DE2 Sustainable Design Engineering

Submission 1.1: Sustainability Analysis of Product and System

Collins Aerospace

Table of Contents

Owen Lee Scott, Vasco de Noronha, Xiaoyun Li, Lara Merican

Global Aircraft Seating Market

Market Size

Market valued at **7.61 billion dollars** in 2024

Market expected to **grow 55%** by 2032

Market Trends

	Trend
Material	**Lightweight non-metallic** materials (e.g., nylon, synthetic leather, silicon, polyethylene, fireproof fabric) are increasingly used in aircraft seating to reduce weight and fuel consumption.
Joining methods	The large use of **permanent** joining techniques and composite materials makes it impossible to reuse or repurpose seats after their lifespan.
End of life	Increased initiative to **recycle and reuse components** of aeroplane seats. Some companies such as AIRA and Safran offer takeback services.
Design	**USB charging points** and **device holders** are increasingly becoming standard features. Furthermore, features such as reclining seats and the tray table are being removed.
Type	**16G seats** dominate the market due to their **shock absorbance**, which provides higher safety and comfort for passengers /favoured due to **government regulations.**
Class	The **economy class** segment holds the **largest market share** due to the demand for **budget airlines and low-cost carriers**.
Manufacturer	**OEM** (original equipment manufacturers) **will lead the market in 2024.** This means a trend towards planes that come with seats pre-installed, which streamlines operations, can increase space efficiency and reduces retrofitting costs.

Insights from Market Trends

- There needs to be a shift in industry from using permanent joining methods like glue to **non-permanent alternatives,** like screws etc.
- It is vital we interview passengers to find out what features they value least.

Competitor Analysis

There are three main aircraft seating suppliers: Safran, Collins Aerospace and Recaro Aircraft Seating. They have a combined control of 80% of the market.

Competitor	Sustainability Analysis	Comparison to Collins Aerospace
Safran	• Use of **lightweight materials** in seat manufacturing, which contributes to overall fuel efficiency, hence decreasing CO2 emissions. • **75%** of our **R&T** efforts dedicated to the **environmental efficiency of our products.** • Push towards a more **circular** approach by designing seats that are more easily recyclable. Including **modular designs**. • **-30% in greenhouse gas emissions** (for scopes 1 and 2) by 2025, -50% by 2030 vs. 2018. [1]	Advantages: • Like the other seating companies, Collins seats are **lightweight**, which contributes to overall fuel efficiency, hence decreasing CO2 emissions. • All the companies compared, including Collins, all design their seats with **durability** in mind this is extremely important as it prolongs the life cycle of the seats, leading to less CO2 emissions. [4]
Recaro Aircraft Seating	• **Weight reduction,** use of the latest materials and intelligent design: our Economy Class Seats help airlines save on kerosene and therefore fly more ecologically. • The communality of spare parts with the R1 seat makes **maintenance easier** and decreases recurring costs for the airlines. • Besides shared components due to its slim design the R1seat enables **high density layouts**, however they compromised by removing the reclining feature. [2]	
Mirus Aircraft Seating	• Like the other seats, Mirus seats are extremely **lightweight at only 6.9kg** per seat hence saving on fuel emissions. • Provide **fast aftermarket support** with a dedicated team and global spare parts stock, ensuring **minimal downtime** for airlines. • Highly **customizable base economy seats** enable use in various projects, supporting economies of scale and more sustainable manufacturing techniques. [3]	Disadvantages: • Despite progress, manufacturing processes for aircraft seats remain energy-intensive and **resource-heavy.** • All the companies partake in the extraction, processing, and disposal of petrochemical-based materials, which contributes to pollution and carbon emissions. • Most of the aircraft seat's materials are discarded and **don't enter back in the supply chain.** [4]

Insights from Competitor Analysis

- All companies, including Collins Aerospace, prioritize weight reduction, **signalling** an area for further research and seat redesign to **minimize weight.**
- Additionally, while companies focus on repairing and replacing broken seat parts, there's **minimal attention to end-of-life**. This opens an opportunity to design seats for extended use beyond recycling.

Brand Analysis - Collins Aerospace

Commitments made by RTX (Collins Aerospace parent co.)

2019	2023	2025	2030	2050
Baseline	**20% reduction** in wast sent to **landfill.** **Repaired** 567,820 parts.	**10%** of energy used from **renewable sources**	Reduce **greenhouse gas** emissions by **46%**	Net **zero** *[9]*

Sustainability Efforts

Development of modern **Thermoplastic materials** → **50% lighter** and **100% recyclable** *[11]*

In 2023 opened electric airborne power research centre to develop more **energy efficient motors**. *[10]*

Sustainability Shortcomings

Collection & Recycling Systems

Unlike parent company RTX, Collins Aerospace has **not implemented buy back schemes** and have **no method** of **collecting, recycling or repurposing** seats at the end of their lifetime.

Waste Generated

RTX produced **28 million kg** of waste in 2023 *[9]*, this has been increasing year-on-year.

Lack of attention to Airplane Seats

Airplane seats are small portion of Collins Aerospace revenue, they have **not been prioritised** when reducing the companies sustainable impact. Resulting in relatively little R&D.

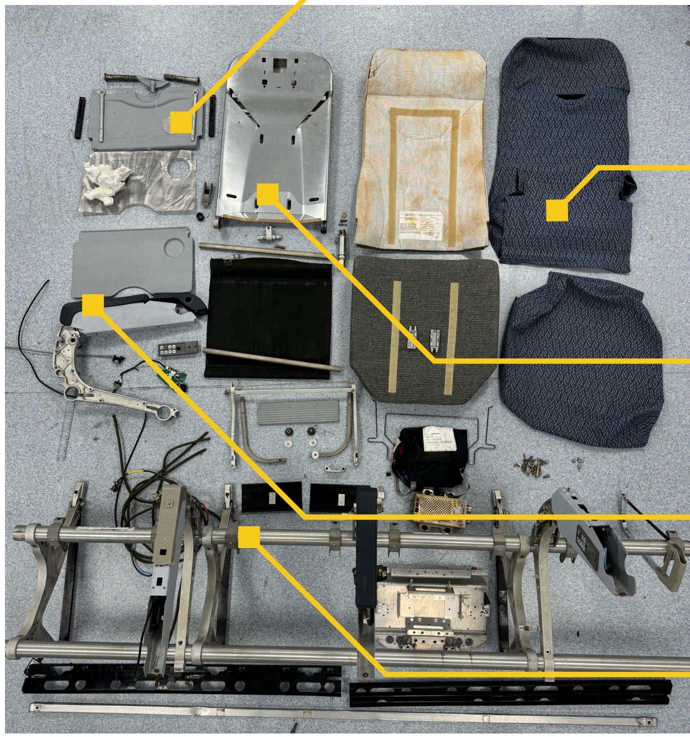
Insights

Parent company **RTX is highly recognized** in aerospace for its sustainability initiatives and goal achievement (#25 global & **#1 aerospace & defence for Environmental, Social, Governance**). **Collins Aerospace** prioritizes sustainability but **lags behind RTX** overall.

Collins Aerospace has prioritised **R&D of new technologies** to address their environmental impact. There is a **lack of focus** on reducing the impact of the **existing products**.

Airline seats are **not a priority** for sustainable development.

Teardown



Tray Table
Material: Polycarbonate
Function: Eating surface
Mass: 0.593kg

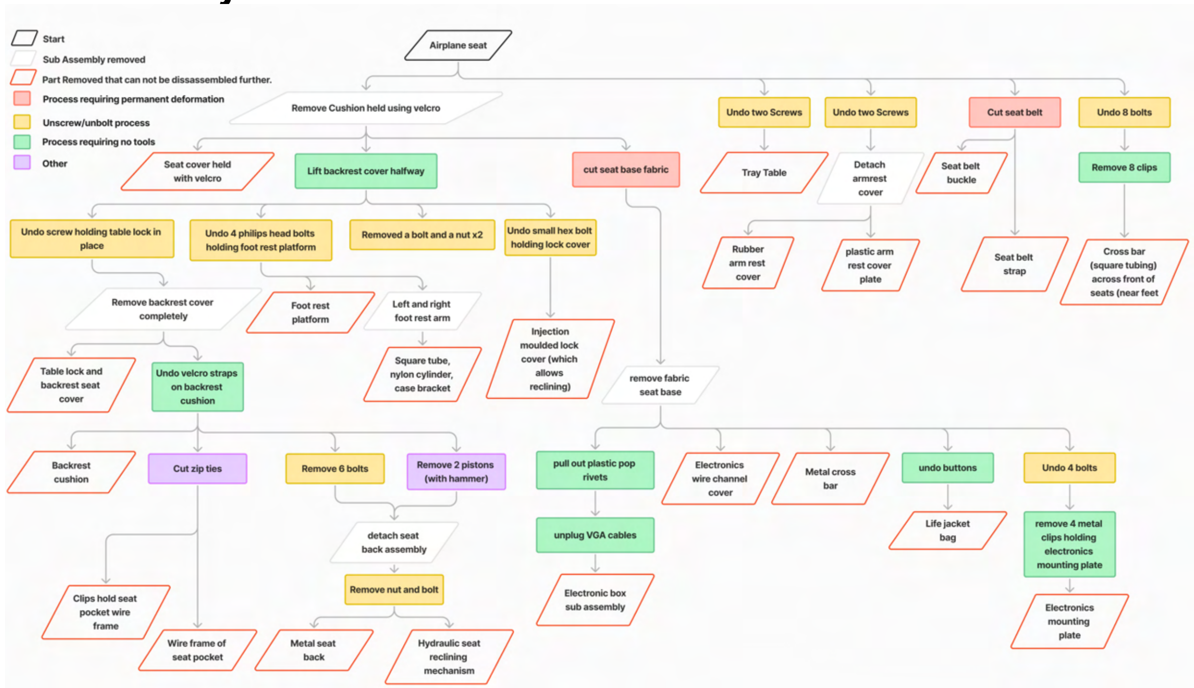
Seat Cover
Material: Nylon Polyester
Function: Aesthetics, protect seats, easy removal & cleaning
Mass: 0.275kg

Seat Back
Material: Aluminium sheet
Function: Provide seat structure
Mass: 1.352kg

Armrest cover
Material: Polyurethane
Function: Comfort and grip for user
Mass: 0.067kg

Seat rails
Material: Aluminium
Function: Seat mount, adjustable seat spacing and number
Mass: 3.895kg

Disassembly Tree



Disassembly Analysis

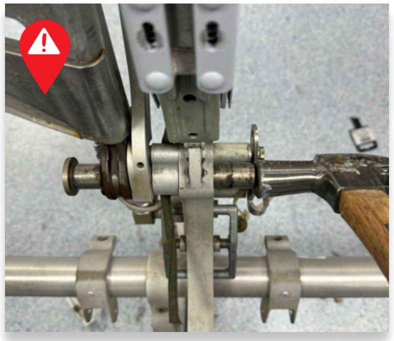
25+ unique connectors

9+ different tools required

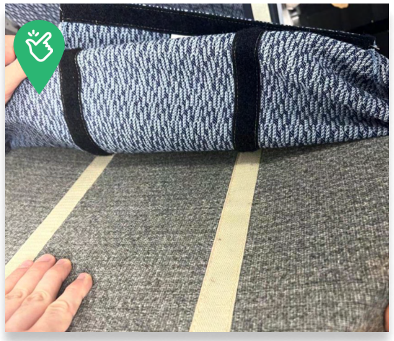
43+ unique components

11 unique materials identified

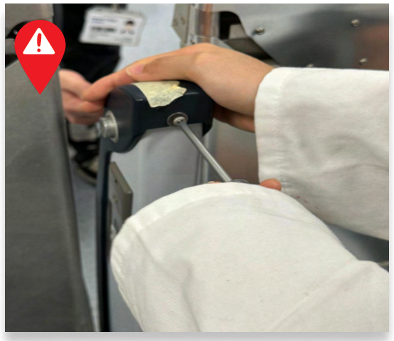
5h and 4 people required to fully disassemble



Exceptionally difficult to remove pin. Required hammer and a lot of force/time.



Velcro and a single screw used on seat covers **made removal effortless**.



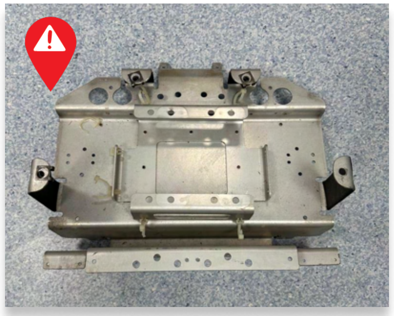
Parts held with **screws** could be disassembled but it was **laborious**.

Excessive use of glue & multiple materials used in table make recycling impossible.

No polymers had Plastic Resign Recycling Codes or material labels - **making sorting difficult.**

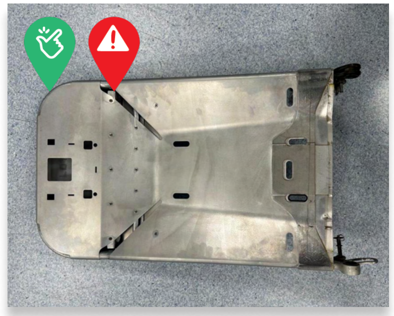
Zip ties require a **tool** to remove - but were very q**uick to disassemble**.

Electronics box held with plastic push rivets making replacement simple with no tools. However, it was **difficult to access** without removing other components.

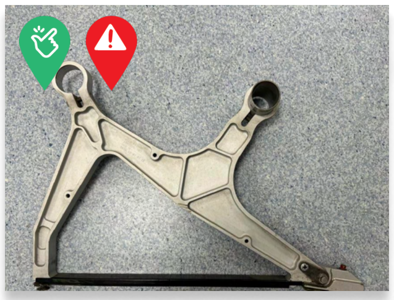


Electronics mount had an **overcomplicated design**, which was also **very heavy** (1.1kg) for its size.

Seat base doubles as **floatation device** (easy removal, **space efficient design**).



Seat back is **lightweight (1.3kg) for its size** but 60mm thick and hollow - **thickness could be reduced**.



Cavities milled to reduce weight, further potential weight savings possible.

Pain Points & Insights

1. Although screws allow for disassembly, **many screws make disassembly slow**. **Faster disassembly methods** should be used to make the process more **economical**.
2. **Unclear order of disassembly** made the process difficult and sometimes caused unnecessary destruction. **Guides or numbered parts could solve this issue.**
3. Seat back, seat legs, and electronics mount could have **volume and/or weight reduced**.
4. Velcro, zip ties, plastic push rivets are useful for fast, **painless disassembly.**
5. Simplifying disassembly requires considering both **component positioning** and **disassembly methods.**
6. **Black** plastic cannot be **identified** with spectrometers and hence can not be recycled.

Summary

Collins Aerospace have done a great job making the most **frequently replaced parts easy to remove**. They have also used few materials and **made weight efficient decisions**.

Primary issue was **disassembly was time-consuming and laborious** due to use of adhesives, and bolts. Making it **uneconomical** for the seats to be **recycled**.

Passengers

Research Methods

10+ interviews with frequent economy class fliers (average 8.3 flights & 48.4h flown per year).

15% of the population account for 70% of flyers. *[15]*

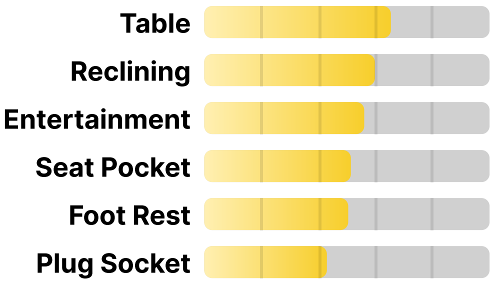
Frequent Flyer Fiona

Age: 20 Occupation: Student

- Will not compromise on **comfort** and price for **sustainability**
- **8.3** flights per year
- **48.4h** flown per year

Interview Results

Feature Importance



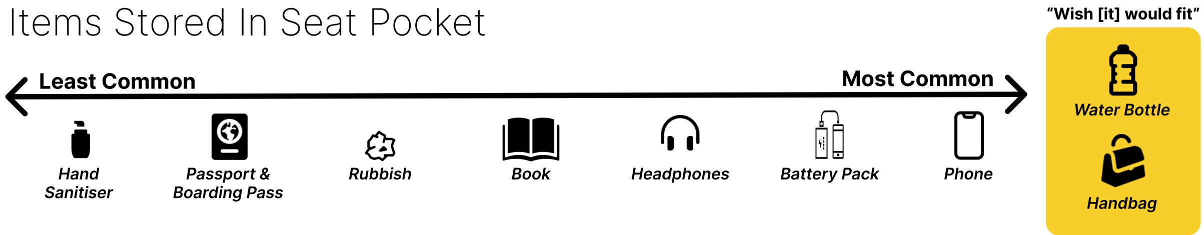
Key Quotes

> After 13 hours of suffering, I don't really care if the plane seat is recyclable or not.

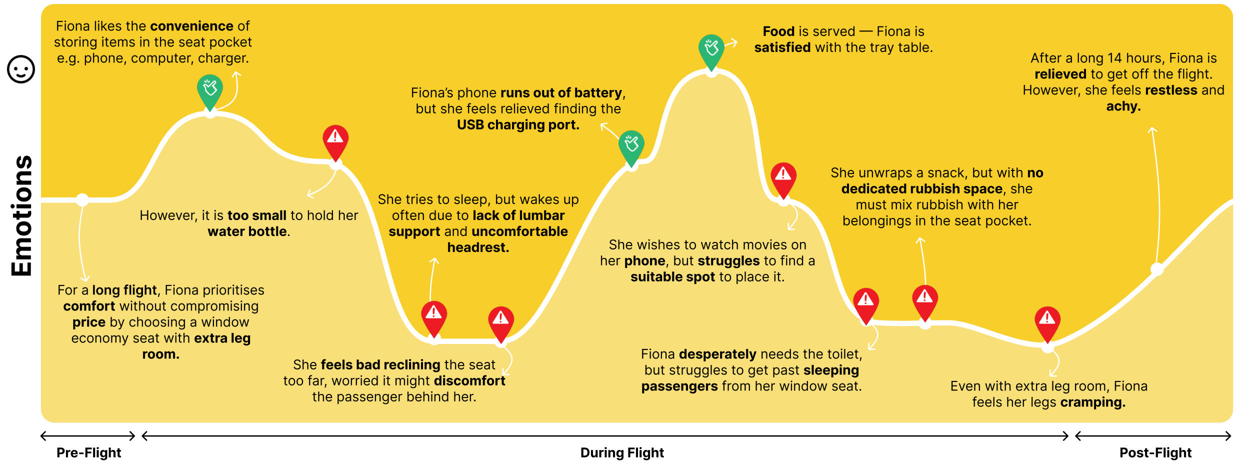
> I just want something that holds my phone at eye level.

> 14 hours puts strain on my lower back.

Items Stored In Seat Pocket



User Experience Map



Experts

Gary Doy

Founder of DOY Design, a transport design consultancy specialising in sustainable design solutions for aviation.

Insider Info

1. Seats are often **discarded** or replaced **before wearing out**, often due to rebranding.
2. **Seat widths vary** across different parts of the plane, even within the same class.
3. The **car industry outperforms aviation** in recycling efforts → potential source of **inspiration.**
4. Many **seat pockets** sustain **damage** after just **one** flight.
5. Removing **unnecessary** features **reduces weight** and **simplifies assembly**.
6. **Curved seats** give passengers a greater sense of legroom.

Mitchell Johnstone

Mitchell, a transport designer, has personal experience with economy class seating assembly facilities.

1. Strict regulations, like the **FAA's 16g** crashworthiness rule, prevent reusing seat aluminium in other seats. [13]
2. **Low-efficiency** manufacturing methods, such as milling, are **common** and **wasteful**.
3. Armrests serve as essential **psychological** dividers.
4. All grabbable parts must withstand at least **200 lbs** of force for **durability**.
5. Challenging conflict: Seats should be **easy to disassemble** at end-of-life but **challenging** for passengers to take apart.
6. **Composite** fabrics can not be dry-cleaned, forcing their **disposal**.
7. **Glue** is widely used during assembly.

Insights

1. People are **not willing** to compromise on **comfort** for sustainability.
2. Nobody objects to sustainable materials as long as the seats are still **cheap**.
3. Arm rests purpose is to act as a divider/barrier between people more than provide support.
4. Features have **varying importance** between people. For some Entertainment is **essential**, others **never** use it.
5. Addressable issues with seat comfort are: **headrest support and lumbar support.**
6. Seat pockets **wear down** easily and are **missing** desired functionality.
7. Components designed to **tessellate** will **significantly reduce waste** during manufacturing.

Eco Audit

Results

Materials *(2.93e+03 MJ & 215 kg)*

- **Ferrous** (likely low alloy steel) **and non-ferrous** (aluminium) **metals**: Identified by magnet test.
- **Wool-nylon blend**: Verified by DOY Design experts as material for seat covers.
- **PC and PVC**: Identified by spectrometer analysis - flame-retardant and used in level 3 aerospace databases.
- **PU foam**: Used in cushions based on expert input.

Manufacture *(308 MJ & 23.2 kg)*

- **Aluminium**: Casting for stock form; milling as fine machining process for seat parts (based on JPA Design experts' feedback).
- **Polymers:** Moulding with secondary cutting and trimming.
- **Wool fibre:** Fabric production - specified manufacturing technique.
- **Material removal rates:** Estimated by part shape due to high material waste.

Transport *(6 MJ & 0.4 kg)*

- *Assumption:* Seats were transported **320 km** from Collins' plant in North Carolina to Boeing's plant in South Carolina by a **26-tonne (3-axle) truck**. [5]

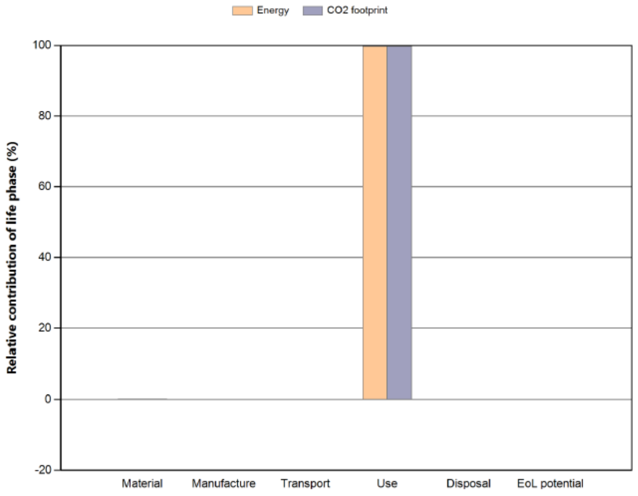


Figure 1: Airplane Seat including use.

Use *(1.57e+06 MJ & 1.13e+05 kg)*

- Seat set to mobile mode on long-haul aircraft (kerosene), with a **6-year product lifespan**, flying **8,000 km daily** for **300 days per year**.
- Estimate allows for maintenance downtime, as long-haul planes typically operate more frequently. [6]

EoL Potential *(-831 MJ & -57.3 kg)*

- *Assumption*: Due to rising aerospace grade standards, **aluminium** would be down-cycled. All other materials went to **landfill**. [7]

Analysis

Figure 1 (Flying):

99.8% of both CO2 and embodied energy come from the mobile use of the seats.

This means that the greatest impact on sustainability of the seats is via minimising fuel burn by:

- Reducing weight of the seats.
- Increase the packing density.

Figure 2 (No flying):

After removing the use factor, material choice was the biggest contributor to embodied energy and CO2 footprint (90%).

This is because:

- Seats are made from raw materials due to legislation. [8]
- Low scale of production of seat parts require using manufacturing techniques, such as milling, which are resource inefficient.

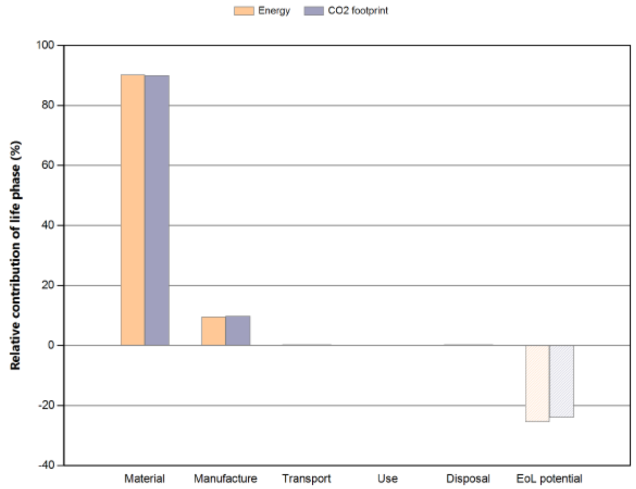


Figure 2: Airplane Seat not-including use.

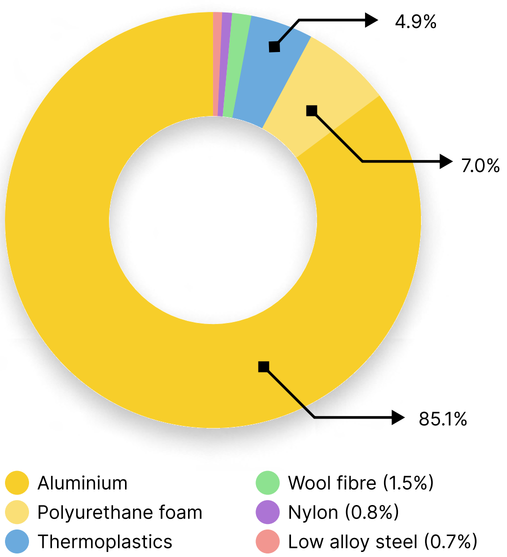
Insights:

- Reduce features to potentially **reduce weight** of the seat?
- Standing up seats would greatly increase cabin efficiency?
- Implementation of **recycled metals** in non-essential parts?

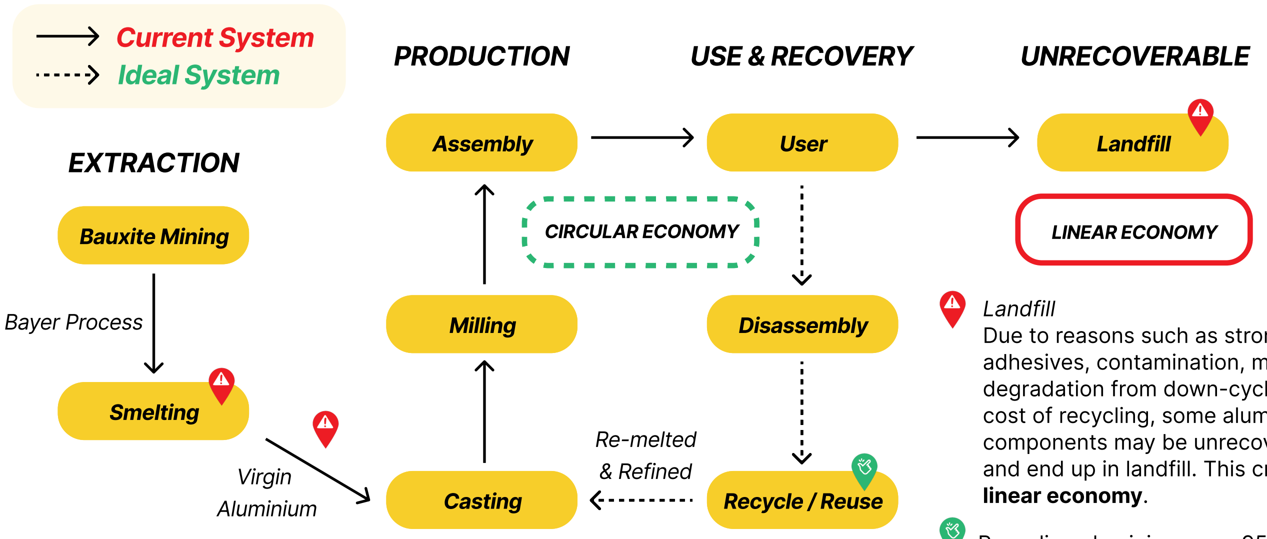
Material Circularity

Embodied Energy of Materials

With aluminium making up 85.1% of the 2900 MJ embodied energy, we prioritized it in our material circularity analysis.



Aluminium System Map



Smelting
It is typically an energy-intensive process with high greenhouse gas emissions, but can be altered to be slightly more sustainable. For example, using renewable energy and inert anodes can cut emissions by up to 85%. [29]

Virgin Aluminium
Materials need to be strong enough to undergo dynamic 16g and static 9g testing, hence **virgin material is a requirement.** Unfortunately, the use of virgin material is energy-intensive and contributes to high carbon emissions.

Landfill
Due to reasons such as strong adhesives, contamination, material degradation from down-cycling or cost of recycling, some aluminium components may be unrecoverable and end up in landfill. This creates a **linear economy**.

Recycling aluminium uses 95% less energy than producing virgin aluminium. [28]

Analysis

The MCI calculator was used to evaluate the circularity of our seats:

- In the **current** system, our seat achieved a **0.1 MCI**.
- In the **ideal** system, the seat achieved a **0.36 MCI**. This was achieved with a 100% collection rate of aluminium parts. A recycling rate of 76%, based on current EU standards [30].

Insights:

- Recycling aluminium greatly impacts the MCI, and extending lifespan after EOL further boosts its MCI.
- Ease of disassembly is key to a seat's re-entry into the economy.
- **Legislation** must change to allow recycled aluminium, as it's far more sustainable.

Flow Mapper

Resource

This is the tangible matter that flows. Take, for example, a flow of a water bottle made from PET:
- Product: bottle filled with water.
- Component: PET bottle. The HDPE/PP cap is also a component, but it is not necessarily part of the same flow.
- Material: PET

What is the product?	What is the component?	What is the material?
Quad economy plane seat	Seat Frame, Armrest	Mainly aluminium, Steel, Polymers

Consumer

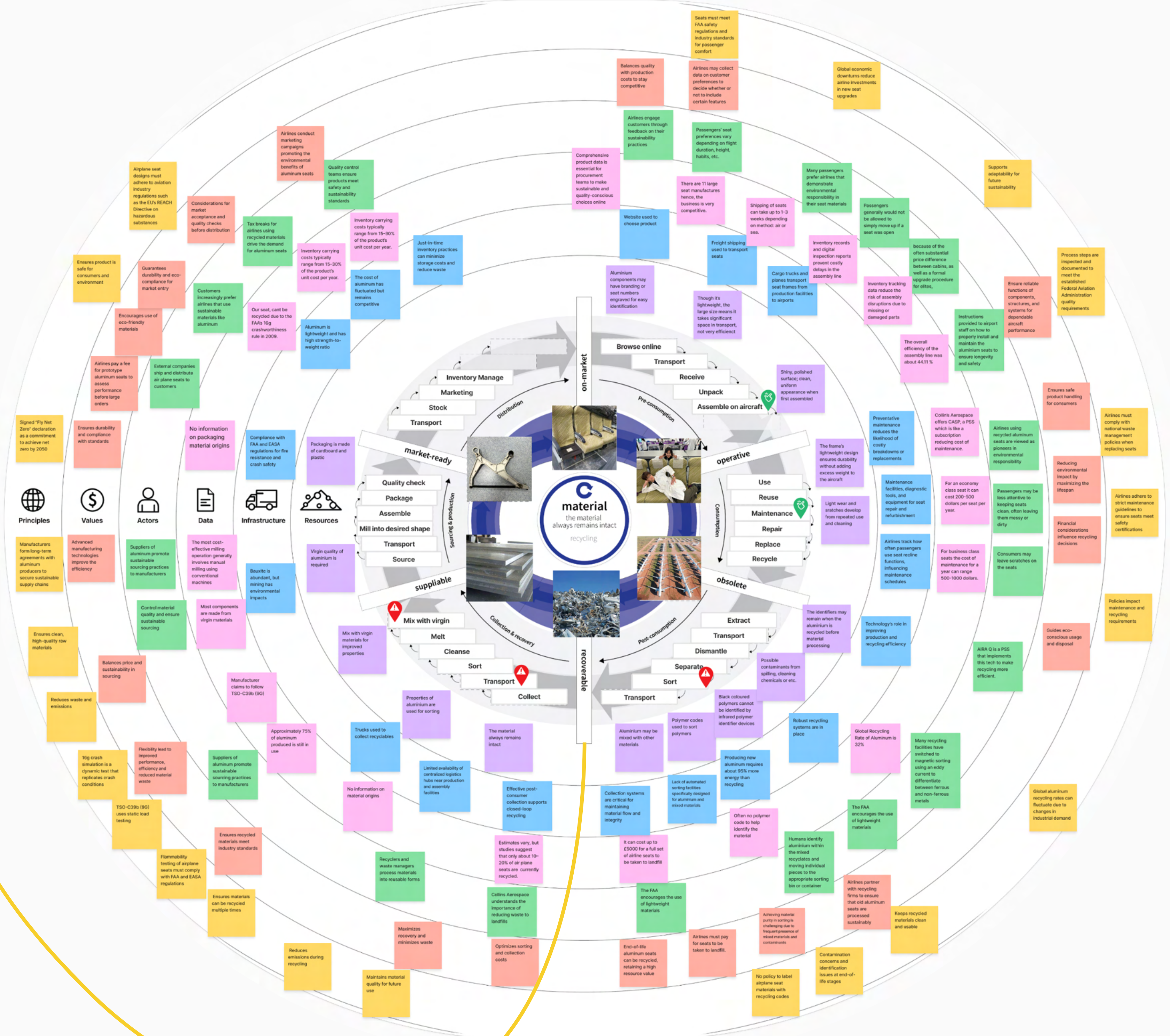
Choose a single consumer to specify the scenario.

Which need does the product satisfy?	What is the function of the product?	Who is/are the key consumer(s)?
Travel comfort, convenience	Seating for airplane travel	Airline passengers, in economy class section

Context

Define the context of the consumer. If more contexts are possible, choose one specific context. For example, decide whether your scenario involves consumption on-the-go or at home.

In which geographic region is the product consumed?	Where does consumption take place?	How intense is the consumption?
Global	On plane	Depend on flight duration (high during long flights)



Pivotal Analysis

Process: Transport

Scope of process

Movement of materials from suppliers to manufacturing and assembly facilities

Why is this process pivotal?

Transportation is costly, and it is difficult to efficiently stack items for transport. This discourages material recovery.

Transport is pivotal because it ensures material recovery, minimises environmental impact and controls costs, directly affecting the circular flow and sustainability.

Relevant elements

- Packaging is made of cardboard and plastic
- Limited availability of centralized logistics hubs near production and assembly facilities
- It can cost up to £5000 for a full set of airline seats to be taken to landfill
- Airlines must pay for seats to be taken to landfill
- Freight shipping used to transport seats
- Though it's lightweight, the large size means it takes significant space In transport, not very efficient
- Cargo trucks and planes transport seat frames from production facilities to airports.

Process: Sort

Scope of process

Sorting involves categorizing materials based on type, quality, and potential for reuse or recycling

Why is this process pivotal?

Effective sorting increases the quality and quantity of materials diverted from landfills, essential for a circular economy.

Lack of labelling & overuse of adhesives makes sorting a challenge.

Relevant elements

- No policy to label airplane seat materials with recycling codes
- Black coloured polymers cannot be identified by infrared polymer identifier devices
- Often no polymer code to help identify the material
- Lack of automated sorting facilities specifically designed for aluminium and mixed materials
- Contamination concerns and identification issues at end-of-life stages
- Achieving material purity in sorting is challenging due to frequent presence of mixed materials and contaminants
- Humans identify aluminium within the mixed recyclates and moving individual pieces to the appropriate sorting bin or container

Process: Mix with virgin

Scope of process

Combining recycled materials with virgin materials to achieve desired product properties

Why is this process pivotal?

Stringent policy prevents use of recycled/ sustainable materials, forcing use of less sustainable alternatives.

Balancing recycled and virgin materials can help ensure the structural integrity and durability of airplane seats while promoting the use of sustainable materials.

Relevant elements

- Mix with virgin materials for improved properties
- Manufacturer claims to follow TSO-C39b (9G)
- Suppliers of aluminium promote sustainable sourcing practices to manufacturers
- Ensures recycled materials meet industry standards
- 16g crash simulation is a dynamic test that replicates crash conditions
- No effective policy on mixing with virgin

Process: Inspect

Scope of process

Conducting detailed inspections on seats to assess wear and damage which helps determine if parts can be reused or need to be replaced

Why is this process pivotal?

Damage is not easily viewable without complete disassembly.

This process is key to optimizing resource use, as evaluating parts for reuse over replacement minimizes waste, cuts costs, and supports a circular economy in the airline industry.

Relevant elements

- Maximizing resource efficiency and minimizing waste by reusing materials wherever possible
- Reusing functional parts reduces the environmental impact of manufacturing and waste disposal
- Allows for precise identification of reusable parts, helping to minimize waste
- Enable technicians to make choices about which parts can be reused, supporting cost-efficiency goal
- Inspect seats and materials for damage, assessing whether they can be reused or require repair
- Their expertise ensures only safe and durable parts are reused, supporting sustainability
- As the reuse of components reduces the need for replacement, contributing to higher profitability

Process: Assemble on aircraft

Scope of process

Integrating seats into the aircraft, focusing on installation efficiency and sustainability

Why is this process pivotal?

Effective assembly techniques can enhance the efficiency of the production line and ensure high-quality installations.

Relevant elements

- Shiny, polished surface and clean, uniform appearance when first assembled
- Instructions provided to airport staff on how to properly install and maintain the aluminium seats to ensure longevity and safety
- Process steps are inspected and documented to meet the established Federal Aviation Administration quality requirements
- Ensure reliable functions of components, structures and systems for dependable aircraft performance
- The overall efficiency of the assembly line was about 44.11%

Process: Maintenance

Scope of process

Regular inspection, repair, and refurbishment of airplane seats throughout their lifecycle

Why is this process pivotal?

Maintenance practices extend the lifespan of seats, reducing the need for replacements and lowering the environmental impact.

Relevant elements

- Light wear and scratches develop from reported use and cleaning
- Preventative maintenance reduces the likelihood of costly breakdowns or replacements
- Reducing environmental impact by maximising the lifespan
- Airlines adhere to strict maintenance guidelines to ensure seats meet safety certifications
- Passengers may be less attentive to keeping seats clean, often leaving them messy or dirty
- Consumers influence end-of-life decisions and product longevity

Insights & Solutions

Reducing packaging waste and increasing efficiency in cargo space are essential to minimise environmental impact. **Eco-friendly packaging** and **shared logistics solutions** with other airline components can streamline transport and reduce landfill dependency.

Effective sorting can recover high-quality materials, but contamination and mixed materials pose challenges. Advanced **sorting technology** and **standardised material tagging** can enhance accuracy, helping maintain quality for recycling.

Ensuring structural integrity requires blending recycled aluminium with virgin materials. **Quality testing** and **sustainable sourcing partnerships** can support industry standards while reducing the need for new resources.

Effective inspection maximizes **resource utilization.** Assessing seats for reusability **reduces waste and conserves materials,** ultimately lowering costs and supporting sustainable practices in airline operations.

Enhances production line flow and meets high-quality standards for safety. Detailed **installation guides** and **stringent inspection protocols** ensure each component's longevity and reliability, boosting aircraft performance.

Routine maintenance prolongs seat lifespan. **Frequent inspections** and customer care standards help maintain seat conditions, ultimately supporting safety certifications and customer satisfaction.

Product-Service Systems

1. Recycling System

What is AIRA?

- AIRA offers a B2B, result-oriented recycling service that helps airlines recover materials from aircraft seats at end-of-life. [12]

How it works?

- Uses AIRA Q system to standardize and log materials, improving recycling efficiency. [12]
- Supports a circular economy in aerospace through modular seat designs for easier part replacement.
- Extends seat lifespan, reduces waste, and lowers costs for airlines.

Pain points

Older airplane seat materials don't meet the **FAA's 16g** crash worthiness rule, implemented in **2009** to ensure seats withstand extreme forces in emergency situations. [13]
Hence, they **can't be reused** directly in new seats and instead must be **downcycled**. This limits the potential for high-value recycling and poses a challenge for sustainability efforts.

2. Repair System (CASP)

What is CASP?

- Airlines enrol in the CASP program, which offers tailored solutions for avionics maintenance throughout the year. [14]

How it works?

- Airlines enrol in CASP, and when a part breaks, CASP swiftly sends a replacement from one of their many locations to refurbish the seat. The broken part is then collected, repaired, or recycled, allowing it to re-enter the system and promoting a circular economy. [14]

Pain points

A potential problem with these programs is that **parts can't be distributed to the repair location efficiently.**
Causing broken seats to become obsolete hence, undermining the whole purpose of the PSS.

Insights and Looking forward

Source	Pain Points	Insights	Opportunities
Disassembly Analysis (Page 4)	Disassembly is slow and difficult to disassemble, making it uneconomical.	Plane seats not designed for disassembly, overuse of adhesives, unclear order of disassembly.	1. Guides or designed features that make the disassembly process clear
User Research (Page 5)	Low-efficiency manufacturing methods, such as milling, are common and wasteful.	Low volume production makes more efficient production methods with high set up costs uneconomical.	1. Parts designed to tessellate efficiently to reduce waste 2. Use of alternative manufacturing methods with greater efficiency 3. Planned uses of the swarf/waste material
Eco Audit (Page 6)	The **embodied energy** of the chair is **1.57e+06 MJ** over the course of its lifetime.	With **98%** of total energy used occurring during **use**, reducing in-use energy should be prioritized to significantly lower the chair's environmental impact.	The following improvements could greatly reduce environmental impact: 1. Reduce weight 2. improve space efficiency
Pivotal Analysis (Page 8)	Collection and transportation for recycling and disposal is costly.	Sending a set of seats to landfill costs many thousands of pounds. This could provide a financial incentive for more sustainable options.	1. Cheaper collection for recycling 2. More space efficient stacking of assembled seats 3. Shared logistic solutions for more efficient transport

Appendix: Statement of Contribution

	Individual Contribution	Collaborative Contribution
Owen Lee Scott	Page 3: Brand Analysis and Teardown Page 4: Disassembly Analysis Page 5: Experts Page 9: Insights and Looking Forward	Page 5: Passengers Interview Results and Persona with Lara Merican Page 7: Flow Mapper with Vasco de Noronha, Lara Merican and Xiaoyun Li
Vasco de Noronha	Title Page Graphic Page 2: Global Aircraft Seating Market Page 6: Eco Audit and Material Circularity Page 9: Product-Service Systems Page 11 (Appendix): Component Table (Eco Audit)	Page 14 (Appendix): MCI Tables with Lara Merican Page 7: Flow Mapper with Lara Merican, Owen Lee Scott and Xiaoyun Li
Lara Merican	Page 5: User Experience Map Page 6: Material Circularity Map	Page 5: Passengers Interview Results and Persona with Owen Lee Scott Page 7: Flow Mapper with Vasco de Noronha, Xiaoyun Li and Owen Lee Scott Page 12 & 13 (Appendix): Disassembly Log with Xiaoyun Li Page 14 (Appendix): MCI Tables with Vasco de Noronha
Xiaoyun Li	Page 8: Pivotal Analysis	Page 7: Flow Mapper with Lara Merican, Vasco de Noronha and Owen Lee Scott Page 12 & 13 (Appendix): Disassembly Log with Lara Merican

It should be noted that **<u>all students</u>** contributed to every slide and gave *feedback* or *suggested improvements*.

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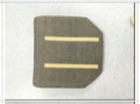
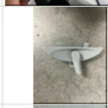
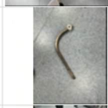
Component Table:

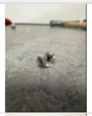
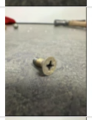
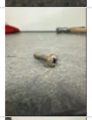
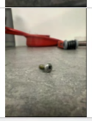
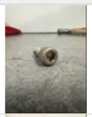
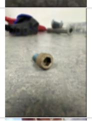
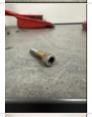
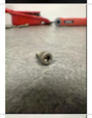
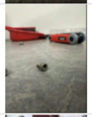
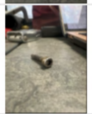
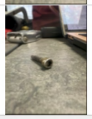
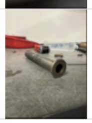
Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass processed** (kg)	Energy (MJ)	%
Seat Cushion (lower)	Polyurethane foam (flexible, closed cell, 0.16)	Virgin (0%)	1.3	1	1.5	1.3e+02	4.3
Cushion cover (lower)	Wool fiber	Virgin (0%)	0.28	1	0.31	15	0.5
Backrest	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	1.4	1	1.7	2.8e+02	9.5
Seat Cushion (upper)	Polyurethane foam (flexible, closed cell, 0.16)	Virgin (0%)	0.72	1	0.84	73	2.5
Cushion cover (upper)	Wool fiber	Virgin (0%)	0.56	1	0.62	30	1.0
Seat-pocket wireframe	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.081	1	0.085	16	0.6
Under-cushion base	Polyamide fiber (Nylon-6)	Virgin (0%)	0.16	1	0.18	22	0.8
Side of chair piece	ABS+PC (flame retarded)	Virgin (0%)	0.34	1	0.36	37	1.3
Chair leg	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	1.8	1	3.7	4.3e+02	14.5
Metal pipe (under cushion base)	Low alloy steel, SAE 4335M, cast, quenched & tempered	Virgin (0%)	0.2	2	0.45	13	0.4
Metal pipe (hold seats together)	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	4	1	4.2	8e+02	27.3
Metal pipe (base of seat)	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.44	1	0.46	87	3.0
Tube clamp	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.024	1	0.034	5.1	0.2
Lock cover	PVC (semi-rigid, molding and extrusion)	Virgin (0%)	0.014	1	0.015	0.8	0.0
Metal pipe clip (base of seat)	Low alloy steel, SAE 4335M, cast, quenched & tempered	Virgin (0%)	0.01	1	0.011	0.31	0.0
Seat belt strap	Polyester fiber (Dacron)	Virgin (0%)	0.051	1	0.057	4.5	0.2
Seat belt buckle	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.09	1	0.13	19	0.7
Lifejacket pocket	Polyamide fiber (Nylon-6)	Virgin (0%)	0.087	1	0.097	12	0.4
Arm	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	1.7	1	4.2	4.2e+02	14.2
Armrest cover 1	PC+PBT (flame retarded)	Virgin (0%)	0.14	1	0.15	16	0.6
Armrest cover 2	Polyurethane rubber (unfilled)	Virgin (0%)	0.067	1	0.071	5.8	0.2
Under arm rest piece	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.04	1	0.062	8.7	0.3
Tray	PVC (rigid, high impact, molding and extrusion)	Virgin (0%)	0.26	1	0.28	17	0.6
Tray table lock	PVC (semi-rigid, molding and extrusion)	Virgin (0%)	0.04	1	0.042	2.3	0.1
Tray table frame	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.29	1	0.35	60	2.0
Tray table rails	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.33	1	0.47	70	2.4
Footrest pedal	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.2	1	0.29	43	1.5
Foot pedal arms	Low alloy steel, SAE 4335M, cast, quenched & tempered	Virgin (0%)	0.12	2	0.27	7.4	0.3
Foot pedal connectors	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.027	2	0.068	11	0.4
Electronic cover	PC+PBT (flame retarded)	Virgin (0%)	0.05	2	0.1	12	0.4
Electronic box cover	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	1.1	1	1.9	2.5e+02	8.4
Hose clamps	Low alloy steel, SAE 4335M, cast, quenched & tempered	Virgin (0%)	0.01	2	0.021	0.62	0.0
Wire	Copper, cast (h.c. copper)	Virgin (0%)	0.022	4	0.09	8.7	0.3
Cable holder	PC+PBT (flame retarded)	Virgin (0%)	0.3	1	0.32	35	1.2
C bracket	Aluminum, 513.0, permanent mold cast, F	Virgin (0%)	0.009	2	0.019	3.6	0.1
Total				44	23	2.9e+03	100

Appendix: Disassembly Log

No.	Component	Function	Photo	Material type	Dimensions (mm)	Weight (gr/unit)	Count	Manufacturing process	Joining method	Tool required for disassembly
1	***Main seat components***									
1.1	Seat cushion	For passengers to sit on		Polyurethane foam	485x550x185	1323	1	Foam moulding	Velcro to seat base	Separate velcro by hand
1.2	Seat cover	To protect the seat cushion		Nylon polyester mix	460x510x8	275	1	Weave	Velcro to cushion (velcro sewed on)	Separate velcro by hand
1.3	Backrest	For passengers to lean on		Non-ferrous (aluminium)	740x400x60	1352	1	Punch/stamp + sheet metal bending	Bolts and pistons	Screwdriver and hammer
1.4	Backrest cushion	For passengers to recline on		Polyurethane foam	125x720x420	716	1	Foam moulding	velcro to seat base	Separate velcro by hand
1.5	Seat cover for backrest	To protect backrest		Nylon polyester mix	830x460x8	556	1	Weave	Velcro to to backrest and bolt screwed through cover and table lock	Separate velcro by hand and screwdriver
1.6	Seatpocket wireframe	Part of the fabric		Non ferrous - aluminium	210x375x3	81	1	Automated wire bending	Clips	Blade
1.7	Under-cushion base	Holds cushion		Polyester	450x455x5	164	1	Weave	Sewed on around pipe	Blade
1.8	Side of chair	Supports the side of the seat		ABS	490x250x50	344	1	Injection Moulding	Screws	Screwdriver
1.9	Bottom of chair	Supports the bottom of the seat		Non-ferrous (aluminium)	485x240x50	1836	1	Milled	Screws	By hand after all screws unscrewed
1.10	Metal pipe	Holds under-cushion base		Ferrous (steel)	20 (diameter) 490 (length)	202	2	Extrusion	Held together by tension of fabric	Blade
1.11	Big metal pipe	Holds all seats		Non-ferrous (aluminium)	39 (id) 44.5 (od) 2000 (l)	3895	1	Extrusion	-	-
1.12	Long metal pipe	Holds all seats		Non-ferrous (aluminium)	190 (length)	437	1	Extrusion	Clamp	By hand
1.13	Tube clamp	Clamps tube to frame		non ferrous (aluminium	40x26x18	24	1	Milled	Screws	By hand
1.14	Lock cover	Covers the lock for recliner		PVC	80x40x25	14	1	Injection moulding	Bolt to lock	Allenkey
1.15	Long metal pipe clip	Locks pipe to frame		Ferrous - steel	100x26x30	10	1	Press brake bending	Screws	Screwdriver
2	***Safety features***									
2.1	Seat belt strap	Keeps passengers safe		Ferrous (steel)	300x70x20	51	1	Multiple processes	-	Blade
2.2	Seat belt buckle	Keeps passengers safe		Non-ferrous (aluminium)	70x70x50	90	2	Multiple processes	-	Blade
2.3	Lifejacket compartment	Holds lifejacket under seat		Nylon	440x320x8	87	1	Weave	Buttons onto frame	By hand
3	***Accessories - Armrest***									
3.1	Arm	For passengers to rest their arm		Aluminium	550x450x50	1668	1	Milled	Screws to frame	Screwdriver
3.2	Armrest cover 1	Protects armrest		Polycarbonate	290x55x70	140	1	Injection moulding	Tension	By hand
3.3	Armrest cover 2	Protects armrest		Polyurethane rubber	290x50x70	67	1	Injection moulding	Tension	By hand
3.4	Under arm rest	Holds armrest together		Aluminium	80x30x13	40	1	Casting	Screws to armrest	Screwdriver
4	***Accessories - Tray table***									
4.1	Tray	Opened when passengers want to eat or use their computer		PVC, Polystyrene inside, aluminium	415x210x2	593	1	Injection moulding	Bolts to frame	Screwdriver
4.2	Tray table lock	To keep tray table locked in place		PVC	120x50x15	40	1	Injection moulding	Bolt to seat	Screwdriver
4.3	Tray table frame	Connects table to seat		Aluminium	370x280x35	294	1	Injection moulding	Bolts to bracket	Screwdriver
4.4	Tray table frame ring	Reinforces table frame		Polyurethane rubber	24 (d) 16(l)	3	2	Injection moulding	Tension	By hand
5	***Accessories - Footrest***									
5.1	Footrest paddle	For passengers to rest their feet		Non ferrous - aluminium	279x75x10	200	1	Injection moulding	4 bolts into paddle	Screwdriver
5.2	Foot paddle arms	Holds the footrest paddle		Steel	200x150x20	116	2	Extrusion + bend	Bolt to seat	Wrench
5.3	Foot paddle connector	Connects foot paddle to seat		Aluminium	55x25x30	27	2	Casting	Screws to seat	Screwdriver

Appendix: Disassembly Log (cont.)

6	***Accessories - Electronic components***									
6.1	Electronics box	provides power to armrest controls		Mix	320x220x200	755	1	Multiple processes	Rivet joined to underside of seat	By hand
6.2	Electronic covers	Covers for electronics under seat		Polycarbonate	205x90x5	50	2	Extrusion	Tension	By hand
6.3	Metal plate	supports electronics box		Aluminium	360x260x170	1116	1	Punch/stamp cutting + bending	Screw to seat	Allenkey
6.4	Metal ring	Holds electronics box to plate		Steel	48x47x30	10	2	Injection moulding	Tightened by hex bolts	Alleykey
6.5	Metal plate connector	Holds metal plate		Aluminium	52x34x16	9	2	Stamp + press brake pending	Screw to metal plate	Screwdriver
6.6	Wire	Connects electronics box to seat		Copper	40x120x14	22	4	Drawn	Zipties to metal plate	Blade
6.7	Cable holder	Holds cable underneath the chair		Polycarbonate	80x20x990	302	1	Extrusion, punch/stamp OR if made from sheet then press brake bend, punch/stamp	Screws to seat	Allenkey

No.	Connector	Photo	Material type	Dimensions (mm)	Weight (gr/unit)	Count	Manufacturing process	Components connected	Tool required for disassembly
1	***Philips screws***								
1.1	Philips head countersunk screw		Steel	7 (diameter) 8 (length)	1	2	Thread rolling	Armrest cover	Screwdriver
1.2	Philips head countersunk screw		Steel	9 (d) 11 (l)	1	1	Thread rolling	Tray table lock	Screwdriver
1.3	Philips pan head screw (MS27039-0813)		Low alloy steel	8 (d) 24 (l)	2.75	4	Thread rolling	Foot pedal	Screwdriver
1.4	Philips pan head screw		Steel	8 (d) 16 (l)	2	3	Thread rolling	Tray table	Screwdriver
2	***Hex Socket Cap Screws***								
2.1	M6 Hex Socket Cap Screw		Steel	10 (d) 25 (l)	12	3	Thread rolling	Lock cover, seat	M6 Allenkey
2.2	M6 Hex Socket Cap Screw		Steel	11 (d) 20 (l)	10	1	Thread rolling	Underneath backrest cover	M6 Allenkey
2.3	M6 Hex Socket Cap Screw		Steel	11 (d) 31 (l)	14	1	Thread rolling	Axle	M6 Allenkey
2.4	M6 Hex Socket Cap Screw		Steel	10 (d) 40 (l)	15	2	Thread rolling	Metal pipe	M6 Allenkey
2.5	M4.5 Hex Socket Cap Screw		Steel	9 (d) 22(l)	6	2	Thread rolling	Electronics box, plate	Allenkey
2.6	M4 Hex Socket Cap Screw		Steel	8 (d) 14 (l)	3	2	Thread rolling	Long pipe	M4 Allenkey
2.7	M4 Hex Socket Cap Screw		Steel	8 (d) 17 (l)	4	2	Thread rolling	Side of chair	M4 Allenkey
2.8	M4 Hex Socket Cap Screw		Steel	8 (d) 42 (l)	10	2	Thread rolling	Long pipe	M4 Allenkey
3	***Washers***								
3.1	Backrest cushion elastomer washer			49x24x1	2	2	Injection moulding	Connected to velcro straps	By hand
3.2	Washer			N/A	14 (altogether)	7	Injection moulding	-	By hand after unscrewing
4	***Others***								
4.1	Zip ties		Nylon	N/A	1	2	Injection moulding	Seat pocket	Blade to cut off zip ties
4.2	Clips		Nylon	43x10x12	4	2	Injection moulding	Wireframe, long pipe	Blade to cut off zip ties
4.3	Nut		Steel	15 (d) 12 (l)	6	2	Forging	Underneath backrest cover	Wrench
4.4	Hex head bolts		Cadmium plated steel	13 (d) 47 (l)	12	2	Thread rolling	Seat backrest	Wrench
4.5	Pin of chair		Steel	29 (d) 135 (l)	155	1	Boring	Seat frame	By hand
4.6	Velcro		Nylon	N/A	N/A	a lot	Weaving and Extrusion	Seat covers to cushion	By hand

Appendix: MCI Analysis

Case 1

Utility based on (Selec	Longevity	
This product lasts:	7	Years
Typical product lasts:	7	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Cushions	2.0390	1	Plastics	Virgin	0%	0%	Landfill	0.10
Seat frame	24.4250	1	Aluminium	Virgin	0%	0%	Landfill	0.10
Seat covers	0.8310	1	Composites	Virgin	0%	0%	Landfill	0.10
Under-cushion base & life j	0.6090	1	Plastics	Virgin	0%	0%	Landfill	0.10
Metal pipe components	0.4140	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Seat belt buckle	0.0900	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Seat belt buckle 2	0.0900	1	Aluminium	Virgin	0.00%	0%	Landfill	0.10
Seat belt strap	0.0510	1	Composites	Virgin	0.00%	0%	Landfill	0.10
Armrest	1.7080	1	Aluminium	Virgin	0.00%	0%	Landfill	0.10
Armrest cover	0.2070	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Tray table & lock	0.6330	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Tray table frame	0.2940	1	Aluminium	Virgin	0.00%	0%	Landfill	0.10
Footrest paddle & connecto	0.2540	1	Aluminium	Virgin	0.00%	0%	Landfill	0.10
Foot paddle arms	0.1160	2	Steel	Virgin	0.00%	0%	Landfill	0.10
Electronics box & wires	0.7770	1	Electronics	Virgin	0.00%	0%	Landfill	0.10
Electronic cover & cable ho	0.4020	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Metal plate & rings	1.1360	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Metal plate holder	0.0090	2	Aluminium	Virgin	0.00%	0%	Landfill	0.10
Screws, bolts, nuts & washe	0.3610	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Zip ties, clips, etc.	0.0140	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Product Mass (kg):	34.585							0.10

Case 2

Utility based on (Selec	Longevity	
This product lasts:	7	Years
Typical product lasts:	7	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Cushions	2.0390	1	Plastics	Virgin	0%	0%	Landfill	0.10
Seat frame	24.4250	1	Aluminium	Virgin	0%	100%	Recycle	0.44
Seat covers	0.8310	1	Composites	Virgin	0%	0%	Landfill	0.10
Under-cushion base & life ja	0.6090	1	Plastics	Virgin	0%	0%	Landfill	0.10
Metal pipe components	0.4140	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Seat belt buckle	0.0900	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Seat belt buckle 2	0.0900	1	Aluminium	Virgin	0.00%	100%	Recycle	0.44
Seat belt strap	0.0510	1	Composites	Virgin	0.00%	0%	Landfill	0.10
Armrest	1.7080	1	Aluminium	Virgin	0.00%	100%	Recycle	0.44
Armrest cover	0.2070	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Tray table & lock	0.6330	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Tray table frame	0.2940	1	Aluminium	Virgin	0.00%	100%	Recycle	0.44
Footrest paddle & connecto	0.2540	1	Aluminium	Virgin	0.00%	100%	Recycle	0.44
Foot paddle arms	0.1160	2	Steel	Virgin	0.00%	0%	Landfill	0.10
Electronics box & wires	0.7770	1	Electronics	Virgin	0.00%	0%	Landfill	0.10
Electronic cover & cable ho	0.4020	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Metal plate & rings	1.1360	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Metal plate holder	0.0090	2	Aluminium	Virgin	0.00%	100%	Recycle	0.44
Screws, bolts, nuts & washe	0.3610	1	Steel	Virgin	0.00%	0%	Landfill	0.10
Zip ties, clips, etc.	0.0140	1	Plastics	Virgin	0.00%	0%	Landfill	0.10
Product Mass (kg):	34.585							0.36

	Recycled Content:		Recycling Rate:	
Material Type	Default	Custom	Default	Custom
Aluminium	45%		56%	76%
Bioplastic	5%		5%	
Composites	5%		26%	
Electronics	10%		10%	
Glass	52%		76%	
Natural Material	50%		73%	
Plastics	30%		30%	
Steel	40%		83%	

Case 1: 0.10 (real world scenario)
Case 2: 0.36 (recycling of aluminium)

Problems & Users

Product & System Issues

- **Difficult disassembly**: Use of adhesives and connectors, such as screws, makes disassembly challenging - thus reducing the feasibility of recycling.
- **High energy during usage**: Although advancements have been made to reduce seat weight, more improvements must be made to further improve their sustainability.
- **Lack of environment-related policies**: There is a lack of policies in the aviation industry for improving sustainability in seat manufacturing and end-of-life recycling.
- **Aviation industry restrictions on materials**: The industry prioritises strength of materials to adhere to strict regulations - this can limit the ability to use more sustainable alternatives.
- **Lack of recycling systems**: Limited infrastructure and commitment to recycling seats at their end-of-life.

Design Variables

Travel scenario	Cold world	Flying back on time	Race for zero	Survival of the fittest	
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	As-is material mix	Mono-material	Multi-materials	Technical materials	Recycled materials
Architect	As-is architecture	Modular architecture	Integral architecture		
Produce & assemble	Traditional manuf. &	Advanced manuf. & ass.			
Distribute	Road	Rail	Sea	Air	
Order (airline)	Economy	Business	First		
Buy (airline)	Traditional sale	Rental model	Leasing model		
Choose	Leisure travellers	Business travellers	Students & jun. trave	Senior travellers	Budget tourists
Use	Single use-cycle: 7 y	Two use-cycles: 14 y	Three use-cycles: 21 yrs		
Prepare to return	Order collection serv	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	Incineration

The **Race for zero** travel scenario describes the journey to achieving net-zero carbon emissions. Following the chosen design variables, an **economy** airplane seat will be designed for **long-haul** usage (6-12 hour flights) for **budget, low cost airlines** in **20 years** time. The seats will be installed in a **blended wing body (BWB)** - an aircraft where the wings and fuselage are combined seamlessly as a single unit. More on BWB and other air frames is shown on Page 3. Components will be manufactured with **technical and recycled materials** which will ultimately be **refurbished 3 times** before materials are **upcycled**, **downcycled** or recycled. Refurbishment helps seats have a lifespan of **21 years**.

Consumer Pain Points

Especially on long flights, passengers experience **discomfort** due to lack of **lumbar** support, uncomfortable **headrests** and cramped **legroom**.

No designated **rubbish compartment**, hence passengers are forced to mix rubbish in the **seat pocket** with their personal items.

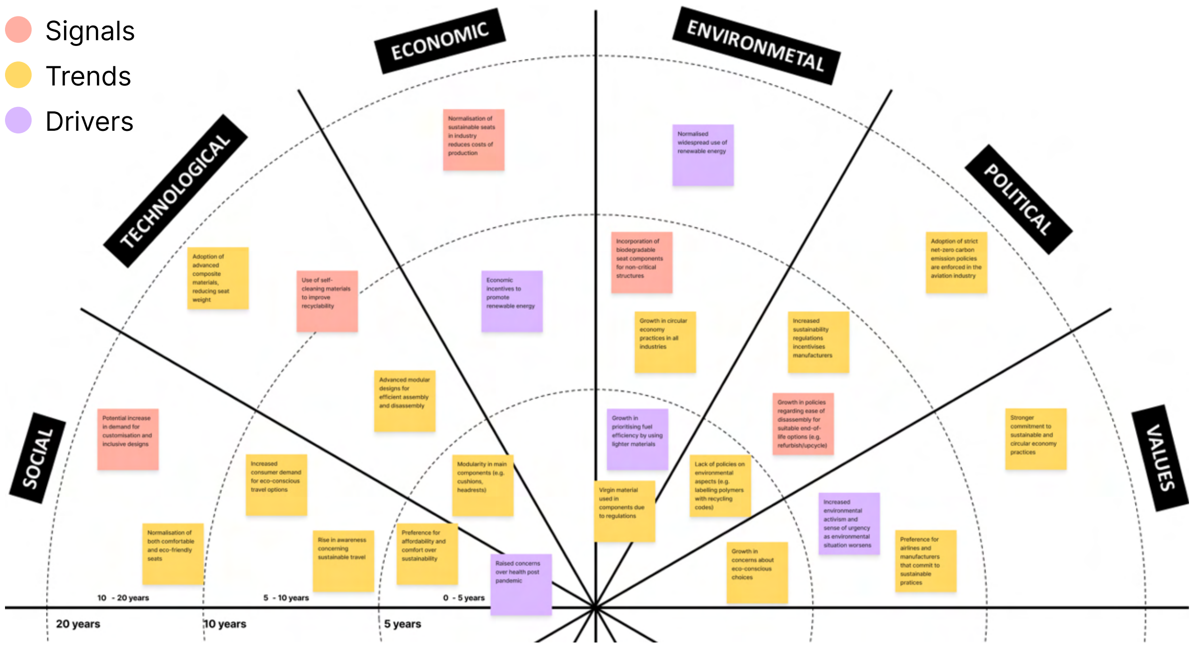
Consumers are **reluctant to compromise comfort or affordability** for sustainable options.

Nowadays, many consumers use their **phones or tablets** for entertainment rather than in-flight services - they struggle to find **suitable places to hold** them.

Passengers are **hesitant to recline** their seats fully as it might disturb the passenger behind them.

Passengers find the seat pocket **inefficient**, as smaller items tend to **sink to the bottom** and bulkier items fit **awkwardly**.

STEEPV Scope Wheel



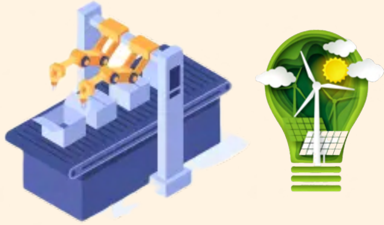
System Diagram

material flow
component flow
seat flow

Material Sourcing

All suppliers must meet **strict environmental standards** to sustainably source **bio-based polymers** and **recycled composites**. This can occur once **aviation regulations** account for environmental factors rather than solely material strength. AI and blockchain ensures **transparency** in tracking material origins and lifecycle.

Manufacturing & Assembly



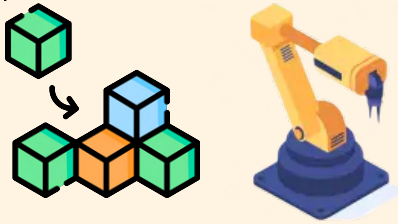
Use of **renewable energy** minimises negative environmental impact.

A team of engineers design **modular components** to be used in the seat for **easy refurbishment.** AI-driven robotics plays a role in production and assembly in order to **minimise waste**.

Distribution

Seats are transported by eco-friendly methods such as **electric vehicles**.

Installation



By using smart installation techniques such as using **robotic arms** or **modular mechanisms**, the process can be more efficient and precise.

Usage

Biodegradable cleaning materials improves the chances of the materials being reused or refurbished.

Real-time maintenance sensors monitor for wear and sends alerts as required, thus reducing **unnecessary replacements**.

Autonomous transport systems send the seat to the manufacturer's recovery centre where AI inspects the condition of each component.

End-of-Use Phase

Usable components are sent to be **refurbished**.

Damaged components are redirected to **upcycling or disposal**.

Refurbishment

AI refurbishment facilities use satisfactory components to refurbish seats with **minimal waste**.

Refurbishments aim to extend seat life by **7 years**. Seats can undergo **3 refurbishments (21 years total)** before being directed to upcycling, downcycling or disposal.

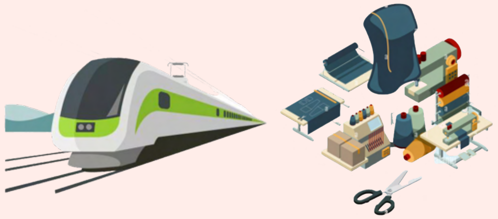
Upcycling & Downcycling

Component is upcycled for other aviation applications. For example, fabric from seat covers can be used for a **plane's carpeting**.

OR

Component is dismantled and **materials are downcycled** to form new components or materials for other industries. From example, the fabric can be used to manufacture **bags**.

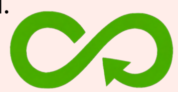
Redistribution



Upcycled and downcycled components and materials are **transported** to the relevant industries. They are given a new life and remain in a **circular economy**.

Circular Disposal

Recyclable materials are **recycled** and biodegradable materials are **composted**.

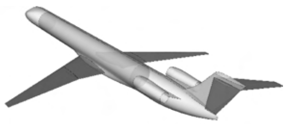


In a last-resort scenario, they can undergo **energy conversion**.

Design & Analysis

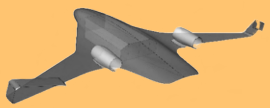
Aircraft Frame Overview

Tube-and-Wing



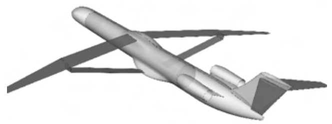
- Most **traditional** design
- **Simple** and **strong**
- Easy to manufacture
- Limited cabin space

Blended Wing Body



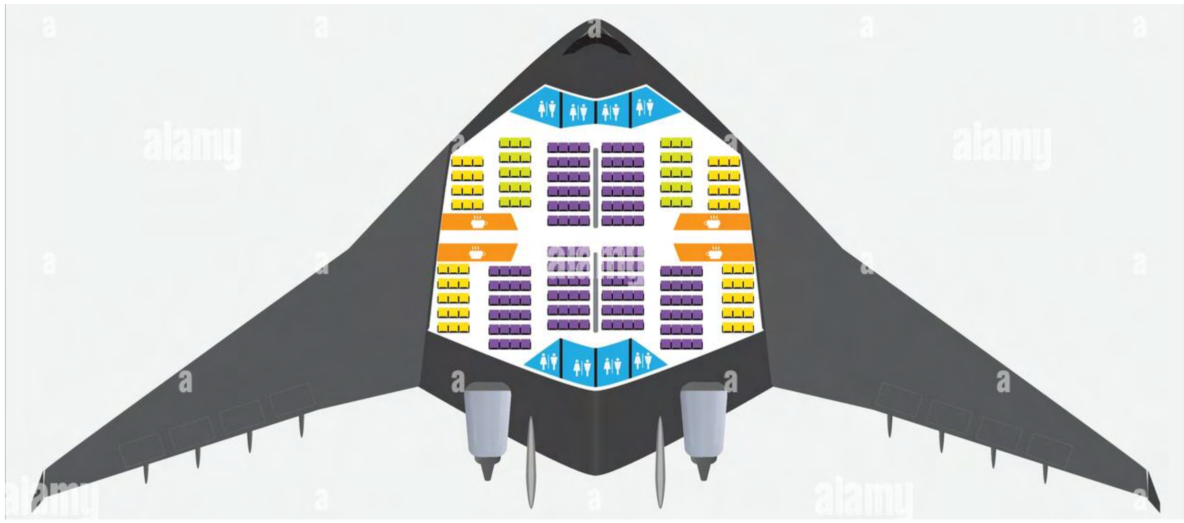
- Notable **drag reduction** makes it very **aerodynamic**
- Very **fuel efficient**
- Large **internal volume**

Truss-Braced Wing



- Extended wingspan **reduces drag**
- Maintains **traditional** tube shape

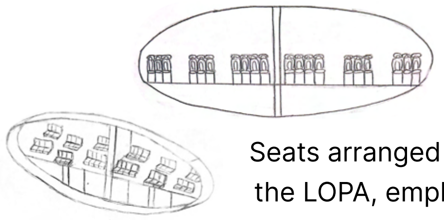
LOPA (Location of Passenger Accomodations)



The **"Blended Wing Body"** frame was chosen, as it aligns well with the selected design variables (shown on Page 1). Especially for long-haul flights, **minimising drag is crucial** in **reducing fuel consumption**, corresponding well with the **"Race for Zero"** scenario. Due to the structure's **large internal volume**, seats are able to be more **spread out**, addressing consumer's current concerns about cramped legroom and hesitation to recline. Increased cabin volume also allows **staggered seating** to be implemented - this creates a greater **sense of privacy** for passengers. Currently, blended wing aircraft frames are not widely used for passenger flights as its larger size is **incompatible with airports gates** and it is more **complex to manufacture**. However, as aviation advances in the next **20 years**, it is likely to be feasible.

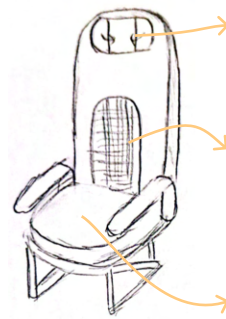
Seat Concept Specification

Cross Section View



Seats arranged as shown in the LOPA, emphasising the **efficient use of cabin space**.

Front View

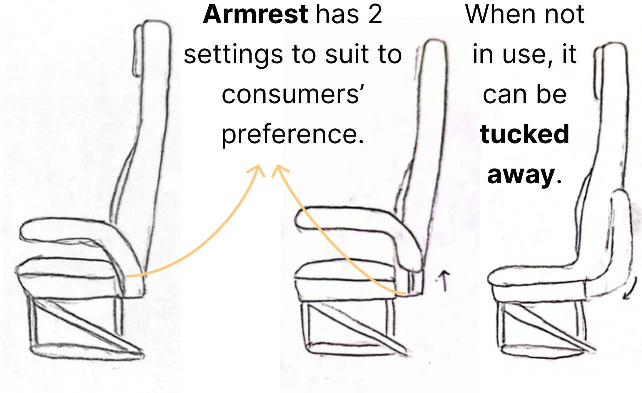


Headrest has **wings that fold in** to support the head.

Tensioned mesh used to support lumbar section instead of full foam.

Biodegradable foam

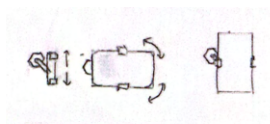
Side View



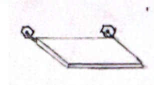
Armrest has 2 settings to suit to consumers' preference.

When not in use, it can be **tucked away**.

Detachable Features



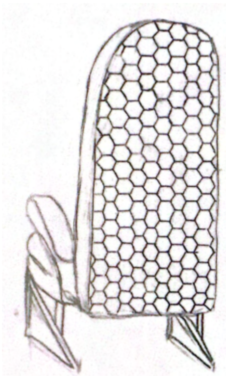
Device holder supports **phones** and **tablets**.



Tray table is **given** to passengers when food is served.

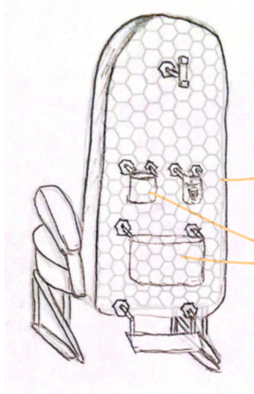
Recyclable **hammock-like** footrest is flexible and lightweight.

Rear View



The back structure follows the **biomimetic design** of a honeycomb, **reducing material usage** and promoting airflow while **maintaining strength**.

Default orientation of features



Features such as device holders and seat pockets can be attached into the honeycomb frame by **hexagonal magnets**.

Designated rubbish pocket

Varied seat pocket size

This system supports **modularity** and **customisation** for passengers.

Environmental Impact Analysis

- By removing the in-flight screen and tray table, using a biomimetic design and switching to more lightweight materials, an **estimated 5kg of weight is reduced.** This means for a flight of **180 seats, 900kg of weight is reduced** - a significant difference contributing to lower fuel consumption and emissions.
- The hexagonal magnets integrated into the honeycomb structure **promotes modularity and circular economy** as it simplifies maintenance and disassembly for refurbishment.
- Using recyclable and biodegradable materials minimises landfill waste. Generally, a sustainable and modular design enables around **75% of materials to be repurposed**.

Primary System Specification

Track & Rail Mounting System

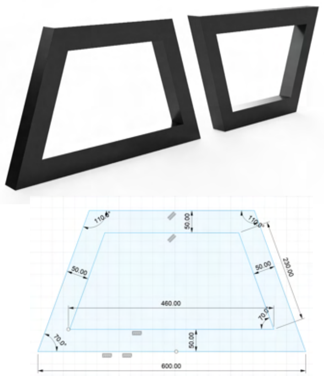
Material: Forged Carbon Fibre
Manufacturing: Compression Moulding

The **rail slides into the track** and locks into place via **circular connectors that screw upward** into the rail's pre-drilled holes, ensuring secure seat mounting.

Seat Leg

Material: Aluminium
Manufacturing: Casting

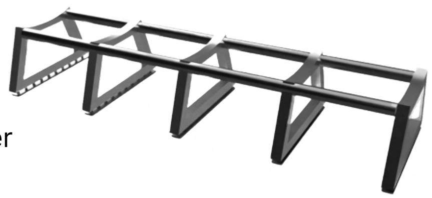
The seat leg has an **A-frame, trapezium-like structure**. It is designed to be **symmetrical** to allow **tessellation** for efficient packaging.



Cross Tube

Material: Aluminium
Manufacturing: Extrusion

Hollow tubular structure connects seat legs together and distributes weight load across all four seats.



Armrest

Material: Natural Fibre Composite
Manufacturing: Compression Moulding

Button underneath armrest allows passengers to vary armrest height.

Back Frame

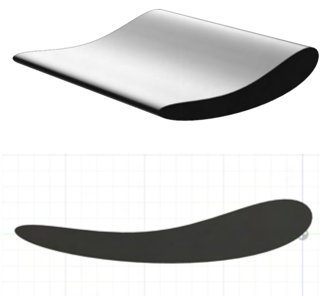
Material: Aluminium
Manufacturing: 3D Print

Biomimetic honeycomb design promotes **weight reduction** and allows for **modularity pegs**.

Seat Pan

Material: Forged Carbon Fibre
Manufacturing: Compression Moulding

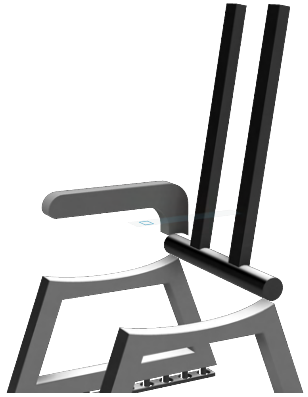
The seat pan has **contours** for passenger comfort as well as **stability** during turbulence.



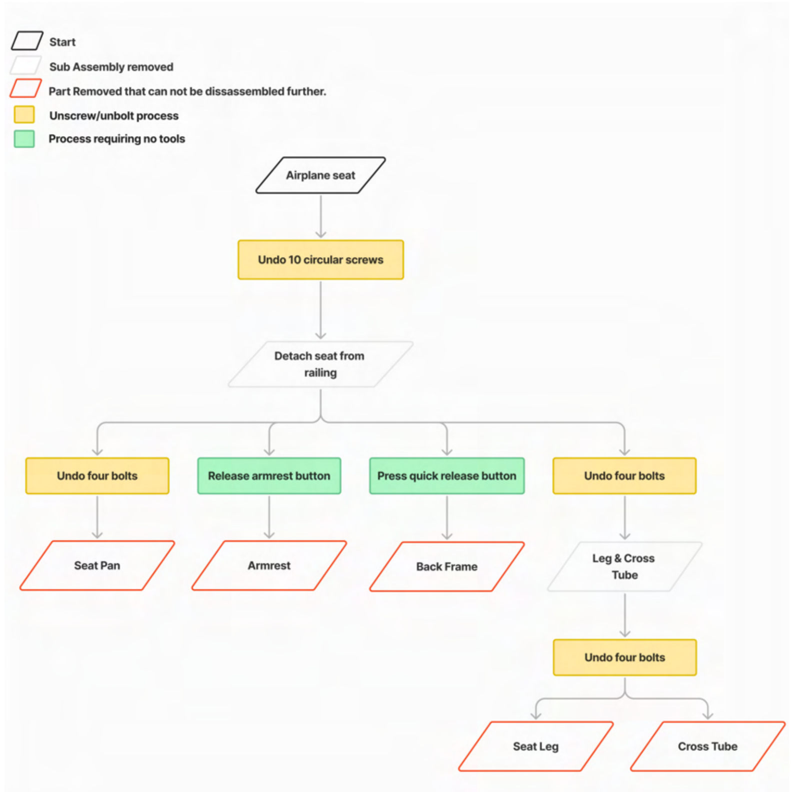
Reclining System

Material: Aluminium
Manufacturing: Extrusion

Cylindrical tube in the seat pan is attached to two tubes that is attached to the backrest.



Disassembly Tree



Where possible, **tool-free** assembly and disassembly is implemented. This promotes the refurbishment process which adds **7 years of life** to the product each time.

By eliminating the need for many screws, it also **reduces the overall weight** of the seat.

Environmental Impact Analysis

Eco Audit

Materials

- **Forged Carbon Fibre**: A **lightweight, strong** material that improves fuel efficiency by **reducing emissions** during usage. However, its production is energy-intensive, contributing to a higher environmental impact during manufacturing. Despite this, its lightweight properties help overcome these impacts by reducing fuel consumption in the long term. The end-of-life disposal of forged carbon fibre is challenging due to the difficulty in recycling, though advancements are being made in **recycling technologies**. If it cannot be recycled, it could be still **downcycled**.
- **Aluminium**: While its initial production from bauxite is energy-intensive, **recycling aluminium requires only a fraction of the energy**. Aluminium is also **lightweight** and this helps r**educe fuel consumption** and operational emissions when used in products like aircraft. Aluminium is fully **recyclable** at the end of its life, minimising waste and promoting a **circular economy**.
- **Natural Fibre Composite**: Made from renewable plant-based materials, it offers an eco-friendly alternative to synthetic fibres. They require **less energy** to produce than the synthetic fibres, resulting in a lower environmental impact during manufacturing. These materials also help reduce carbon emissions by storing carbon during the growth of the plants used. In addition, natural fibre composites are **biodegradable**, offering a sustainable option for disposal and contributing less to long-term waste compared to non-biodegradable materials.

Manufacturing

- **3D Printing**: High precision, layer-by-layer construction of parts, **reducing material waste** and enabling the creation of **complex geometries** that would be difficult to achieve with traditional manufacturing. In aviation, it can be used to create lightweight, complex components such as the **honeycomb design**, leading to cost savings and **efficient production**. It also allows for on-demand production, which is useful in **reducing lead times for spare parts**.
- **Compression Moulding:** Has the ability to produce strong, lightweight components with **dimensional stability** and **surface finishes** - critical for aviation applications where strength-to-weight ratios are crucial. This method is particularly suitable for creating durable seat parts that can **withstand rigorous air travel** while maintaining **consistent qualit**y across production. Additionally, compression moulding's **cost-effectiveness** for high-volume manufacturing aligns well with the need for scalable, sustainable seat designs. Its capability to incorporate **recycled or bio-based materials** also supports the proposal's focus on environmental impact and circularity.

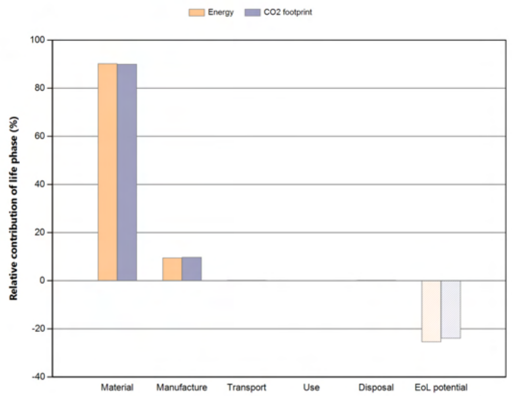


Figure 1: Existing plane seat

- **Material & manufacturing** take up the largest proportions of energy and CO2 footprint

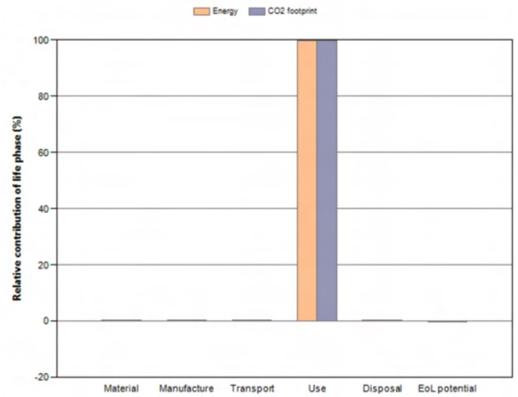


Figure 2: Proposed primary system

- **Use** covers the largest proportion
- Material & manufacturing footprints are relatively reduced

MCI

Hoskins
Adventures in the Circular Economy

Utility based on (Select):	Longevity	
This product lasts:	21	Years
Typical product lasts:	7	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Arm	0.3600	5	Composites	Biological	100%	100%	Reuse	**1.00**
Back Frame	3.1000	4	Aluminium	Recycle	75%	100%	Reuse	**0.92**
Rail	1.5000	5	Composites	Virgin	0%	100%	Reuse	**0.85**
Seat leg	0.7000	5	Aluminium	Recycle	75%	100%	Recycle	**0.85**
Seat pan	1.1000	4	Composites	Virgin	0.00%	100%	Reuse	0.85
Reclining bars	1.2000	8	Aluminium	Recycle	75.00%	100%	Reuse	0.92
Seat pan tube	1.0000	4	Aluminium	Recycle	75.00%	100%	Reuse	0.92
Product Mass (kg):	**43.2**							**0.90**

Calculating the Material Circularity Index (MCI) for the primary system shows a promising index of **0.90**. Analysing an existing economy plane seat gives an index of **0.10** due to the amount of landfill waste and short utility lifetime of only 7 years. With the new proposed system, weight is reduced, **overall lifetime is tripled** with refurbishments, more input materials are regenerative and all materials end up reused or recycled.

Secondary System Specification

Functions, Ergonomics and Experience

Changes to Primary System based on group discussion:
- Altered shape of backrest for further weight reduction
- QR codes on components hold data to monitor their circular lifestyle
- Numbering components encourages easy assembly and disassembly

Headrest

Material: Latex Foam (Cushion), Wool (Cover)
Manufacturing: Foam Moulding (Latex), Textile Weaving (Wool)

Designed to provide **stability** and **comfort**, reducing **neck strain**.

Footrest

Material: Recycled PET (Footrest), Aluminium (Attachments)
Manufacturing: Injection Moulding (rPET), Casting (Aluminium)

Hammock-like footrest adapts to passengers **varied leg positions**.

Table

Material: Bamboo Composite (Table), Aluminium (Connectors)
Manufacturing: Hot Pressing (Bamboo), Casting (Aluminium)

Provided for meal times only, it is designed to attach securely using **hexagonal click-on connectors** where **height can be varied**.

Seat & Backrest Cushion

Material: Latex Foam
Manufacturing: Foam Moulding

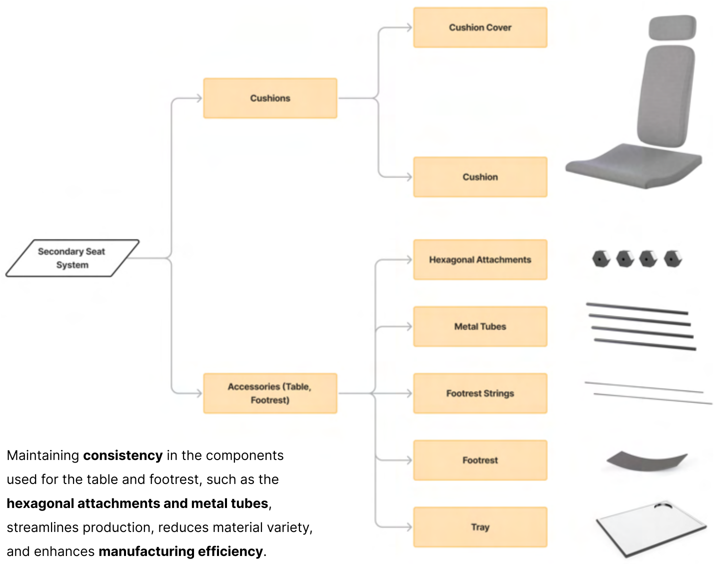
The latex foam provides a **soft and supportive** resting surface. The **contoured** cushion conforms to the human body, providing **pressure relief** and **posture alignment**, which is vital for comfort in long-haul flights.

Cushion Covers

Material: Wool
Manufacturing: Textile Weaving

This **skin-friendly** material enhances comfort during long-haul flights, providing a **cosy and soft** layer. It also features **temperature-regulating** properties.

Product Tree



Maintaining **consistency** in the components used for the table and footrest, such as the **hexagonal attachments and metal tubes**, streamlines production, reduces material variety, and enhances **manufacturing efficiency**.

Disassembly Tree

Tool-free assembly and disassembly is implemented, promoting the refurbishment process which adds **7 years of life** to the product each time.

Eliminating the need for many screws also **reduces the overall weight** of the seat.

Environmental Impact Analysis

Materials

Latex Foam: As it is derived from **natural rubber**, it is a highly renewable choice for cushions, as it is **compostable**. It also requires **less energy to produce** compared to synthetic foam, thus **reducing carbon emissions**. However, it is important to note that additives may be needed to adhere to **aviation policies** such as flammability standards.

Wool: Being **100% biodegradable and renewable**, it decomposes naturally, hence eliminating the need for an designated end-of-life process.

Recycled PET (rPET): Using rPET cuts down the demand for virgin polymer production and **diverts plastic waste** in landfills and oceans. After usage, it can still be **recycled further** - mechanically or chemically - or **downcycled**.

Aluminium: Recycled aluminium uses **95% less energy** than producing virgin aluminium - it can virtually **infinitely recycled**.

Bamboo Composite: Being a **biodegradable**, low-carbon material, it **reduces landfill waste and carbon footprint**. Bamboo farming also requires **less water and pesticides**, preserving the surrounding environment.

Manufacturing

Foam Moulding: Moulding precisely to shape, **material wastage is minimised**. Energy is also conserved by efficient batch production.

Casting: Efficient for **mass production**, where excess material can be **recycled**.

Textile Weaving: Can be further optimised to use **renewable energy**.

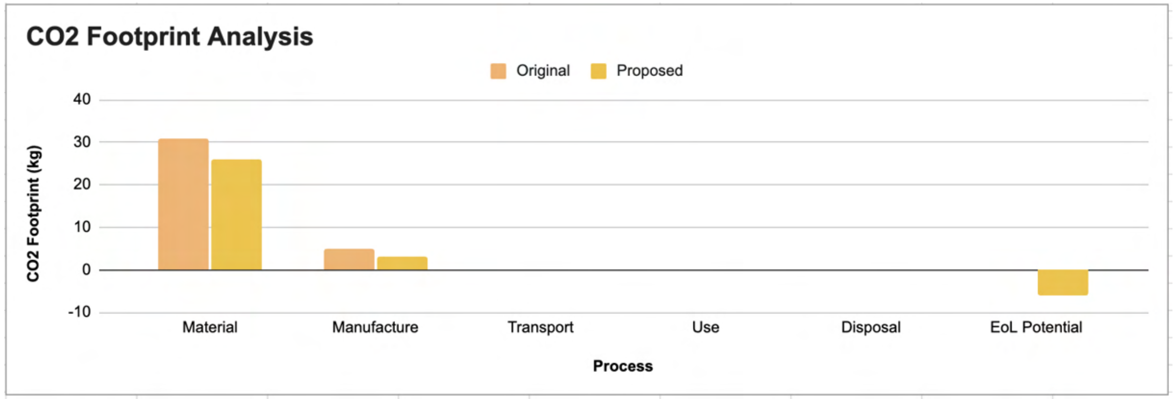
Hot Pressing: Utilises **less energy** compared to other moulding processes due to **lower temperatures** and **shorter processing times**. In addition, **bio-based additives** can be used to further enhance eco-friendliness.

Injection Moulding: Moulding precisely to shape, **material wastage is minimised**. Excess material can be **recycled**.

Utility, Services, Lifetime

- **Seat cushions and covers** are predicted to have a **shorter lifespan** (~ 7 years) then they are **downcycled** into textile fibres and other materials
- Other components are expected **refurbished 2-3 times** before being upcycled/downcycled
- Manufacturers offer a **take-back and refurbishment program** where components are refurbished until they do not meet aviation standards, where they are then downcycled, upcycled or recycled
- **QR codes** on the seat allow for data to be stored about the seat for manufacturers

Eco Audit



- The proposed system introduces an EoL potential contribution which **reduces CO2 footprint by around 5kg** - this reflects on the improvement of the system's circularity
- CO2 footprint for **materials** is also **reduced by around 5kg** and footprint for **manufacturing** is **reduced by 50%**

MCI

Hoskins
Adventures in the Circular Economy

Utility based on (Select):	Longevity	
This product lasts:	21	Years
Typical product lasts:	7	Years

			Input Materials			Output Materials		MCI
Component Name	Each (kg)	Quantity	Material Type	Source	% Regenerative	Collection Rate	Destination	
Seat Cushion	1.2749	1	Natural Material	Biological	0%	100%	Compost	**0.85**
Seat Cushion Cover	0.2500	1	Natural Material	Biological	0%	100%	Compost	**0.85**
Backrest Cushion	0.9144	1	Natural Material	Biological	0%	100%	Compost	**0.85**
Backrest Cushion Cover	0.3500	1	Natural Material	Biological	0%	100%	Compost	**0.85**
Headrest Cushion	0.4100	1	Natural Material	Biological	0.00%	100%	Compost	0.85
Headrest Cushion Cover	0.1500	1	Natural Material	Biological	0.00%	100%	Compost	0.85
Footrest	0.5320	1	Plastics	Recycle	100.00%	100%	Recycle	0.79
Footrest String	0.0003	2	Plastics	Recycle	100.00%	100%	Recycle	0.79
Tubes	0.0254	4	Aluminium	Recycle	100.00%	100%	Recycle	0.85
Hexagonal Attachments	0.0733	4	Aluminium	Recycle	100.00%	100%	Recycle	0.85
Tray	0.4880	1	Natural Material	Biological	0.00%	100%	Compost	0.85
Product Mass (kg):	**4.764374**							**0.83**

- Significant improvement in Material Circularity Index (MCI) from **0.10 to 0.83**
- **Cushions, covers and tray** had the **highest MCI of 0.85** due to use of natural material and end-of-life compostability
- **Tubes and hexagonal attachments** also had the highest MCI due to the **recyclability of aluminium**
- **Footrest and strings** had the **lowest MCI of 0.79** due to the use of polymers, however this is still significantly better compared to the original seat

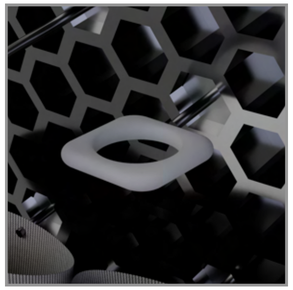
Seat Accessories Specification

Changes to Secondary System based on group discussion:
- Latex foam was replaced with TPU foam to accommodate individuals with latex allergies
- TPU is also more lightweight, reducing weight of the secondary system

REAR VIEW

FRONT VIEW

Cup Holder



Material: Recycled PET (rPET)
Manufacturing: Injection Moulding

Product Ergonomics & Experience:
As tray tables are only available during meal times, the cup holder is a convenient solution for passengers to secure their drinks, minimising spills.

Environmental Impact: Using rPET, like the device holder, it can be recycled or downcycled, hence supporting circularity.

Safety Card

Product Ergonomics & Experience:
Aligning with the modern day travel habits of using devices on flights, passengers will be familiar with QR codes, making it a streamlined and user-friendly experience.

Environmental Impact: Traditionally, materials such as paper, plastic and laminate is used - this is often not recyclable due to the mixture of materials. With the QR code, the need for materials, energy usage for manufacturing and an end-of-life process is eliminated.

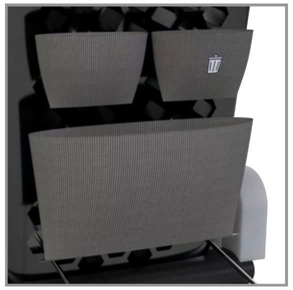
Device Holder

Material: Recycled PET (rPET)
Manufacturing: Injection Moulding

Product Ergonomics & Experience:
Designed to adapt to personal devices, passengers can adjust viewing angles to reduce neck strain. This feature integrates well with existing travel habits.

Environmental Impact: Weight is reduced by eliminating the need for a traditional in-flight entertainment system. Made from rPET, it is lightweight, durable and can be further recycled or downcycled. Additionally, it reduces demand for virgin polymer production.

Seat Pockets



Material: Woven Polyester
Manufacturing: Weaving

Product Ergonomics & Experience:
Varied seat pocket size allows passengers to store items of different sizes. This prevents smaller items from sinking to the bottom of large pockets. Furthermore, there is a designated rubbish pocket so that passengers will not have to mix personal belongings with waste.

Environmental Impact: Weaving allows for the use of recycled fibres, which can be further recycled or downcycled.

Privacy Separation

Material: Recycled PC (rPC)
Manufacturing: Injection Moulding

Product Ergonomics & Experience:
In addition to enhancing passenger privacy, the panels also act as a secondary headrest in order to reduce neck strain.

Environmental Impact: rPC is lightweight, impact-resistant and durable, which has a long lifespan. It reduces the need for virgin materials and frequent replacements.

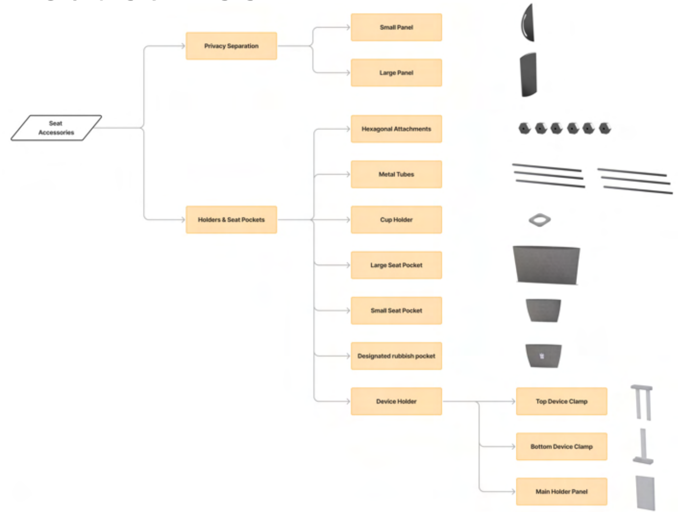
Sensors

Environmental Impact: Sensors monitor degradation of materials in each component. Sensors include:

- Ultrasonic Sensors
- Strain Gauge
- Temperature Sensors
- Acoustic Emission Sensors
- Piezoelectric Sensors
- Humidity Sensors

This can trigger alerts when degradation exceeds aviation safety regulations. This prevents unnecessary replacements and allows for predictive maintenance - this increases efficiency and reduces costs.

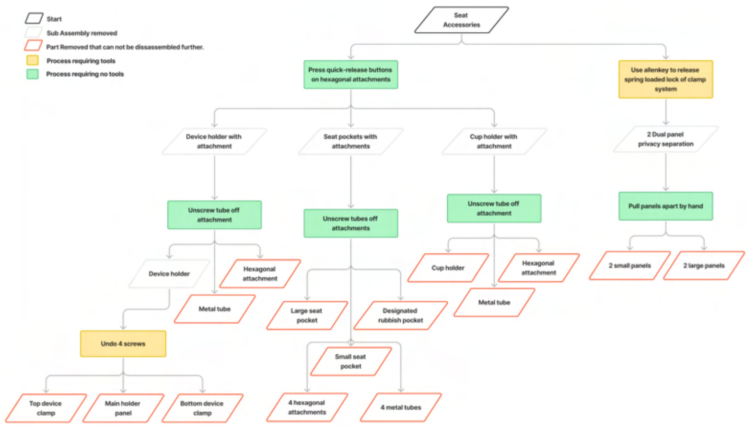
Product Tree



Based on the chosen materials and the seat's expected 21 year lifespan (with 3 refurbishments), these are the estimated lifespans for each accessory:

- **Cup Holder:** 21 years
- **Device Holder:** 14 years
- **Seat Pockets:** 7 years
- **Privacy Separation**: 21 years

Disassembly Tree



As mentioned previously, **tool-free assembly and disassembly** is implemented where possible in order to **promote refurbishments**. In addition, **consistency in components** (e.g. hexagonal attachments and metal tubes) allows for efficient manufacturing.

The allenkey used to release the privacy separations adds a layer of **security** as passengers will not be able to remove them on the flight. Although a tool is still required, it acts as a **quick release mechanism**, rather than unscrewing a fastener - this allows for **easy disassembly**.

System Problems:

- **Expensive** seat **recycling** and transport processes.
- Traditional sales cause low-batch production and **inefficient manufacturing/EOL** schemes.

Product Problems:

- The chair's embodied energy is **1.57e+06 MJ** over its lifetime, **98%** from the **use** of the chair. Hence, minimising weight of the chair is essential.
- Disassembly is **slow**, **adhesive**-heavy, and poorly organised.

User Problems:

- **82%** of interviewees said they wouldn't sacrifice on comfort for a more sustainable seat.
- Economy passengers often experience discomfort due to **limited space** and **inadequate cushioning.**

Aircraft Specification & Future Scenario

Travel scenario	Race for zero	Neglect of sustainability must be addressed to align with emerging climate goals.
Time horizon	10-20 years	Time is required for changes in the aviation industry's legislations.
Aircraft range	Medium/Long	Longer flights have greater environmental impact due to high fuel consumption.
Aircraft frame	Blended wing body	Explored due to reduced drag and improved fuel efficiency.
Airline type	Budget/Scheduled	Flexible design allows downgrading from scheduled airlines to budget carriers.
Source	Recycled, mono-materials &	Recycled & mono-materials simplify end-of-life processing.
	technical materials	Technical materials offer significant weight reduction.
Architect	Modular architecture	Allows for easier refurbishment and adaptability to varied airline needs.
Distribute	Road/Rail	Electric vehicles and rail transport reduce emissions compared to air freights.
Order (airline)	Economy	Designated seat researched.
Buy (airline)	Leasing model	Boosts resource efficiency and circularity through improved lifecycle management.
User	Budget/Student travellers	Targets budget-conscious travellers while maintaining comfort and durability.
Use	Three use-cycles: 21 years	Designed for reuse by lower tier airlines over three life cycles.
Prepare to return	Order collection service	Streamlines return process during the end-of-use stage.
Collect / take to	Manuf.'s own service	Allows for specialised and efficient material recovery.
Sort / separate	Mechanical sorting	Efficient material separation supports end-of-life processes.
Revalorise	Refurbish/Upcycle/Downcycle	Extends seat life while preserving material value and reducing waste.

Future Scenario Summary: Extreme weather events and consumer boycotts are driving urgent **sustainability changes** in aviation. As eco-friendly travel becomes standard, innovative features like **modular design** and **circular system** help meet both environmental and market demands. This future scenario is highly probable given the pressing need to address global warming and current i**nsufficient sustainability efforts.**

Seat Design Concept

Primary System Overview

- **Tessellating Design:** Enables efficient use of space, enhancing transport efficiency.
- **Rail Mounting:** Seats attach to rails, similar to current systems.
- **Reclining Feature:** Crucial for long-haul flights, addressing passenger comfort—a key concern.
- **Modular Components:** Allows quick part replacement and efficient repairs, reducing material waste and extending seat lifespan.
- **Milled Channels:** Reduces weight whilst maintaining the same strength. [1]
- **Lightweight Structure:** Made from recycled aluminium for its strength and lightness, assuming future feasibility. [2] Lightweight design is crucial as 98% of energy use and CO_2 emissions are proportional to weight.

Accessories Overview

- **Removable Tray Table:** Clips onto hook system via a notch when food is served, reducing overall weight of the seat.
- **Biomimetic Honeycomb Mounts**: Two hotspots at the top and bottom of the seats enables passengers to customise accessories - detachability promotes modularity.
- **Device Holder**: Adapts to personal devices, allowing adjustable viewing angles, and compensates for the removal of the in-flight entertainment system.
- **12V USB-C Charging Ports**: Strategically placed between seats to prevent obstruction, passengers are able to charge devices throughout the flight.
- **QR Code Safety Card**: User-friendly and eco-friendly alternative to traditional designs, reducing material use and eliminating the need for an EoL process.

Secondary System Overview

- **TPU Lattice seat cushion:** Lightweight, comfortable, and non-absorbent, these materials are recyclable, resist toxicity, and enhance passenger comfort. [3] They also last up to three times longer than traditional seats (approx. 7 years vs. 2 years).
- **Mono-Materials:** Secondary components are made from easily removable mono-materials, enhancing recyclability, manufacturing, sourcing, and re-manufacturing. [4]
- **TPU Extrude:** Water-resistant, flame-retardant, lightweight whilst still proving user comfort which was a significant problem. [3]

1.East IS. I Beams | Strength, Dimensions, and Uses [Internet]. Intsel Steel/Bushwick Metals. 2022. Available from: https://www.bushwickmetals.com/i-beam-uses/
2.GME Recycling. Aluminium Recycling in Aviation - GME Recycling [Internet]. GME Recycling -. 2024 [cited 2024 Dec 10]. Available from: https://www.gme-recycling.com/the-future-of-aluminium-recycling-in-aviation-sustainable-practices-and-industry-insights/
3.Omnexus. Thermoplastic Polyurethane (TPU) Material: Properties & Applications [Internet]. omnexus.specialchem.com. 2024. Available from: https://omnexus.specialchem.com/selection-guide/thermoplastic-polyurethanes-tpu
4.Mono-materials: Single in its structure, but together for the future | Cflex [Internet]. cflex. 2022 [cited 2024 Dec 10]. Available from: https://www.cflex.com/newsroom/mono-materials-single-in-its-structure-but-together-for-the-future/

System Diagram

This page depicts a system overview for a plane seat currently and in a world that is racing for **net zero**.

Key:
- **Current System** (7 Years)
- **Ideal System** (21 Years)

Sourcing

Materials and parts are sourced from **virgin sources** in the current system, while the ideal system uses **bio-based** polymers and **recycled** composites with blockchain **tracking** for transparency.

Manufacturing

Parts are manufactured together and then assembled.

Transport

The complete plane seats are transported to the Original Equipment Manufacturer using **electric vehicles**.

In the current system plane seats would be purchased however, in the ideal system they would be **leased** to promote sustainability.

Installation

The seats are installed in the aircraft using **modular mechanisms** or robotic arms.

Use

Plane flies around the world collecting passenger comfort **feedback** until seats reach the EoL stage.

EoL

Landfill

Plane seat gets thrown away, even if there are **valuable** materials and parts.

Collection

Seats at end-of-life are returned to the manufacturer, with drivers delivering **replacement** seats on route.

Inspection

Each chair is thoroughly inspected: repairable chairs **receive** new parts. This is all possible due to their **modular structure** design.

AI-assisted inspection systems evaluate chair condition. Irreparable chairs are dismantled for parts.

New parts

Refurbish

Old seats get leased again.

New parts added to old chairs extends their lifecycle, **reducing costs** and enhancing sustainability, such as by replacing the leather exterior of the seat.

Refurbishments aim to extend seat life by **7 years**. Seats undergo **3 refurbishments (21 years total)** before being redirected to upcycling, downcycling or disposal.

Broken Parts

Sorting

Non-recyclable parts go to landfill, while recyclable parts are processed accordingly.

Recycle

Recyclable parts are **reintegrated** into manufacturing, supporting circular practices, with **80-85%** of current seats recyclable. [5]

Upcycle, Downcycle

Component is upcycled for other aviation applications, e.g. fabric from seat covers can be used for a **plane's carpeting**.

After dismantling, **materials are downcycled** to form new components or materials for other industries, e.g. the fabric can be used to manufacture **bags**.

In a last-resort scenario, they can undergo **energy conversion**.

Summary: The ideal system aims to enhance circularity and reduce environmental impact by adopting **a leasing model**, enabling manufacturers to manage end-of-life (EoL) processes, use **recycled materials**, and extend product lifecycles with **modular designs** to minimize waste. This approach improves the Material Circularity Indicator (MCI) from 0.1 in the current system to **0.8** in the ideal system.

5.Grey E. Aircraft recycling: up to the challenge [Internet]. Airport Technology. 2017. Available from: https://www.airport-technology.com/features/featureaircraft-recycling-up-to-the-challenge-5710942/

Primary and Secondary System Specification

Material: Primary system made from primarily recycled aluminium for its strength and lightness, assuming future feasibility. [2] Lightweight design is crucial as 98% of energy use and CO_2 emissions are proportional to weight.

Manufacturing: Most parts will be extruded (pipes), cast or milled. A leasing model makes mass manufacturing methods economical and reduces material waste.

Tessellating legs: Optimise the manufacturing process by minimising waste while also improving transport efficiency during installation and end-of-life handling, both of which can cost thousands of dollars. This design effectively addresses a significant challenge.

Hook System: A thick hook design ensures durability, addressing expert concerns. Its redesigned circular end doubles as a cup holder and alignment feature. In addition to supporting food trays, cushions, and rubber grips, the hook serves as a platform for user-developed accessories. With standardised dimensions under a leasing model, this system becomes widely feasible, enabling passengers to enhance their experience with custom accessories.

Quarter-Turn Fasteners: Shortens disassembly of primary system from **5h** to **<15min** using only a flathead screwdriver. Their spring-loaded design ensures safety by preventing loosening from vibrations, unlike standard fasteners.

Snap fit parts: Allow quick, tool-free assembly and disassembly while maintaining safety in crash scenarios.

Rail Mounting: Seats attach to rails, as in current systems, enabling easy assembly and disassembly within the aircraft.

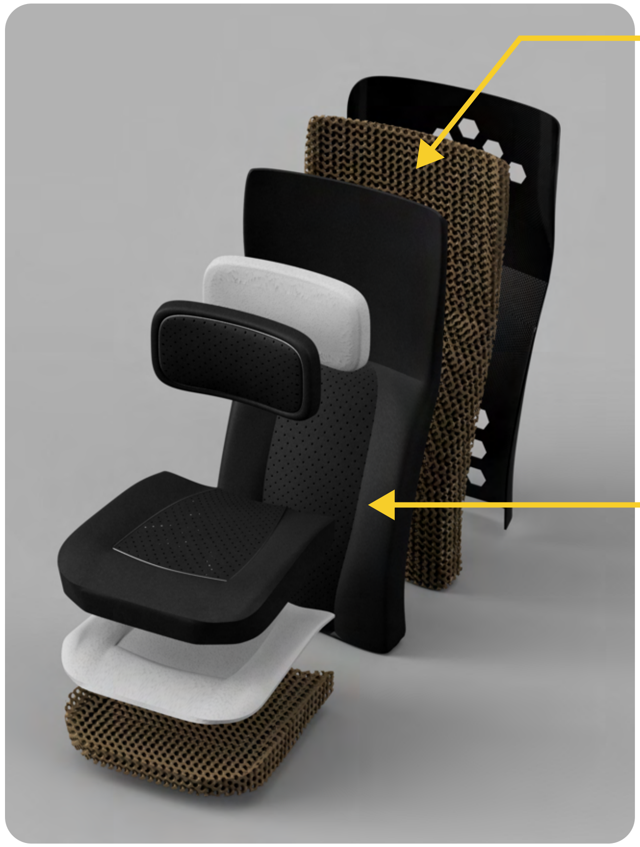
Carbon fibre backrest: Despite higher manufacturing costs, its lightweight properties lower operational expenses and enhance recyclability. [7] It will be made from forged carbon fibre with a top layer of prepreg carbon weave.

Reclining: The seat reclines, addressing comfort, a top concern for passengers on medium to long-haul flights.

Modular Components: Modular armrests and cushions enable quick part replacement, efficient repairs, and reduced material waste, extending the seat's lifespan. They also allow upgrades without replacing the entire primary system.

Repair Service: With a leasing model and higher production volumes, a repair service becomes feasible, supported by small stockpiles at major hubs for quick seat repairs or replacements.

Structure and Function: The design features three density zones for optimal comfort: firm for head support, medium for back support, and soft for the seat base. This arrangement provides **more ventilation** surface area and better pressure distribution compared to solid foam cushions.



Lifetime:
Cushion: **7 years** under normal airline use.
Cover: **5 years** under ideal condition; 3 years in regular airline service.
Primary system: maintains structural integrity and safety compliance throughout **21 years'** service life.

Environmental Impact

66% reduction in weight

225 metric tonnes of CO2 sequestered per seat row

TPU Lattice cushion

Materials & Manufacturing: It's abrasion resistance ensures durability under constant passenger movement, maintaining shape throughout its 7-year lifespan. The material's natural microbial and water resistance maintains hygiene during long-haul flights while ensuring **easier end-of-life recycling**,minimizing both in-service maintenance and pre-recycling treatment.[8]

Assembly & Disassembly: The TPU lattice is placed inside the seat cover (with a zip), which attaches to the seat using Velcro.

Mono-Material Cover

Materials and Manufacturing: Using 100% polyester eliminates the typical multi-layer fabric problems. The single material manufacturing process **minimizes energy waste** by eliminating lamination or bonding steps between different layers.

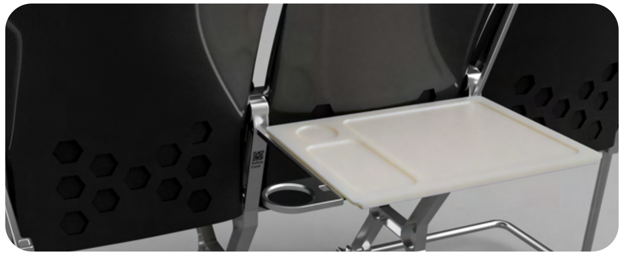
Structure and Functions: This virgin material composition maintains performance requirements: **durability** for constant use, **flame resistance** for safety, and consistent appearance for airline branding.[9]

Assembly & Disassembly: The cover uses a straightforward Velcro attachment system, eliminating the need for complex fastenings, or permanent glue. When airlines want to change their look, they can switch covers without replacing cushions. The all-polyester material makes **recycling simple** - everything goes in the same bin.[10]

7.Spartec Composites. Spartec Composites Inc [Internet]. Spartec Composites. 2023. Available from: https://www.sparteccomposites.com/2023/10/18/forged-carbon-fibre-what-it-is-and-how-its-used/
8.Beloshenko V, Beygelzimer Y, Chishko V, Savchenko B, Sova N, Verbylo D, et al. Mechanical Properties of Flexible TPU-Based 3D Printed Lattice Structures: Role of Lattice Cut Direction and Architecture. Polymers. 2021 Sep 3;13(17):2986.
9.Rositsa Petkova-Slipets, Penka Zlateva, Desislava Staneva. Influence of the polyester non-wovens production type on their thermal and flammability properties. Journal of Engineering and Applied Science. 2022 Jun 13;69(1).
10.Wei L, Zhan S, Zhou M, Xu X, You F, Zheng H. A Powerful Strategy for Carbon Reduction: Recyclable Mono-Material Polyethylene Functional Film. Polymers [Internet]. 2024 Aug 1 [cited 2024 Dec 11];16(15):2196–6. Available from: https://www.mdpi.com/2073-4360/16/15/2196

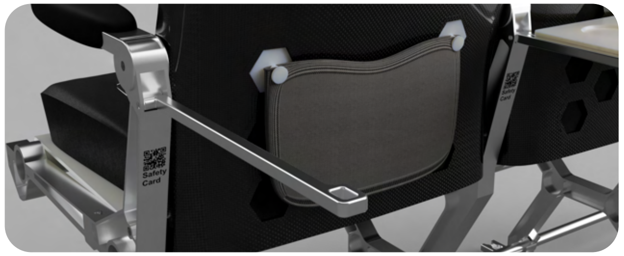
Accessories and Validation

Food Tray: Removing tray tables from air plane seats can save 200 kg in weight and 30 litres of fuel per trip. This translates to an average of **75 metric tons of CO_2 saved annually**. Use of recyclable & flame retardant polypropylene aligns with circularity goals & adheres to aviation flammability legislation.



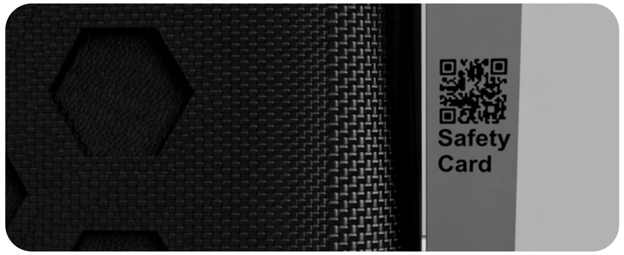
Device Holder: Eliminates the need for traditional in-flight entertainment which **saves 960kg** in weight & **364 tons of CO_2 annually**. Made from rPET, it is durable, lightweight and can be further recycled. It also reduces the demand for virgin polymer production.

Seat Pockets: Made out of polyester, the pockets can flexibly be varied in size and shape by independently moving the two ends. This allows for multiple pockets to be added if needed. Using 100% polyester has the same benefits as mentioned in the secondary system specification.



12V USB-C Charging Ports: Ports are placed between seats to minimise obstruction when passengers enter/exit, ensuring a seamless user experience. Wiring runs around the seat frame, beneath the cushions, making it easy to repair while remaining inaccessible to passengers.

QR Code Safety Card: Eliminates the need for materials, manufacturing and end-of-life processes typically needed for traditional safety cards. Having it online also makes it easier to update.



Innovation

Detachable Accessories:
- **Lightweight** cup holder and **removable** tray table system replaces traditional heavy fold-down mechanisms.
- **QR code** replaces traditional paper safety cards, enabling easy updates.

Modular Architecture:
- Quick-release snap-fit fasteners and velcro attachments enable customization **across different airline** configurations.
- Modular components with **standardised attachments** allow for easy part replacement and upgrades.

Material and Circularity:
- Fully **traceable** through number codes on aluminum parts for closed-loop tracking.
- Construction combining **forged carbon fiber** with **carbon weave** for optimal strength-to-weight ratio.

Feasibility

Technical:
- Design follows strict minimum **industry standards** for strength (180lbs load requirement shown).
- Modular attachments meet aviation **safety** standards with secure fastening systems.

Manufacturing:
- **Single material** polyester cover eliminates complex multi-layer manufacturing.
- Standardized parts enable **regional repair hub** feasibility.
- Velcro attachment systems simplify **assembly/disassembly** processes.

Business:
- **Modular design** enables airlines to change aesthetics without full system replacement.
- **Reduced weight** through carbon fiber integration provides ongoing fuel savings.

Sustainability

Material Recovery Strategy:
- High collection rates (**90-100%**) across most components.
- Aluminum components designed for complete **recyclability.**

Carbon Impact:
- **225** metric tonnes of CO2 sequestered per seat row.
- Most components achieve MCI ratings between **0.78-0.89**, showing consistent sustainability across parts.

Weight Reduction:
- Total product mass of only 19.65 kg represents a **66%** reduction from the original 57.8 kg baseline design.
- Reduced weight leads to significant **fuel savings** and **lower emissions** during the product's use phase.

Appendix: Statement of Contribution

	Individual Contribution	Collaborative Contribution
Owen Lee Scott	• Reworking group members CAD files so they fit together • doing CAD	Added more facts, figures and sources across the document.
Vasco de Noronha	• System, Product and User Problems • Primary and Secondary System Overviews • System Diagram • Primary System Specification Annotation • Eco Audit	• CAD models from S2
Lara Merican	• Airplane Specification & Future Scenario • Accessories Overview • Accessories Specification Annotation	• Update Vasco's system diagram to align with our final concept • Material Circularity Index (MCI)
Xiaoyun Li	• Future Scenario Summary • Secondary System Specification Annotation • Validation	• Update Vasco's system diagram to align with our final concept • Material Circularity Index (MCI)

It should be noted that **all students** contributed to every slide and gave *feedback* or *suggested improvements*.