overall priority	LOW	MED	LOW	MED	MED	MAX	MAX	MAX	MED
MA grade	5	4	2	2	2	3	1	1	1
description	entering the plane was okay because the airline, [removed], allowed only 10 people at the time to enter the plane. So I felt, okay, that is safer than what it used to be before	I was walking through the corridor, and there was this woman, she was in a hurry somehow, I don't know why, she just crashed my back, and I felt like, all the measures now are wasted, because this woman just didn't care about keeping the distance. So okay, they let only 10 people in at the time, but if one of them had a virus and then you're still close to each other, the other ones will also get it. Maybe they could still take less people, but be kind of more assertive to passengers to keep their distance.	And then the third one, the luggage compartment, everyone is touching it. Also, for my flight, they didn't allow the cabin luggage into the plane, so everyone needed to put their luggage to the airplane check-in. I felt better, because I didn't need to deal with this luggage while entering the plane. I still had something to store in this compartment, and everyone was touching it, and let's say someone tries to put their luggage, and they're touching my bag, and then I was like "Oh my god, she touched my bag!"	I think it was okay, but when I was sitting in the corridor place, and then there were 2 more people who were supposed to sit next to me, and they came in different times, they stayed really close to me while I tried to move, and meanwhile other people were moving around, for example.	Sitting in the seat - so on my flight from Amsterdam to Istanbul it wasn't really full, so they arranged the seats like, try to keep the distance from each other. I had a seat gap between the other passenger and I felt really safe. And I thought "Okay, if I stay this way, I could travel more often with planes". But when I was going back, it was Sunday evening. It was full, people were in a hurry, and then the passenger sitting next to me he was moving a lot and couldn't fit in his seat, it was too small for him, and	Of course, before corona we had more food, the meals were more full of things, but I didn't know they changed the meal after corona, so I kept myself hungry before the flight, and that was a stupid idea. When I saw the meal, I thought "I hope I will survive this flight", because I only got a sandwich. Of course, during corona I also try to keep my mouth not open for a long time, but if there is a one seat gap, and also the other people face forward, I feel more comfortable, so I also takes some time to open my mouth and eat.	I felt really uncomfortable, especially during eating process, because he was definitely careless, he was talking a lot, and while eating he was talking too, and I saw him spitting water from his mouth, and I was like "I hope I won't get any corona today"	And then during landing, they announced: "please remain seated, only leave after the row before you leave". So during the first flight, from Amsterdam to Istanbul, I saw him spitting water from his mouth, one by one. And I was again so happy with that. But then again when flying back it was terrible. So this guy sitting next to me he was pushing me like "hey, move, I want to leave as soon as possible", and then there were other people who were in a hurry, they just did not listen the rules, there was a line in the corridor, so I thought they made all these measures when entering the plane, and then they didn't make sense, because everyone was so close, no distance. Literally everybody just touching each other. I had to also go into the line, because this guy was pushing me all the time, and where do I go? Everywhere a room full of people, and I just had to push other people... so annoying. This time they didn't say anything, I think they should be more assertive to passengers, that they need to keep their distance, but they were like "whatever, we're just so tired, we'll just let them go" (laugh).	Okay, so the corridor is really narrow, and there are two toilets. I just left the toilet and there were two people waiting outside of the toilet, and there was no place to pass through to my seat. And I had to again be really close to them, maybe have physical contact with them, which felt really unsafe. Being inside of the toilet made me feel safer because there were no people around me and I realised, there is fresh air in the toilet. Also, they use light colors, white, and it is more fresh-looking. I felt more safe.
AG grade	3	2	1	1	2	1	1	3	-
description	what I did, I was entering the plane as one of the last people. I didn't want to be in the crowd so then I was able to keep a distance in front and also I think almost no one behind me, maybe one person. So I was feeling neutral.	because there were just a lot of people in front of me it was quite crowded. And there was also because I was one of the last people so there were people on the aisle they were on the right and on the left and also not wearing a distance a mask in the correct way so covering their nose and face. Just when I realised and see the way they're wearing masks it made me feel less safe and but then it's not one it's not the maximum because yeah I was able to be able to keep a distance from those people as being one of the last people being in control of the distance	I had to really close the person which was sitting below the compartment. Almost touching that person to get there I'm not even sure if my luggage was quite heavy and I had problems if someone came to help me. So I would choose this as one as I am so close to other people. It cannot keep distance anymore.	I was sitting close to the window so I asked the person to stand up and let me pass. So I would just say I didn't have to go like a climb over the person. He gave me the space. It's not the maximum.	As I'm saying overall I think I can be in control just not trying to, I don't know, hold my arms close, be aware what I'm doing with my hands not to touch too many things and I just trying also not talking to the person, trying to keep a distance as much as possible sitting that close, but I had experienced that someone was not wearing a mask, he was taking it off during the flight. But I asked the person if he can put it back. He was nice and he said sure.	For me it's so crazy that it still happens. It is like what I did. I bought an expensive flight from the Netherlands to Poland. It was in August and I thought if it's expensive it's from [removed], it'll be the safest flight. But what happened is the opposite because [removed] was serving food to everyone on the plane.	So everyone took off their masks and I was just in shock. A I was keeping my mask, I didn't take it off for a minute but I was extremely feeling unsafe. One person next to me was just without a mask and everyone was without the mask, everyone was eating, and it was a stressful situation for me. And I was really regretting being on this plane and taking this flight.	again I was sitting until almost the end so that I could be the last person to leave so no people behind my arm, just I prefer not to have people behind me. And when they're only in front of me I can keep a distance and also I don't breathe on them they don't breathe on my back. I would say this is quite neutral, three.	-
ME grade	5	2	5	4	2	3		1	using toilet - 2
description	I think the person welcoming you was also wearing a mask, so that was fine.	Well, because over there everyone was already closer to each other and you're in each other's social area with people that you don't know and also I was my first view into the cabin. So I was shocked, everyone sitting and then you see like, now, these are actually quite a lot of people. And so that moment had a big impact I would say.	It was fine but I felt a bit humiliated. But it was safe.	I think I had a seat in the middle so I didn't have to pass anyone.	when I was doing the belts, you sort of have to touch each other and that was just very new for me in that whole period of time	they didn't come by, so neutral or no answer.	Did not eat during a flight	I got a bit annoyed, my boyfriend as well, because they seriously asked you to stay seated until they open the doors, so everyone can walk out just one by one. But no one listened, so that was very annoying. Because they tried to give you the right information and they try to guide you, but in the end no one did the thing, so that was just very annoying and it felt unsafe because I was waiting in my chair but everyone's standing already and grabbing their stuff. It was unsafe. Also annoying	there's not a lot of space to stand. If there is someone in front of you waiting for it as well then you go back into the cabin and then you're at row one or two and then you're close to the people that are sitting there.
SS grade	4	3	3	4	4	3	2	3	3
description	you're not really close to people and people are wearing masks and I think the cabin crew is really aware of what they're doing in terms of safety.	it actually depends on the people but I think when I was taking a plane, people were not so crowded down on the aisles, they just they just quickly went to their seats. And there were less people at a time.	I don't feel that unsafe. It's not fully safe because you're still moving and people are still around you.	I was sitting there in a window seat and then when I arrived there was no one. That was somewhat safe. But the thing is that I sanitized my whole seat, to make myself feel safer.	nothing was happening at that time.	they still serve meals during the flight.	Well I kind of feel somewhat unsafe that time because although they announced that it is suggested for you to have a different dining time than people around you. I'm one seat apart from that neighbor, but I didn't talk with him so yeah we both had received the meal at the same time, and that was somewhat not safe for me. But I just want to eat so I didn't think that much about it. After landing.	There were less people so I don't think it was really crowded at that time. It was really smooth when I got out, so I felt neutral because there were a lot of people but I saw that people were wearing masks and there's less people so I didn't feel that unsafe.	I'm sitting in a window seat, so at that point it was somewhat unsafe because I have to pass through my neighbor. But the one on the aisle seat, he was actually very thoughtful, he just went all the way to the middle to wait for me to pass. So I think that in that sense I feel safe. Also after we used the bathroom the cabin crew sanitized everything with alcohol after every use so in that way I felt safe.
JR grade	4	1	1	2	2	4		1	-

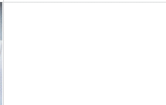
Appendix D

Processing interviews - 9 cabin moments

Activity	Entering the plane	Walking through the alley Looking for a seat	Storing luggage in the overhead compartment	Taking your seat	Sitting in the seat	Flight Attendants service	Eating	After landing - disembarking	using toilet
Indicative image									
high concern	2	2,2,3	3,3	2,2,2	1,2,2	1,1	1,1,1,2	1,1,1,3,3,2	1,2
all grades	5,3,5,4,4,5,4,5,4,5	4,2,2,3,1,5,4,5,2,2	2,1,5,3,1,5,3,4,3,3	2,1,4,4,2,5,4,3,4,4	2,2,2,4,2,5,3,5,4,5	3,1,3,2,4,5,2,5,2,5	1,1,2,2,2	1,3,1,3,1,5,4,3,	1,2,3,3
average grade	4.4	3	3	3.3	3.4	3.4	1.5	2.7	
overall priority	LOW	MED	LOW	MED	MED	MAX	MAX	MAX	MED
description		you pass quite a few people	That's the beginning of the flight, and people are still kind of wandering around the cabin.	I think outside taking your seat is very similar because it all happens in the same kind of timeframe.	Since you are close with other people, I think that really depends on the behaviour of the people sitting next to you. If there's like somebody coughing or something. Even if it doesn't sound serious. It kind of freaks you out. And you feel like you can't really move away. Once you are still walking in the alley you can still somehow maneuver. Whereas when you're sitting you're kind of bound to the place. It can feel from really unsafe to neutral. Another thing is that not everybody kind of fully complies with the rules I would say, so you know there's a lot of people that would like you know, not take their masks off completely, but take them down a bit, so their nose sticks out or something like that. That does make a difference.	the flight attendant takes proper distance when she's talking to me. I think they are kind of trained how to do it and I think they also probably have to take a lot of tests, so they more less know what's their health.	Did not eat on the flight	I think a lot of people, at least on my flight, are really rushing to go out of the plane and maybe be less cautious on distancing and safety. So I think it creates more chaos. But on the other hand it is because they don't want to be in the plane anymore.	-
LD grade	5	5	5	5	5	5	2	5	2
description	very safe	there were 2 hallways on my plane and they were also boarding from the last rows to the front rows, and you were walking through like an empty plane because you don't have people that were boarding, people that were sitting.	there was basically no one, there was only me and only one person in front of me so we just gave each other space and time.	I was the only one in the row, and actually every row has only one or 2 people, if the people were flying together, then they were allowed to sit together.	I was alone	the flight attendants were wearing surgical face masks and they never removed it, always kept it on and they were really professional I think.	Yeah maybe eating actually. I would say. Now I'm not sure, I would and say two but it's more like my personal idea. You are supposed to wear masks and the flight is only 40 minutes long so it's not necessary to give food to the people, because people start removing their masks, so I just really believe that is not necessary and it's unsafe.	because letting people out of the plane row by row, starting from the beginning to the end, and if someone was trying to anyway you get up, the flight attendants were telling them not to, to please respect your orders, so they were really taking the initiative and trying to make people respecting the rules.	
KFA grade	4	4	3	4	3	2	N/A	4	3
description	Passengers are being guided to go by I think 10 passengers at a time. So they're coming in small groups. And well they can pass pretty quickly past me. And I think the planes are not very full at the moment. So they can keep some kind of distance. I don't really feel unsafe. But at the moment also passengers are only saying hello and that we give them a cleaning towel but before corona, it was very different. People were always with many people in the pantry because they can't get through the aisle and they had questions and they're not listening and it was chaotic. Before boarding you have to make the cabin ready for safety reasons, you have to greet passengers and it's a lot more quiet now. We don't have to do as much as we used to. It's easier.	I think because passengers have to pass each other. They come very close. Maybe they have to speak to each other. "Can I pass?" and maybe they make little fights [laugh]	The luggage bins are usually opened, they don't really need to touch it, they just put their bags and I think well that must be fine.	I think all the seats and the tables have been cleaned by a cleaning staff at the airport. So it should be safe. Also they have the towel so they can clean their hands. And sometimes on the flight you're sitting next to other people. Maybe you have to ask him to get up so you can pass to your seats. But I think that are short moments. And without a lot of talking to each other, it all goes right	I think most people are sitting next to the travel companion. Maybe there is a stranger next to you. But I see people are wearing their face masks most of the time. Yeah, I don't see a lot of interaction between passengers who don't know each other. Eating - I think not so many people are eating or drinking and I don't see many people talking and sneezing, coughing. They're all sitting and that's it.	Well they have to speak to us and I'm not sure if the face mask will keep the virus inside. And it's also that we cannot hear them so we may have to ask many times what they said and if the passengers at the aisle seat, I have to bring my ear to their mouths because I cannot hear them. So I think for both of us it might not be really safe. It's the moment you come really close if you want to hear somebody.		I think the people who are really afraid, they remain seated. They wait until everybody has left and they go but everybody who's not really afraid of the virus they just get up.	I don't know how infectious the virus is in the toilet and how much do you think the whole activity of using a toilet is saying in terms of feeling of safety. Neutral.
AFA grade	5	5	4	3	5	5	N/A	2	
description	the contact is brief, a passenger walks in and immediately goes into the aisle.	Walking through the aisle, looking for a seat. It's very safe because contact is brief. As a passenger you pass others who are already seated, faces are not on the same level.	Again, if you do that quite quickly, even though some people take forever, or so it seems, it's easy you know, you put in your bag you take out your phone you take out whatever entertainment you need and you sit down.	sometimes people have problems with comparing the symbols, I appreciate that everybody's on a plane on a daily basis, so there's a confusion, so is A a window seat or C is the window seat? Even though it's indicated, and then sometimes people have to sort of get up, change seats, allow someone to pass and then you come into close contact. Faces are on the same level, so I would say neutral.	Sitting in the seats, and then everybody's facing forward. You know, the air conditioning that's blowing and the air that comes out of the little vents, sitting in your seat is very safe.	Because again faces are not on the same level and contact is very brief. You keep a safe distance.		Yeah after landing people are so incredibly used to getting up all at once. Even though we make announcements to sort of keep a safe distance between everyone, everybody gets up at the same time, faces are on the same level sort of and everybody is squeezed together in a tight space so that would be somewhat unsafe. Because even though contact is short you know it's within the 15 minute limit. Just when the fasten seatbelt sign goes off it's like the start of a race you know, bam! And I noticed over those years, because well I've been with that company for over 20 years, I've noticed that it's always the people in the middle that get up. And then I always think to myself, okay it doesn't matter which door we're going to use you are going to be that last. I don't know, I mean it's a psychological thing I guess.	even though we tell passengers to wait in the aisle, and we've been telling him that for the past 5 years, nobody does that. And so you know, I close the curtain, I keep them outside the pantry and then the restrooms are behind the last row but before the pantry so that's fine. So that's because we eat our meals in front of course at some point or we have something to drink and then when passengers are going in and out I don't know maybe it's not based on any science, but it's an emotional decision to sort of okay now let's keep them out.
IFA grade	4	2	3	4	4	3		3	

Appendix D

Processing interviews - 9 cabin moments

Activity	Entering the plane	Walking through the alley Looking for a seat	Storing luggage in the overhead compartment	Taking your seat	Sitting in the seat	Flight Attendants service	Eating	After landing - disembarking	using toilet
Indicative image									
high concern	2	2,2,3	3,3	2,2,2	1,2,2	1,1	1,1,1,2	1,1,1,3,3,2	1,2
all grades	5,3,5,4,4,5,4,5,4,5	4,2,2,3,1,5,4,5,2,2	2,1,5,3,1,5,3,4,3,3	2,1,4,4,2,5,4,3,4,4	2,2,2,4,2,5,3,5,4,5	3,1,3,2,4,5,2,5,2,5	1,1,2,2,2	1,3,1,3,1,5,4,3,	1,2,3,3
average grade	4.4	3	3	3,3	3.4	3.4	1.5	2.7	
overall priority	LOW	MED	LOW	MED	MED	MAX	MAX	MAX	MED
description		I think it is better to sit in the plane than to walk around. I think when walking around you are seeing more people and I think that is less safe.			So if you just sit down and breathe that is in an intimate neighborhood, then I think that's pretty safe.	as a flight attendant I'm walking up and down and I think walking is unsafe. I'm safer but if I am sitting down then it doesn't bother me anymore. I think as a person it is less safe to walk up and down the aisle, because then you will breathe some air which you may be infected with.	N/A	I order people to remain seated until the row in front of you has been cleared. And I'm pretty strict, so I will use the BA to direct that you are only allowed to stand up if you are on the first row. All the other passengers have to remain seated. So this in order to facilitate the smooth disembarking. And then there is less chaos in the cabin, and there is less contact by a lot of people. So it takes up some energy and it also takes up a certain mindset, because now I'm not the flight attendant who I was, now I'm more of an airport police officer. So if somebody's not wearing a face mask, I will ask it 10 times politely. But I have to take in consideration that I have to ask him 10 times nicely because you know, I'm not going to check on him 20 times. I will check again 10 times, put on your mask. If there was a passenger on row 9 that is not wearing a mask, I would go there and do something with it. I will ask him 10 times politely. For me that works.	
JFA grade	5	2	3	4	5	5	2	4	
description	Well if people come on board wearing a mouth mask, it's very safe as long as everyone is well and is actually wearing a mask. You can't adhere to the 1.5 metre distance, so I would say in the first image I would say very safe. Because there's not a lot of contact between welcoming the passengers doesn't take long.	The second image I would say is somewhat unsafe. People really stay too close to one another.	It really depends on how many passengers are around the person. So I would say neutral. We do advise passengers to take as little hand luggage as possible but in my experience people will take everything they want anyway, so they don't really listen to that advice.	Taking a seat, actually this is the same argument. I would go for "somewhat safe" as long as the people are not breathing on their neck.		I think it's our human nature but sometimes when you ask for someone's order they will take up the face mask to speak more clearly and so you have to remind people to keep on the mouth masks. As long as the people are not too close to you, then it's not a really big problem, but it does make it a little less safe of course. We've adapted our service for the shortest time possible.	some people do take advantage of the situation or abuse situation, maybe better said, and they would have a coffee or a coke or a beer or whatever and instead of finishing it in intended 15 minutes, they will finish it in an hour. Just not to wear a facemask.	It depends on the distance people keep. It should be between one another. So that could be somewhat unsafe or neutral. Any other activities, if there's not a big queue for the toilets, I would say very safe. If there is a queue building up I would go from somewhat safe to neutral.	You can never know of course, but you just hope that people when they use the lavatory, they also wash their hands. But you don't have any insight on that of course. You never know if they properly pay attention to hygiene. I see people going into the lavatory with bare feet so I don't think it always happens that way. It happens a lot.

Appendix E

Processing interviews - Quirkos analysis report

Interview analysis report generated with Quirkos software

https://drive.google.com/file/d/1uk_wOrV0j1ll5Hjsy_OB6oGWFZjmRfWr/view?usp=sharing



Co-creation session presentation

Co-creation session

Increasing the perception of viral safety in planes

TU Delft EMBRAER

“Increasing the perception of viral safety in planes”

Proven safety = Perceived safety

What are we going to do?

Present

Evaluate

Choose

Now vs. future

Now: feasibility, cost

Future: effectiveness, environment

Co-creation session presentation

PROCEDURE:



Concepts

Multiple per challenge



Discussion

Pros and cons, feasibility



Voting

Selecting the best + most feasible



1. Uncertainty about measures

Masks uncertainty

Code: 1.1



CONCEPTS:

- A) Free certified safety mask when entering the plane **1**
- B) Leaflets/stickers explaining how masks work **1**
- C) Describe the benefits of wearing a mask during the in-flight safety briefing/on screens **4 11**
- D) Compulsory medical masks bought before flight
- E) Free WiFi + phone notifications informing about all safety features

Cabin air uncertainty

Code: 1.2



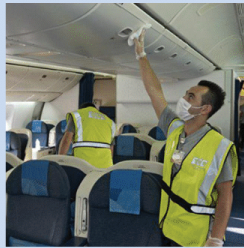
CONCEPTS:

- A) Leaflets when entering, showing the details on how cabin air works **4 1**
- B) Ads on the airport, explaining how safe the cabin air is **1**
- C) Free WiFi + phone notifications informing about all safety features
- D) Safety measures described online, sent together with the boarding pass **3 1**

Co-creation session presentation

Cleaning uncertainty

Code: 1.3



CONCEPTS:

- A) Little cards indicating the seat was cleaned **2**
- B) Free WiFi + phone notifications informing about all safety features
- C) A real-time video of interior cleaning shown at the airport **2 11**
- D) A sign at the entrance: "Interior disinfected" with signatures of cleaners **2 1**



2. Need for increased measures

Seat redesign/enhancers

Code: 2.1



CONCEPTS:

- A) Antimicrobial materials/coatings **4 1**
- B) Foldable screen divider **2 1**
- C) Additional cover that is replaced after flight **2**
- D) Redesigned armrests for less contact **1 11**
- E) Cleaner seat design with no gaps, seams etc. **1**
- F) Integrated UV light cleaning **1**
- G) Air outlet between passenger heads
- H) Reversed central seat in the row

Too much physical contact

Code: 2.2



CONCEPTS:

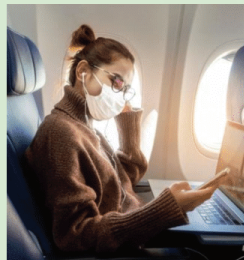
- A) Stricter, organized (de)boarding **1**
- B) Checked-in luggage only
- C) Using light to indicate which rows can disembark **4 11**
- D) Penalty for disobeying rules
- E) No lines to the lavatory allowed

Appendix F

Co-creation session presentation

Personal safety equipment

Code: 2.3



- CONCEPTS:
- A) Face shields for free when entering **3 111**
 - B) Gloves for free



3. General anxiety

Uncertainty over passengers' health

Code: 3.1



- CONCEPTS:
- A) Required making a PCR test before entering the plane **1 11**
 - B) Free WiFi+App that describes the unlikelihood of catching a virus on board
 - C) Temperature screening **4 11**

Worrying about infecting others

Code: 3.2



- CONCEPTS:
- A) Additional protection on top of the mask. (shield?) **11**
 - B) Foldable barriers between seats **11**
 - C) **3 1**

Appendix F

Co-creation session presentation

Hearing coughing/sneezing

Code: 3.3



CONCEPTS:

- A) Free extra protection masks that mute sounds
- B) Personal helmets which protect, mute and provide entertainment **11**
- C) Tissue given away **3 1**



4. Disobedience

Not wearing masks (properly)

Code: 4.1



CONCEPTS:

- A) A right to offload a passenger who is not obeying the rules, can be banned from the next flights (open system of tracking) **1 1**
- B) A face recognition camera in the seat that detects masks off **1**
- C) (after pandemic) Section of the plane for people who want to wear mask
- D) An app where you can report disobedience anonymously to the cabin crew **1 11**
- E) Seatbelts+masks on **111 1**

Different rules in different countries

Code: 4.2



CONCEPTS:

- A) Standardised flight rules **1 1**
- B) Section of the plane for people who don't want to wear a mask
- C) App informing about the current safety measures **111 11**

Appendix F

Co-creation session presentation

Unsafe when eating without masks

Code: 4.3



CONCEPTS:

- A) No food allowed on the plane **11**
- B) Staggered food ordering **111**
- C) Removable barriers during eating **1 1**
- D) Liquid food **211**
- E) Food when entering **1**

People rushing to the exit

Code: 4.4



CONCEPTS:

- A) An app telling when passengers can leave
- B) Using light to indicate which rows can disembark **4 111**
- C) Flight attendants walking outside-in through the alley to let people disembark **11**
- D) App detecting movement, ringing if you leave too soon **1**



5. More control by flight attendants

Stewards should be more assertive

Code: 5.1



CONCEPTS:

- A) A right to offload any passenger for not adhering to viral safety measures (com) **1**
- B) Fines for disobedient passengers (com) **3 11**
- C) Warning on fines through the radio **111111**

Co-creation session presentation

Stewards should control wearing masks

Code: 5.2



- CONCEPTS:
- A) A right to offload any passenger for not wearing a mask (com) 1
 - B) Fines for no mask (com) 3 1
 - C) Face detection camera in the seat
 - D) App where you can anonymously report not wearing a mask 1
 - E) Warning on fines through the radio 1111
 - F) 1



6. New future attitudes

Lower willingness to fly in the future

Code: 6.1



- CONCEPTS:
- A) More eco-friendly aircrafts/technology 1111
 - B) Find new niches of travellers 2 1
 - C) Improving entertainment/comfort 111111
 - D) More space, more expensive flights 111
 - E) Easy booking, rebooking, cancellation, refunds 3 11
 - F) Diversification of business 1111

Sustainability concerns

Code: 6.2

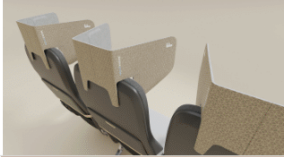


- CONCEPTS:
- A) Indicating footprint of each flight 1111
 - B) Include CO2 offset in each ticket 1
 - C) More efficient aircrafts 111
 - D) Communicating more the ongoing development of sustainable aviation 111

[illegible]

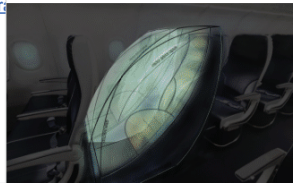
Appendix H

Overview of existing concepts

No	Name	Creator	Description	Website	Photos	
1	PlanBay	Avioninteriors	Physical, transparent divider between the passengers. Uses the middle seat	https://edition.cnn.com/2020/04/02/health/coronavirus-airplane-seats/index.html		
2	Antiviral surface	Eboco	Antimicrobial and antiviral armrest and tray surfaces	http://journal-dow.com/2020/04/02/antiviral-airplane-seats/		
3	HeadZone	Factorydesign	Safety solution, which wraps around the head to give support, personal separation and a sense of reassurance.	https://www.aircraftinteriors.com/headzone/		
4	Isolate screen kit	Factorydesign	An opportunity to transform a vacant seat into a screen that maximises personal space and helps separate passengers from each other or the aisle.	https://www.aircraftinteriors.com/isolate-screen-kit/		
5	S2 Stagger seat	Molon Labe Design	Seat system that can vent fresh cabin air from the headrest directly towards the passenger's face, with controllable flow rates and direction similar to overhead cabin vents.	https://www.aircraftinteriors.com/s2-stagger-seat/		
6	Soft divider	Jamco	Airflow down the cabin could be disrupted by fitting Jamco's Soft Divider, a leather-wrapped eyebrow-type hanging class divider for single-aisle aircraft.	https://www.aircraftinteriors.com/soft-divider/		

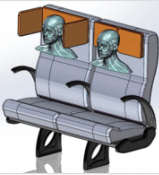
Appendix H

Overview of existing concepts

7	Lightweight seat divider	Lufthansa Technik	Seat dividers which are installed around the headrest of the middle seat in order to separate passengers. LHT says that airflow tests have shown that the shields prevent the spread of aerosols, without reducing the beneficial ventilation effects of the cabin air conditioning.	https://www.aircraftinteriors.com/en/aircraft-interior-components/seat-dividers/		
8	Dual Disposable Seat Cover	AviationRFI	Intended to help reduce germ transfer from seats to clothing during travel. The one-piece cover is double-ended, with one end suitable for fitting to an aircraft seat, and the other a car seat (useful for taxis, etc).	https://www.aircraftinteriors.com/en/aircraft-interior-components/dual-disposable-seat-cover/		
9	Aircraft passenger protection	Science Lab	Physical, sealed barrier between passengers. The design is a full cocoon that fits over an aircraft seat and its occupant, keeping them completely isolated in the cabin.	https://www.aircraftinteriors.com/en/aircraft-interior-components/aircraft-passenger-protection/		
10	Protection screens	Aviation Glass	Large glass screens that can be fitted onto existing aircraft seats to give a greater feeling of protection.	https://www.aircraftinteriors.com/en/aircraft-interior-components/protection-screens/		
11	Removable Divider System	Aerofoam	Removable seat-blocking device that can be easily installed on any seating platform using the existing passenger restraint system, without restricting the function of the seat.	https://www.aircraftinteriors.com/en/aircraft-interior-components/removable-divider-system/		
12	Protective screens	Autostop Aviation	Passenger protective screens to help reassure passengers in economy class.	https://edition.cnn.com/2020/04/02/health/coronavirus-air-travel/index.html		

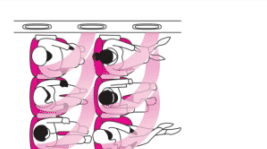
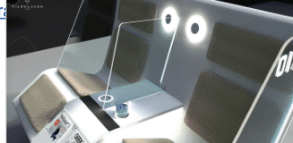
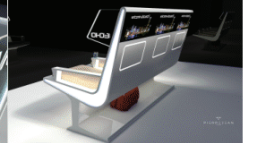
Appendix H

Overview of existing concepts

13	Adjustable headrest	Reinhold Industries	Adjustable headrest that can be fitted to any economy seat platform, with both privacy and passenger safety in mind.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	  
14	Glassafe	Aviointeriors	A kit-level solution that could be installed on existing seats to help separate passengers sitting in double or triple seats.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	
15	Priva	Golnoosh Torkashvar	An adjustable interactive shade which opens and closes over the occupant's head on demand. The wearer can choose adjustable visibility, dimmable lighting and IFE options, as well as a messaging system with flight attendants.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	
16	Passenger protection system	Vision systems	A light, compact and transparent barrier that separates passengers and also features an anti-germ treatment – without requiring an empty seat between passengers.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	
17	The Travel Safe range	Safran	The social distancing aspect of Travel Safe involves equipment such as Ringfence, a simple removable partition that isolates neighbouring passengers. Other designs include touchless interaction equipment for suite door actuation, and pedal actuators for backrest recline functions. The virus-free solutions incorporate a range of coatings for seats and tray tables which facilitate disinfection and cleaning.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	
18	Interspace Lite	Safran	An easily retrofittable table and shield fits over the centre seat, providing delineation and privacy between passengers by locking out either the central or outboard seats of a row.	https://edition.cnn.com/2020/04/02/tech/airline-headrests/index.html	

Appendix H

Overview of existing concepts

19	AirShield	Teague	A single 3D-printed component that fits directly onto the passenger service unit (PSU) positioned above every passenger in the cabin. Airflow from the existing overhead air-gaspers is channelled through the AirShield, transforming freshly purified air into engineered 'air-blades' capable of controlling the spread of droplets much more effectively.	https://edition.cnn.com/2020/04/02/air-travel/index.html		
20	Janus	Avioninteriors	A new design which sees the centre seat in a row of three reversed "to ensure the maximum isolation between passengers seated next to each other". An additional clear plastic screen provides further protection.	https://www.flightaware.com/news-blogs/airline-cabin-reconfigurations/		
21	Pure Skies	PriestmanGoode	Dividers would be erected between each seat to provide an additional modicum of protection and privacy for adjacent flyers.	https://www.businessinsider.com/airline-cabin-reconfigurations/		
22	Premium Economy Seats	PierreJean	Instead of individual seats, we could see a bench-like set up in a lacquer material that has few gaps and recesses, making it easier to clean as it has fewer difficult-to-access crevices. Each passenger would have a bubble around their head that would separate them from their neighbour.	https://www.aircrafter.com/2020/04/02/air-travel/index.html		

Appendix I

Rapid prototyping



Appendix I

Rapid prototyping



Appendix J • 59

User test plan

User test plan



The main objective of this study is to test prototypes with users while ensuring no physical contact due to the COVID-19 restrictions. Participants will assess different prototypes in scope of the experience they provide, based on the visual input from VR goggles. All tests will be done individually by participants in their homes.

Test procedure:

The test is divided into two parts. In the first part, participants will be asked to watch videos with different prototypes, pre-recorded using an omnidirectional (360-degree) camera. This type of videos allows for an immersive experience similar to VR (Virtual Reality), and can be viewed using a commonly used YouTube application on a smartphone. In order to facilitate the test, a pair of cardboard Virtual Reality goggles will be sent via postal service. Each provided pair of goggles will be new and sealed, and will remain in the possession of the participant after the test to ensure hygiene.

Preview of such goggles:

https://www.youtube.com/watch?v=hggLGKAHcno&ab_channel=TingaWinga5

Participants will use the goggles to watch a set of videos provided with an URL link. This will allow them to have an experience similar to the one with real prototypes, but in a safe home environment. The videos will be watched in a sitting position to ensure safety, and will simulate the use of prototypes from a first-point perspective.

In the second part, participants will be asked to complete a survey using Qualtrics software (Qualtrics International Inc.), with Likert-scale questions and optional open-ended answers. In this survey, users will be asked to first rate the experience in a regular aircraft seat, and later compare it with the experience when using the prototypes.

Survey questions:

Questions about prototypes 1-4

1. Compared to the regular seat, how safe from viruses would this concept make you feel during eating? **(1-5 Likert Scale)**
2. Please explain your choice. **(open-ended question)**

3. Did this solution make you feel claustrophobic compared to the regular setting? Please indicate how much. **(1-5 Likert Scale)**
4. Do you consider this concept comfortable to use? (ease of use, intuitiveness, physical comfort) Please indicate how much. **(1-5 Likert Scale)**
5. Would you be willing to pay more for the flight equipped with such a solution? Please indicate what would be your maximum amount of a ticket price: (pay less/not pay extra/10% more/20% more/30% and more) **(1-5 Likert Scale)**
6. Would this solution make you more willing to fly during pandemic? **(1-5 Likert Scale)**
7. Would this solution make you more willing to fly after the pandemic is over? **(1-5 Likert Scale)**
8. Do you find this concept useful? Would you like to have it on your flight? Please explain.
(open-ended question)

Questions regarding the test itself

- A. Did the provided materials (videos, instructions, goggles) give you enough data to assess concepts? **(1-5 Likert Scale)**
- B. (optional) Please explain your choice.
- C. Was the test easy to understand and complete? **(1-5 Likert Scale)**
- D. (optional) Please explain your choice.

Possible limitations of the study

- Insufficient sensory input; lack of physical interaction with objects
- No ability of manipulating objects and test their usability
- Distorted visual input and distance perception due to the technology used (VR goggles)
- Limited freedom of movement and interaction
- Lack of direct supervision by the researcher may lead to undesired execution by participants

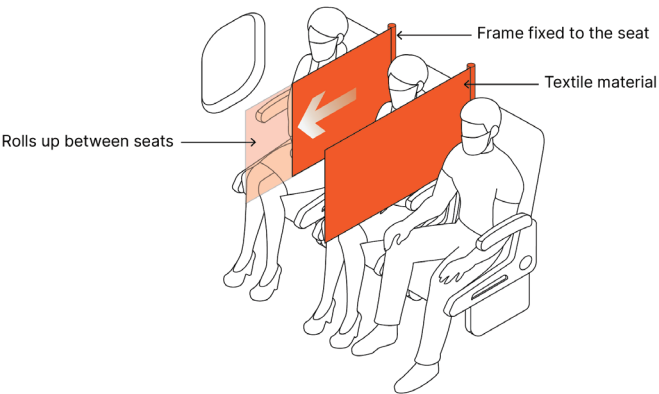
Appendix L

Presentation for a product designer

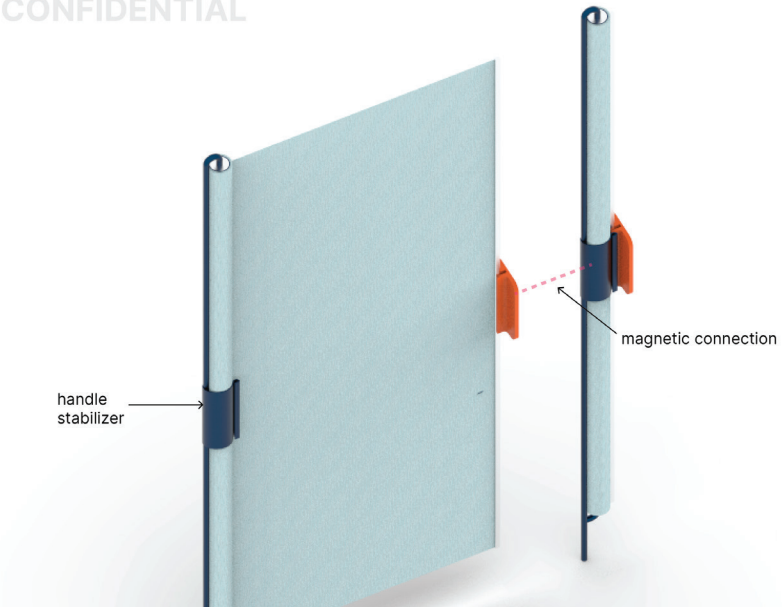
CONFIDENTIAL

Passneger divider

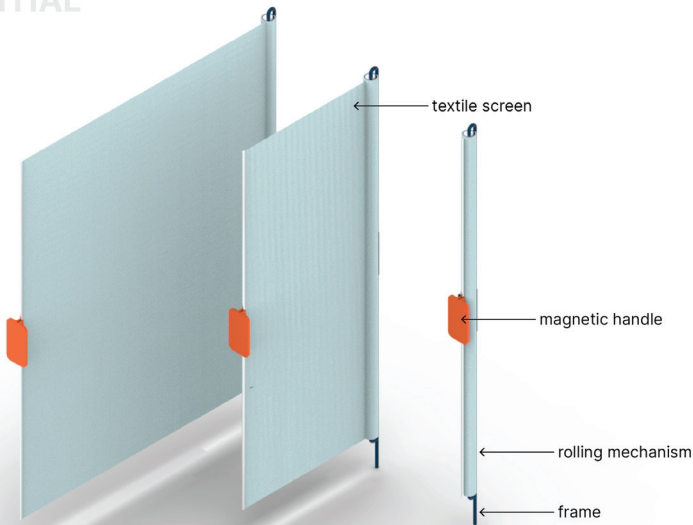
An aircraft interior element that separates passengers to increase virus safety. It consists of a textile screen mounted on a frame fixed to the seat.



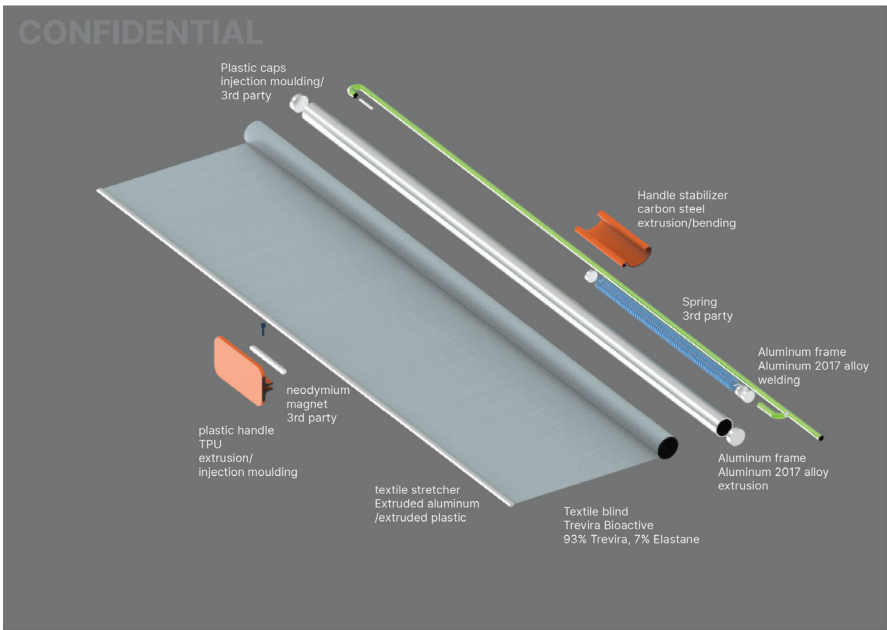
CONFIDENTIAL



CONFIDENTIAL

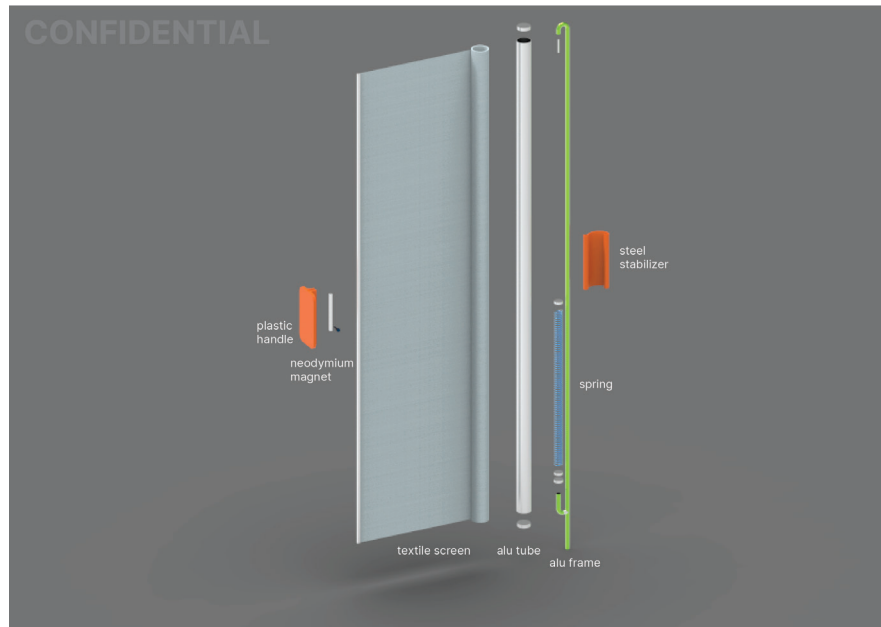


CONFIDENTIAL

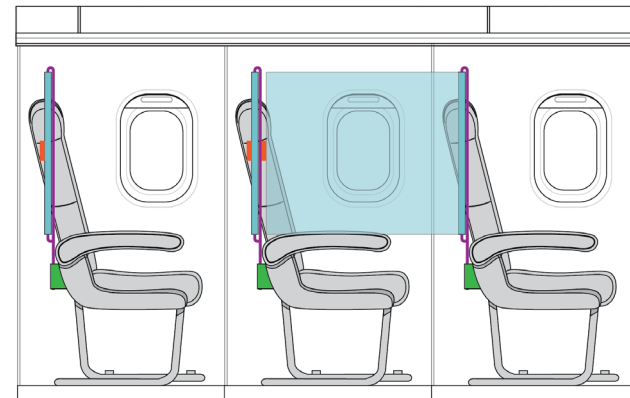


Appendix L

Presentation for a product designer



CONFIDENTIAL



Points for discussion

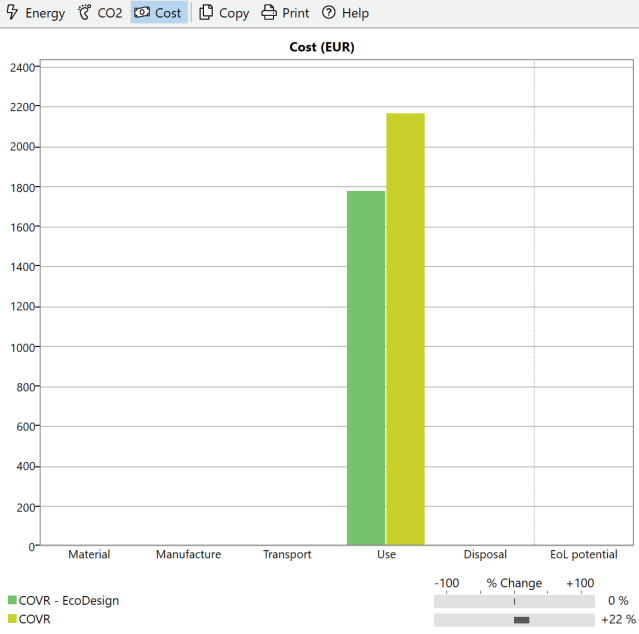
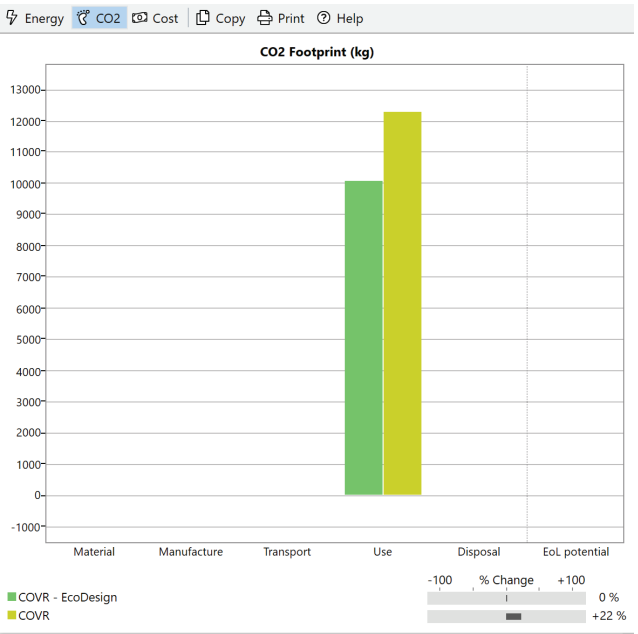
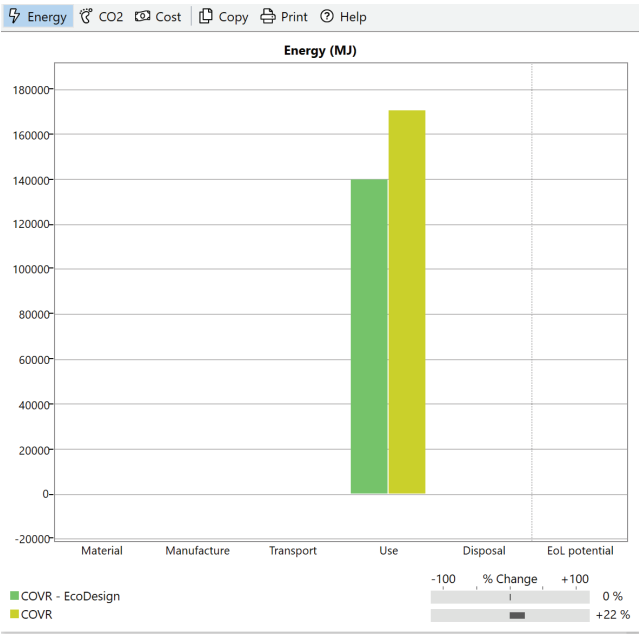
1. What materials are best to produce these elements at lowest weight and durability?
2. What production techniques are most feasible for achieving the desired shapes?
3. How can the design be optimized for ensuring low weight and producibility?

Materials and processes inventory

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	Length (m)	Secondary process	% removed	End of life
1	frame	 Aluminum, 2024, T3  Typical %	0,3	Roll forming	1,6		0	Downcycle	
1	roller axle	 Aluminum, 2024, T3  Typical %	0,085	Extrusion, foil rolling	0,5		0	Downcycle	
1	roller tube	 Aluminum, 2024, T3  Typical %	0,29	Extrusion, foil rolling	0,6		0	Downcycle	
1	stretch panel	 Aluminum, 2024, T3  Typical %	0,05	Roll forming	0,6		0	Downcycle	
1	spring	 Carbon steel, AISI 1020, a... Typical %	0,05	Wire drawing	0,5		0	Recycle	
1	plastic caps	 PP (random copolyme...  Virgin (0%)	0,03	Polymer molding	Not Required		0	Recycle	
1	handle	 Carbon steel, AISI 1020, a... Typical %	0,015		Not Required		0	Recycle	
1	ball bearing, bolts and nuts	 Carbon steel, AISI 1010, a... Virgin (0%)	0,04	Forging	Not Required		0	Re-manufacture	
1	plastic cover	 PET (unfilled, semi-cry...  Virgin (0%)	0,082		Not Required		0	Recycle	
1	plastic mount	 ABS (extrusion)  Virgin (0%)	0,12	Polymer molding	Not Required		0	Landfill	
1	blind	 TPU (Ester, aromatic, S...  Virgin (0%)	0,077	Polymer extrusion	0		0	Recycle	

Appendix N

Comparison of impacts of iterations 2 and 3



EcoAudit report generated with Granta EduPack software

Report generated using
Granta EduPack software

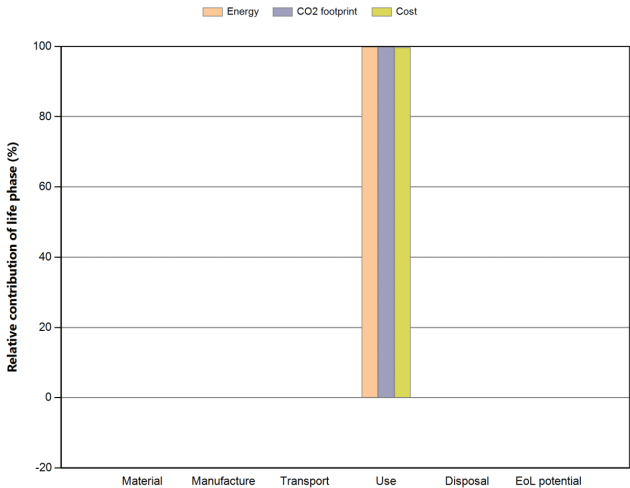
Second product iteration EcoAudit:



Eco Audit Report

Product name COVR - EcoDesign
Country of manufacture Europe
Country of use Europe
Product life (years) 7

Summary:



Energy details

CO2 footprint details

Cost details

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)	Cost (EUR)	Cost (%)
Material	123	0.1	7.6	0.1	2.47	0.139
Manufacture	12.3	0.0	0.924	0.0	2.56	0.144
Transport	0.28	0.0	0.0202	0.0	0.155	0.00867
Use	1.4e+05	99.9	1.01e+04	99.9	1.78e+03	99.7
Disposal	0.572	0.0	0.0401	0.0	0.00654	0.000367
Total (for first life)	1.4e+05	100	1.01e+04	100	1.78e+03	100
End of life potential	-47.6		-2.77			

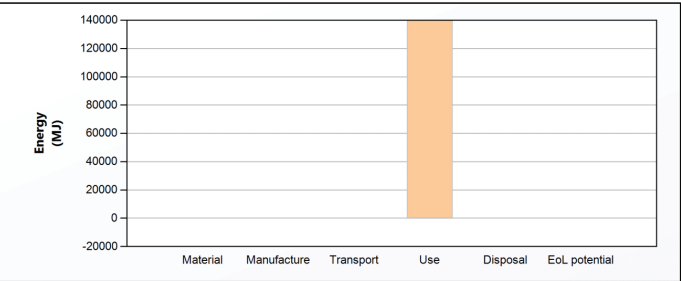
EcoAudit report generated with Granta EduPack software



Eco Audit Report

Energy Analysis

[Summary](#)



	Energy (MJ/year)
Equivalent annual environmental burden (averaged over 7 year product life):	2e+04

Detailed breakdown of individual life phases

Material:

[Summary](#)

Component	Material	Recycled content*	Part mass (kg)	Qty.	Total mass processed** (kg)	Energy (MJ)	%
frame	Aluminum, 2024, T3	Typical %	0,3	1	0,3	38	30,6
roller axle	Aluminum, 2024, T3	Typical %	0,085	1	0,085	11	8,7
roller tube	Aluminum, 2024, T3	Typical %	0,29	1	0,29	36	29,6
stretch panel	Aluminum, 2024, T3	Typical %	0,05	1	0,05	6,3	5,1
spring	Carbon steel, AISI 1020, as rolled	Typical %	0,05	1	0,05	1,1	0,9
plastic caps	PP (random copolymer, low flow)	Virgin (0%)	0,03	1	0,03	2,1	1,7
handle	Carbon steel, AISI 1020, as rolled	Typical %	0,015	1	0,015	0,34	0,3
ball bearing, bolts and nuts	Carbon steel, AISI 1010, annealed	Virgin (0%)	0,04	1	0,04	1,3	1,0
plastic cover	PET (unfilled, semi-crystalline)	Virgin (0%)	0,082	1	0,082	6,7	5,5
plastic mount	ABS (extrusion)	Virgin (0%)	0,12	1	0,12	11	9,0
blind	TPU (Ester, aromatic, Shore A70)	Virgin (0%)	0,077	1	0,077	9,3	7,6
Total				11	1,1	1,2e+02	100

*Typical: Includes 'recycle fraction in current supply'

**Where applicable, includes material mass removed by secondary processes

Manufacture:

[Summary](#)

Component	Process	% Removed	Amount processed	Energy (MJ)	%
frame	Roll forming	-	0,3 kg	2,2	17,6
roller axle	Extrusion, foil rolling	-	0,085 kg	1,2	9,7
roller tube	Extrusion, foil rolling	-	0,29 kg	4,1	33,2
stretch panel	Roll forming	-	0,05 kg	0,36	2,9
spring	Wire drawing	-	0,05 kg	1,1	8,6
plastic caps	Polymer molding	-	0,03 kg	0,64	5,2
ball bearing, bolts and nuts	Forging	-	0,04 kg	0,11	0,9
plastic mount	Polymer molding	-	0,12 kg	2,2	18,1
blind	Polymer extrusion	-	0,077 kg	0,47	3,8
Total				12	100

Transport:

[Summary](#)

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Energy (MJ)	%
Factory to OEM	40 tonne (6 axle) truck	3e+02	0,28	100,0
Total		3e+02	0,28	100

Breakdown by components

Component	Mass (kg)	Energy (MJ)	%
frame	0,3	0,074	26,3
roller axle	0,085	0,021	7,5
roller tube	0,29	0,071	25,5
stretch panel	0,05	0,012	4,4
spring	0,05	0,012	4,4
plastic caps	0,03	0,0074	2,6
handle	0,015	0,0037	1,3
ball bearing, bolts and nuts	0,04	0,0098	3,5
plastic cover	0,082	0,02	7,2
plastic mount	0,12	0,03	10,5
blind	0,077	0,019	6,8
Total	1,1	0,28	100

EcoAudit report generated with Granta EduPack software

Use: [Summary](#)

Mobile mode

Fuel and mobility type	Kerosene - long haul aircraft
Country of use	Europe
Product mass (kg)	1,1
Distance (km per day)	7,4e+03
Usage (days per year)	3,7e+02
Product life (years)	7

Relative contribution of static and mobile modes

Mode	Energy (MJ)	%
Static	0	
Mobile	1,4e+05	100,0
Total	1,4e+05	100

Breakdown of mobile mode by components

Component	Energy (MJ)	%
frame	3,7e+04	26,3
roller axle	1e+04	7,5
roller tube	3,6e+04	25,5
stretch panel	6,1e+03	4,4
spring	6,1e+03	4,4
plastic caps	3,7e+03	2,6
handle	1,8e+03	1,3
ball bearing, bolts and nuts	4,9e+03	3,5
plastic cover	1e+04	7,2
plastic mount	1,5e+04	10,5
blind	9,5e+03	6,8
Total	1,4e+05	100

Disposal: [Summary](#)

Component	End of life option	% recovered	Energy (MJ)	%
frame	Downcycle	100,0	0,15	26,2
roller axle	Downcycle	100,0	0,043	7,4
roller tube	Downcycle	100,0	0,15	25,3
stretch panel	Downcycle	100,0	0,025	4,4
spring	Recycle	100,0	0,035	6,1
plastic caps	Recycle	100,0	0,021	3,7
handle	Recycle	100,0	0,011	1,8
ball bearing, bolts and nuts	Re-manufacture	100,0	0,008	1,4
plastic cover	Recycle	100,0	0,057	10,0
plastic mount	Landfill	100,0	0,024	4,2
blind	Recycle	100,0	0,054	9,4
Total			0,57	100

EoL potential:

Component	End of life option	% recovered	Energy (MJ)	%
frame	Downcycle	100,0	-14	29,2
roller axle	Downcycle	100,0	-3,9	8,3
roller tube	Downcycle	100,0	-13	28,2
stretch panel	Downcycle	100,0	-2,3	4,9
spring	Recycle	100,0	-0,69	1,5
plastic caps	Recycle	100,0	-1,4	2,9
handle	Recycle	100,0	-0,21	0,4
ball bearing, bolts and nuts	Re-manufacture	100,0	-1,2	2,5
plastic cover	Recycle	100,0	-4,4	9,3
plastic mount	Landfill	100,0	0	0,0
blind	Recycle	100,0	-6,1	12,9
Total			-48	100

Notes: [Summary](#)

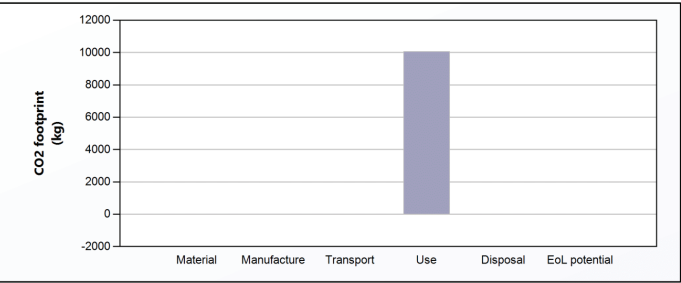
EcoAudit report generated with Granta EduPack software



Eco Audit Report

CO2 Footprint Analysis

[Summary](#)



	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 7 year product life):	1,44e+03

Detailed breakdown of individual life phases

Material:

[Summary](#)

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass processed** (kg)	CO2 footprint (kg)	%
frame	Aluminum, 2024, T3	Typical %	0,3	1	0,3	2,6	33,9
roller axle	Aluminum, 2024, T3	Typical %	0,085	1	0,085	0,73	9,6
roller tube	Aluminum, 2024, T3	Typical %	0,29	1	0,29	2,5	32,8
stretch panel	Aluminum, 2024, T3	Typical %	0,05	1	0,05	0,43	5,7
spring	Carbon steel, AISI 1020, as rolled	Typical %	0,05	1	0,05	0,083	1,1
plastic caps	PP (random copolymer, low flow)	Virgin (0%)	0,03	1	0,03	0,087	1,1
handle	Carbon steel, AISI 1020, as rolled	Typical %	0,015	1	0,015	0,025	0,3
ball bearing, bolts and nuts	Carbon steel, AISI 1010, annealed	Virgin (0%)	0,04	1	0,04	0,095	1,2
plastic cover	PET (unfilled, semi-crystalline)	Virgin (0%)	0,082	1	0,082	0,22	2,9
plastic mount	ABS (extrusion)	Virgin (0%)	0,12	1	0,12	0,41	5,4
blind	TPU (Ester, aromatic, Shore A70)	Virgin (0%)	0,077	1	0,077	0,44	5,8
Total				11	1,1	7,6	100

*Typical: Includes 'recycle fraction in current supply'

**Where applicable, includes material mass removed by secondary processes

Manufacture:

[Summary](#)

Component	Process	% Removed	Amount processed	CO2 footprint (kg)	%
frame	Roll forming	-	0,3 kg	0,16	17,6
roller axle	Extrusion, foil rolling	-	0,085 kg	0,09	9,7
roller tube	Extrusion, foil rolling	-	0,29 kg	0,31	33,2
stretch panel	Roll forming	-	0,05 kg	0,027	2,9
spring	Wire drawing	-	0,05 kg	0,079	8,6
plastic caps	Polymer molding	-	0,03 kg	0,048	5,2
ball bearing, bolts and nuts	Forging	-	0,04 kg	0,0081	0,9
plastic mount	Polymer molding	-	0,12 kg	0,17	18,1
blind	Polymer extrusion	-	0,077 kg	0,035	3,8
Total				0,92	100

Transport:

[Summary](#)

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Factory to OEM	40 tonne (6 axle) truck	3e+02	0,02	100,0
Total		3e+02	0,02	100

Breakdown by components

Component	Mass (kg)	CO2 footprint (kg)	%
frame	0,3	0,0053	26,3
roller axle	0,085	0,0015	7,5
roller tube	0,29	0,0051	25,5
stretch panel	0,05	0,00089	4,4
spring	0,05	0,00089	4,4
plastic caps	0,03	0,00053	2,6
handle	0,015	0,00027	1,3
ball bearing, bolts and nuts	0,04	0,00071	3,5
plastic cover	0,082	0,0015	7,2
plastic mount	0,12	0,0021	10,5
blind	0,077	0,0014	6,8
Total	1,1	0,02	100

EcoAudit report generated with Granta EduPack software

Use: [Summary](#)

Mobile mode

Fuel and mobility type	Kerosene - long haul aircraft
Country of use	Europe
Product mass (kg)	1,1
Distance (km per day)	7,4e+03
Usage (days per year)	3,7e+02
Product life (years)	7

Relative contribution of static and mobile modes

Mode	CO2 footprint (kg)	%
Static	0	
Mobile	1e+04	100,0
Total	1e+04	100

Breakdown of mobile mode by components

Component	CO2 footprint (kg)	%
frame	2,7e+03	26,3
roller axle	7,5e+02	7,5
roller tube	2,6e+03	25,5
stretch panel	4,4e+02	4,4
spring	4,4e+02	4,4
plastic caps	2,7e+02	2,6
handle	1,3e+02	1,3
ball bearing, bolts and nuts	3,5e+02	3,5
plastic cover	7,3e+02	7,2
plastic mount	1,1e+03	10,5
blind	6,8e+02	6,8
Total	1e+04	100

Disposal: [Summary](#)

Component	End of life option	% recovered	CO2 footprint (kg)	%
frame	Downcycle	100,0	0,011	26,2
roller axle	Downcycle	100,0	0,003	7,4
roller tube	Downcycle	100,0	0,01	25,3
stretch panel	Downcycle	100,0	0,0018	4,4
spring	Recycle	100,0	0,0025	6,1
plastic caps	Recycle	100,0	0,0015	3,7
handle	Recycle	100,0	0,00074	1,8
ball bearing, bolts and nuts	Re-manufacture	100,0	0,00056	1,4
plastic cover	Recycle	100,0	0,004	10,0
plastic mount	Landfill	100,0	0,0017	4,2
blind	Recycle	100,0	0,0038	9,4
Total			0,04	100

EoL potential:

Component	End of life option	% recovered	CO2 footprint (kg)	%
frame	Downcycle	100,0	-0,9	32,4
roller axle	Downcycle	100,0	-0,25	9,2
roller tube	Downcycle	100,0	-0,87	31,4
stretch panel	Downcycle	100,0	-0,15	5,4
spring	Recycle	100,0	-0,049	1,8
plastic caps	Recycle	100,0	-0,058	2,1
handle	Recycle	100,0	-0,015	0,5
ball bearing, bolts and nuts	Re-manufacture	100,0	-0,086	3,1
plastic cover	Recycle	100,0	-0,098	3,6
plastic mount	Landfill	100,0	0	0,0
blind	Recycle	100,0	-0,29	10,5
Total			-2,8	100

Notes: [Summary](#)

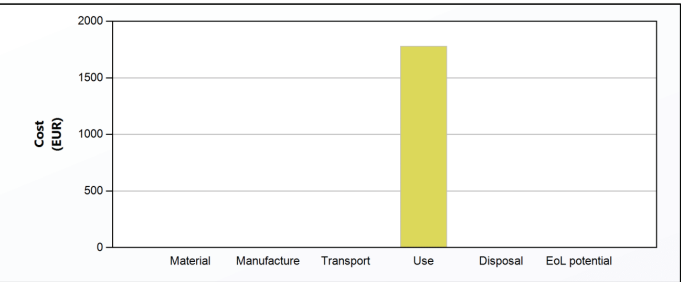
EcoAudit report generated with Granta EduPack software



Eco Audit Report

Cost Analysis

[Summary](#)



	Cost (EUR/year)
Equivalent annual environmental burden (averaged over 7 year product life):	255

Detailed breakdown of individual life phases

Material:

[Summary](#)

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass processed** (kg)	Cost (EUR)	%
frame	Aluminum, 2024, T3	Typical %	0,3	1	0,3	0,72	29,1
roller axle	Aluminum, 2024, T3	Typical %	0,085	1	0,085	0,21	8,4
roller tube	Aluminum, 2024, T3	Typical %	0,29	1	0,29	0,7	28,5
stretch panel	Aluminum, 2024, T3	Typical %	0,05	1	0,05	0,12	4,8
spring	Carbon steel, AISI 1020, as rolled	Typical %	0,05	1	0,05	0,04	1,6
plastic caps	PP (random copolymer, low flow)	Virgin (0%)	0,03	1	0,03	0,039	1,6
handle	Carbon steel, AISI 1020, as rolled	Typical %	0,015	1	0,015	0,011	0,5
ball bearing, bolts and nuts	Carbon steel, AISI 1010, annealed	Virgin (0%)	0,04	1	0,04	0,042	1,7
plastic cover	PET (unfilled, semi-crystalline)	Virgin (0%)	0,082	1	0,082	0,087	3,5
plastic mount	ABS (extrusion)	Virgin (0%)	0,12	1	0,12	0,25	10,0
blind	TPU (Ester, aromatic, Shore A70)	Virgin (0%)	0,077	1	0,077	0,25	10,3
Total				11	1,1	2,5	100

*Typical: Includes 'recycle fraction in current supply'

**Where applicable, includes material mass removed by secondary processes

Manufacture:

[Summary](#)

Country of manufacture Europe

Component	Process	Length (m)	% Removed	Amount processed		Cost (EUR)	%
frame	Roll forming	1,6	-	0,3	kg	0,0035	0,1
roller axle	Extrusion, foil rolling	0,5	-	0,085	kg	0,013	0,5
roller tube	Extrusion, foil rolling	0,6	-	0,29	kg	0,033	1,3
stretch panel	Roll forming	0,6	-	0,05	kg	0,00039	0,0
spring	Wire drawing	0,5	-	0,05	kg	0,00097	0,0
plastic caps	Polymer molding	-	-	0,03	kg	0,22	8,7
ball bearing, bolts and nuts	Forging	-	-	0,04	kg	1,9	75,9
plastic mount	Polymer molding	-	-	0,12	kg	0,34	13,4
blind	Polymer extrusion	-	-	0,077	kg	0	0,0
Total						2,6	100

Transport:

[Summary](#)

Package dimensions

Height (m)	Width (m)	Depth (m)
1	0,1	0,1

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Cost (EUR)	%
Factory to OEM	40 tonne (6 axle) truck	3e+02	0,15	100,0
Total		3e+02	0,15	100

Breakdown by components

Component	Mass (kg)	Cost (EUR)	%
frame	0,3	0,041	26,3
roller axle	0,085	0,012	7,5
roller tube	0,29	0,039	25,5
stretch panel	0,05	0,0068	4,4
spring	0,05	0,0068	4,4
plastic caps	0,03	0,0041	2,6
handle	0,015	0,002	1,3
ball bearing, bolts and nuts	0,04	0,0054	3,5
plastic cover	0,082	0,011	7,2
plastic mount	0,12	0,016	10,5
blind	0,077	0,01	6,8
Total	1,1	0,15	100

EcoAudit report generated with Granta EduPack software

Use: [Summary](#)

Mobile mode

Fuel and mobility type	Kerosene - long haul aircraft
Country of use	Europe
Fuel rate	Commercial
Product mass (kg)	1,1
Distance (km per day)	7,4e+03
Usage (days per year)	3,7e+02
Product life (years)	7

Relative contribution of static and mobile modes

Mode	Cost (EUR)	%
Static	0	
Mobile	1,8e+03	100,0
Total	1,8e+03	100

Breakdown of mobile mode by components

Component	Cost (EUR)	%
frame	4,7e+02	26,3
roller axle	1,3e+02	7,5
roller tube	4,5e+02	25,5
stretch panel	78	4,4
spring	78	4,4
plastic caps	47	2,6
handle	23	1,3
ball bearing, bolts and nuts	62	3,5
plastic cover	1,3e+02	7,2
plastic mount	1,9e+02	10,5
blind	1,2e+02	6,8
Total	1,8e+03	100

Disposal: [Summary](#)

Component	End of life option	% recovered	Cost (EUR)	%
frame	Downcycle	100,0	0,0017	26,3
roller axle	Downcycle	100,0	0,00049	7,5
roller tube	Downcycle	100,0	0,0017	25,5
stretch panel	Downcycle	100,0	0,00029	4,4
spring	Recycle	100,0	0,00029	4,4
plastic caps	Recycle	100,0	0,00017	2,6
handle	Recycle	100,0	8,6e-05	1,3
ball bearing, bolts and nuts	Re-manufacture	100,0	0,00023	3,5
plastic cover	Recycle	100,0	0,00047	7,2
plastic mount	Landfill	100,0	0,00069	10,5
blind	Recycle	100,0	0,00044	6,8
Total			0,0065	100

Notes: [Summary](#)

Appendix P

EcoDesign strategies for product optimization

							
Life cycle stage	Questions	Ecodesign strategy	strategy no.	Criteria	Description	Optimization	Future improvements
Needs analysis	How does the product system actually fulfil social needs? What are the product's main and auxiliary functions? Does the product fulfil these functions effectively and efficiently? What user needs does the product currently meet? Can the product functions be expanded or improved to fulfil users' needs better? Will this need change over a period of time? Can we anticipate this through (radical) product innovation?	New concept development	0	• Dematerialisation • Shared use of the product • Integration of functions • Functional optimisation of product (components)	It fulfills the need for the feeling of safety when travelling. Main function is to enhance perceived safety, additionally protects from viruses, which may be important during periods of increased infection risk, and provides privacy, which is a desired feature in public transport It provides these functions effectively, as shown in user testing, and efficiently - uses minimum space in the aircraft It currently meets the users' needs to feel safe, be protected from viruses and have privacy The product can be expanded to create a flexible interior arrangements, or cover a larger area of the body. It may be installed in different places in the cabin. The need of virus protection may change over time, but privacy is likely to remain relevant.	An additional function was added, which indicates the seat number.	As the main problem addressed by this product may become less relevant in the future, focus might be put on emphasizing the privacy features this product gives. Additional focus may be put on making the product adaptable to different contexts, e.g. switching between different modes of transport. Furthermore, this product may be optimized to serve as a multi-functional space divider in the vehicle interiors, providing secluded spaces in a shape that is needed.
				Score (0-4)	3	4	5
Life cycle stage 1: Production and supply of materials and components	What problems arise in the production and supply of materials and components? How much, and what types of plastic and rubber are used? How much, and what types of additives are used? How much, and what types of metals are used? How much, and what other types of materials (glass, ceramics, etc.) are used? How much, and which type of surface treatment is used? What is the environmental profile of the components? How much energy is required to transport the components and materials?	Selection of low-impact materials	1	• Clean materials • Renewable materials • Low energy content materials • Recycled materials • Recyclable materials	The current state of material production makes it challenging to develop a fully clean, recyclable product. The complexity of the process needed to recycle aviation-grade aluminum make it difficult to become a viable option. Furthermore, some types of plastic that suit the needs of this product are not fully suitable for recycling. This product would use a relatively many injection molding processes which increase the energy use in the production phase. This product uses materials that are on EU and US Critical Elements List, specifically aluminum alloy 2024 and neodymium magnets. The product uses mainly metals (alu, steel, neodymium) and plastics (PP, PET, TPU, ABS). Aluminum is generally recyclable, however aircraft grade alloys are challenging to recycle due to the complexity of the process and material degradation. As the alloys utilized in the aerospace industry must meet high standards regarding the material composition with low tolerances on impurity (Totalmateria, 2009), the end-life of the product may require downgrading the aluminum and repurposing by industries in which higher tolerances are accepted.	Not using neodymium magnets; replacing the with hooks Using recycled plastic in the production process	New innovative materials may pave the way of making this product more sustainable in the future. One way to optimize it is to use more green materials, such as: - New type of cobalt-based permanent magnet that does not require dangerous chemicals and rare materials (https://phys.org/news/2020-03-permanent-magnet-cheap-sustainable.html) - Introducing new types of aluminum that are composed of more recycled materials - use more eco-friendly plastics and processes - use of the blind material made from recycled materials - optimize the weight of the product to reduce resulting fuel consumption
				Score (0-4)	2	3	4
		Reduction of materials usage	2	• Reduction in weight • Reduction in (transport) volume	Currently, the weight of the product is about 2 kg. The main components adding to weight are the frame, roller tube, and a plastic cover. As a plastic casing is integrated, relatively little packaging can be achieved. The frame has an irregular shape, which increases the transportation volume.	Less plastic for cover - less weight	Using parametric design to define the most optimal structure for the frame Excluding the plastic cover, or optimizing it using FEM analysis Including a frame that can be folded into pieces to reduce size Using a single axle for the roller
				Score (0-4)	3	4	5

EcoDesign strategies for product optimization

Life cycle stage 2: In-house production	What problems can arise in the production process in your own company? How many, and what types of production processes are used? (including connections, surface treatments, printing and labelling) How much, and what types of auxiliary materials are needed? How high is the energy consumption? How much waste is generated? How many products don't meet the required quality norms?	Optimization of production techniques	3	- Alternative production techniques - Fewer production steps - Low/clean energy consumption - Less production waste - Few/clean production consumables	The processes used are primarily extrusion and injection moulding. Problems that can arise regarding the frame are the need to bend it and the welding process required, which may make the process more costly and labor intensive. Injection moulding is required for many plastic parts, which uses relatively high energy. The current process uses about 18 MJ per product. The plastic cover, roller tube and plastic mount require most energy.	Less plastic due to optimizing the cover and reducing the plastic parts. Simpler construction of the frame allows for fewer production steps. No neodymium which uses rare materials and toxic chemicals	Less plastic would reduce the energy use. Some aluminum parts may have a simpler design to use different production techniques and be less energy intensive.
				Score (0-4)	3	4	4
Life cycle stage 3: Distribution	What problems can arise in the distribution of the product to the customer? What kind of transport packaging, bulk packaging, and retail packaging are used (volumes, weights, materials, reusability)? Which means of transport are used? Is transport efficiently organised?	Optimization of distribution system	4	Reduction in weight Reduction in (transport) volume	The product is being transported to the aircraft OEM and assembled on the airplanes. Little packaging is required as no retail distribution is considered. Packaging may be optimized to reduce transport volume.	Foldable design, weight reduction, less volume, more packaging may be required	Improved packaging, green or no packaging, volume and weight reduction, more foldable design
				Score (0-4)	4	4	5
Life cycle stage 4: Utilization	What problems arise when using, operating, servicing and repairing the product? How much, and what type of energy is required, direct or indirect? How much, and what kind of consumables are needed? What is the technical lifetime? How much maintenance and repairs are needed? What and how much auxiliary materials and energy are required for operating, servicing and repair? Can the product be disassembled by a layman? Are those parts often requiring replacement detachable? What is the aesthetic lifetime of the product?	Reduction of impact during use	5	- Low energy consumption - Clean energy source - Few consumables - Clean consumables - No wastage of energy or consumables	This product does not require direct energy consumption. There is high indirect energy consumption due to being used in the aircraft. The product may require disinfecting and/or washing. May require maintenance or repair. Moderate to low maintenance due to antimicrobial properties. Cannot be disassembled by layman. The blind material can be detached moderately easily. 7+ years aesthetic lifetime due to removable blinds.	Reduction in weight, optimized construction for easy removal, of the upper part, easier removal of the blind material	Reduction in weight. Optimizing construction for easy removal. Blinds fully removable. Can be washed in the aircraft instead of the laundry machines. Optimization of the use per passenger, using big data to calculate the amount of seats needed.
				Score (0-4)	3	4	5
		Optimization of initial lifetime	6	- Reliability and durability - Easy maintenance and repair - Modular product structure - Classic Design - Strong product-user relation	The product uses a relatively simple mechanism which should be relatively easy to repair. Maintenance is easy due to few mechanical parts. Design is similar to other current solutions.	Hooks will be more reliable than magnets. Easier to disassemble and maintain due to simpler construction.	Access to the mechanism should be facilitated. design can be modular to make the parts easily removable.
				Score (0-4)	4	5	5
Life cycle stage 5: Recovery and disposal	What problems arise in the recovery and disposal of the product? How is the product currently disposed of? Are components or materials being reused? What components could be reused? Can the components be reassembled without damage? What materials are recyclable? Are the materials identifiable? Can they be detached quickly? Are any incompatible inks, surface treatments or stickers used? Are any hazardous components easily detachable? Do problems occur while incinerating non-reusable product parts?	Optimization of end-of-life system.	7	- Reuse of product (components) - Remanufacturing/refurbishing - Recycling of materials - Safe incineration	Materials can be generally recycled, but not all. The product will be most likely disposed of in en masse by the airline, so a controlled process is possible. Can be reassembled without damage to the components. The materials can be detached in medium time. Antimicrobial surface treatments. The materials are identifiable. Some of the materials are recyclable.	Optimized for faster detachability. Simpler, modular design for easier reassembly or reuse.	More recyclable materials can be used. Remanufacturing for different purposes should be considered.
				Score (0-4)	3	3	4
	Sources:						
	http://www.madehow.com/Volume-4/Polyester-Fleece.html						

