Submission 1.1- Sustainable DesignEng

Sustainability Analysis of Aircraft Business Class Seats as a Durable and High-Value Product System

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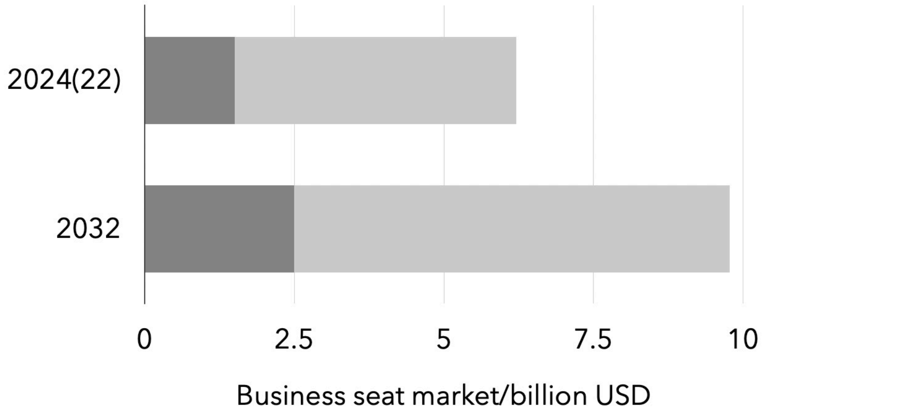
Seat Market Insights

Our Product: Zodiac (Safran) Business Class Seats: Market research shows that demand for all business class is continuously increasing. Although these products inherently have unsustainable characteristics, companies are working to enhance seat sustainability or propose future solutions.

Market Trends

Market Trends	
Product	Business Class Aeroplane seating is expected to experience a rise in usage due to globalisation, tourism and increasing population. [1]
Utility	Implement circular economy so parts can be repaired and reused, extending product lifespan from the typical 7 years.
Consumers	Corporate workers and those who want to fly long haul in luxury.
New Materials	Focus on utilising sustainable materials, i.e. lightweight composites, carbon fibre and 3D printing.
Premiumisation	Cater to affluent travellers through ever improving user experience. [6]
Modularity	Adaptable configurations to meet the everchanging need of passengers (inclusivity).
Hygiene	Post pandemic has highlighted the need for increased sanitation and ventilation.

Market Size



The two sections in the bar chart represent two different data sources, both providing information on the global business class seat market.

As of 2022 revenue was **4.71** billion USD
Estimated to reach **7.28** billion USD by 2032.
Compound Annual **Growth Rate** (CAGR) of **6.3%** expected by 2032.[1]

How Safran Will Enhance Seat Sustainability in the Future

By 2050, **Safran** hopes to achieve net **zero carbon emissions**.

Hoping for Disruptive Technologies to pave the way for **lightweight equipment**

Aims to implement **hybrid electric** technology and sustainable aviation fuels. [5]

Brands / Sustainable Innovations / Compare with Zodiac

Brands	Sustainable Innovations	Compare with Zodiac
RECARO	Offers global repair stations to increase the lifespan of their chairs. Prides itself on being lightweight and thus fuel efficient. Aircraft covers are made from upcycling leather offcuts. Instead of landfill, old seats are burnt and used as fuel in factories. [2]	Similarly to Recaro, zodiac offers worldwide repair stations to extend lifespan of seating.
STELIA RELIABILITY. PERFORMANCE.	Opera Essential Seats are 30% lighter, reducing fuel consumption. Excess cabling removed, which makes maintenance cheaper. Prioritises using thermoplastics, composite shells and bio leathers. [3]	Lightweight materials also used, to reduce fuel consumption.
AIRTEK	Project AirTek Adopted a Unibody Structure, which increases product simplicity and thus makes maintenance easier. Reduced weight to be more fuel efficient. Seat is made from recycled materials and composites. [4]	Seats are not majorly made from recycled materials; however seats are said to be durable to withstand wear and tear and thus prolong usage.

Market Trends in Sustainability Aspects

summary and trend analysis based on the data provided about the **cost incentives** and sustainability of **aircraft seat recycling**

> **Landfill Costs**: Disposing of aircraft seats in landfills is **costly**, ranging from **€2,000 to €4,500** depending on the inclusion of in-flight entertainment (IFE) and composite frames. Hazardous materials increase disposal fees.

> **Recycling Benefits**: Manufacturers are shifting toward recycling valuable materials like carbon fiber, **reducing** raw material **demand**. Companies such as Adient Aerospace use sustainable materials to **enhance fuel efficiency** and **reduce emissions**.

> **Decommissioning and Reuse**: Up to **90%** of an aircraft's weight is **now recyclable**, with over **6,000 parts reusable**. The Aircraft Fleet Recycling Association (AFRA) has increased **recycling rates** from below **50%** in 2009 to over **85%** today.

> **Future Outlook**: With 12,000 aircraft **set for decommissioning** in the **next 20 years**, sustainable recycling processes will become crucial for cost management and environmental compliance.

Key Insight: AirTek, Stelia Aerospace, and Recaro have more established sustainable seating lines compared to Zodiac. AirTek and Recaro focus on upcycling offcuts for seats, a practice not followed by Stelia or Zodiac. While Zodiac emphasizes post-manufacture sustainability (maintenance), the others integrate eco-friendly practices throughout design and production.

Product Claims

Safran, the manufacturer have committed towards a more sustainable future, vowing to match the EU's goal of being carbon net zero by 2050.

To work towards this they have been helping design much more efficient airplane engines alongside much more aerodynamic plane designs to be completed by 2030-35.

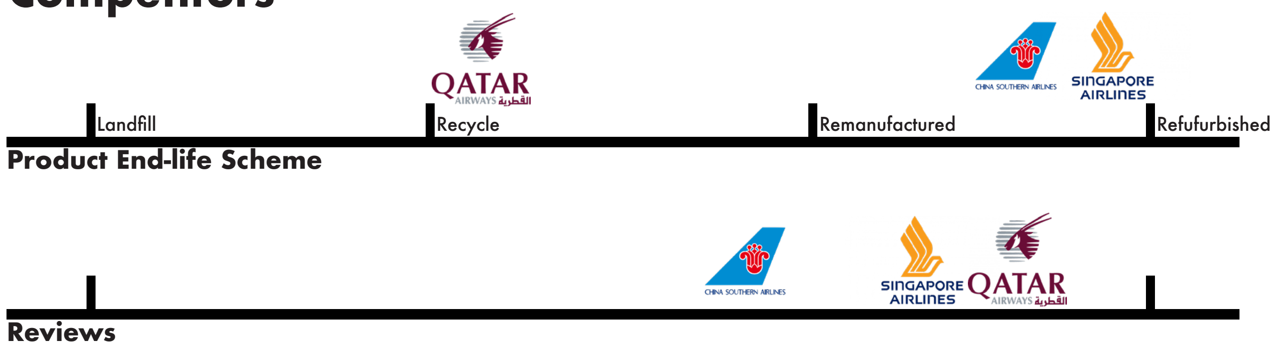
Similarly, Safran have been working alongside Daher and Airbus on the EcoPulse project, a hybrid aeroplane using electricity alongside traditional fuel, to try and solve the issues with plane carbon emissions.

Finally, Safran have targeted to drop their CO2 emissions 30% by 2025 in regards to their 2018 emissions.

To help incentivise the company to do this an Internal Carbon Price (ICP) has been made which is used to 'fine' in relation to the amount of carbon produced.

	Sample Seat	Current Day Seats
Model	Safran, Zodiac, Contours Premium Double Business Class Seat	Acro, Series 7, Narrowbody Domestic Business Class Seat
Image		
Base Attributes	- Extendable Legrest - Padded Armrest - Reclinable Seat - Retractable Cocktail Table - Leather Cover - TV Entertainment System - Reading Light	- Luxury Cushion - USB Provisioning - Padded Armrest - Synthetic Leather Cover - Cocktail Table - Bespoke Cover & Cushions - Privacy Wing - Articulated Legrest - Reading Light
Claims	Maximises the passenger capacity of the airplane by using a paired seating configuration without compromising on luxury for passengers. Supposedly were very customisable seats so airlines could adjust the seats how they wished to fit an image or different airlines needs.	"Excellence comes as standard when you choose Acro, balancing weight, purchase and maintenance costs without compromising comfort or visual appeal" Description of the seat highlighting it's strengths "brings the comfort dividend to Domestic Business, with ergonomically sleek design and detailed finish"

Competitors

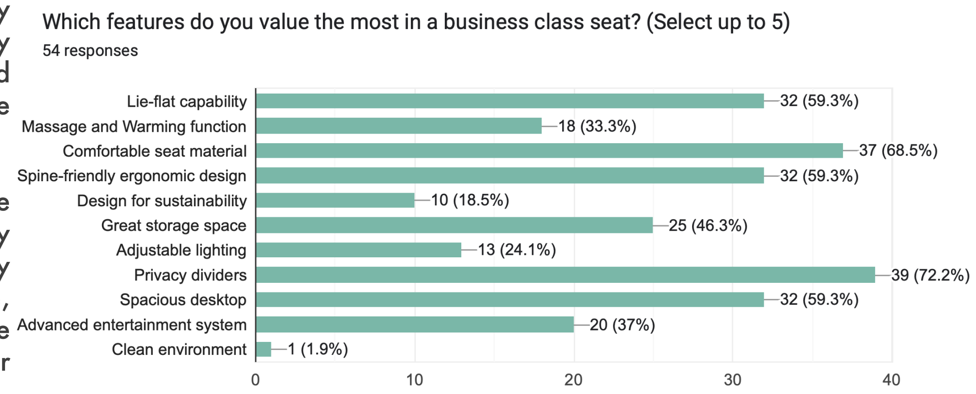


User Research - Survey

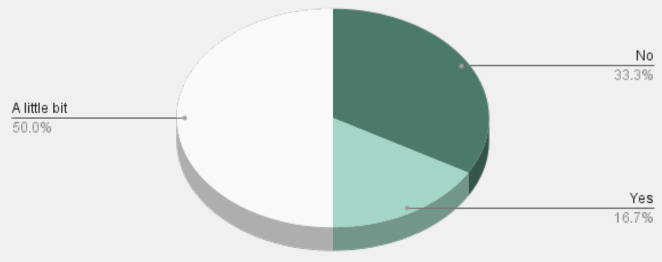
> Survey participants: (the first two survey questions have shown that, 40% of them fly with business class seats 2-5 times a year, and a half of less than 2. so most of them do have business class trip experience.

> The Survey received 54 responses in total

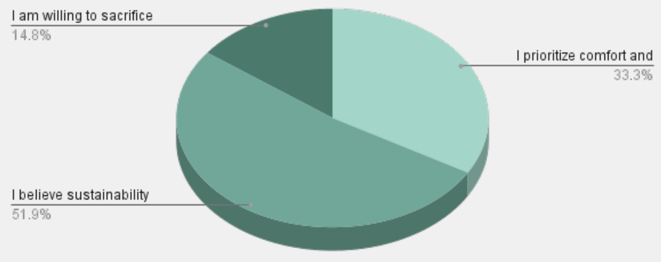
> The most valued features for people are comfortable seat materials and privacy dividers, as expected. However, sustainability design ranks second to last in importance, suggesting that we should not compromise core seat functionality and comfort for sustainability.



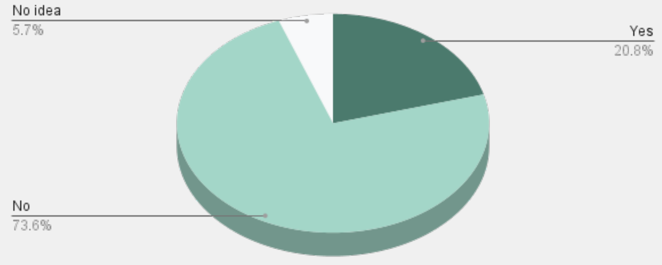
Count of Have you ever considered the environmental impact of the materials used in aircraft seating?



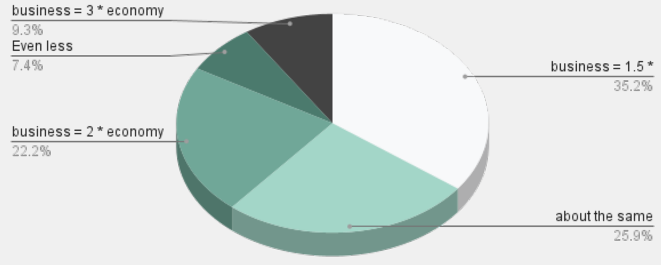
Count of Which of the following statements best reflects your opinion?



Count of Do you think sustainable design and materials means less quality and comfort



Count of Based on your attempt to guess how much more carbon emissions business class will produce than economy



Insights & Opportunities from survey results

> Only **16.7%** of the respondents have really considered the environmental impact of airplane seats. This means that many people have a **superficial understanding of sustainability** and may not be aware of the environmental impact of the materials used in airplanes. This provides an opportunity for the aviation industry to inform and engage passengers about the environmental costs associated with seat materials, potentially **influencing future customer preferences** for sustainable choices.

> The fact that **33.3%** still **prioritize comfort over sustainability** means that while there is demand for sustainable products, these products must **still meet high standards of comfort and quality** to be fully accepted. Airlines can use this insight to develop seating options that combine both and promote them as 'sustainable luxury' options.

> With nearly **74%** of respondents believing that sustainable materials do not degrade the quality of seats, consumers are **positive** about sustainable design.

> Respondents' differing guesses about the emissions of business and economy seating indicate a **lack of clarity about the environmental costs of the different seating classes**. 35.2% of respondents estimated that the emissions would only increase by a factor of 1.5, and a further 25.9% thought that the emissions would be 'about the same', which is clearly a knowledge gap. This lack of awareness could mean that passengers are not fully aware of the impact of cabin class on carbon emissions. Airlines could use this as an educational opportunity to be transparent about the environmental impact of seat class.

Persona & User Journey Map

Further research like interviews was conducted to characterize the behaviors of two distinct user groups among business class travelers. This is important to identify design opportunities at various stages of the user journey, especially concerning sustainability enhancements.

Persona

Sustainable Charlie, 31

Degree of concern for sustainability

The proportion of airfare in monthly income

The necessity for business class travel

Age: 31
Occupation: Project Manager
Location: London, UK
Income: Medium

Needs:
Comfortable seating for rest; reduce environmental impact.

Goals:
Balance personal comfort with commitment to sustainability; influence industry toward greener practices.

Pain Points:
Lack of environmental measures in business class, such as energy-intensive seat designs
Excessive packaging and wasteful in-flight amenities

Travel Habits

"I only make 2 long-haul flights per year, mainly to attend international conferences. Prior to departure, I minimize unnecessary travel and prefer to use video conferencing. During the flight, I refuse to use disposable plastic products. Upon arrival, I will share my experiences to advocate green travel.

Business Traveller Nicole, 40

Degree of concern for sustainability

Price sensitivity

The necessity for business class travel

Age: 40
Occupation:Executive at a multinational corporation
Location: London, UK
Income: High

Needs:
Maintain productivity during travel; seek ultimate comfort; desire seamless, time-efficient services.

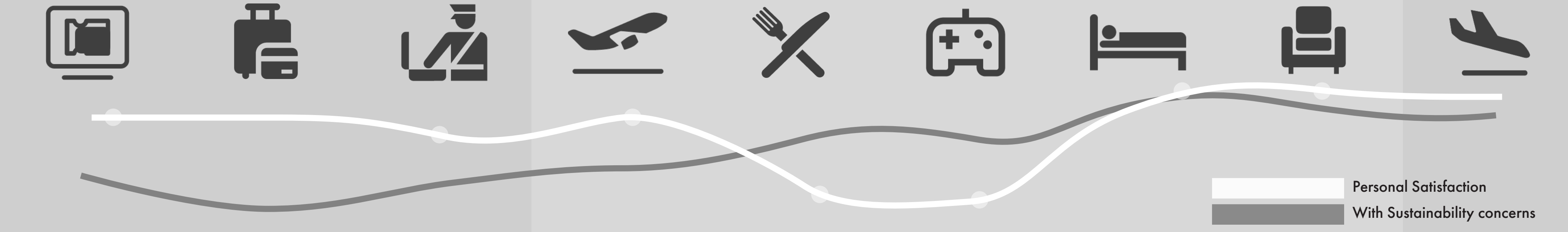
Goals:
Experience a hassle-free journey to work and rest effectively, maximizing efficiency.

Pain Points:
Seats not fully comfortable especially for neck; table boards are not large and stable enough; limited storage; cabin noise.

Travel Habits

"I flying at least 2 international routes a month with business class. During the flight, I expect efficient service, comfortable seats and environment that ensures proper work and rest. To be honest I don't have much effort to care about sustainability in my daily life."

User Journey Map

Section	Before the flight			During the flight					After the flight
Phase	Flight Booking & Seat selection	Preparation & Packing	Checkin & Secutiry Check	Boarding and Take off	Meal Time	Entertain-ment	Sleep & Rest	Get up from the seat	Landing & Leaving
Emotion									
Goal & Expec-tation	Book a comfortable business class for a 10 hours long flight that aligns with her schedule, with an airline she trusts and less polluted. Book the most convenient and time-efficient flight.	Minimize the burden of flights while saving energy. Pack efficiently for comfort and convenience during the journey.	Navigate airport procedures efficiently, try to not through away anything during security check. Complete check-in smoothly and navigate security with minimal delays.	clean and welcoming seating area, settle in for a comfortable flight, Smooth take-off with minimal disruptions. Settle into the business class seat and prepare for a comfortable journey.	High-quality meal options, including vegetarian dishes; easy-clean table; Doesn't easily stain other areas Enjoy a high-quality meal experience for food I prefer	Relax & Enjoy; A variety of entertainment options; Smooth operation of equipments. Stay entertained with in-flight options to pass the time.	Rest well to arrive refreshed; Comfortable sleeping arrangements. Get sufficient rest or sleep for arrival.	Stretch her legs and attend to personal needs without disturbing others; easily and gracefully get up from her seat with minimal effort and impact. Move around to stay comfortable during long flights.	smooth landing & An orderly exit process; Dispose of garbage and leftovers in the most environmentally friendly way possible Disembark quickly and gather belongings for a smooth exit.
Action	1.Chooses direct flights to minimize total travel time and emissions. 2.Select airports with easy access to public transportation for both departures and arrivals. Booked a satisfactory flight without considering the price, with best service.	Packs light to reduce the aircraft's load, brings a reusable water bottle and a set of noise-canceling headphones to avoid using disposable earphones. Organize and pack luggage, ensuring all essentials are included.	Uses mobile boarding passes to reduce paper use; opts out of printing receipts. Carries her own empty reusable water bottle through security to fill later. Arrive early to check in, follow security protocols, and proceed to the gate.	Stows her belongings efficiently; notices the seat shows heavy signs of use, seat belt is old but strong. Board the plane, store luggage, and follow crew instructions for take-off.	Chooses a vegetarian meal, declines unnecessary items like plastic stirrers or extra napkins. Keeps the same glass for refills to reduce dishwashing and waste. Select meal preferences and enjoy the food service.	Try to use her own headphones to watch a movie; adjusts the screen brightness to a comfortable level to conserve energy and protect eyes. Choose from various movies, shows, or games.	Adjusts seat to a reclining position; uses only necessary bedding. Keeps personal items organized to avoid losing or misplacing them. Recline the seat, use provided amenities, and relax or sleep.	Decides to stretch for comfort; doesn't returns her seat to upright as it's unnecessary; Uses armrests designed for ergonomic support to assist in standing smoothly Stand up, stretch, or visit the restroom as needed.	Try to use her own headphones to watch a movie; adjusts the screen brightness to a comfortable level to conserve energy and protect eyes. Follow crew instructions for landing, gather luggage, and leave the plane.
Eco--Realted Feeling	She choose economy seats most of the time, a extra long flight let her choosed a **relatively unsustainable** options.	Traveling requires a lot of **disposables** but she prefer **long-term** items, which makes her confused as this will make her package heavy.	Most people **disposed** clean water before security, and she doesn't like that kind of **waste**. but the **PDX water collection** make airport go a bit greener.	She doesn't expect the chairs to be new, but I do expect them to be **cleaned and cared** for on a regular basis.	Appreciates thoughtful meal service; Chairs and table tops are still designed to **harbor dirt** easily, making **cleaning** more difficult and costly.	Does not support private headphones; The handle and the touch screen are very **unresponsive**, making it difficult to adjust the screen brightness	Feels satisfied with a good rest; appreciates the comfort provided **without excess**.	It feels like most business class seats are designed to be **bulky** in order to look comfortable, but not every part actually serves a specific purpose (i.e. assistance, storage)	Take toiletries and food that can still be used; keeps any waste to dispose if recycling options aren't immediately available.Chooses public transportation to her destination.
Insight & oppor--tunity	• Highlight direct flights and fuel-efficient aircraft in booking platforms. • Provide information on fleet efficiency subtly for those interested.	• Encourage light packing by offering tips during pre-flight communications. • Support use of personal reusable items by providing refill stations.	• Streamline digital processes and promote them as both convenient and eco-friendly. • Provide water refill stations post-security.	• Ensure the cabin is clean and well-maintained to enhance the perception of care and sustainability.	• More consideration on cleanliness, as passengers concerned about hygiene, the small table should be designed to be less prone to soiling the passenger and the seat • provide pre-order food to avoid food waste.	• Consistently using the **same batch of onboard equipment** is frugal, but it can also result in a degraded experience • reduce the maximum brightness of the screen.	• Design seats and bedding for comfort with minimal materials. • Provide storage options to help passengers keep their area tidy.	• Utilize space more rationally, add meaningful functionality, or reduce the use of materials and improve the quality of materials to make them stronger and more durable	• Encourage use of personal devices by providing compatible connections • reduce the maximum brightness of the screen. • Provide clear waste disposal options upon disembarkation. Place recycling bins at convenient locations.

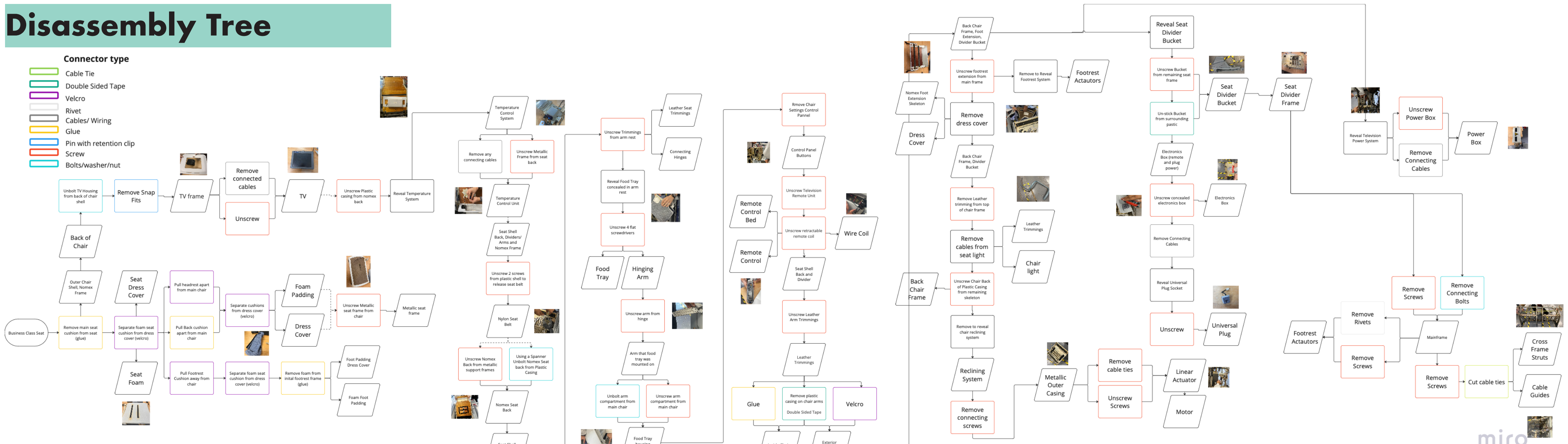
HMWs

HMW redesign the material selection and shape of business class **table** to improve surface area and ease of cleaning, while maintaining strength and material sustainability?
HMW design **lighter** and more efficient business class seats to reduce aircraft fuel consumption and overall carbon footprint?
HMW redesign the seats for disassembling so that it allows for easy replacement of electronic screens and cleaning of seat covers.
HMW minimize in-flight waste by reimagining amenity kits and service items with eco-friendly and reusable alternatives?

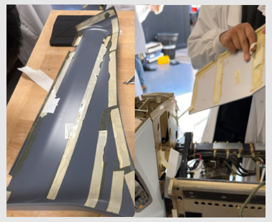
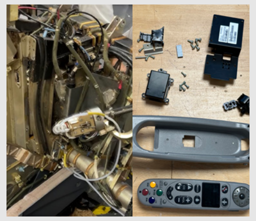
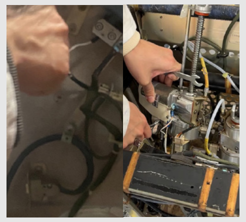
Tear-Down Analysis

During disassembly, we documented each part and analyzed the manufacturer's joining techniques. This allowed us to identify areas of the chair that could be simplified, lightened, and redesigned for easier assembly, disassembly, and recycling.

Disassembly Tree



Disassembly Analysis

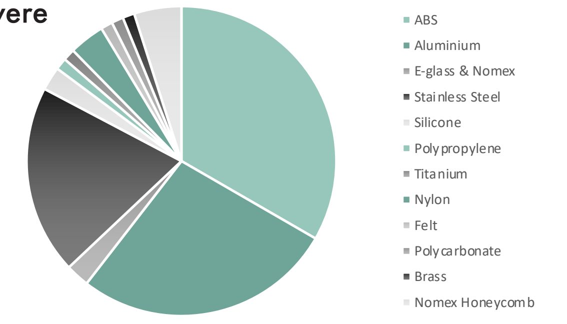
	Outer Shell	Electronics	Framing	Cushion & Cover	Safety Pin
Connector	Glue, double sided tape and screws	Screws and Cabling	Zip ties and rivets	Tape and Velcro	A special connector
Image					
Availability to Reassemble	●○○○○	●●●○○	●●○○○	○○○○○	●●●●●
Disassembly Difficulty	●●○○○	●●●○○	●●●○○	●●○○○	●○○○○
Analysis	Glue was used in excess to secure the plastic shell as well as to keep the dress covers on cushions.	Cabling management was poor which made for difficult component separation.	An abundance of zip ties were used to secure components to the metallic frame.	Velcro is sewn onto the seat cover and the velcro on the foam is held in place with tape	Pins for connecting important interfaces for secure connection and easy removal.
Insights in DFA & DFD	> Parts had to be ripped away which meant they could not be put back together. > The tape should also be removed for plastic recycling.	> Cables had to be cut due to lack of organisation. > The remote control is difficult to remove from the seat and therefore difficult to service.	> Zip ties had to be cut, meaning the connectors could not be reused after disassembly.	> The tape can easily tear the foam when removing the seat cover. > For the removal of the seat cover, the seat cover cannot be easily removed in its entirety, only destroying the fabric.	> A connection that zodiac chair designer likes to use, easy to produce and easy to dismantle, low cost and commonplace, a clever and sustainable design.

Connectors

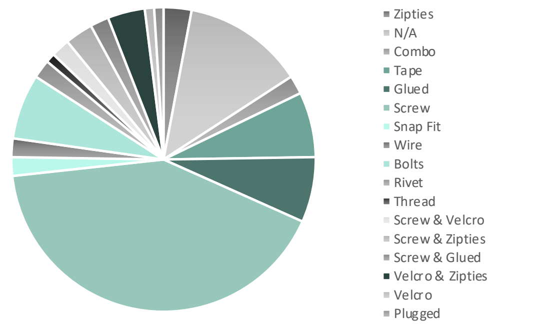
At the end of the disassembly process, qw counted 76 different types of connector were used.

Material & Manufacturing Classification

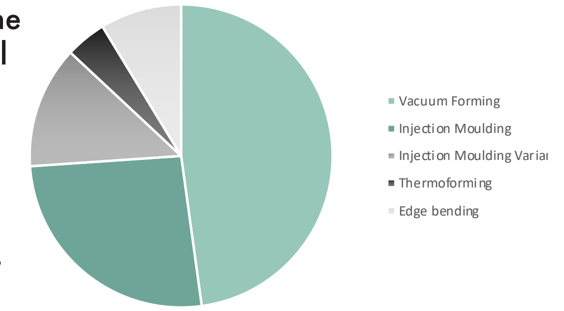
The chairs themselves were comprised of around 11 different materials with the majority of components and pieces being made of ABS and Aluminium.



When joining the chair together during manufacturing. Safran used over 17 different process to connect pieces together, with the majority of components being screwed together.



Finally, as ABS was the most common material we decided to look at how its components were manufactured. Of the 5 methods used Vacuum Forming was shown to be the most used.



Insights on Sustainability

Disassembly

Airplane seats are designed for **permanence**, with many permanent or semi-permanent joints, as they have a **long lifespan** and require minimal disassembly. Layers of plastic shell cover metal frames with wiring throughout, ensuring passenger safety.

Lifecycle

The typical airplane seat last for 23 years with **little adjustment** during its lifecycle.
By the time it is removed most of the technology has been rendered obsolete, leading to to the chair being **discarded**.

Business Model

The aircraft seat market seems to focus on manufacture and use of the product, with very **little focus** on **recyclability**, as shown by the difficulties disassembling and high costs. This indicates reliance on a **closed-loop system** with limited emphasis on **material reuse.**

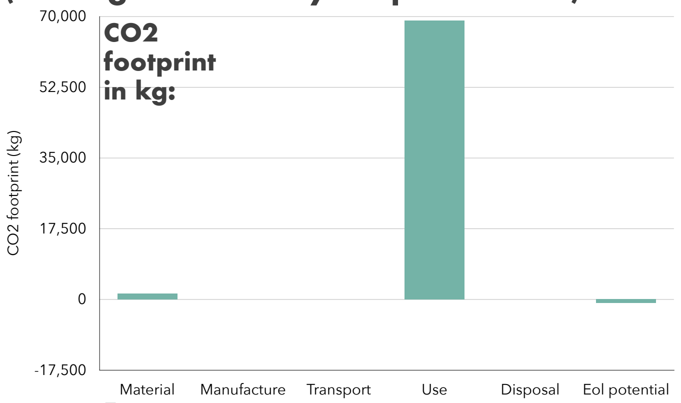
Key Insights

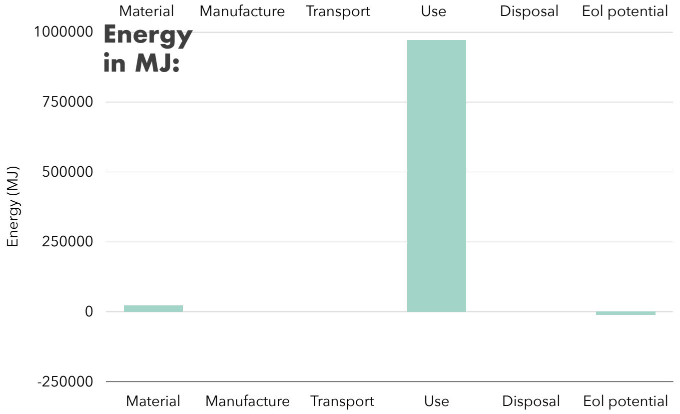
> The chair was not designed for disassembly as it took multiple hours (6 hours) and hands to tear it down to its frame, shows difficulty in recycling because of the high cost of classifying all materials.
> The amount of ABS used in the chair could be recyled easier but is often screwed down to it's adjacent components so reducing unnecessary metal joining would improve the products carbon footprint.

Eco Audit & Material Circularity

Eco Audit Report Analysis

Equivalent annual environmental burden (averaged over 25 year product life):





Key Assumptions:

Material:

> Materials for most of the components are educated predictions (e.g.We assume ABS as the plastic shell material and aluminum for the metal frame based on industry norms and material properties suited for aircraft seat applications.)

> For components not fully disassembled due to time constraints, we manually separated them by material type.

> for those materials thay cannot be found on EduPack, Materials with similar sustainable characteristics are used.

Manufacturing Method:

> Injection Molding for most of the plastics.

> Inferring the use of casting, drawing or forging based on the shape of the metal part.

Transportation:

> Assume Zodiac seats are produced in the UK, transported by sea to Zodiac's Tianjin assembly plant in China (NanFang Airline). At Tianjin, seats undergo final assembly and transported by truck to final installation.

End-of-Life (EoL):

> Most components go to landfill.

> Some of the less contaminated metal and plastic components will be recycled or reprocessed.

Result:

Both charts show that the **use phase** contributes the **most** to the CO_2 footprint and energy consumption, indicating that the seat's **weight** has a significant impact on fuel consumption throughout its lifecycle on an aircraft.

Insights:

> The result highlights the critical impact of weight on fuel efficiency. we should prioritise the need to use lightweight, durable materials over reducing manufacturing and material emissions alone, as operational efficiency has a far greater effect on sustainability.

Material Circularity Indicator

Results

Utility based on (Selec	Longevity	
This product lasts:	20	Years
Typical product lasts:	25	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Plastics	10.7880	1	Plastics	Recycle	80%	60%	Recycle	**0.15**
Aluminium	18.2350	1	Aluminium	Recycle	80%	80%	Recycle	**0.38**
Steels	7.7510	1	Steel	Recycle	80%	80%	Recycle	**0.47**
Screws	0.7061	1	Steel	Virgin		50%	Reuse	**0.16**
Foam	3.9840	1	Composites	Virgin		25%	Landfill	0.00
Zipties	0.1150	1	Bioplastic	Recycle	80.00%	50%	Recycle	0.00
Connectors	0.3440	1	Steel	Recycle	80.00%	60%	Recycle	0.38
Frame	20.0000	1	Steel	Recycle	60.00%	80%	Recycle	0.47
Product Mass (kg):	**61.9231**							**0.35**

Key Assumptions:

Collection Rate:

> **Metal** collection rate is assumed at 80%, due to the high value and recyclability of steel in industrial recycling systems.

> **Screw** is assumed to have 50% collection rate that reflects the difficulty in retrieving small components during disassembly, reducing overall recovery efficiency.

> **ABS Plastics** should normally have a recycling rate of more than 60%, but the plastic of converted airplanes is often not completely separated from other materials (e.g., wood) or is contaminated with glue, thus reducing the recycling rate.

> **Foams**, and other **composites** have lower collection rates of 50%-20% as they are typically harder to recycle due to contamination and limited recycling options, leading to a significant portion ending up in landfill.

Regenerative:

> 80-60% regenerative, meaning they are primarily sourced from recycled materials and contribute positively to circularity. This reflects the feasibility of using recycled content without compromising material integrity。

> Screws require high-strength metal, often sourced new for quality control, while foams are challenging to source from recycled content due to material properties

Insights & Opportunities

> The overall MCI score of **0.35** indicates partial circularity, suggesting that while some materials are recovered and recycled, a large portion still relies on virgin inputs and linear disposal paths.

> Airlines may partnering with automotive and consumer electronics sectors could help the industry use shared recycling networks to lower the costs. e.g. Aircraft foams could be recycled with automotive seat foams, reducing landfill waste and improving collection rates, benefiting both industries.

> Manufacturers may change the connection methods between material components, such as minimizing the use of adhesives and opting for more detachable mechanical structures.

Material Circularity Analysis

This diagram of material circularity helps us to understand the lifecycle from sourcing and manufacturing to end-of-life of key materials. It evaluates options for reusing, recycling, and disposal of each material, which decribed an ideal situation - a circular economy.

> **Plastic Shell (e.g., ABS)**: Plastics used for outer shells are durable but challenging to recycle due to their bonding with other components. End-of-life options may include incineration for energy recovery or downcycling for lower-grade plastic products.

> **Electronic Components:** Comprising mixed metals and plastics, electronics are difficult to separate and are usually recycled for metal recovery or sent to e-waste recycling facilities, though contamination remains a challenge.

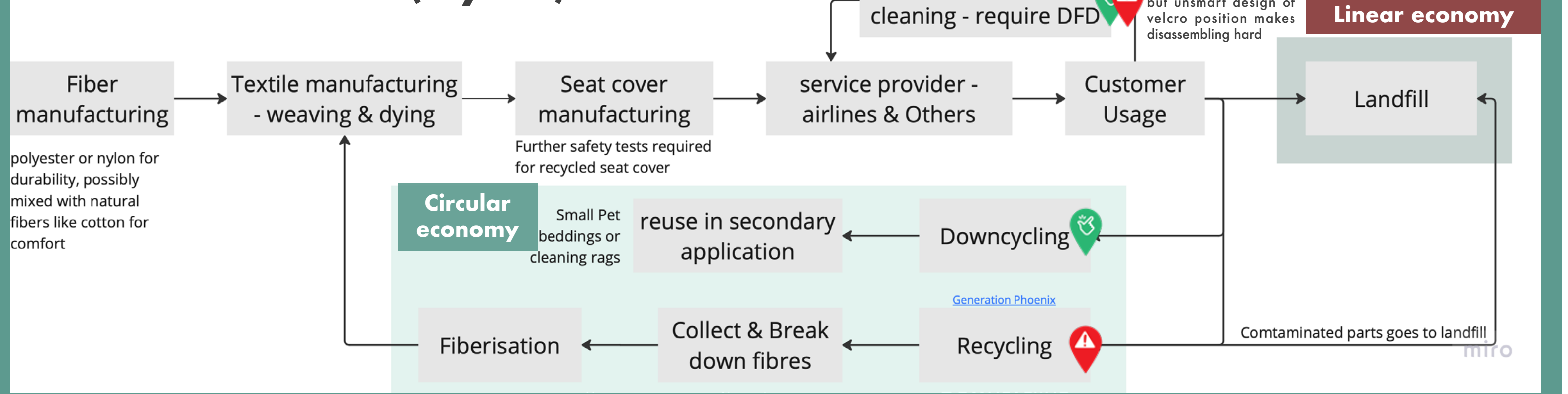
According to the 3 principle of circular economy, HMW...

> Enhanced Recycling Processes: Investing in technologies that allow for effective recycling of mixed materials, such as textile-plastic composites, can increase material recovery and reuse.

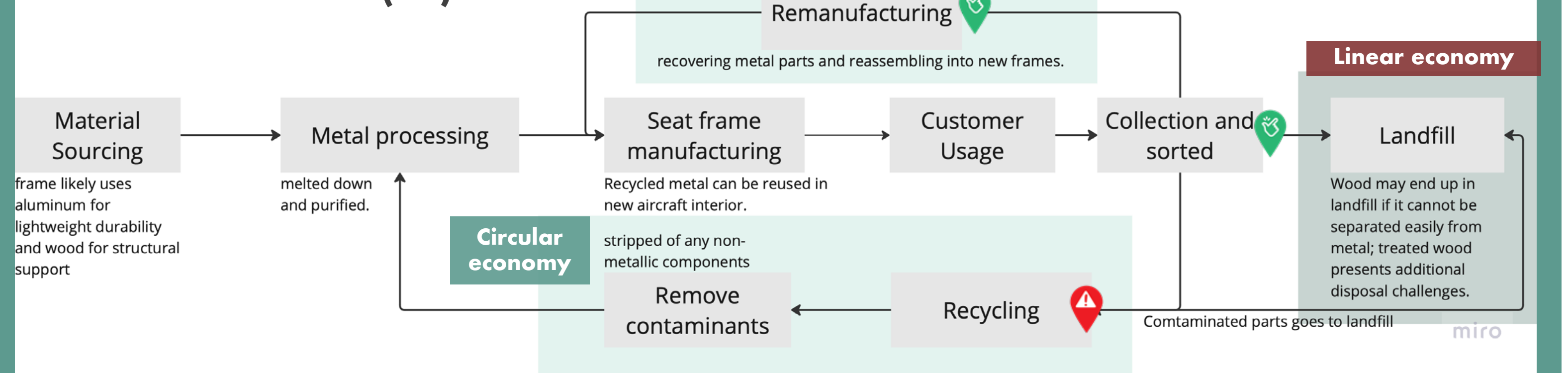
> Biodegradable Materials: Researching and integrating biodegradable or bio-based materials, especially for textiles and foams, could reduce long-term environmental impact

> Improve Waste Management: Establishing take-back programs for airlines to return seats at end-of-life can minimize waste, ensuring components are responsibly handled and repurposed.

Material1: Textile (Nylon)



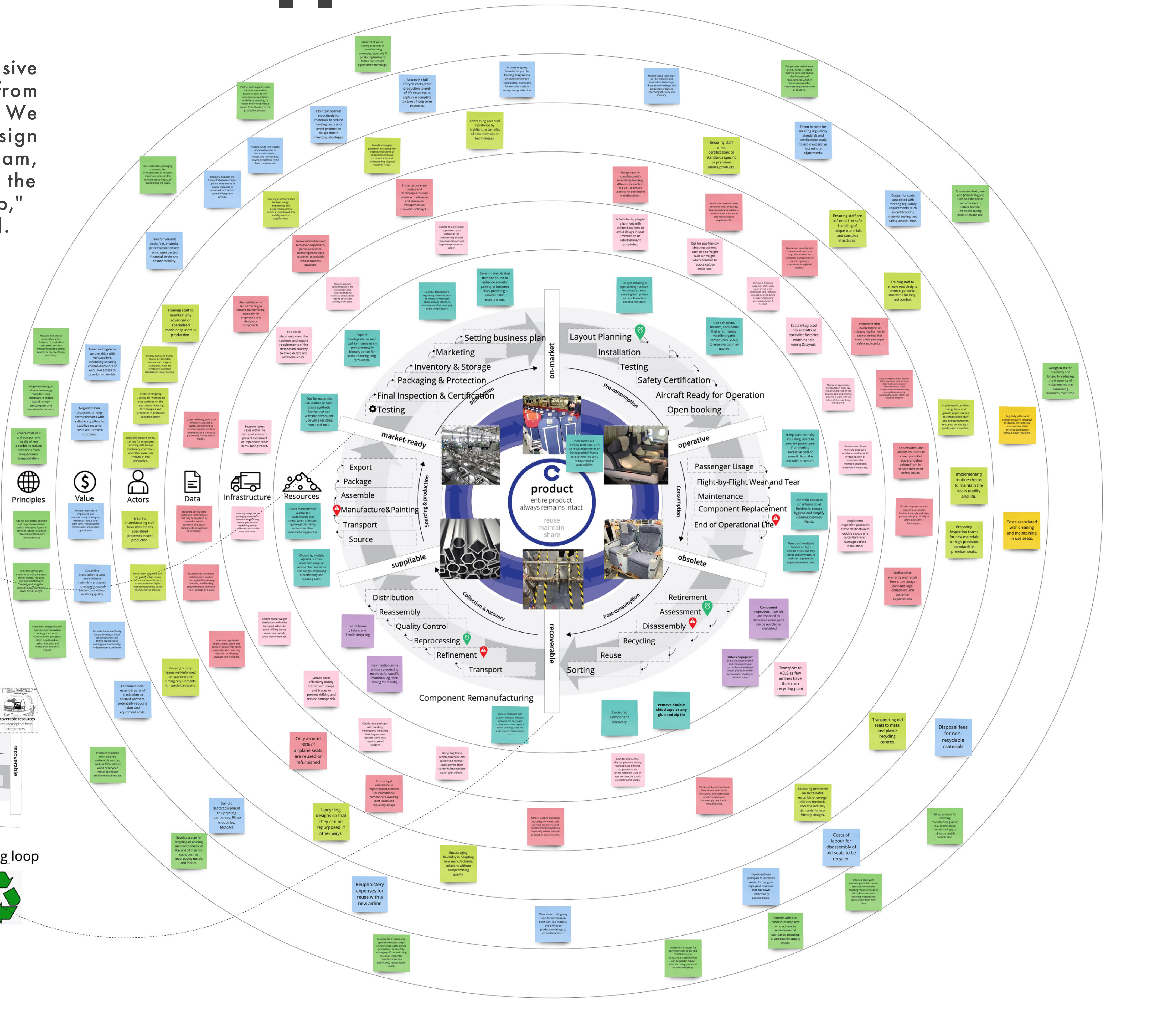
Material2: Metal (Al)



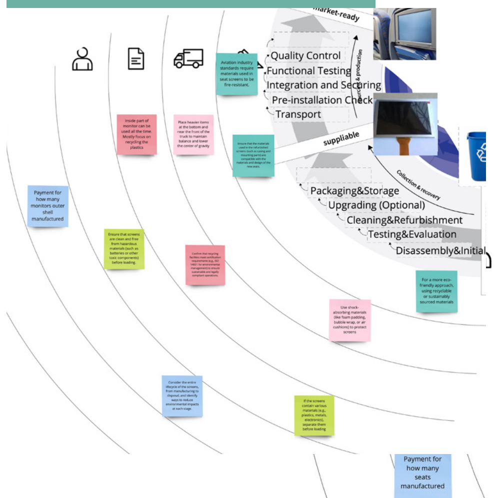
System Analysis - Flow Mapper

The circular chart on this page represents a comprehensive analysis of the aircraft seat lifecycle, detailing steps from production to sale, use, disposal, and recycling. We included three branches representing sustainable design considerations for different materials: aluminium, foam, and the electronic screens that cannot be dismantled in the recycling process. These branches form a "recycling loop," emphasizing sustainability tailored to each material.

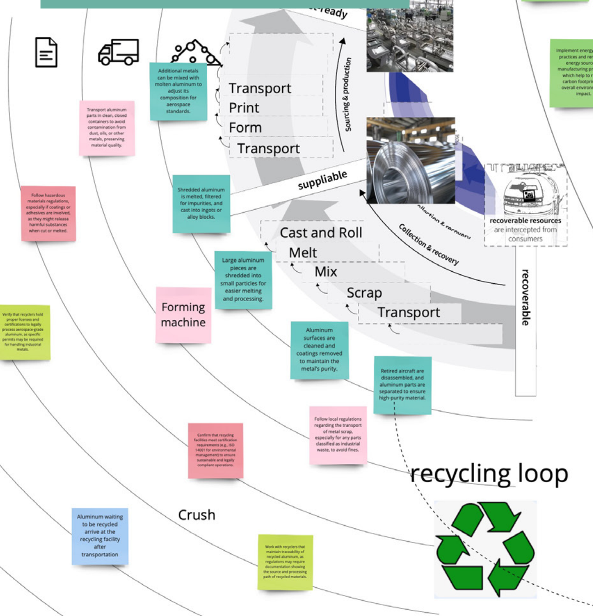
Opportunities are marked at stages like reprocessing, aircraft readiness, and maintenance to highlight where sustainability can enhance efficiency and lifecycle extension. Risks are highlighted in manufacturing, packaging, protection, and recycling due to their potential environmental impact and logistical challenges in achieving sustainability.



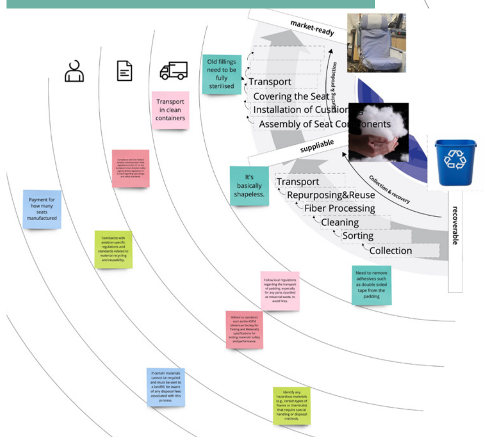
TV Screen



Aluminum



Form



Pivotal Analysis from Flow Mapper

Process	Scope	Importance	Relevant Elements			
Reprocessing	Possibility to further reduce the wastage of the old unused seats.	The majority of old seats end up sent to landfills due to their age and the lack of use for them. So reprocessing them would help reduce their lifecycles carbon footprint.	Choose materials that support modular designs, allowing for easy part replacements and repairs, which prolongs seat life and reduces maintenance costs.	Upcycling firms which purchase old airlines to recover and convert their contents into unique seating/products.	Develop a plan for recycling or reusing seat components at the end of their life cycle, such as repurposing metals and fabrics.	Only around 30% of airplane seats are reused or refurbished
Manufacture	Opportunity to improve the manufacturing process involved with the seats.	The manufacturing process for the seats is generally changing due to the updating technology so finding a way to simplify the process so it can be modified/adapted when needed would help the industry.	Utilize thermoformed plastics for customizable seat shells, which offer both lightweight durability and a streamlined manufacturing process.	Hire or train personnel who can quickly adapt to new tech advancements, such as automation or digital monitoring systems, in the manufacturing process.	Allocate resources to implement lean manufacturing techniques, which can reduce long-term costs through waste minimization and process optimization.	Implement energy-efficient practices and renewable energy sources in manufacturing processes, which help to reduce carbon footprint and overall environmental impact.
Packaging & Protection	This step focuses on ensuring the product is safe when arriving at it's destination.	This is a pivotal process as it's important that the products are correctly shipped however the packaging the seats are shipped in will often be left unrecycled, contributing negatively to the seats carbon footprint.	Opt for materials like leather or high-grade synthetic fabrics that can withstand frequent use while resisting wear and tear.	Securely fasten seats within the transport vehicle to prevent movement or impact with other items during transit.	Comply with regulations on emissions, packaging waste, and handling of environmentally sensitive materials during transport, particularly for sea and air freight.	Use sustainable packaging solutions, like biodegradable or reusable materials, to lessen the environmental impact of transporting the seats.
Aircraft ready for Operation	Finishing steps to ensure the seats are ready for consumer use.	The penultimate steps which need to be completed for safe flight, lots of which require extra labour or materials, which should/could be encompassed in the manufacturing processes.	Use adhesives, finishes, and foams that emit minimal volatile organic compounds (VOCs) to improve cabin air quality.	Implement strict quality control to mitigate liability risks in case of defects that could affect passenger safety and comfort.	Factor in costs for meeting regulatory standards and certifications early to avoid expensive last-minute adjustments.	Choose non-toxic, low-VOC (Volatile Organic Compound) finishes and adhesives to reduce harmful emissions during production and use.
Maintenance	Guaranteeing that for each flight the seats are up to the standards of the airline.	Pivotal process in the seats lifetime as it ensures the seats have a longer lifecycle in the plane. This enables the airlines to use them for as long as possible, reducing their proportionate carbon footprint.	Use stain-resistant or antimicrobial finishes to ensure hygiene and simplify cleaning between flights.	Preparing inspection teams for new materials or high-precision standards in premium seats.	Costs associated with cleaning and maintaining in use seats.	
Recycling	Crucial step of the lifecycle, recycling any materials which can be recycled.	Lots of the materials in the seats can be recycled and are worth money, such as the aluminium in the seat frames which can be sold on once gathered.	Transport to AELS as few airlines have their own recycling plant	Disposal fees for non-recyclable materials	Costs of labour for disassembly of old seats to be recycled	Set up systems for recycling manufacturing waste (e.g., foam scraps, metal shavings) to minimize landfill contribution.

Keys

- Successes
- Barriers/Opportunities
- Resources
- Infrastructure
- Data
- Actors
- Value
- Principles

Summary

> Pivotal analysis focuses on analysing the crucial steps in the products lifetime and looking at what issues come with these steps and how we could go about solving them as design engineers.
> This includes analysing the basis of these steps followed by what it is that makes these steps crucial in the lifecycles circularity and how they are impacting upon the circularity.
> Finally we analysed what physical issues were stopping the product from attaining circularity.

Insights

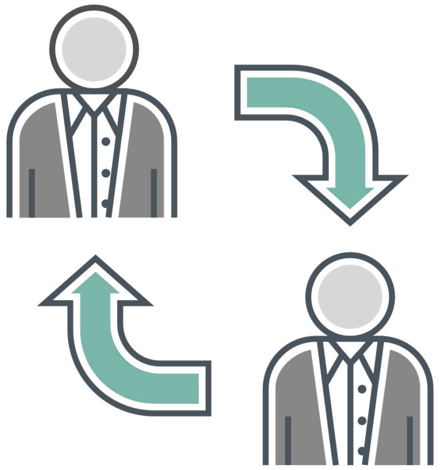
> A big issue with all of the pivotal steps was trying to find a way to reduce the carbon footprint in differing ways.
> As the differing steps all have varying issues which have separate solutions, so the question is how to solve all these issues with as little change as possible.
> Manufacturing needs to adjust to changing technologies without voiding old equipment.
> Maintenance enabling flights without such routine labour checks.
> Making Recycling more accessible by having less permanently built seating.

HMW

How might we create adaptable, efficient, and sustainable solutions to meet evolving industry needs?

Product Service System Analysis

Aeroplane seats are primarily a B2B product, as the manufacturers sell their seats directly to the airlines.



Repair Stations

Cons:
> Different countries have different maintenance standards, which lead to quality inconsistencies.
> Costly to set up repair stations in all locations in which the plane may visit.
> Airlines may stick with outsourcing maintenance as it is cheaper than the manufacturers provided stations.

Retrofitting

Cons:
> High cost due to complexity with changing preexisting seat designs to fit new fleets.
> Airlines may be sceptical as this increases idle time for fleets.
> Retrofitted parts cannot be completely modernised, so uniformity in plane limited.

Legislations

Extended Producer Responsibility:
Making the manufacturers responsible for the product's end of life management may encourage sustainable design.

ELV Directive & ISO 11469 Plastics Identification:
A legislation which mandates the labelling of components in the chair would make recycling/ reusing after disassembly easier.

Current PSS | **Potential Improvements** | **Other Industries**

Zodiac offers many Product Service Systems aimed at promoting the longevity of their products.

Readily available maintenance extends the lifespan of seating and reduces wastage.

Retrofitting allows for upgrades to the functionality of older seats. This reduces waste and lowers resource consumption

Leasing Seats is currently done in the automotive industry due to said sustainable benefits and flexibility to leaser.

IKEA furniture currently uses modular design such that its products are easy to disassemble facilitating future reuse and recycling.

H&M gives vouchers to users who give in old clothes, so that they can facilitate re-wearing, reusing and recycling.

Siemens, an Engineering company, has implemented predictive maintenance in its industries to improve efficiency and reduce downtime.

In the furniture industry, companies like 'RoveConcepts' include upholstery subscriptions to some lines to increase lifespan of products.

Leasing Seats

> Seat manufacturers can lease seats to airlines instead of selling them. This way the manufacturers maintain ownership, so that maintenance, repairs and upgrades can be provided as part of the service.
> The benefits of this is to extend the product's lifecycle and encourages the use of more durable and recyclable material.

Modular Seat Design

> Implementing modular components to seat designs allows for specific parts to be easily repaired, reused and/ or upcycled at the end of their 7-year use.
> Not all components in a chair degrade at the same rate, therefore by implementing this, waste produced by chairs can be reduced as more seat parts can be given a new lease of life.

End of Life Take Backs

> Manufacturers can establish take-back programs, like what is used by phone companies, so that manufacturers can refurbish seating to either resell them to lower tier airlines or to upcycle parts.
> This would reduce the amount of material going into landfill in the aerospace field, as well as reduce raw resource extraction.

Predictive Maintenance

> Using sensors paired with predictive software on aeroplane seatings can provide manufacturers with data on the wear and tear of their products.
> These predictions will allow for proactive component replacements and repairs, such that the states of the seats don't get to a point beyond repair. This then minimises wastage.

Upholstery Subscription

> Introducing a subscription-based upholstery system to aeroplane seating allows for manufacturers to regularly tend to their installed products. This once again reduces waste and maintains the appearances without needing to replace the whole seat. This also reduces textiles waste which is one of the largest contributors to pollution.

B2B Process

Airlines express the requirements of the seat to manufacturer.

Manufacturer designs brand specific seats.

Seats are made and tested to meet standards.

Seats are delivered and installed.

Reference & Appendix

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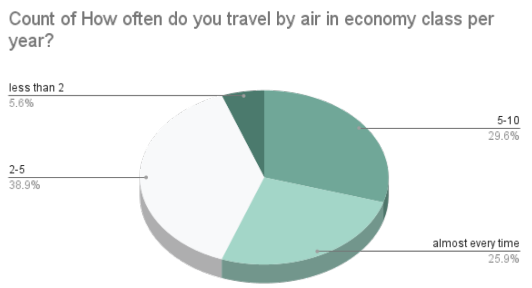
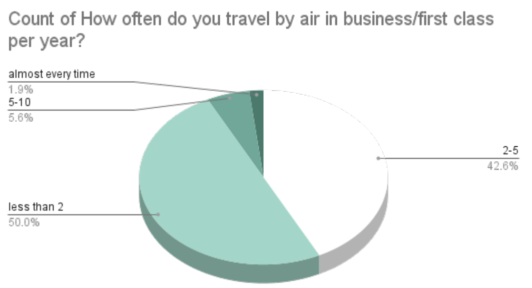
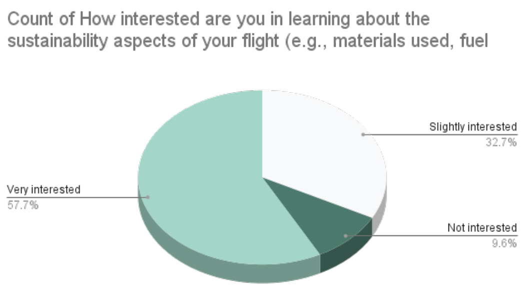
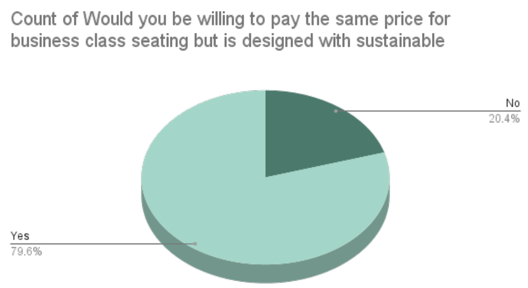
Additional Survey Results









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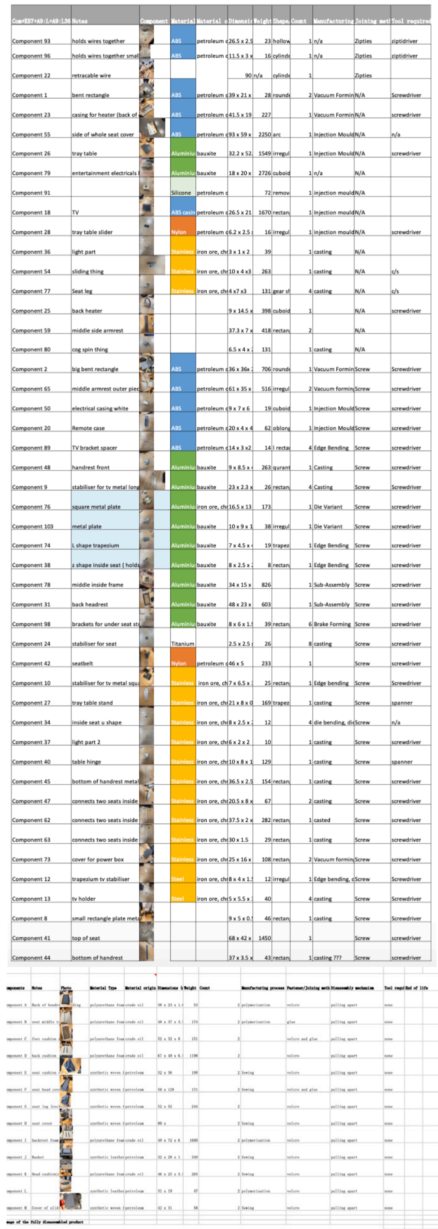
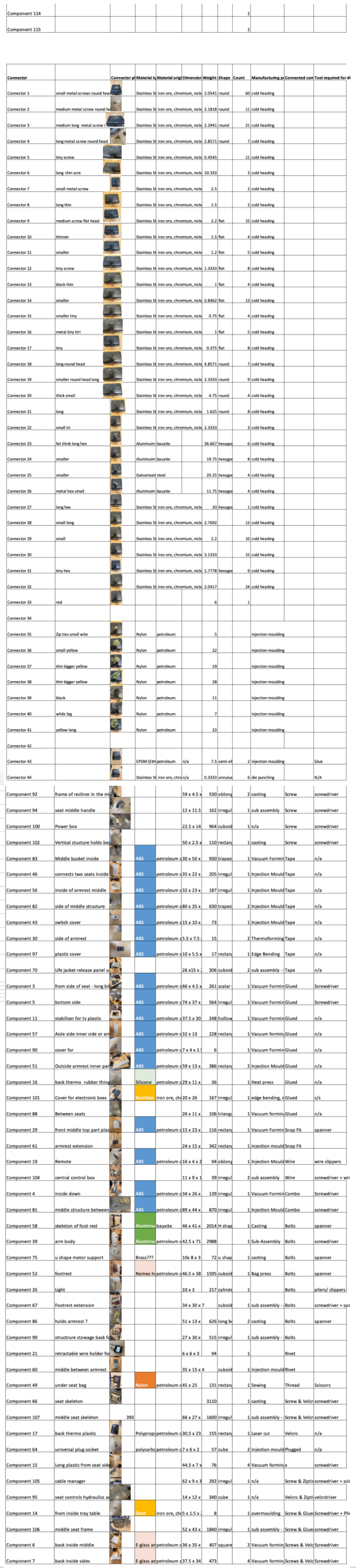
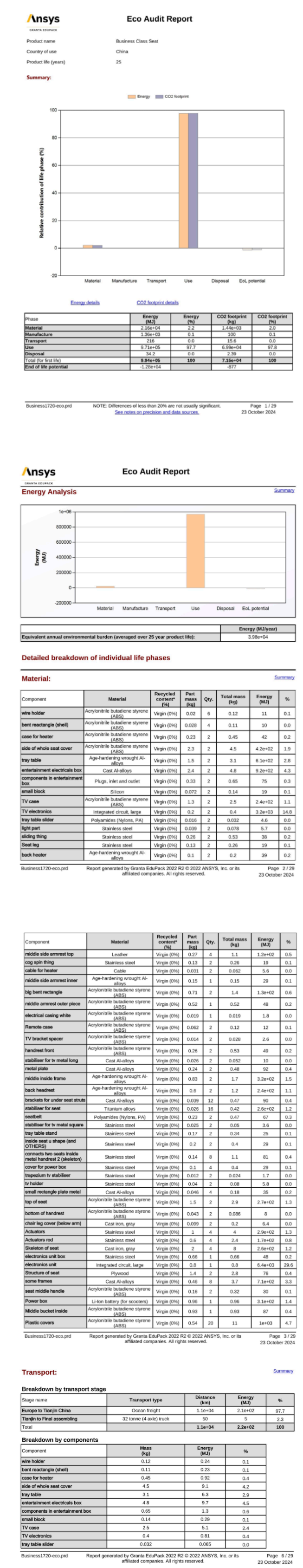




Eco Audit Report



Statement of Contribution

	Individual Contribution	Collaborative Contribution
Helen Shi	> I contribute to the layout for all the pages. > I contributed to the Market Trends in Sustainability Aspect & Market Size in page 2. > I contributed to the User Research section in page 3. > I contributed to all the contents in page 4 > I contributed to all the contents in page 6 excpet the MCI Results. > I contributed to the cover in page 1	> I contributed to the Disassembly Analysis in page 5. > I contributed to the appendix in page 10
Amelia	> I contributed to the all the contents in page 2 except the Market Trends in Sustainability Aspect & Market Size. > I contributed to the Disassembly Tree in page 5. > I contributed to all the contents in page 9.	> I contributed to the Disassembly Analysis in page 5.
Dylan	> I contributed to the Produect Claim section in page 3 except the 'Competitors'. > I contributed to the Material & Manu Classification & Insights on Sustainablity in page 5. > I contributed to the the MCI Results in page 6. > I contributed to all the contents in page 8.	> I contributed to the reference in page 10
Bohan	> I contributed to the 'Competitors in Produect Claim section in page 3. > I contributed to all the contents in page 7	> I contributed to the reference in page 10

Business Class Seats System Specification

Design Variable Table

The Design Variables Table outlines potential design choices for various aspects of aircraft seating. The choices made here prioritize **both sustainability and comfort** by using recycled materials, extending the product lifecycle, employing advanced and efficient manufacturing, and focusing on modularity for easy maintenance and reusability.

Travel Scenario	Cold world	Flying back on time	Race for zero	
Time Horizon	5 Years	10 years	20 years	
Aircraft Range	Short	Medium	Long	
Aircraft Frame	Tube and wing	Blended wing body	Truss-braced wing	
AIrline Type	Charter	Budget (low cost)	Scheduled	
Source	Technical materials	Mono-material	Multi-materials	Recycled materials
Architect	As-is architecture	Modular architecture	Integral architecture	
Produce & Assemble	Traditional manuf. & ass.	Remove, Disassemble, & Pack		
Distribute	Road	Rail	Sea	

Order (airline)	Economy	Business		
Buy (airline)	Traditional sale	Rental model	Leasing model	
Choose	Leisure travellers	Business travellers	Students & jun. travellers	Senior travellers
Use	Single use-cycle: 7 yrs	Two use-cycles: 14 yrs	Three use-cycles: 21 yrs	
Prepare to Return	Order collection service	Remove, disass. & pack		
Collect / Take to	Take to recycler	Manuf.'s own service	Manuf.'s recomm. service	
Sort / Separate	No sorting	Manual sorting	Mechanical sorting	
Revalorise	Refurbish	Repair	Upcycle	Downcycle

Reasons & Discussion

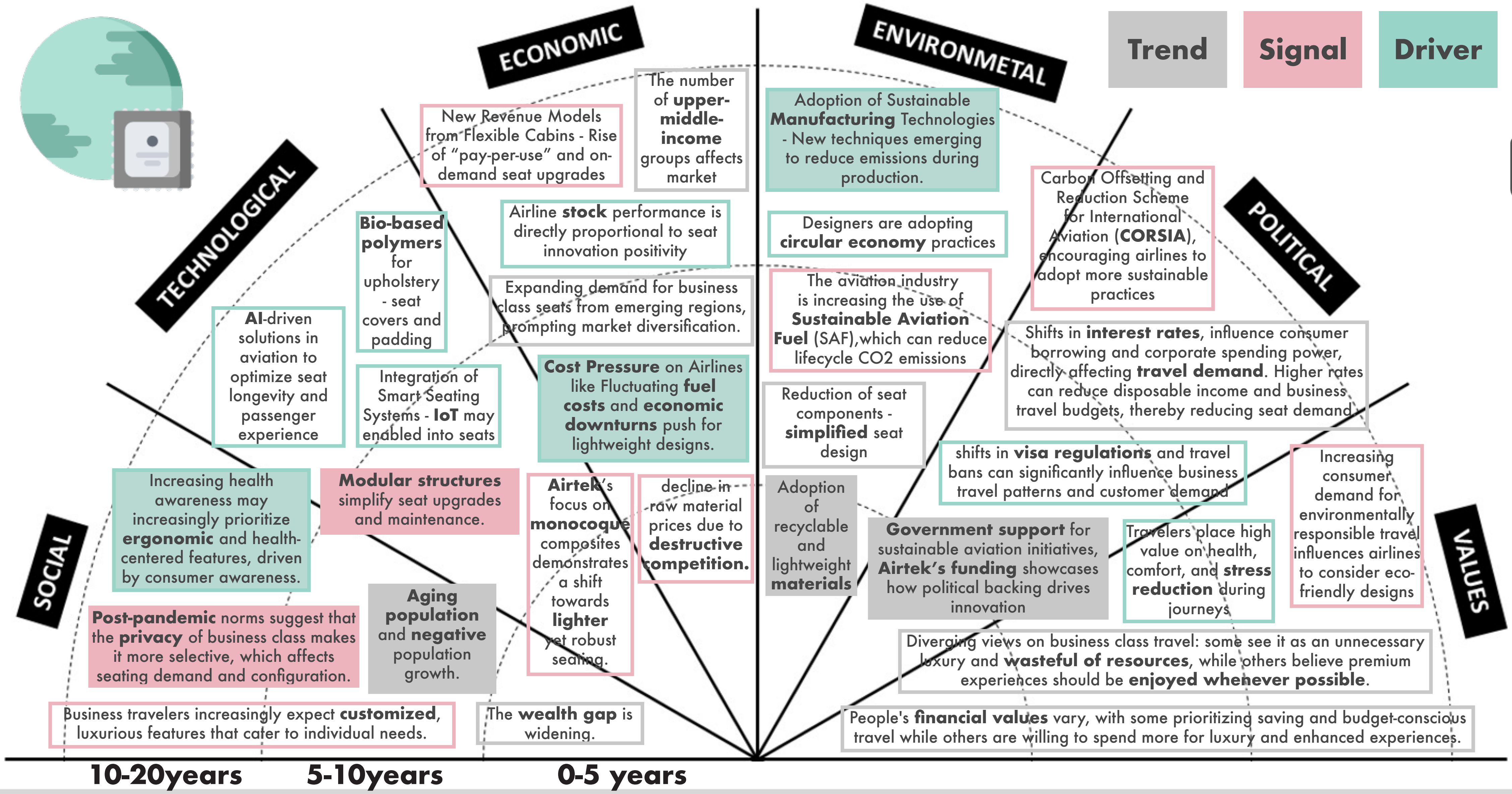
> **Senior travelers**: This choice aligns with the ongoing aging population trend, emphasizing comfort and accessibility needs.

> **Take to recycler**: Taking seats to specialized recyclers ensures proper material recovery, aligning with circular economy principles and minimizing landfill contributions.

> **21 years**: Extending the seat lifecycle maximizes resource utilization, reduces waste, and minimizes environmental impact through periodic refurbishments and upgrades.

> **Manual and mechanical sorting**: Combining these 2 options creates job opportunities and addresses high costs of fully automated disassembly, as current technology is not yet mature.

Future travel scenario and time horizon specification



Problems in the system, product and users.

system

> Inadequate systems for the refurbishment, recycling, or downcycling of seats.
> **Lack** of coordination and **infrastructure** for **collecting** and processing used seats.
> Policies such as **EU ETS** should have **stricter** controls on aviation emissions, Not just traditional **trading** system of **carbon Emisions.**
> Lack of **design** consideration for **disassembling** and recycling

product

> Seats that do not optimally balance **comfort and space efficiency**, affecting passenger satisfaction.
> **Outdated in-seat technology** that fails to meet current passenger expectations for connectivity and entertainment.
> In the **post-epidemic era**, where higher demands are placed on **hygiene and antimicrobial** protection, **fabrics** in seats are not yet ready for standardized and **less costly cleaning** systems.

user

> Poor **ergonomic support**, especially the **neck support**, does not adapt well to people of **different heights**, especially women
> **Long-haul** airplanes should have **more** seats with the same configuration as business class, as passengers have a **higher demand** for comfort.

System Diagram

What is the purpose?

- > **Decreasing Environmental Impact**: Using *recycled and bio-based* materials for seat frames, cushions, & cover reduce resource extraction. **Lightweight design** decreases fuel consumption and emissions, enhancing overall environmental performance.
- > **Increasing Circularity**: Modular design and easy disassembly promote material recycling at end-of-life. Collection and recovery initiatives ensure materials are reused, supporting continuous material circulation.
- > **Addressing the Problems**: These interventions directly tackle environmental degradation by reducing resource extraction and waste production. Modular designs support the circular economy by promoting the reuse and recycling of components, enhancing both environmental and economic sustainability.

System Diagram Key

- Large System Loop
- Detailed System Loop
- Resources States
- Principal
- Value
- Actor
- Data
- Infrastructure
- Resource

Design & Order

Airline requirment → Design & specification → Production Order Confirmation

Stakeholders: airline marketing teams, seat design engineers.

The designers customize the seats according to the type of flight, the length of the flight, and the region.

Usage of passenger feedback and ergonomic research to guide design adjustments.

CAD tools and simulation software for precise design modeling.

Material Sourcing

Manufactring & Assembling

Material

frame	recycled Alloys	Welding and Assembly of Seat Frames	Surface Treatment	Safety test of frames
cushion & seat cover	bio-based foams, fabrics made from sustainable	Processing	Testing	Manufacturing
Entertainment system	Electronics	purchased from other suppliers	Installation	wiring & Testing
Case and Handles	Recycled plastics	Injection Molding		Surface Finishing
Case and frame	Composites	Carbon Fibre Composites	Testing	Manufacturing

Stakeholders: Production line workers, technicians, engineers

Ensuring all materials sourced are at least 70% recycled content.

Sourcing of technical and bio-based material alternatives that are lighter and more durable than traditional materials.

Manufacture

Collection of real-time data on energy consumption and waste generation.

Introduction of bio-based epoxy adhesives for assembly to reduce volatile organic compound emissions.

Modular seat assembly for quick replacement and end-of-life dissassambling for recycling.

Testing

Testing after seat frame production → Assembly → Testing after final assembly

Stakeholders: European Union Aviation Safety Agency, regulatory bodies in airline seat design

The testing ensures that new seat designs withstand extreme scenarios like decompression and collisions, adhering to stringent safety and durability standards.

Regulations drive innovation by setting safety baselines that manufacturers strive to exceed, enhancing seat comfort and sustainablity.

Distribution

Seat manufacturing factory → Final seat installation → Ready to use

Safran Europe → Southern Airline factory → Airport

Stakeholders: Logistics Company

1. Reducing emissions by locating plants in areas where seat demand is sufficiently high.
2. Collaboration with airlines to use return flights for transporting seats, reducing empty load trips.

Reusable protective covers made from recycled materials to protect seats during transit.

Circular Economy

Collection & Recovery

Stakeholders: recycling centers,certified centers

Collection

Seats designed for disassembly into material-specific recycling streams.

Monitoring of end-of-life seats to ensure proper sorting and recycling.

Dedicated facilities for seat disassembly and material sorting near major airports.

Developed and low cost system for seat (and other compilacted products) recycling

Reuse

Reusing: electronics, seat frames

Partnerships between airlines and refurbishment centers

Refurbished seat frames are reused in lower-tier services or training simulators where brand new aesthetics are less critical.

Collection → Transportation → Disassembling & Sorting

Disassembling & Sorting → cleaning → Recycling → reprocessing of materials → Recycling → Material Sourcing

Disassembling & Sorting → cleaning → Reusing → updating & refurbishing → Reusing → component manufacturing

Recycle

Recycling: Plastic, Textile

Extending the lifecycle of seat frames through meticulous refurbishment, As the production of frames requires more time, energy ,and testing

Agreements with material recovery facilities to handle and repurpose recycled outputs.

Analysis of polymer type and contamination levels to determine suitable recycling pathways.

Recycled plastics are downcycled into internal cabin fixtures.

Textile processing plants capable of cleaning, shredding, and reweaving or repurposing fibers.

Use

Ticket Booking & Seat Selection → On board → Seat Operation → Landed

maintenance

Stakeholders: Flight attendants and in-flight service managers

The integrated design reduces hygienic blind spots, and the hydrophobic and oleophobic material makes the table and fabric surfaces easy to keep clean during regular cleaning.

Standardization of replacement parts like bolts and electronic components to speed up repairs.

Seats designed for the elderly and disabled with easy grip, simple systems and comfortable seat materials

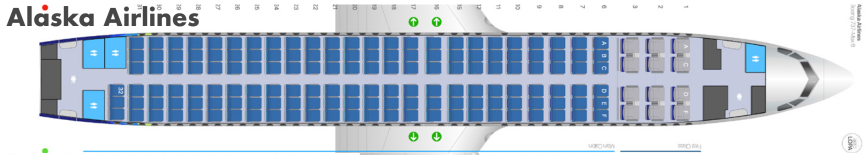
Landed → Cleaningd → Functionality Check → Repair & Adjustment → Data Collection → On board

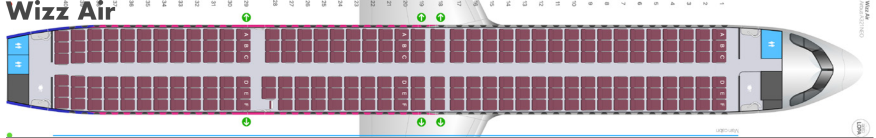
Seat concept specification

Location of passenger accommodations (LOPA) Specification

Alaska Airlines

Wizz Air



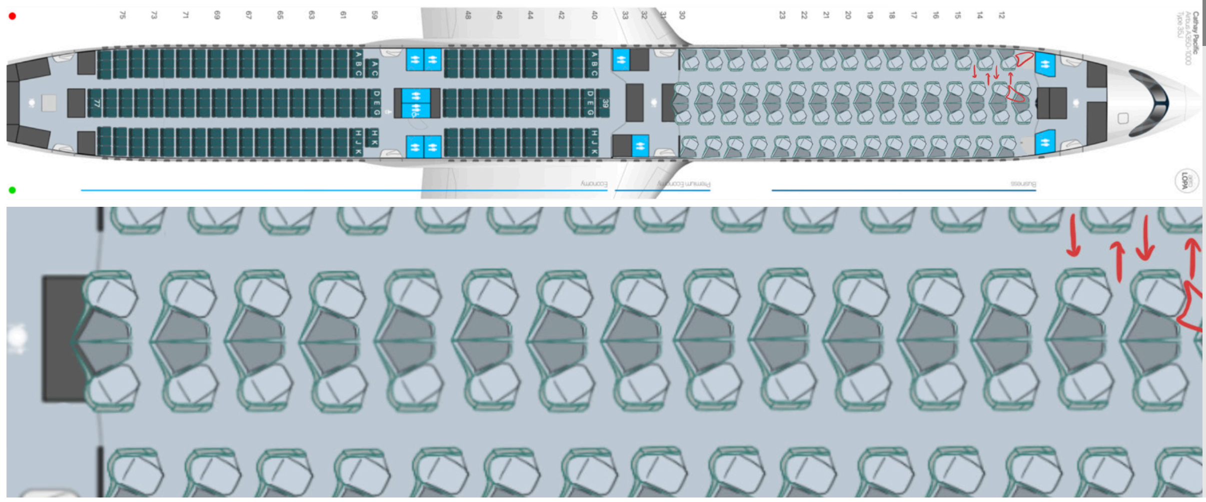


Airline with the lowest carbon emissions

- **Wizz Air** uses the ultra-efficient Airbus A321neo aircraft, which provides significant fuel savings and reduces emissions. This forms a part of Wizz Air's broader commitment to achieving zero net emissions by 2050 with investments in SAF.
- **Alaska Airlines** also commit to achieve net-zero carbon emissions by 2040. Their initiatives include the use of biofuels, partnership with other companies to promote SAF, and recycling programs.
- Observing the LOPA of these two airlines, it can be noted that the **proportion of business class seats in their seating arrangement is very small or even non-existent**, which facilitates the reduction of aircraft weight and thereby helps in lowering emissions.

Airline with the most comfortable seats

- **Japan Airlines** are equipped with fully closing doors, lie-flat seats with high-quality speakers built into the headrests, and a storage cubby on the floor that can accommodate a full-size carry-on bag
- **Cathay Pacific** offers seats with a full-length leg rest, leather-padded footrests, and a retractable armrest.
- their focus tends to be **less pronounced in sustainability** communications compared to Wizz Air and Alaska Airlines, with more emphasis on passenger comfort and service quality.
- **Wizz Air** reports a clear carbon intensity of 53.8 grams per passenger kilometer with a strategic goal to reduce this by **25% by 2030**. which is the **only one** among these four airlines to disclose such data.



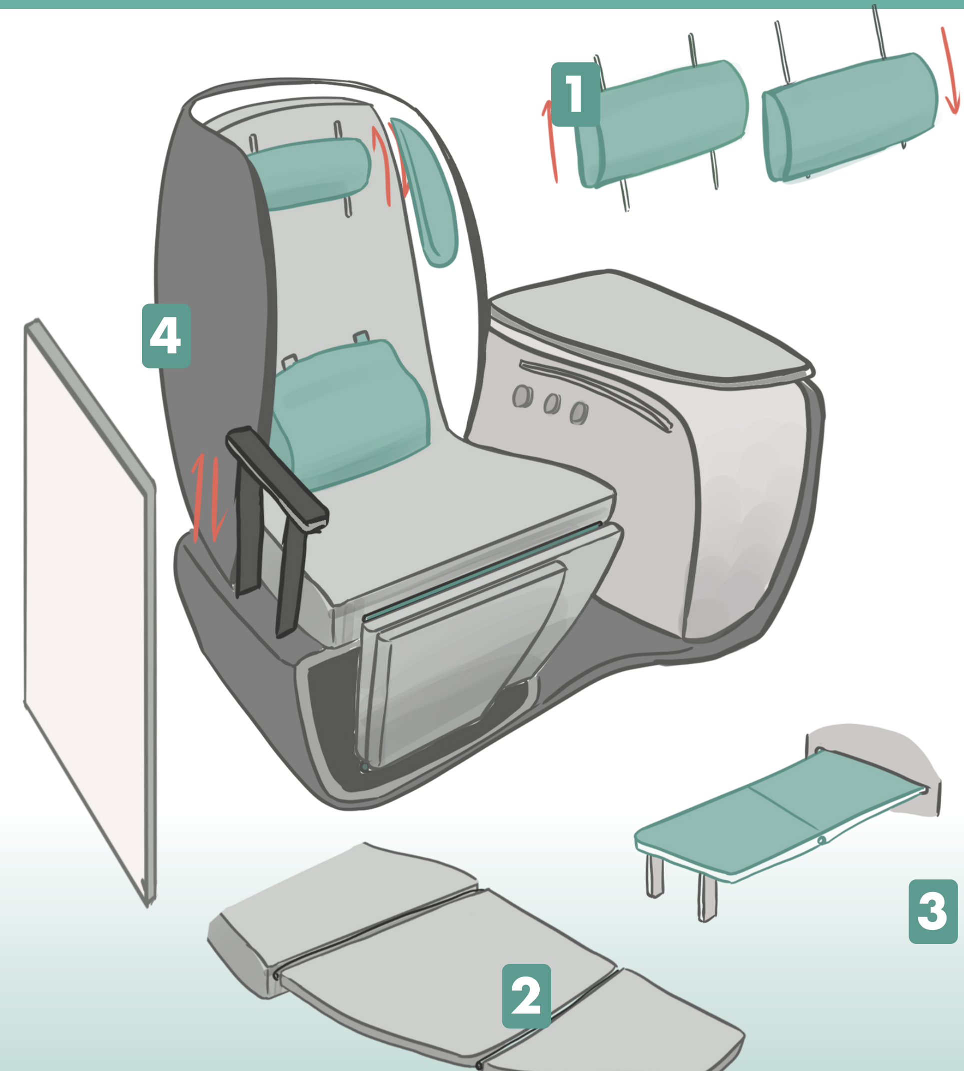
Seat LOPA Design Specification

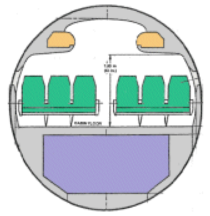
- **Increased Privacy by Misaligned Arrangement :** Reduces direct line-of-sight between seats. Minimizes visual and acoustic disturbances across rows, thus providing a more secluded and personal space for passengers.
- **Increase in the Number of Business Seats for Large Planes on Long-Haul Flights:** By reallocating space in larger aircrafts to increase the number of business seats, the layout caters more effectively to the growing market demand for premium services on long-haul flights. This strategic adjustment not only enhances passenger satisfaction but also boosts airline revenue.

Environmental impact analysis.

Improve fuel efficiency	Minimize carbon footprint	Promote resource efficiency	Maxi. capacity	Energy efficiency
Enhancing the lightweight design of seat structures directly contributes to the aircraft's overall fuel efficiency. Since the usage phase of an aircraft seat consumes more than 95% of energy and carbon emissions, employing advanced composite materials like carbon fiber or lightweight alloys can significantly decrease these emissions.	Instead of disposing of seats in landfills, end-of-life strategies focus on reusing or recycling seat materials. This approach aligns with sustainable waste management practices. Then the environmental footprint from waste is minimized, contributing to a circular economy.	The use of recycled materials in the production of new seats curbs the demand for virgin resources and reduces the energy and emissions associated with raw material extraction and processing. This not only lessens environmental degradation but also promotes resource efficiency	Optimizing the LOPA can lead to more efficient use of space and, potentially, a reduction in the total number of flights needed by maximizing passenger capacity per flight. which indirectly contribute to reduced overall emissions	Reducing emissions related to the transportation of seats from manufacturing sites to airlines and airports is crucial. Implementing strategies such as manufacturing closer to key markets or using more efficient logistics can have a significant impact.

Seat concept specification





The cross-section structure shown is similar to most aircraft, featuring a single layer of seats above, with mechanical components or a cargo hold beneath. The primary layout and seat design are illustrated in other images on the page.

Seat Components Specification

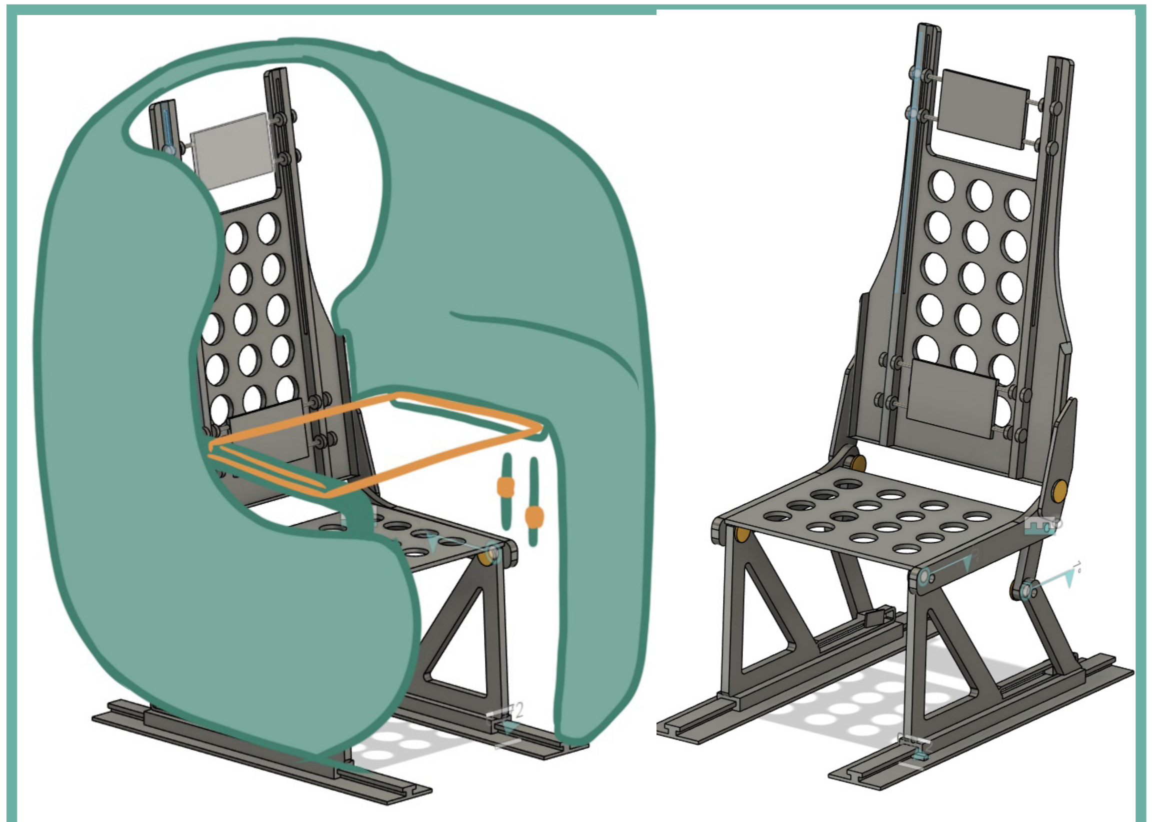
- **1. Adjustable Neck Pillow & Side Pillow made from bio-based foam**: Cusion and pillows utilize **bio-based polyurethane foam** derived from renewable resources such as soybeans. Pillows are ergonomically designed to provide adjustable support for the neck, enhancing passenger comfort with **all ages and heights**. And additional lateral support for omfort during rest
- **2. Retractable Recliner**: Allows the seat to convert into a fully flat position for sleeping, using a smooth, mechanical retracting system to maximize space efficiency and comfort.
- **3. Aircraft Tabletop Suitable for business traveller**: A **sturdy, foldable** surface that provides enough space for laptops and other devices, making it ideal for working on screen.
- **4. Privacy Board for sustainbility education**: Made from **Waste and Downcycled Plastic**: Utilizes environmentally friendly materials in its construction, and labelling the sustainability of their practices with text on the boards.

Seat Structure Specification

- **Design for Lightweight:** The seat design integrates advanced composite materials, structural simplification, and component integration to significantly reduce the overall weight. This approach utilizes **carbon fiber and lightweight alloys** for frames, to enhance fuel efficiency and reduce environmental impact without sacrificing passenger comfort or safety.
- **Integrated Entertainment System**: Offering on-demand entertainment options, flight information, and a personalized passenger experience. The system is designed to be intuitive, catering to a wide range of passenger preferences and digital interaction habits.
- **Material Consideration for Maintenance, Hygience & Comfort**: The seating surface is upholstered with a breathable, hypoallergenic fabric that regulates temperature and resists moisture. The materials chosen are also **durable and easy to clean**, aligning with **hygiene** and maintenance standards.
- **Modular Design of Seat Structure**: The seat components are modular, allowing for **easy upgrades or replacements** without needing to dismantle the entire seat. Enhancing the **lifespan and versatility** of the seating.
- **Design for Assembly**: The seat is designed with minimal parts and uses **snap-fit connections** where possible, greatly **simplifying the assembly process**. This reduces manufacturing and maintenance time and costs, promoting efficient assembly line operations and easier installation within the aircraft.

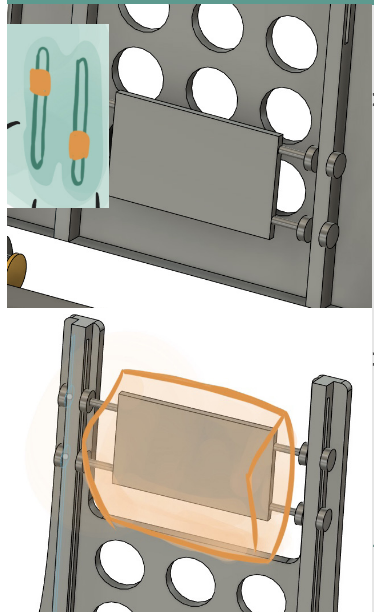
Business Class Seats System Specification

Seat Primary System Specification



The primary structure of this business-class seat aligns with future travel demands by emphasizing **ergonomic** excellence, **sustainability**, and **modularity**. Designed to support an **aging population** and address spine-related issues, it offers customizable lumbar and neck adjustments through a mechanical system, enhancing comfort **without electronics**. **Lightweight**, recyclable materials like CFRP and aluminum reduce weight while ensuring durability. The seat's modular design simplifies maintenance and promotes circularity. Features such as a single-actuator reclining system, stowable armrests, and a spacious tray table **maximize comfort and space efficiency**. This innovative design meets evolving passenger needs, reduces environmental impact, and supports resource efficiency for **10-15 years' future** air travel.

backrest and frame(rail system)



Structure
- Lightweight frame with integrated rail system for adjustable lumbar and neck support.
- Purely mechanical adjustment to minimize electronic components.

Functions
- Provides a strong structure for the back pan and supports the adjustable neck and lumbar **cushions.**
- Manual adjustment of supports for **persona-lized ergonomic comfort.**

Materials Used
- **Aluminum Alloy 6061**: Lightweight and corrosion-resistant, good machinability.
- Why: Chosen for ease of integration into complex assemblies and high recyclability.

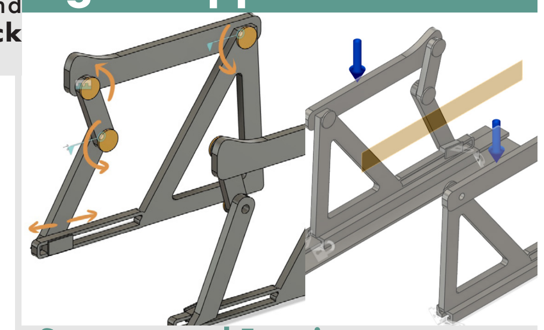
Manufacture Processes
- **Additive** Manufacturing for Custom Rail System: Precise, weight-optimized rails.
- **Extrusion and Machining** for Frame Components

Lifetime and Utility
- 15-25 years with proper maintenance.
- Reason: Aluminum's durability ensures longevity, and mechanical components can be replaced easily and **more durable**

This design enhances passenger comfort and ergonomics, reducing the need for additional cushions. Reduces electronic waste and simplifies maintenance due to mechanical design.

leg & Support Structure

- Incorporates a **damping** system, **linkage** system, and **sliding** mechanisms for **shock absorption and stability.**

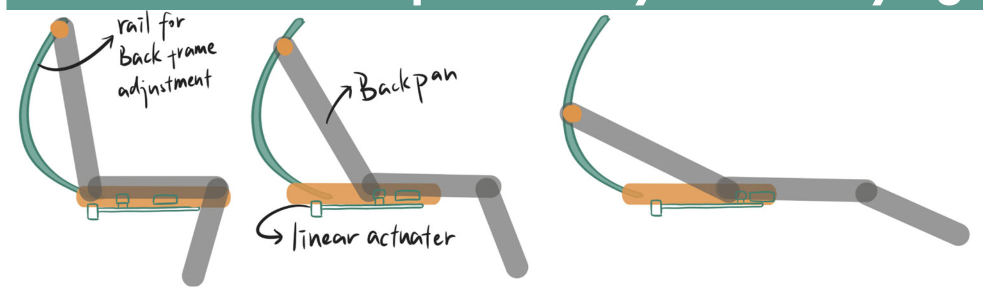


Structure and Functions
- Optimized geometry for maximum stability under load (**finite element analysis** should be performed).
- **Absorbs impact** and provides stability during extreme flight conditions.

Material used
- **Titanium Alloy** (e.g., Ti-6Al-4V) for critical load-bearing components: Lightweight, high strength, corrosion-resistant.

Manufacturing Processes
- **3D Printing** for Complex Geometries.
- Machining for critical interfaces ensures precision fit.

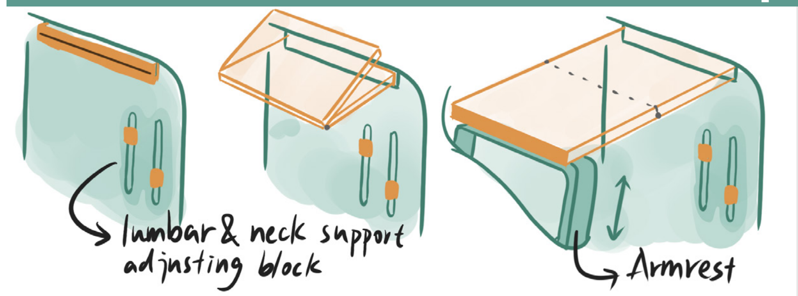
Seat Adjustment System - Staying comfortable on long-haul flights



Structure and Functions
- Incorporates a **single linear actuator** with an arcuate **guide rail** for backrest adjustment, enabling the seat to recline to a flat sleeping position.
- **Simplified system**: Features a connecting linkage system that synchronizes the movement of the backrest and bottom pan while also rotating the foot pan.

Material used
- Actuator and rail: Aluminum 6061 for durability and weight savings.
- foot Pan and other connectors: **Bamboo** to enhance sustainability and Carbon Fiber Reinforced Polymer for its high strength-to-weight ratio.

Dual Purpose Armrest & Tray Table



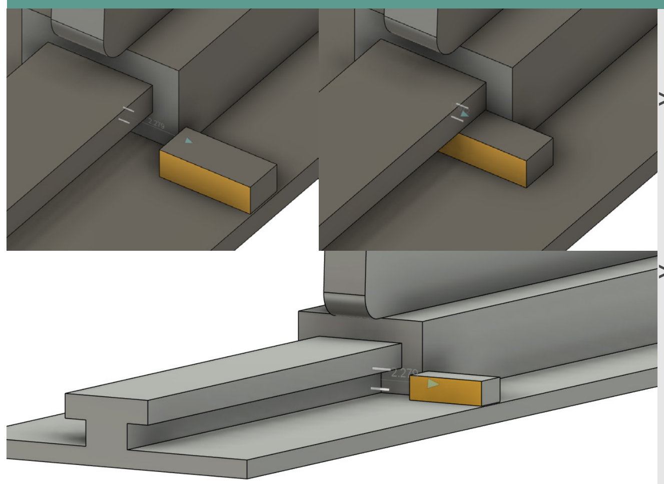
Structure and Functions
- **Adjustable armrest** with a sliding mechanism to lower or **retract** into the seat body when not in use, providing more space when needed.
- Tray table stored within a side compartment, designed to be **pulled out and unfolded** into a **large** surface for dining and work supported by the raised armrest.

Material used
Recycled lightweight **bio-degradable** thermoplastic (**PLA**) with metal frame and protection layers on the surface, which offers excellent wear resistance, ease of cleaning and recyclability.

Manu. Processes
Additive Manufacturing for thermoplastic: may realise more **precision** and energy **saving** in the **future** for **massive production.**

Lifetime and Utility
10-15 years: durable materials ensure longevity despite frequent use and dynamic loading.

Floor Mounting - Rails and Slide Locks



Structure
- Rails **embedded into** the aircraft floor, with slide locks designed to secure the seat precisely in place.
- Slide locks with a slider mechanism that enables **secure positioning** and **quick locking** of the seat when it reaches the desired location.

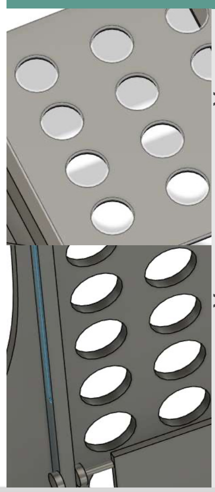
Functions
- Ensures accurate and secure mounting of the seat in the aircraft, preventing movement during operation.
- Facilitates **easy installation** and removal for maintenance, enhancing modularity.

Materials Used
- **Aluminum Alloy 7075** (lightweight, strong, corrosion-resistant):
- Why: Aluminum alloys balance **weight reduction** with **strength** and are commonly used in aerospace applications for their durability and recyclability.

Manufacturing Processes
- **Additive Manu-facturing** (3D Printing) for complex locking mechanisms
- Extrusion and Precision Machining for rails: Ensures dimensional accuracy and **smooth operation**.

Lifetime and Utility
- Designed for **long-term use** with minimal **degra-dation**

Bottom & Back Pan



Structure
- Lightweight, contoured design with **lattice patterns** for weight reduction,
- **3D-printed** for precise **ergonomic** shaping.

Functions
- Provides support to cushion and the passenger's back
- Distributes load evenly, enhancing long-haul comfort.

Materials Used
- **Carbon Fiber Reinforced Polymer (CFRP)**: Lightweight, strong, excellent **fatigue resistance**.
- Why: Offers high stiffness, low weight, and is recyclable or **repurposable through re-molding**

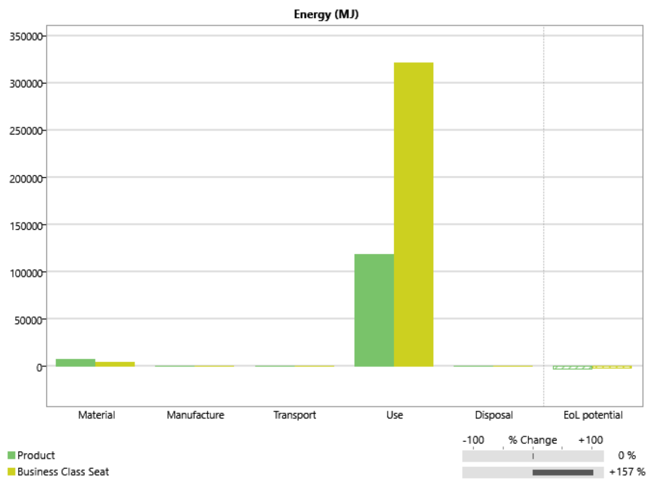
Manufacture Processes
- 3D Printing using Continuous Fiber Technology & Lattice Reinforcements

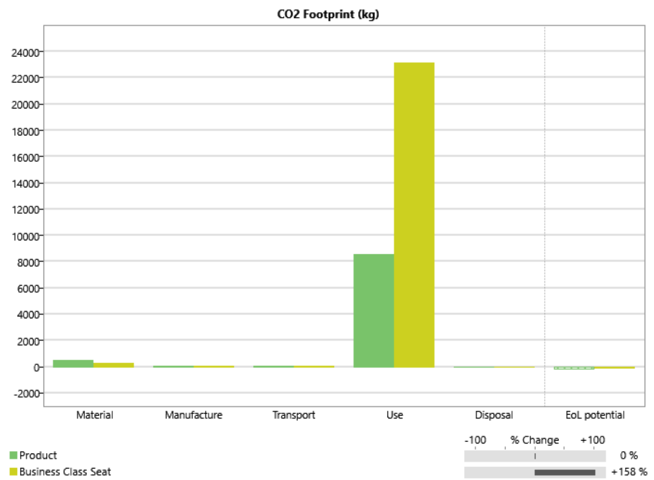
Lifetime and Utility
- Estimated lifespan: 15-20 years.
- Carbon fiber's fatigue resistance & strength make it suitable for prolonged usage with minimal performance degradation.

Disassembly Tree and environmental impact analysis

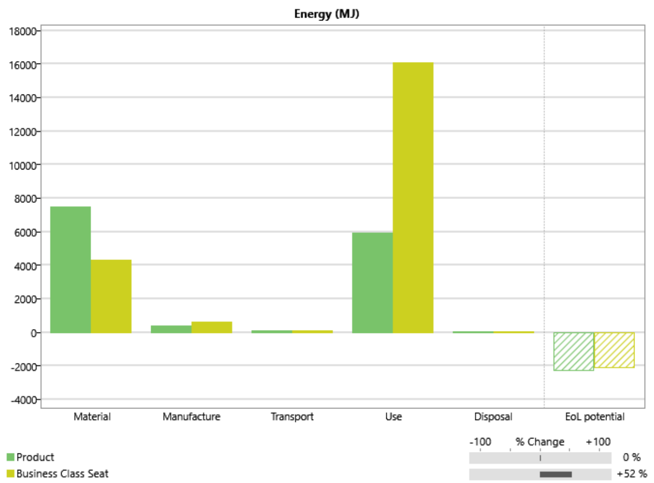
Eco Audit Report Analysis

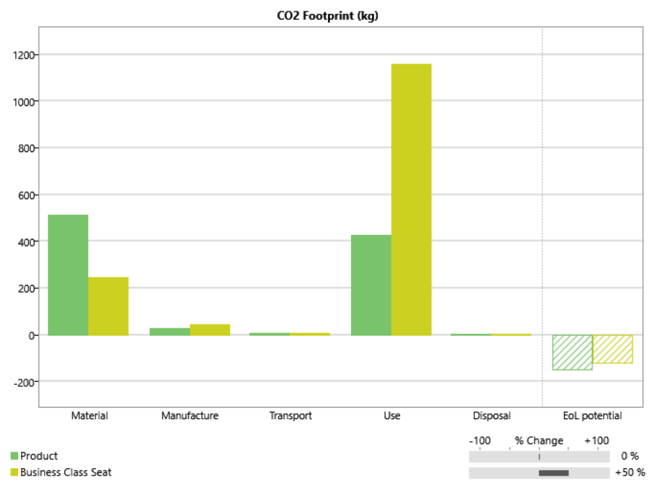
Results assuming a seat life of 25 years - Reality Situation





Results assuming a seat life of 1 years - Experimental Situation





Key Result:

Proposed design

Old Sample Seat

> The environmental impact analysis demonstrates **significant improvements** in energy consumption and CO_2 footprint for our design compared to the business-class seat from 20 years ago.

> (25-year lifespan): New design shows substantially reduced energy consumption and emissions during the **usage phase** due to its lighter weight, resulting in lower fuel consumption during flights.

> (1-year lifespan): In the **short-term** analysis, the new seat design exhibits **higher environmental impact** during the material and manufacturing phases due to the use of CFRP, highlighting the **trade-offs** between short-term impact and long-term benefits. See below for details.

Key Assumptions:

> **Weight data** for components were generated from **CAD models**, providing estimated weights that may be slightly **heavier** than in reality due to simplified structural designs and lack of detailed mechanical elements.

> The simplified CAD model may **not fully capture** weight reductions possible through optimized mechanical structures, but this **balance** is assumed reasonable for calculating environmental impact.

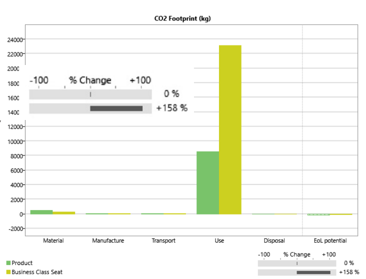
CFRP vs Aluminium for seat frame

> Whilst our seats have performed well in 'use', they have not performed as well as the older seats in terms of 'material', and this is largely down to the use of CFRP. Why do we still use this material?

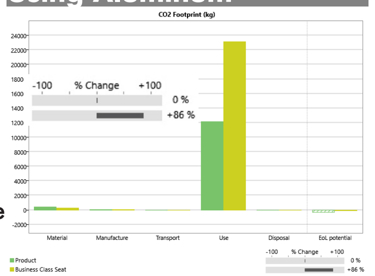
> Weight Reduction Benefits: CFRP offers good strength-to-weight ratio, **lower density** compared to Al, resulting in a **lighter seat structure**. This significantly **reduces operational emissions** during the aircraft's lifetime.

> **Long-Term** Performance: Over a 25-year lifespan, the reduced weight of CFRP delivers a **72%** improvement in environmental performance compared to aluminum.

Using CFRP



Using Aluminum



Adjustments for rigour

Adjustments for rigour

electrical casing white	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.019	0	0	0	0.0
Remote case	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.062	0	0	0	0.0
TV bracket spacer	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.014	0	0	0	0.0
handrest front	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.26	1	0.26	25	0.6
stabiliser for tv metal long	Cast Al-alloys	Virgin (0%)	0.026	0	0	0	0.0

> For the previous analysis of the seats, we removed all the parts that were not part of the primary system, and because the table contains parts for 2 seats, we deleted the plural parts to ensure consistency with the current design of the seats and to make the analysis rigorous.

Table of components

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%
bottom seat frame	Age-hardening wrought Al-alloys	50.0%	1.7	2	3.3	3.8e+02	5.1
seat leg support	Cast Al-alloys	50.0%	6.4	2	13	1.4e+03	19.2
seat leg support2	Cast Al-alloys	50.0%	1.2	1	1.2	1.4e+02	1.8
bottom to back connecotr	Cast Al-alloys	50.0%	1.5	1	1.5	1.7e+02	2.3
bottom pan	CFRP, epoxy matrix (isotropic)	Virgin (0%)	2.1	1	2.1	1.4e+03	19.3
Back PAN	CFRP, epoxy matrix (isotropic)	Virgin (0%)	5.4	1	5.4	3.7e+03	49.6
cushion stand	Bamboo	Virgin (0%)	0.5	2	1	34	0.5
little wheel	Cast Al-alloys	Reused part	0.076	2	0.15	0	0.0
tray table	Polylactide (PLA)	60.0%	1.2	1	1.2	33	0.4
Armrest	Polylactide (PLA)	60.0%	0.8	1	0.8	22	0.3
actuator	Stainless steel	50.0%	1	1	1	44	0.6
foot rest	Bamboo	Virgin (0%)	2.1	1	2.1	72	1.0
Total				16	33	7.5e+03	100

Connector type

- Cable Tie
- Double Sided Tape
- Velcro
- Rivet
- Cables/ Wiring
- Glue
- Pin with retention clip
- Screw
- Bolts/washer/nut
- Snap-fit connection

Eco Audit Report Analysis

Seat designed for future

Hoskins

Adventures in the Circular Economy

Utility based on (Sele	Longevity	
This product lasts:	20	Years
Typical product lasts:	25	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
bottom seat frame	1.7000	2	Aluminium	Recycle	80%	90%	Reman	0.61
seat leg support	6.3000	2	Aluminium	Recycle	80%	90%	Reman	0.61
seat leg support2	1.2000	1	Aluminium	Recycle	80%	90%	Reman	0.61
bottom to back connector	1.5000	1	Aluminium	Recycle	80%	90%	Recycle	0.41
bottom pan	2.1000	1	Composites	Recycle	90.00%	90%	Recycle	0.03
back pan	5.4000	1	Composites	Recycle	90.00%	90%	Recycle	0.03
cushion stand	0.5000	2	Natural Material	Recycle	90.00%	90%	Recycle	0.52
little wheel	0.0760	2	Aluminium	Recycle	80.00%	90%	Reman	0.61
tray table	1.2000	1	Bioplastic	Biological	90.00%	90%	Recycle	0.41
armrest	0.8000	1	Bioplastic	Biological	90.00%	90%	Recycle	0.80
actuator	1.0000	1	Steel	Reuse	70.00%	90%	Reman	0.92
foot rest	2.0000	1	Natural Material	Recycle	90.00%	90%	Recycle	0.52
Product Mass (kg):	32.352							0.47

Seat from 20 years ago

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Plastics	5.0000	1	Plastics	Recycle	80%	60%	Recycle	0.15
Aluminium	9.1200	1	Aluminium	Recycle	80%	70%	Recycle	0.35
Steels	3.4750	1	Steel	Recycle	80%	50%	Recycle	0.33
Screws	0.7061	1	Steel	Virgin		40%	Reuse	0.10
Connectors	0.3440	1	Steel	Recycle	80.00%	60%	Recycle	0.38
Frame	20.0000	1	Steel	Recycle	60.00%	80%	Recycle	0.47
Product Mass (kg):	38.6451							0.38

Key Result:

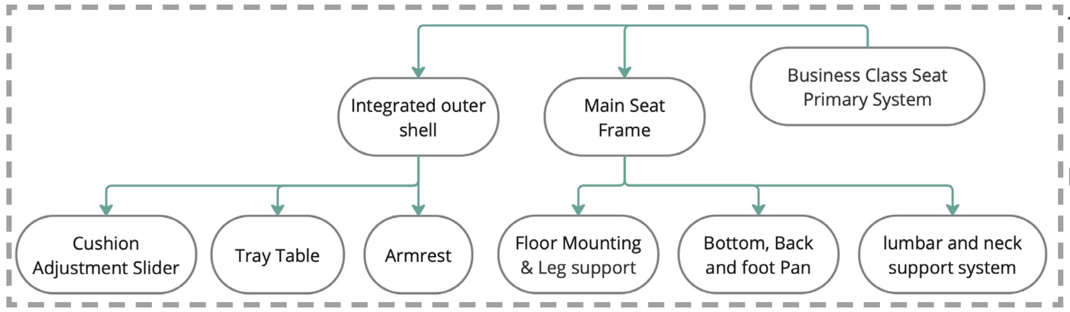
> The MCI value for the newly designed seat is **0.47**, while the seat from 20 years ago has an MCI of **0.38**. This indicates a **more circular design** for the new seat, reflecting a higher use of recyclable, renewable, and reusable materials.

> **The new design achieves this through** a greater focus on recycled aluminum, bioplastics, and components designed for remanufacturing. While MCI improvements are clear, there is still room to enhance regenerative content and recyclability in composites and advanced materials.

> Our group's design uses **additive manufacturing** for many of the parts, but since this method of production is not widespread and therefore **not included** in the MCI calculator, accurate data is not available, but this will be a **trend** in the future.

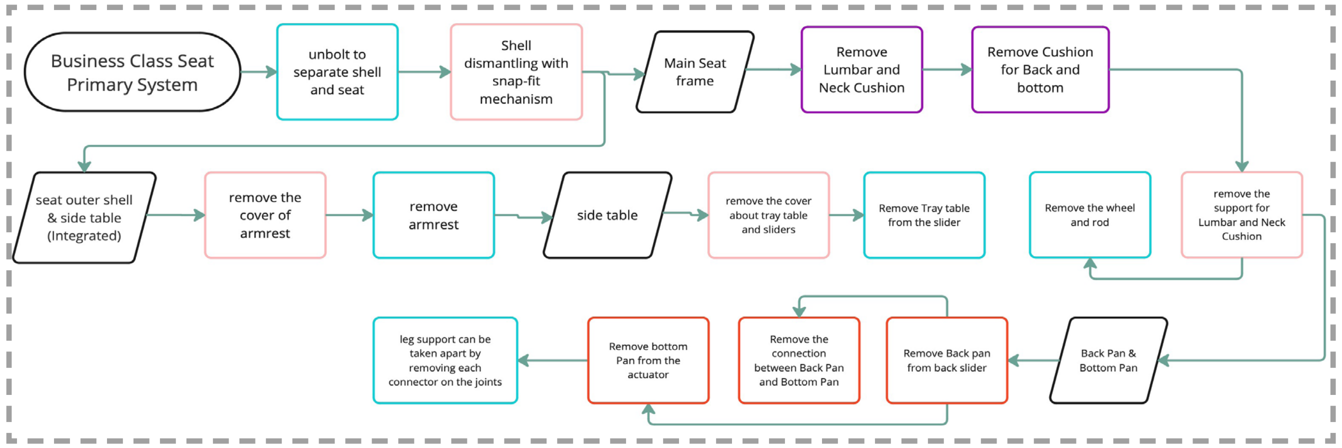
Disassembly Tree & Product Tree

Product Tree



The Product Tree outlines the business-class seat's modular structure, including the Integrated Outer Shell for protection and aesthetics and storage. Main Seat Frame to withstand pressure and shocl and Pans for cushion support

Disassembly Tree

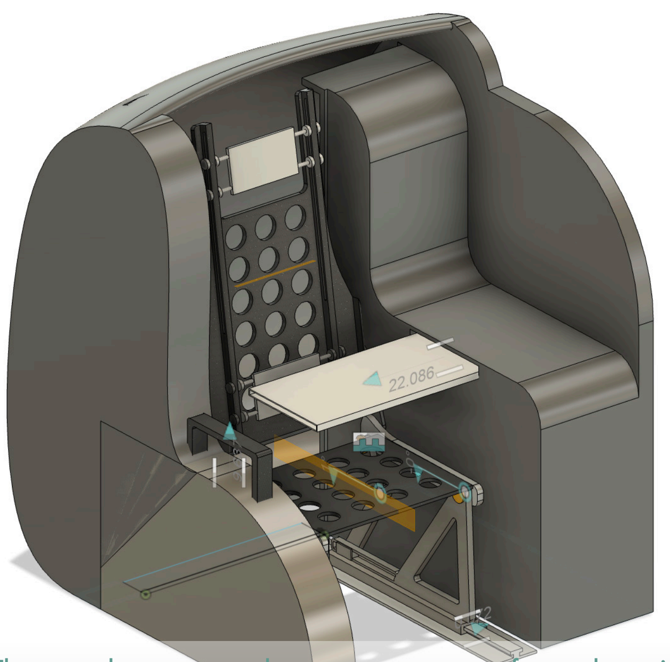


The Disassembly Tree details the step-by-step process to dismantle the seat, which contains very few steps, demonstrating the modularity and simplicity of the structure.

Seat Secondary Structure Specification

System Overview

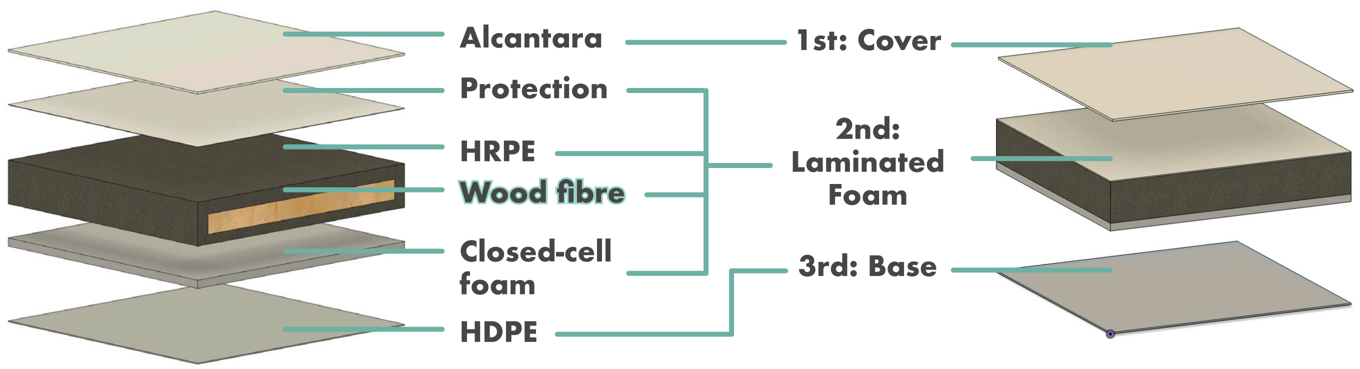
Seat Primary System



Seat SecondarySystem

The secondary system enhances passenger comfort and sustainability through modular, ergonomic components. It includes an adjustable neckrest, a side-sleeping pillow, a footrest, and a multi-layered cushion system made of Alcantara, laminated foam, and recycled HDPE. Materials like recycled PET, polyurethane foam, and bio-based components are used for durability and eco-friendliness. Components are assembled with sustainable methods, such as water-based lamination and integrated track clips for ease of disassembly. The system is designed for recyclability, with a clear disassembly process enabling material separation and reuse, aligning with comfort, sustainability, and circular economy principles.

Materials for Cushion & Cover - Laminated foam



Cover - Alcantara

A synthetic material made from polyester (68%) and polyurethane (32%). It is durable ,light, breathable, and stain resistant. also it has low maintainance as it is warm in the winter and cool in the summer, can be washed and ironed it is suitable to be used in aviation, as it complies with fire safety standards while providing a premium appearance and comfort.

Sustainability of Alcantara

- **Carbon Neutral**: Alcantara offsets all emissions from its production processes.
- **Recyclability**: While Alcantara itself is not fully biodegradable, it aligns with circular economy goals by being **long-lasting** and reducing the need for **frequent replacements.**

Laminated foam

This layer combines closed-cell foam for shock absorption, HRPE memory foam for ergonomic support. A wood fiber core made from softwood shavings improves breathability and reduces weight, contributing to sustainability. The entire layer is protected by a water-based eco-coating, ensuring waterproofing and hygiene while maintaining environmental friendliness.

Base - HDPE

Recycled plastic (HDPE) with good strength and durability serves as the structural base, connecting the cushion to the seat frame. It is lightweight, and its **recyclability** supports sustainable design principles.

Manufacturing - Lamination & Connection

- The foam layers are laminated using a **water-based adhesive**, ensuring strong bonds **without** harmful solvents, reducing VOC emissions, maintaining sustainability. The **eco-coating** adds waterproofing while preserving foam breathability.
- The cover is attached to the foam using **zipties** for easy **maintenance**, and the foam is bonded to the HDPE base with **bio-resin** adhesive, balancing functionality and biodegradability. The HDPE base connects to the seat frame using a **slide rail and locking mechanism** for secure and simple assembly.

Specification of Seat Components

Adjustable Neckrest

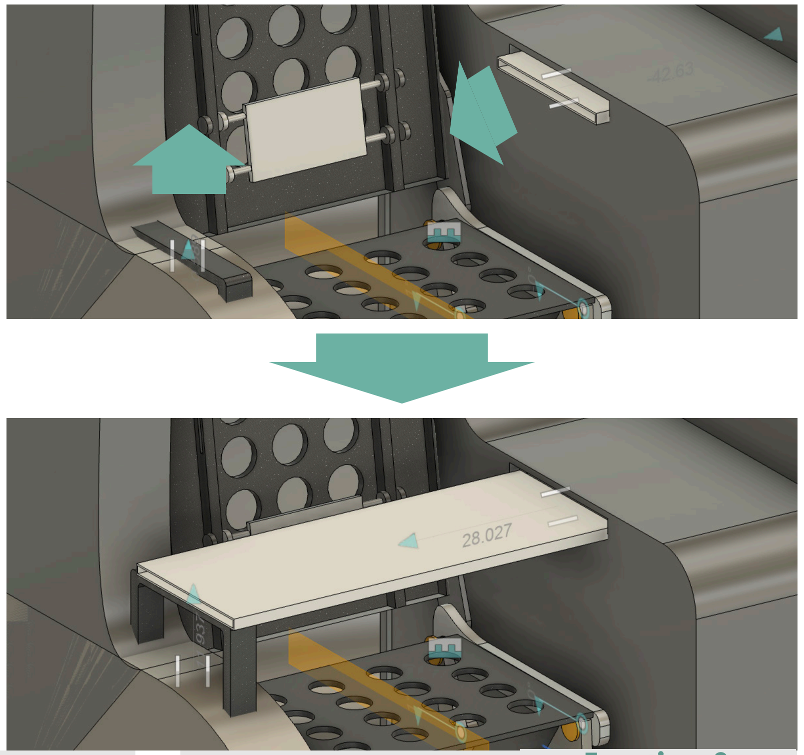
Function & Structure

- The system users with **different heights** to get **neck support** while sitting in this chair. this is done by using a mechanical sliding rail integrated into the seat frame to allow passengers to adjust the pillow's vertical position by **manually slide and lock** it into place.
- This design is preferred over alternative solutions, which was to build **magnets** or use **Velcro** in the backrest and neck pillow, so that passengers can adjust the position with freedom. However, this solution has unreasonable aspects. One is that the **friction** between the pillow and the seat may become smaller over time and cannot be fixed. The strength is reduced, and another is that such a metal structure will be very **heavy.** Therefore I prefer the method in the picture which offers reliability, durability, and lightweight performance, making it ideal for aviation applications.

Assembly Method

The **Integrated Track Clip** method is used to attach the neck pillow to the rail. In this design, the pillow support includes a **pre-molded clip** that securely **snaps** into the rail's track, allowing for smooth vertical adjustments while minimizing assembly complexity. Ensures **tool-free connection** between the pillow and the rail, facilitating easy maintenance and long-term reliability.

Tray Table & Armrest



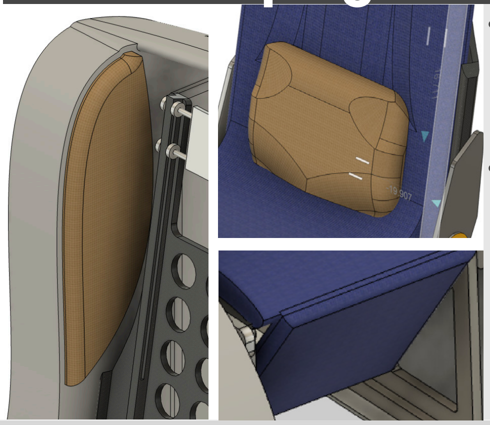
Assembly Method

- **Linkage and Table**: The **linkage rod** is connected to pre-drilled holes on the tray table with screws or rivets.
- **Armrest and Linkage**: The armrest is mounted onto the linkage using a sliding pin or pivot joint for synchronized movement.
- **Frame Integration**: Both the tray and armrest assemblies are attached to the seat frame using **snap-fit** components for stability.

Function & Structure

This system integrates the armrest and tray table (with cup support) with a **mechanical** linkage. When the tray table is pulled out, a linkage at its inner end raises the armrest to provide support. When stowed, the linkage lowers the armrest back to its original position. This ensures smooth operation and dual functionality for compactness and stability.

Side-sleeping Pillow & Footrest



- The side-sleeping pillow is designed to provide **lateral support**, allowing passengers to rest comfortably in a **side-sleeping position**.
- The footrest is integrated into the lower seat structure and provides adjustable support for the legs. **Protection layers (PET)** similar to main cushion protection is used in the footrest to avoid freqeut cleaning, waterproof and maintain hygiene.

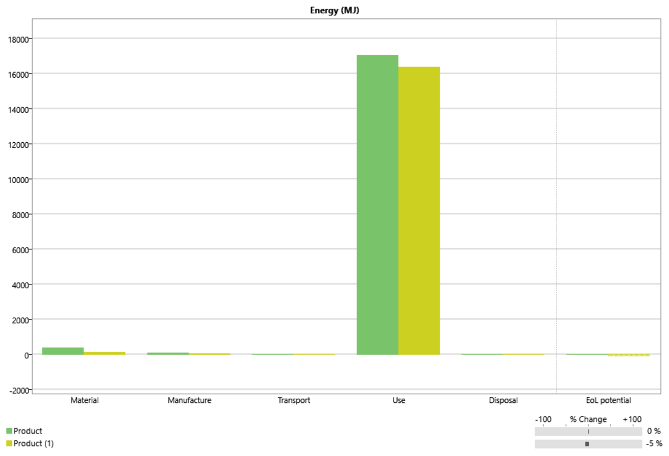
Material & Manufacturing

- **Tray Table**: Made from natural materials like oakwood (good mechanical property), covered with bio-based composites for lightweight, durable surface, and recyclable properties. Manufactured via compression moldingn for precision and efficiency.
- **Armrest**: Constructed from HDPE. Produced using 3D printing for ergonomic and lattice structure to reduce weight.
- **Linkage Mechanism**: Uses recycled aluminum for lightweight and durable performance. Manufactured via die casting, stamping, or pultrusion for strong and precise components.

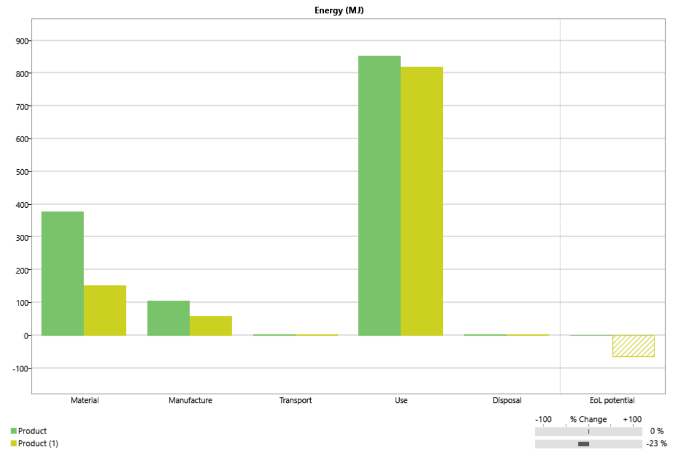
Disassembly Tree and environmental impact analysis

Eco Audit Report Analysis

Results assuming a seat life of 20 years - Reality Situation



Results assuming a seat life of 1 years - Experimental Situation



Key Result:

Proposed design

Old Sample Seat

> The left chart demonstrates the significant influence of seat weight on the **usage stage**, as the energy required to transport and use heavier seats is amplified. However, there is minimal difference in the usage stage between the two seats. (Fortunately, weight reduction in our seat's **primary** system has already **minimized** its impact during use.)

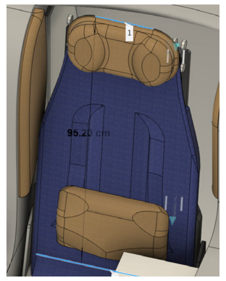
> The right chart highlights the differences in **material and manufacturing** stages. Our seat performs significantly **better** due to the use of lightweight, recyclable materials such as HDPE, wood fibre and bio-based plastics and foams, which reduce the energy and environmental cost during production. The sample seat, by contrast, relies on heavier and less sustainable materials.

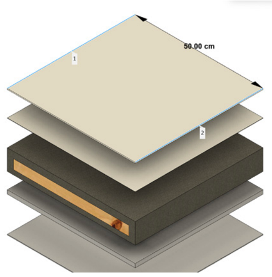
> The **allowance** for slightly more weight in the secondary system is justified by its direct contribution to passenger **comfort**. In our senario, we prioritize **both** sustainability and comfort. And this approach aligns with our goals of **reducing** the overall environmental impact while **enhancing** the passenger experience.

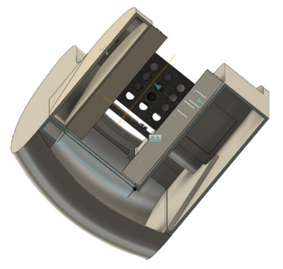
Detailed Report of Materials & Key Assumptions

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%
back and bottom foam1	Polyurethane (tpPUR)	Reused part	0.5	1	0.5	0	0.0
back and bottom foam2	Polyethylene terephthalate (PET)	100.0%	0.1	1	0.1	2.8	1.8
back and bottom foam3	Polystyrene (PS)	80.0%	0.4	1	0.4	16	10.2
back and bottom base	Polyethylene (PE)	100.0%	0.7	1	0.7	19	12.3
back and bottom cover	Polyester (UP)	Virgin (0%)	0.8	1	0.8	71	46.6
side, neck, and lumber cushion	Polyurethane (tpPUR)	Reused part	1	1	1	0	0.0
side, neck, and lumber cushion	Polyester (UP)	Virgin (0%)	0.5	1	0.5	44	29.1
back and bottom foam3	Plywood	Reused part	0.5	1	0.5	0	0.0
Total				8	4.5	1.5e+02	100

How is the weight Estimated and rationalized?







To estimate the seat's weight, the approximate dimensions were measured from the existing **seat model**. These dimensions were used to create **simplified rectangular geometries** for each layer of the material, reflecting the **overall size and thickness** of the seat components.

The material **properties and densities** were then applied to these simplified geometries to calculate the weight of each layer (with simplified feature in fusion 360). However, the results were adjusted for practical considerations:

- **Geometrical Simplifications**:The design includes hollow structures(picture 4) and material optimizations, which reduce the overall weight compared to the simplified block geometries.
- **Material Processing Losses**:During manufacturing, material is removed or wasted due to cutting, shaping, and assembly processes. This loss was estimated and factored in, reducing the calculated weight by approximately 20–30% to reflect the final design.

Why use these materials and how they lowers environmental impact?

Reused PUR Foam:

PUR is the main material for memory foam and is reused in our design from **discarded mattresses**. This is a sustainable option as polyurethane foam can be recycled by **grinding** into powder or fragments, which can then be used to create new foam. Many suppliers already provide recycled foam derived from discarded furniture and mattresses, which makes it feasible to establish a **collection** and recycling **system**.

Recycled PET for Protection Layer:

The waterproof protection layer is made from recycled **PET bottles**. This is inspired by outdoor product brands like Patagonia, which widely use recycled PET in waterproof applications. PET is a sustainable choice due to its abundance and ease of recycling.

PS Foam for Shock Absorption Layer:

The shock absorption layer is made of **closed-cell foam** using recycled polystyrene (PS). Closed-cell foam has higher **mechanical strength**, high impact resistance, and durability.

Polyester(68%) for Cover:

The seat cover uses polyester as one of its main materials. Recycled polyester from post-consumer waste, such as plastic bottles, was selected to reduce environmental impact.

Material Circularity Indicator

Seat designed for future

Hoskins
Adventures in the Circular Economy

Utility based on (Select	Longevity	
This product lasts:	20	Years
Typical product lasts:	20	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Back and Bottom - middle la	0.5000	1	Bioplastic	Reuse	60%	80%	Recycle	0.57
Back and Bottom - middle la	0.5000	1	Natural Material	Reman	60%	80%	Energy Recovery	0.53
Back and Bottom - foam pro	0.1000	1	Bioplastic	Biological	60%	80%	Reman	0.71
Back and Bottom - Shock Ab	0.4000	1	Bioplastic	Reman	50%	80%	Recycle	0.55
Back and Bottom - Base	0.7000	1	Plastics	Recycle	70.00%	80%	Recycle	0.34
Back and Bottom - Cover	0.8000	1	Bioplastic	Recycle	20.00%	80%	Recycle	0.14
Side, neck and lumber cushic	1.0000	1	Bioplastic	Reuse	60.00%	80%	Recycle	0.57
Side, neck and lumber cushic	0.5000	1	Plastics	Recycle	60.00%	80%	Recycle	.34
Product Mass (kg):	4.5							0.43

Seat from 20 years ago

Hoskins
Adventures in the Circular Economy

Utility based on (Select	Longevity	
This product lasts:	20	Years
Typical product lasts:	20	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Fabrics	0.7000	1	Plastics	Virgin	30%	50%	Landfill	0.10
Foam	3.9840	1	Plastics	Virgin	40%	55%	Landfill	0.10
Product Mass (kg):	4.684							0.10

Key Result:

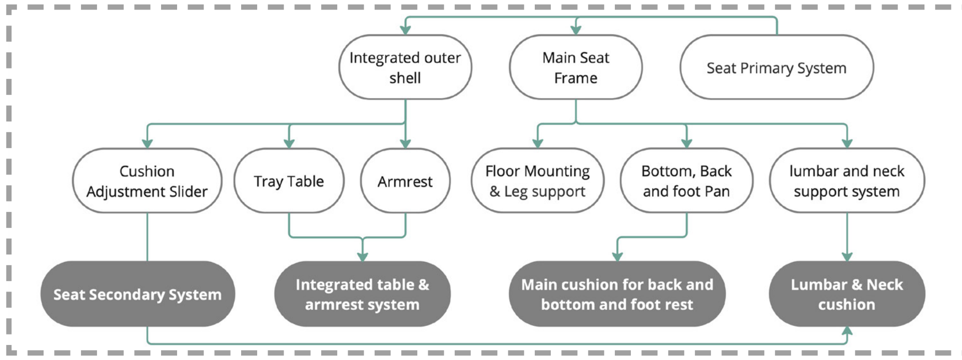
The cushion we designed achieves an MCI of **0.43**, significantly higher than the sample cushion's **0.10**. This improvement is due to the use of bioplastics, recycled materials, and reusable components, with high regeneration (50–70%) and collection rates (80%). The higher collection rate assumes a **future scenario** with a more **mature waste collection system** focused on recycling, reusing, and remanufacturing (3Rs), enabling efficient recovery and processing of materials. The destination of materials in our design reflects this system, with most components either recycled or remanufactured, minimizing waste to landfill. In contrast, the sample cushion relies on virgin plastics, with a large proportion of materials sent to landfills due to poor recovery infrastructure, highlighting the need for circular design and improved collection systems.

Disassembly Tree & Product Tree

Product Tree

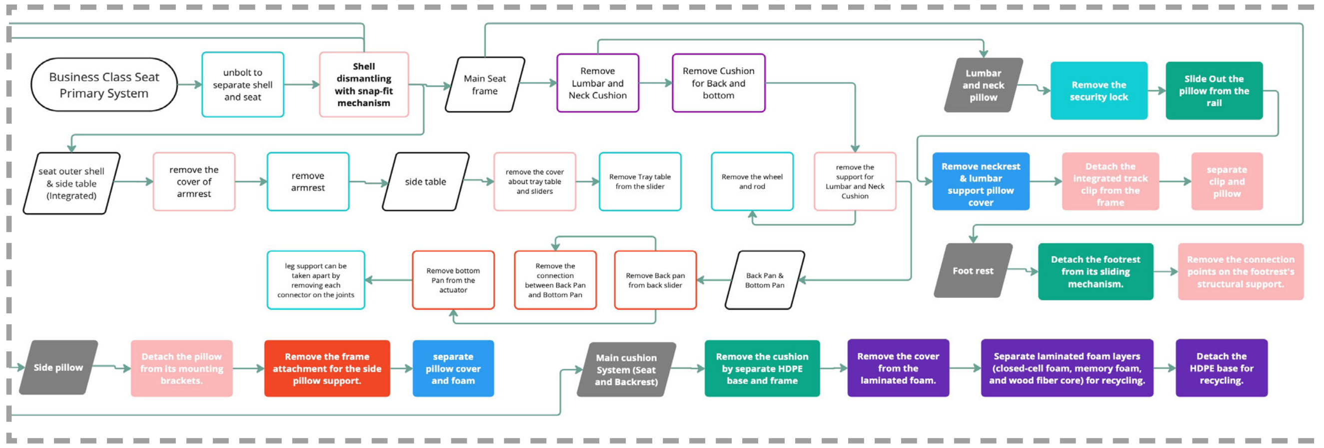
Connector type

- Cable Tie
- Rail & Slide
- Velcro
- Rivet
- Cables/ Wiring
- Glue
- zip tie
- Screw
- Bolts/washer/nut
- Snap-fit connection
- Water-based adhesive



In this disassembly tree, the solid-colored boxes represent the steps for dismantling the secondary system, while the hollow boxes indicate the disassembly process for the primary system. Since the tray table system is already addressed as part of the primary system

Disassembly Tree

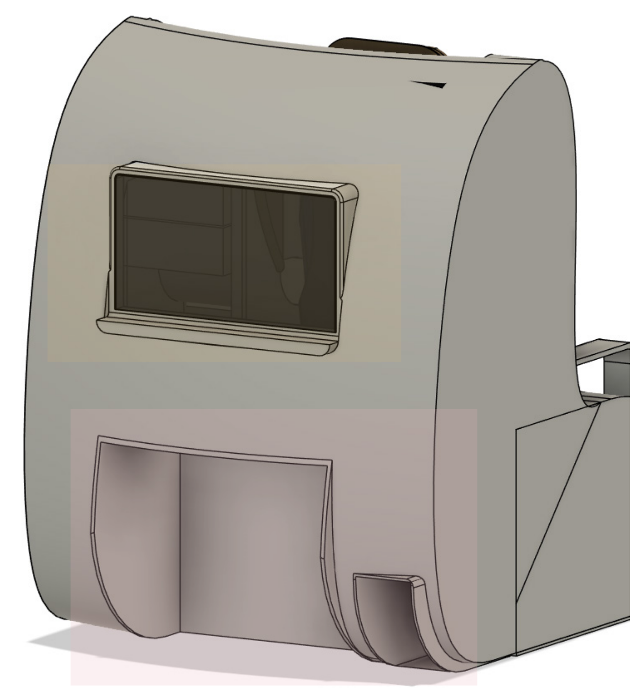


Seat Accessories Specification

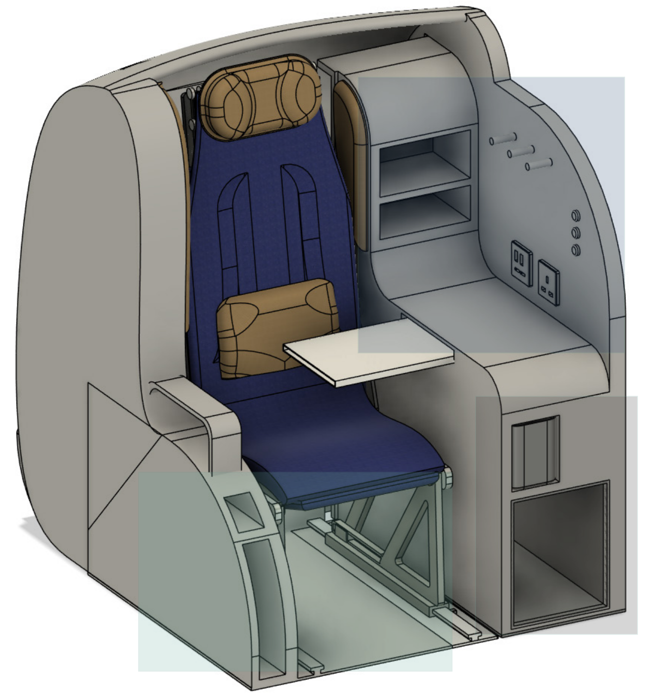
The seat accessory system is designed to enhance passenger comfort and functionality while prioritizing sustainability. Unlike conventional seats, it integrates modular, lightweight components and innovative storage solutions for bedding, trash, and luggage. Key advancements include IoT sensors for monitoring material degradation, energy-efficient power systems, and integrated privacy panel made partially made from natural materials. this system offers improved usability, reduced environmental impact, and a forward-thinking approach to in-flight comfort and efficiency.

System Overview with accessories

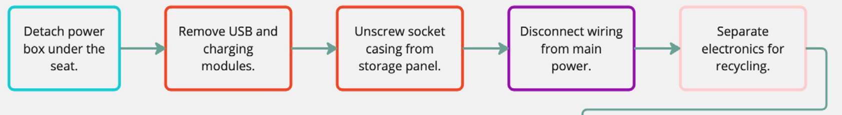
Back View



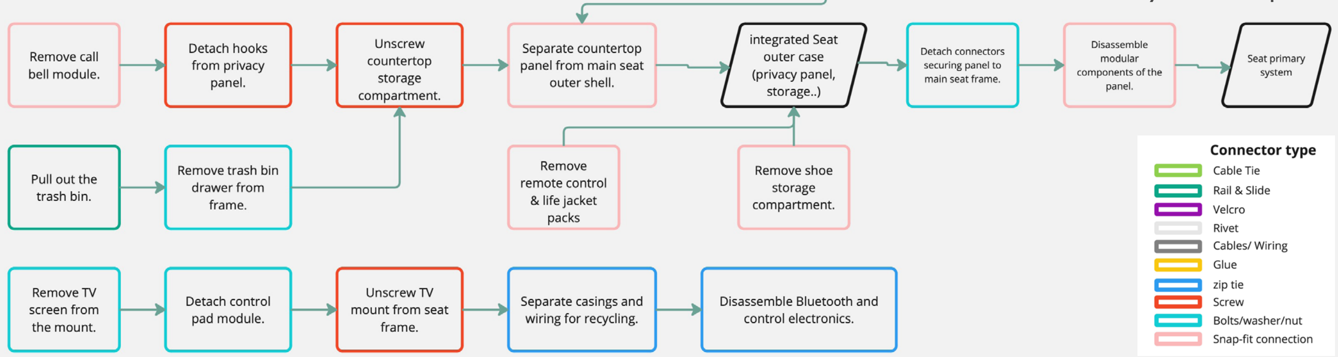
Front View



Product & Disassembly Tree



Since the aircraft seat adopts an integrated design, most of the storage space and the aircraft seat shell (privacy panel) are integrated, and no additional disassembly work is required.



___ & Sustainability Considerations

Material

To make **electronics** more sustainable, the entertainment system casing and control pad are constructed using recycled plastics, reducing the need for virgin materials. **Energy-efficient** components, such as LED displays and low-power Bluetooth modules, minimize energy use during operation. Modular designs ensure that individual electronic parts can be replaced or upgraded, extending their **lifespan** and reducing electronic waste. Additionally, **sourcing** components from remanufactured or refurbished electronics can further lower environmental impact.

Manufacturing

- a. **Storage Manufacturing**: Storage components are integrated to the main seat panel, which are made using injection molding or AM for HDPE. Some parts such as trash bins are made from reused boxes.
- b. **Assembly with Primary and Secondary Systems**: Accessories are mounted to the seat's primary and secondary systems using snap-fit connectors, screws, and modular brackets. These connections allow for tool-free(partially) disassembly, enabling repairs or recycling. Modular attachment points ensure compatibility across different seat configurations, enhancing versatility and simplifying assembly.

Design for Sustainability

- The accessory design enhances the seat's sustainability by ensuring modular construction for easy disassembly and material separation at the end of life.
- Integrated IoT sensors monitor wear and usage, enabling predictive maintenance and reducing the risk of premature replacement.
- Storage compartments use recycled composites, lowering material impact while maintaining strength.
- Incorporating lightweight materials and multi-functional components (e.g., combined storage and structural supports) reduces overall material use and fuel consumption during operation.

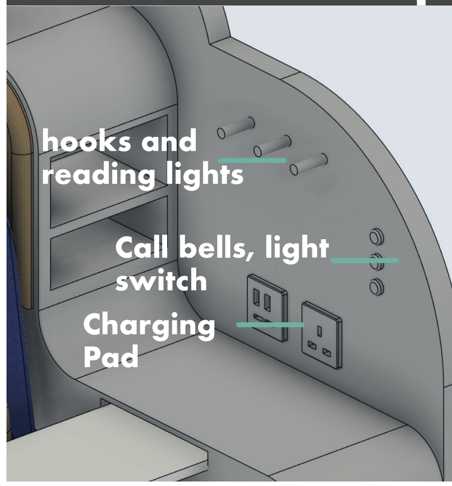
Lifetime & Utility

Accessories are designed to last 20 years, with modular construction enabling maintenance, upgrades, and reuse, ensuring long-term functionality.

- F&S: function & Structuer
- Sus: Sustainability

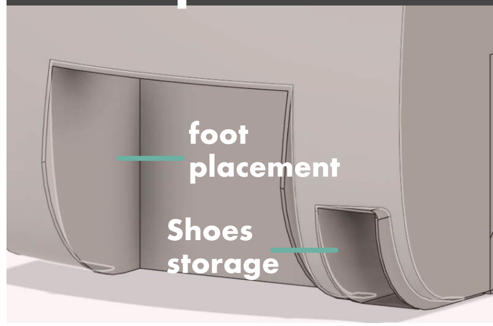
Specification of Seat Accessories

Countertop layout



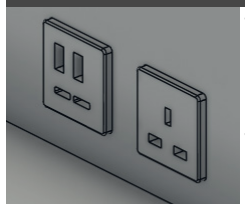
- F&S: Integrated storage space for passenger items, hooks(integrated with lights) for hanging personal belongings, and 2 call bell for service requests & energency. Designed to maximize useable space and maintain organization.
- Sus: Constructed using recycled aluminum for structure and recycled HDPE for smaller components, enabling full recyclability and reduced waste.

Foot space and shoe storage



- F&S: Space is allocated for comfortable foot placement and dedicated shoe storage. The layout enhances legroom and minimizes clutter.
- Sus: Simple and material saving design by 'cutting' on the seat case.

Sockets and power supply



- F&S: Provides USB-C fast charging, wireless charging pads, and a power distribution unit under the seat. Designed for efficiency and ease of passenger use.
- Sus: Employs energy-efficient systems and modular components, reducing operational energy waste and simplifying upgrades.

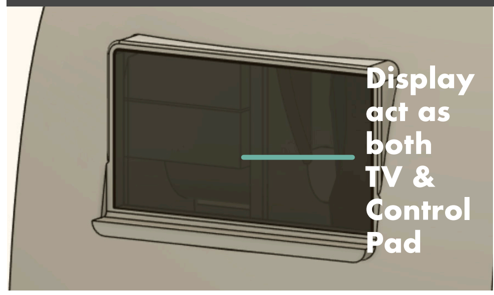
Sensors & Circuits

- F&S: Embedded IoT sensors to monitor seat usage, material degradation, and maintenance needs, enhancing operational efficiency.
- Sus: Powered by low-energy technology, reducing environmental impact while extending the product's lifespan.

Trash and bedding storage

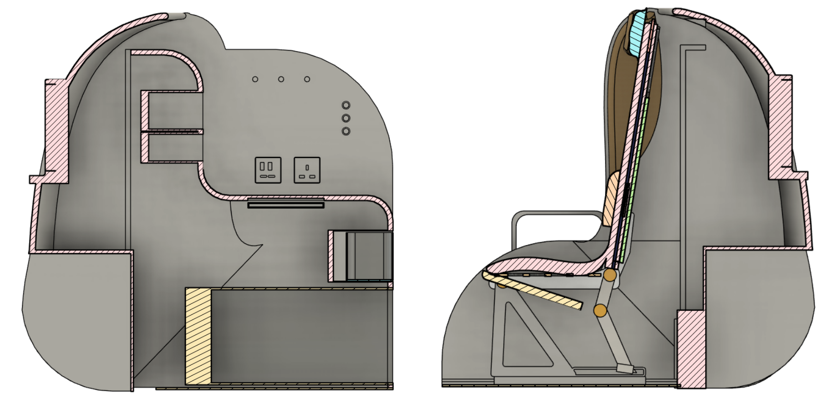
- F&S: Includes a drawer-style bin for trash (easier collection for both airline and consumers) and a compartment for bedding items such as blankets and pillows. Both compartments are easily accessible and modular for flexibility.
- Sus: Manufactured with recycled HDPE for lightweight, integration, durability and disassembly-friendly design, ensuring proper material recovery.

TV and Control Pad



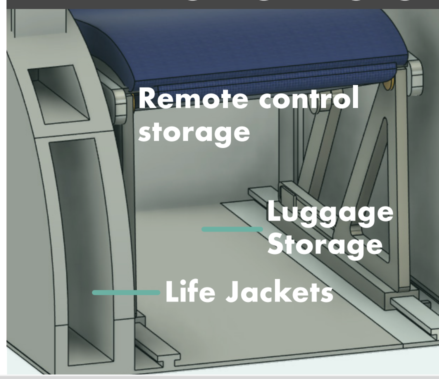
- F&S: Entertainment system with Bluetooth connectivity for headphones and an integrated control pad to adjust seat and pillow positions.
- Sus: Uses LED displays and recycled HDPE casings, reducing energy consumption and material impact.

Privacy panel & inner structure



- F&S: Lightweight partitions for enhanced privacy with minimal material use.(the
- Sus: Made from recycled HDPE and wood, combining weight reduction, aesthetics and durability with material reusability.

Bottom storage space



- F&S: Provides space for carry-on luggage under the seat and includes armrest compartments for life jackets and remote controls. Organized for easy passenger access.
- Sus: Top luggage storage will require less space, saving materials and production energy that would otherwise be used to maintain high durability and load-bearing requirements.