System catalogue Circulaerospace
Interdisciplinary thesis lab 2023-2024

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SYSTEM CATALOGUE

CIRCULAEROSPACE

LDE CENTRE FOR SUSTAINABILITY

INTERDISCIPLINARY THESIS LAB 2023-2024

Universiteit Leiden
TU Delft
Erasmus Universiteit Rotterdam

COLOPHON

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CONTENT

Introduction

This system catalogue is the final result of the Interdisciplinary Thesis Lab: Circulaerospace. It compromises the findings of all participating students and acts as a connector between all their theses.

What is this thesis lab about?

In 2024, a group of eleven Masters students from Leiden University, Erasmus University Rotterdam, Delft University of Technology and The Hague University of Applied Sciences joined the Interdisciplinary Thesis Lab 'Circulaerospace'. This was the second edition of this lab organized jointly by LDE CfS and Airbus around the challenge "How can technology, digital innovations, and alternative business models push towards sustainability targets in aerospace?". Students researched technological innovations such as circular designs, the use of new sustainable (bio)materials for parts of an aircraft, and how digital tools could help optimize production techniques and supply chain monitoring. They investigated how these innovations could be implemented using new circular business models and how circularity indicators and KPIs could help guiding management decisions toward a more sustainable aerospace sector.

How to use the Pattern book?

This system catalogue is inspired by 'A Pattern Language' by Christopher Alexander (1977). A pattern language is a method used to describe and solve complex problems ranging in scale, by identifying knowledge gaps, recurring problems and finding simple and specific solutions and recommendations. The method provides a structured yet flexible framework; by breaking down problems into smaller, manageable 'patterns' and providing a network of solutions, it helps readers navigate the complexities of a challenge, leveraging collective knowledge and experience to create effective, sustainable solutions.

Start reading this catalogue by viewing the pattern diagram which visualizes all patterns, the themes under which they are grouped, and their interconnections. Depending on the theme you are most interested in, you may turn to the chapter covering all patterns collected under that theme. From there, you can learn more about each pattern's background and recommendation, and methods that were used. The author is also credited, so that you may refer to their individual MSc thesis for more in-depth reading on the topic. Finally, the important connections to other patterns are given.
But, you may also open this book at a random page! Read the pattern background and learn about the proposed solutions. Then, find the connecting patterns below and turn back or forward to those pages do learn more about the connecting pattern(s).

All participating lab students developed patterns based on their individual thesis research findings. These patterns, including their interconnections, are presented in this catalogue. We are very proud to present the informative end-product developed by this team. It showcases the diversity of knowledge and insights relevant to the transition towards more sustainable and just landscapes in South Holland.

Enjoy reading this pattern catalogue!

Executive Summary

This catalog was written to display the key findings of the LDE thesis lab called 'Circulaerospace'. It shows the diversity of knowledge and insights that are relevant for the transition towards a more sustainable and circular aerospace.

At multiple moments during the thesis lab, connections have been sought between all the thesis topics and related disciplines. Every student has distilled two 'patterns' from their individual research (i.e. a key finding such as a solution, observation, identified knowledge gap) which have been brought together in multiple collaborative sessions. The patterns were found to be related to four main categories: 'New business models', 'Technology and innovation', 'Governance', 'Complex systems' and 'Human factors', representing the most relevant themes in the transition to a more sustainable aerospace. Next, the student team investigated how their individual patterns were connected to each other.

This Ecosystem Catalog presents the patterns as well as their interconnections. A visualization led to the discovery of four different clusters, i.e. groups of patterns with strong connections. These clusters are: 'New materials', 'Circular End of Life (EoL)', 'Stakeholder interactions, transparency and sharing' and 'Current state of play'. They represent the main enablers or barriers to a more sustainable aerospace.

Key findings & recommendations

1. New materials
- Materials should be selected based on new, more sustainable criteria (not only weight but also recyclability).
- Artificial Intelligence can be a helpful tool for sustainable selection, material discovery and effective simulation in the experimental stage.
- Conducting a Life Cycle Assessment (LCA) at the design stage will help assessing the viability of new products.

2. Circular EoL
- The aerospace industry should aim at more reuse cycles before moving to recycling or incineration.
- Defining the acceptable life cycle of a material or part should focus not just on the potential life cycle of the plane, but also on the potential life cycle of the material/part itself.
- As long as there is no regulation regarding the EoL of aircrafts, companies should develop sustainable guidelines themselves for design and dismantling to increase circularity; this should be done in consultation with recycling parties.
- Use modular design and product/material passports will help track and separate materials for recovery.

3. Stakeholder interactions, transparency & sharing
- There are significant communication issues that lead to stakeholders being confused and improper regulations and guidelines being implemented.
- By enabling transparency throughout the production cycle, it would allow for solutions such as product passport, which would in turn allow for more actionable data analysis across the entire production processes.
- There is no global evaluation criteria for sustainable development which leads to all the stakeholders being able to claim they have the most sustainable LCA, for example.

4. Current state of play
- There is no legal binding definition for sustainability or circularity, which has detrimental effects on resource allocation and encourages greenwashing.
- There is a paradox between what people say they want and how they act on sustainability.
- Offer lifestyle information on work/life balance for shift workers to ensure less waste and more sustainable performance.

JC Gellidon, Unsplash

Who are the partners in this thesis lab?

Airbus

Airbus is a European multinational aerospace corporation. The company's primary business is the design and manufacturing of commercial aircrafts but it also has separate defense, space and helicopter divisions. Since 2019, Airbus has been the world's largest manufacturer of airliners as well as the leading helicopter manufacturer. In this lab, different parts of the organization were involved: Airbus Central Research & Technology and Airbus Netherlands.

AIRBUS

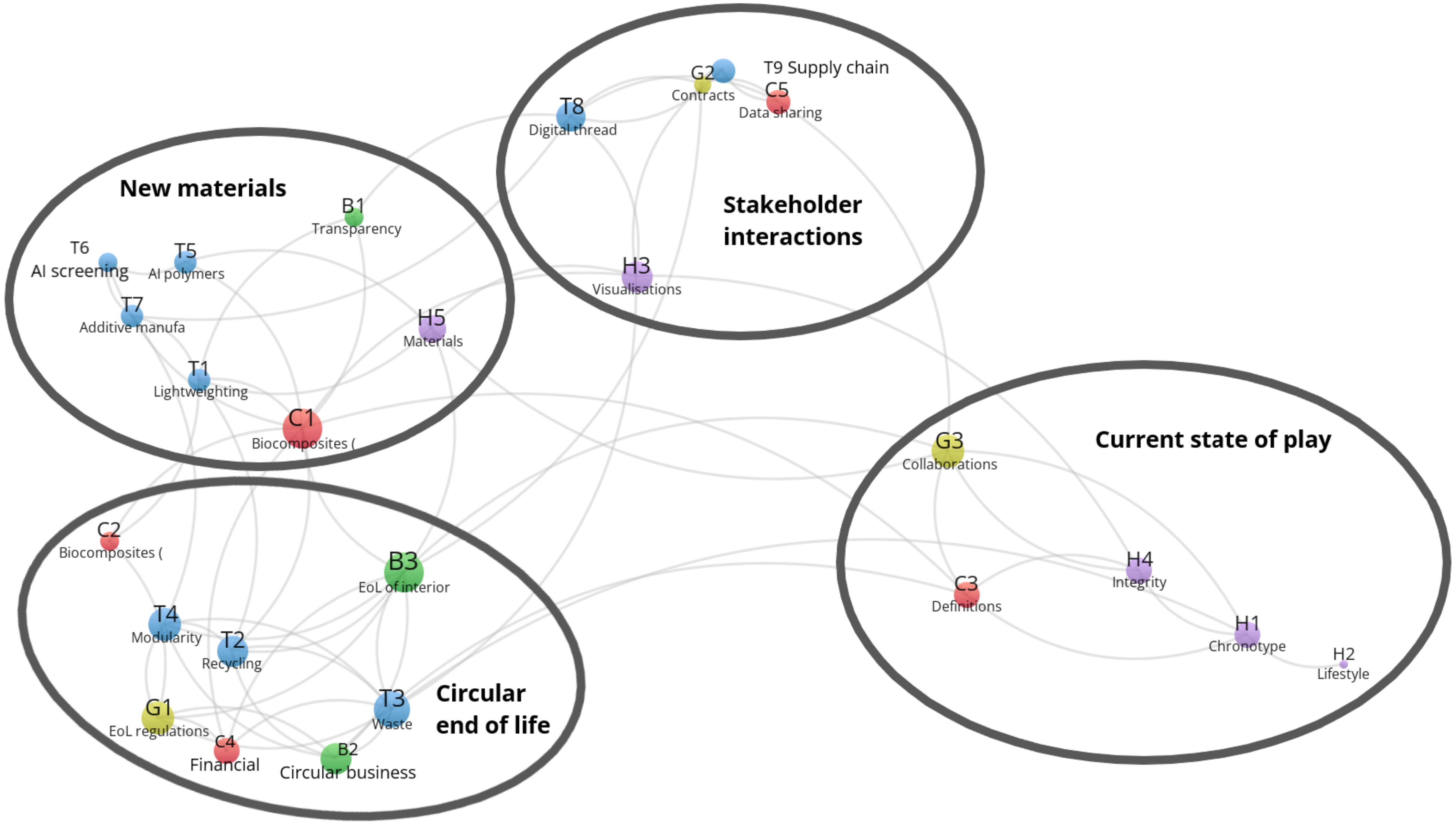
LDE Centre for Sustainability

LDE Centre for Sustainability aims to accelerate a deeper and broader understanding of the circular economy and stimulates collaboration between LDE-universities, applied universities, industries, governments an citizens initiatives. We empower students, researchers and professionals to develop new knowledge and skills for the transition towards a circular economy.

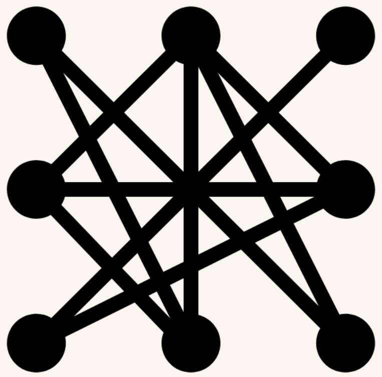
Centre for Sustainability
Leiden-Delft-Erasmus Universities

PATTERN DIAGRAM

showing relations between patterns



COMPLEX SYSTEMS



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C1

‘SYSTEM’ BARRIERS TO BIO-COMPOSITE ADOPTION

SUSTAINABLE INNOVATIONS ARE FACED WITH A LOT OF COMPLEX CHALLENGES DURING THEIR DEVELOPMENT AND DIFFUSION THROUGHOUT GLOBAL VALUE CHAINS. THESE BARRIERS ARE HIGHLY INTERCONNECTED AND ORGANIZING EFFECTIVE INTERVENTIONS IS DIFFICULT DUE TO STRONG RIPPLE AND FEEDBACK EFFECTS.

Theoretical Background

Organizations are faced with a broad range of complex challenges when trying to develop and implement sustainable innovations, such as Bio-composite materials. Examples include technological barriers, such as the complexity of creating new and robust value chains, all the way to economic and financial barriers, like competition and ineffective allocation of resources, and organizational barriers, such as a lack of functional integration and cooperation for sustainable innovation (Gupta et al., 2020). Creating a conceptual model of the interlinkages and hierarchical levels of these barriers, based on their ‘driving’ and ‘dependence power’, revealed that all barriers can be classified as, so-called, ‘Linkage barriers’ (Attri et al., 2013). These highly embedded factors are unstable since any action on these factors will have an effect on others and also a feedback effect on themselves, resulting in an utterly complex challenge to transition toward more sustainable material usage.

References

Attri, Dev & Sharma, 2013
Gupta, Kus-Sarpong & Rezaei, 2020

Recommendations

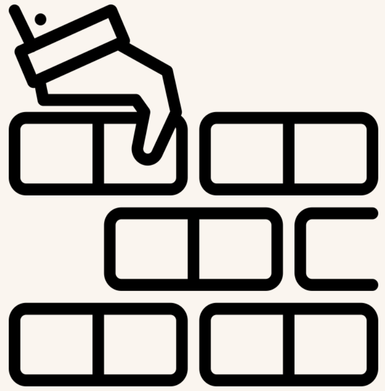
Airbus, in its mission to become a more sustainable enterprise, is faced with navigating the complexity of interactions among barriers and must be aware and cautious when intervening in the system of barriers. Instead of simply addressing any of these barriers a more structural approach is required. More specifically, techniques such as Interpretive Structural Modelling (ISM) allow for the identification of the best leverage points in the current system, i.e. those barriers which have a relatively high ‘driving’ power, while at the same time being affected via relatively few dependence links. This enables Airbus and its value chain partners to engage in the most effective strategic resource allocation, maximization of positive ripple effects throughout the system, and obtain clearer causality of the intended interventions.

Methods

Literature review, Semi-structured expert interviews, Grounded theory analysis, Interpretive Structural Modelling (ISM), Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis

CONNECTED TO
T1, T2, T5, T6, H3, C2, C3, C4, B1

AUTHORS
IVO VAN GESTEL



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C2

‘FOUNDATIONAL’ BARRIERS TO BIO-COMPOSITE ADOPTION

TO MAXIMIZE THE CHANCES OF IMPROVING THE CURRENT SYSTEM, IN WHICH SUSTAINABLE INNOVATION IS UTTERLY CHALLENGING, SIGNIFICANT ATTENTION SHOULD BE ATTRIBUTED TOWARDS INTERVENTIONS AIMED AT ADDRESSING THE ‘FOUNDATIONAL’ BARRIERS.

Theoretical Background

Assessing the critical issues faced with the development and diffusion of sustainable innovations, such as bio-composite materials for future aerostructures, reveals a broad range of twenty-five barriers, which can be mapped using the Interpretive Structural Modelling (ISM) technique (Gupta et al., 2020). This approach facilitates uncovering novel insights beyond simply the identification of barriers, i.e. depicting where factors are located within the system based on their interconnections and enabling the establishment of hierarchies among barriers (Attri et al., 2012). This method reveals that the barriers: regulatory complexity, uncertainty, and inadequacy, inadequate regulatory guidance for Sustainable Innovation, and lack of societal support and sustainable behavior are most fundamental in the current system due to their high ‘driving’ power and relatively low ‘dependence’ on other barriers within the current system. Alternatively, the other promising avenues for future interventions, based on the theoretical model are: lack of sustainability expertise, confusion and lack of perceived urgency around sustainability, lack of functional integration and cooperation, and ineffective GVC collaboration and information sharing.

References

Attri, Dev & Sharma, 2013
Gupta, Kus-Sarpong & Rezaei, 2020
Gioia, Corley & Hamilton, 2013

Recommendations

To ensure the more effective adoption of sustainable innovations, such as bio-composite materials for future aerostructures, Airbus and other global value chain stakeholders should focus on addressing and improving the barriers at the lowest hierarchical levels, which are ‘foundational’ to the current system. More precisely, they should commence by trying to address: the regulatory complexity, uncertainty, and inadequacy, inadequate regulatory guidance for Sustainable Innovation, and lack of societal support and sustainable behavior; after which attention can be attributed to the barriers: lack of sustainability expertise, confusion and lack of perceived urgency around sustainability, lack of functional integration and cooperation, and ineffective GVC collaboration and information sharing.

Methods

Literature review, Semi-structured expert interviews, Grounded theory analysis, Interpretive Structural Modelling (ISM)

CONNECTED TO
T1, C1, G1

AUTHORS
IVO VAN GESTEL

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C3

DEFINING SUSTAINABILITY CONCEPTS TO PREVENT MISUNDERSTANDINGS AND ACHIEVE GOALS

CORE CONCEPTS RELATED TO SUSTAINABILITY AND CIRCULARITY NEED TO BE DEFINED PROPERLY, SO ALL ACTORS ARE TALKING ABOUT THE SAME THING. THIS IS TO PREVENT MISUNDERSTANDINGS AND BE ABLE TO ACHIEVE GOALS.

Theoretical Background

In scientific literature, there is already much discussion on the definition of core concepts regarding sustainability and circularity, for instance when discussing a Circular Economy (CE) (Kirchherr et al., 2017). During the round-table discussion of the thesis lab, there was a lot of discussion about the concept of 'sustainability' as well. When are you allowed to call something a 'sustainable' product or measure?

Geissdoerfer et al (2017) describe how this unclarity can be counterproductive in achieving sustainability and circularity. Additionally, they describe how the different definitions used, causes a reinventing of the wheel in publications and other research, instead of building on earlier research.

Recommendations

With the scientific literature not providing a clear answer to this problem, it is important to always define the concepts you are using in your (internal) discussions to be on the same page regarding concepts such as circularity or sustainability. Additionally, it is important to share the definitions used when communicating your plans/goals/achievements regarding sustainability, this can also help prevent greenwashing and manage expectations.

References

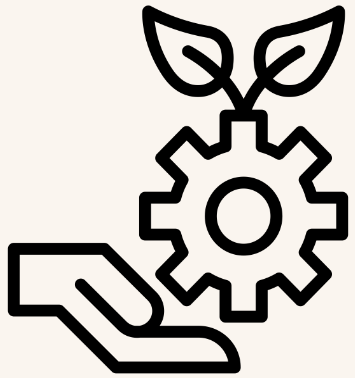
Geissdoerfer, Savaget, Bocken & Hultink, 2017
Kirchherr, Reike & Hekkert, 2017

Methods

Literature review, semi-structured interviews

CONNECTED TO
G3, C1, H1, H4, B2

AUTHORS
CHRISTEL DONKER



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C4

BARRIERS TO SUSTAINABLE DEVELOPMENT & FUNDING

THE INTRODUCTION OF GREEN TECHNOLOGY IN THE AVIATION INDUSTRY IS SIGNIFICANTLY SLOWED BY HIGH FINANCIAL COSTS, STRINGENT SAFETY REGULATIONS, AND A PUSH FOR ONLY CERTAIN INNOVATION DIRECTIONS WITHOUT SUFFICIENT JUSTIFICATION; NOT DUE TO A LACK OF MOTIVATION FOR SUSTAINABLE DEVELOPMENT.

Theoretical Background

The sustainable development funds hold substantial financial opportunities, which raises the question of why the aviation industry is not fully capitalizing on these incentives? There are also significant financial hurdles on the horizon for if they do not comply with the overly strict emissions caps. It is therefore that the industry's slow progress cannot solely be attributed to a lack of motivation. Assumptions like this overlook much deeper issues with feasibility and financial viability.

Recommendations

More discussion and collaboration should take place between government and private industry. More research and funding should be evenly distributed for multiple prevailing solution directions, not just into projects that the EU have deemed the "only" solutions. Rigorous inquiry needs to take place and decisionmakers need to interact with the data for themselves instead of relying on the interpretations of others. There should be more time allowed for testing solutions and experimenting with different fuel types and mixes without assuming that the aviation industry is unwilling to change, and without suggesting that the industry must be dismantled as the only solution to the climate crisis.

References

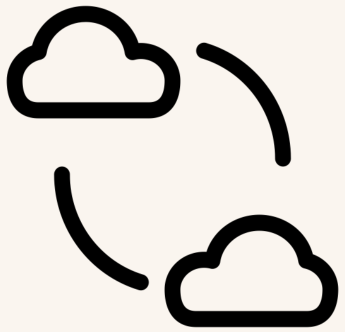
European Commission, 2023
Warwick, 2023

Methods

Literature Review

CONNECTED TO
C1, T13, G1, B3

AUTHORS
JENS VAN DEN BERG



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C5

RISKS OF DATA-SHARING TO ACHIEVE TRANSPARENCY

ONE OF THE BARRIERS TO ACHIEVING SUPPLY CHAIN TRANSPARENCY IS THE RISKS ASSOCIATED WITH DATA-SHARING. EFFECTIVE DATA GOVERNANCE IS ESSENTIAL TO MITIGATE THESE RISKS.

Theoretical Background

Transparency in supply chains requires sharing data among multiple stakeholders, which brings about risks related to data ownership and intellectual property (IP). Manuj & Mentzer (2008) highlighted information security risk and supply chain complexity in their research. Information security risk includes the threat of unauthorized data access and insufficient security measures across the supply chain. Moreover, the dynamic nature of global supply chains adds further complexity, requiring careful management to mitigate risks associated with data and IP.

Recommendations

The stakeholders in the supply chains should establish clear agreements defining data ownership and usage rights to prevent misuse and ensure compliance. Implementing robust data protection measures and conducting regular risk assessments are important strategies to mitigate these risks.

References

Manuj & Mentzer, 2008

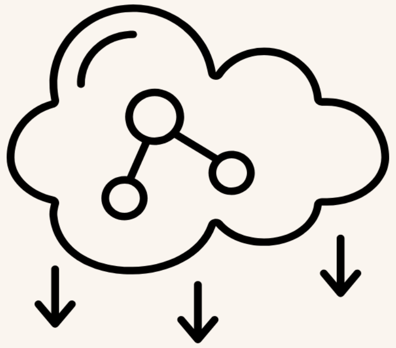
Methods

Literature Review, Interviews

CONNECTED TO
T8, T9, G2, G3

AUTHORS
CHI-CHI FANG

TECHNOLOGY



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T1

SUSTAINABLE AVIATION THROUGH LIGHTWEIGHT BIOCOMPOSITES

WEIGHT REDUCTION USING BIOCOMPOSITES IN AVIATION CAN SIGNIFICANTLY CONTRIBUTE TO EMISSION REDUCTION GOALS.

Theoretical Background

Biocomposites offer substantial weight reduction benefits for aviation, which directly impacts fuel efficiency and emissions. The lighter materials reduce overall fuel consumption, contributing to lower emissions and aligning with sustainability goals (Andrew & Dhakal, 2022).

They are lightweight and account with material properties suitable for aviation (Alaneme et al. 2023). This translates directly into fuel savings and reduced emissions, offering a promising alternative to traditional materials used in aircrafts.

Early LCA studies suggest these biocomposites have the potential for a lower environmental impact compared to conventional materials throughout their life cycle, especially when considering embodied energy and renewable resource utilization.

Recommendations

Aviation industry partners should prioritize the integration of lightweight biocomposites in aircraft design to enhance fuel efficiency and reduce emissions.

pLCA highlights the potential of mycelium biocomposites as an alternative for conventional materials in non-structural components for aircrafts. However, ongoing research and development are crucial to optimize production processes, minimize energy consumption, and ensure responsible end-of-life solutions.

Further assessment to understand economic implications in addition to the associated with the weight reduction.

References

Andrew & Dhakal, 2022
Alaneme, Anaela, Oke, Kareem, Adediran, Ajibuwa & Anabaranz, 2023

Methods

Literature Review, Prospective Life Cycle Assessment (pLCA), Data Analysis

CONNECTED TO
C1, C2, T2, T7, B1, H5

AUTHORS
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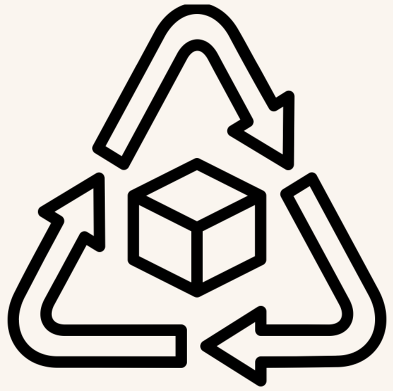

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T2

RECYCLABILITY AND LIFECYCLE BENEFITS OF BIOCOMPOSITE

BIOCOMPOSITES ENABLE MATERIAL RECYCLING, REDUCING EMISSIONS AND AIDING IN ACHIEVING 2050 ZERO-EMISSION TARGETS FOR AVIATION.

Theoretical Background

The current approach to end-of-life management for aircraft interior panels often involves incineration. Traditional panels typically consist of a composite core with additional layers like decorative films, fire retardants, and epoxies. These complex structures make them difficult and expensive to separate and recycle effectively. Bio-sourced composites, particularly those made from mycelium, offer more approaches to end-of-life management.

The use of new biosourced composites (Chauhury, 2023) could potentially eliminate the need for additional materials such as fire retardant layers, surface branding, etc. This simplifies the panel structure and enhances its recyclability (Johnson & Martinez, 2022; Green & Foster, 2023).

Recommendations

- Aviation stakeholders should focus on integrating biocomposites into aircraft design, emphasizing their recycling capabilities and lightweight nature.
- Partnerships with recycling and certification bodies can facilitate the transition.
- The number of reuse cycles achievable with cascading reuse for bio-sourced composites is still under research.
- Understanding the long-term behavior of bio-sourced composites - their moisture sensitivity, durability, and potential biodegradation - is crucial.
- Investing in research to enhance biocomposite performance and developing industry standards for their use will be critical to achieving emission reduction targets.

References

Chauhury, 2023
Shanmugam, Mensah, Försth, Sas, Restás, Addy, ..., & Ramakrishn, 2021

Methods

Literature Review, Prospective Life Cycle Assessment (pLCA)

CONNECTED TO
C1, T1, T3, T4, B2, B3

AUTHORS
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from Noun Project

T3

AVAILABLE WASTE REDUCTION OPTIONS FOR END-OF-LIFE MANAGEMENT

THERE ARE MANY WASTE REDUCTION OPTIONS AVAILABLE TO IMPROVE ENVIRONMENTAL IMPACT, ESPECIALLY IN THE AIRCRAFT PASSENGER SEATING.

Theoretical Background

Various waste reduction options identified in the aerospace industry, which could be implemented in the aircraft cabin passenger seating. Disassembly process could potentially be used to reduce waste, potentially improving environmental impact. However, the challenges lie in the disassembly process of the seating as parts are not designed with end-of-life efficiency, which rendered them economically unviable.

Recommendations

Given the current circumstances, it is important to provide more structural waste reduction approaches in the aircraft cabin seating with more emphasis on the disassembly process.

References

Hasehmi, Chen & Fang, 2016

Methods

Literature review

CONNECTED TO
T2, T4, H3, C4, B2, G1, B3

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T4

DESIGN MODULARITY TO FACILITATE PRODUCT'S END-OF-LIFE TREATMENT

A FOCUS ON MODULAR DESIGN COULD BE USED TO IMPROVE PRODUCT END-OF-LIFE OF AN AIRCRAFT PASSENGER SEATING.

Theoretical Background

A report published by Airbus in 2008 indicates that around 85% of the weight of a commercial aircraft can be potentially recovered despite the latest study showing that only 20% of the potential recoverable materials were actually recovered (Sabaghi et al., 2016). Therefore, a dismantling strategy could be implemented to provide the best strategy in terms of sustainability. However, current aircraft are not designed with efficient end-of-life in mind, resulting in complexity of structure making disassembly not economically viable.

Recommendations

It is recommended to have modular design as a standard in manufacturing aircraft seating to assist aircraft passengers seating end-of-life treatment. This will help in designing aircraft seats as a source of valuable materials that are easy to process.

References

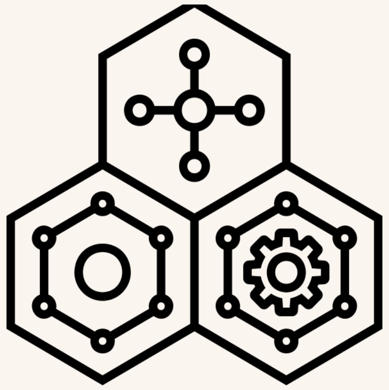
Sabaghi, Mascle & Baptiste, 2016

Methods

Literature review

CONNECTED TO
T2, T3, T7, B2, G1, B3

AUTHORS
YUSUF HAFIDZUN ALIM



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T5

MATERIAL DESIGN AND PROPERTY OPTIMIZATION FOR SUSTAINABLE POLYMER WITH AI

AI CAN ENHANCE THE DEVELOPMENT OF SUSTAINABLE POLYMERS BY OPTIMIZING MATERIAL FORMULATIONS AND MANUFACTURING PROCESSES TO MINIMIZE ENVIRONMENTAL IMPACT. BY INCORPORATING FACTORS SUCH AS RECYCLABILITY, BIODEGRADABILITY, AND ECO-FRIENDLY SYNTHESIS METHODS, AI CAN ASSIST RESEARCHERS IN DESIGNING AND CREATING POLYMERS WITH SUPERIOR SUSTAINABILITY PROFILES.

Theoretical Background

Predicting various polymer properties from their monomer composition has been a challenge for material informatics, crucial for effective material exploration. To address this, a multitask machine learning architecture utilizing polymeric features and graph neural networks, has been developed. This system accurately estimates polymer properties using a database of complex polyesters with experimentally refined properties. The architecture's applicability is demonstrated through a virtual screening of a large, computationally generated database with diverse compositions.

Recommendations

As the library of connections between polymer molecular structures and their known properties expands, the system learns to predict how new polymers can be designed to achieve specific physical characteristics. So, first instead of synthesizing chemical mixture such as acid and glycol embeddings, it is recommended to use the virtual database to desinl and make useful predictions to achieve a desirable material profile..

References

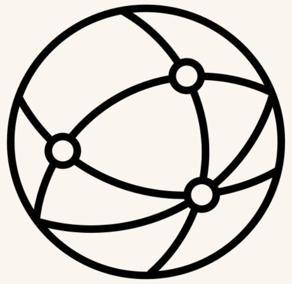
Queen, McCarver & Thatigotla et al., 2023

Methods

Literature review, Graph Neural Network, Neural Architectural Search

CONNECTED TO
C1,T6, H5

AUTHORS
GAYEON KIM



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T6

EFFECTIVENESS OF THE COMPUTATIONAL EXPERIMENT

THIS COMPUTATIONAL MODEL IS HIGHLY EFFICIENT IN PERFORMING RESEARCH. ONCE THE PREDICTION MODEL IS ESTABLISHED WITH THE PREVIOUS SETS OF DATA, THAT CAN BE ALSO APPLIED TO THE ANOTHER SET OF MATERIAL DATA POINTS AND THAT NEURAL NETWORK HELPS TO ACCELERATE THE SPEED OF RESEARCH.

Theoretical Background

AI-based methods are increasingly effective at narrowing down polymer libraries to a manageable selection for experimental investigation. Most current polymer screening approaches rely on manually extracted chemostructural features from polymer repeat units, a labor-intensive task as polymer libraries grow. This study demonstrates that directly "machine learning" important features from polymer repeat units is a cost-effective and efficient alternative. Using graph neural networks, multitask learning, and advanced deep learning techniques, the approach accelerates feature extraction by 1–2 orders of magnitude compared to manual methods, without sacrificing model accuracy. This method facilitates large-scale screening of polymer libraries, advancing polymer informatics.

Recommendations

In situations with limited data, embeddings from a model pre-trained on a task can be used. This GNN demonstrated remarkable accuracy in predicting both properties like critical temperatures for thermal decomposition, melting, and glass transition. So, it is advised to first implement pre-training model to save a lot of time and resource in the early stage of fundamental research before making waste energy and to achieve preliminary profiles like thermal, thermodynamic, physical, and mechanical properties as well.

References

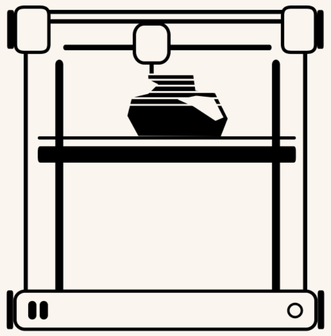
Gurnani, Kuenneth, Toland & Ramprasad, 2023

Methods

Literature Review, Graph Neural Network, Neural Archi-tectural Search

CONNECTED TO
T5, T7

AUTHORS
GAYEON KIM



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T7

ADDITIVE MANUFACTURING (AM) SOLUTIONS FOR COMPLEX AEROSPACE COMPONENTS

AM OVERCOMES GEOMETRIC COMPLEXITY LIMITATIONS OF TRADITIONAL MANUFACTURING, ENABLING EFFICIENT PRODUCTION OF LIGHTWEIGHT, OPTIMIZED AEROSPACE COMPONENTS (SUCH AS BRACKETS).

Theoretical Background

Traditional manufacturing methods are constrained by tool access, mold removal, and high costs when dealing with complex geometries, particularly in topology optimization (Orme et al., 2017). AM technologies, such as laser-based AM, eliminate these constraints, allowing for the creation of weight-optimized shapes that enhance fuel efficiency and reduce emissions (Liu et al., 2018). Additionally, AM can reduce environmental impacts by enabling local production near the use stage, minimizing transportation needs (Kerbrat et al., 2016).

Recommendations

Aerospace industry partners should invest in AM technologies to produce complex, lightweight components more efficiently. They should explore topology optimization in their design processes to maximize material efficiency. Implementing local AM facilities can reduce environmental impacts and streamline the supply chain.

References

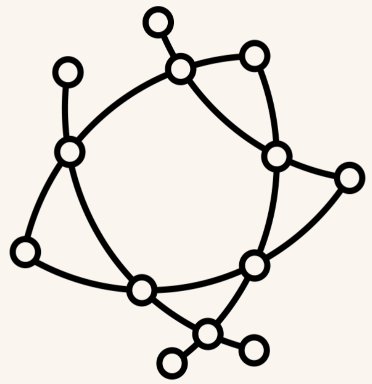
Krebrat, Le Bourhis, Mognol & Hascoet, 2016
Liu, Gaynor, Chen, Kang et al., 2018

Methods

Literature review

CONNECTED TO
T1,T4,T6

AUTHORS
MIRA DE VOOGD



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T8

DIGITAL THREAD FOR ADDICTIVE MANUFACTURING (AM) INDUSTRIALIZATION

DIGITAL THREAD INTEGRATION ENHANCES DATA ACCESSIBILITY, TRACEABILITY, AND DECISION-MAKING, ACCELERATING THE INDUSTRIALIZATION OF AM IN AEROSPACE MANUFACTURING.

Theoretical Background

Digital Thread systems create a connected data framework throughout the product lifecycle, supporting real-time and long-term decision-making (Singh & Willcox, 2018). This integration improves data management, reduces variability, and enhances traceability (Kim et al., 2017). Digital Thread enables effective lifecycle management, which is essential for scaling AM processes to industrial levels (Mies et al., 2016).

Recommendations

Aerospace partners should adopt Digital Thread frameworks to streamline data flow across the product lifecycle. This includes investing in advanced data management systems and real-time monitoring tools to ensure product quality and consistency. Training and development programs should be implemented to enhance workforce skills in Digital Thread technologies.

References

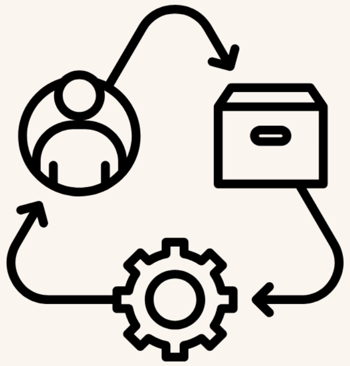
Kim, Witherell & Feng, 2017
Mies, Marsden & Warde, 2016

Methods

Literature Review

CONNECTED TO
B1, T7, T9, G2, C5, H3

AUTHORS
MIRA DE VOOGD



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T9

INTEGRATION OF DIGITAL TECHNOLOGIES FOR SUPPLY CHAIN

THE USE OF DIGITAL TECHNOLOGIES ENHANCES TRANSPARENCY IN THE SUPPLY CHAIN.

Theoretical Background

Digitalization has been transforming the operations of different industries. In this regard, it offers numerous benefits for the supply chains, including improved information visibility, real-time tracking, enhanced inventory management, and increased transparency. For example, blockchain technology is highlighted as one of the most disruptive technologies for supply chains, providing a database for recording all the supply chain transactions (Bigliardi et al., 2022; Hastig & Sodhi, 2020). Keeping information secure and reliable also leads to easier compliance with regulations. As aviation industry include a complex and multi-tier supply network and face a huge demand, its supply chain could benefit from the use of technologies.

Recommendations

To leverage digital tools to enhance overall supply chain monitoring, comprehensive digitalization strategies that align with sustainability requirements are necessary for companies. Key measures include technology assessment, training for stakeholders and the collaboration with suppliers. Continuously monitoring and upgrading digital systems to maintain high transparency standards are important.

References

Bigliardi, Filippelli, Petroni & Tagliente, 2022
Madhwal & Panfilov, 2017

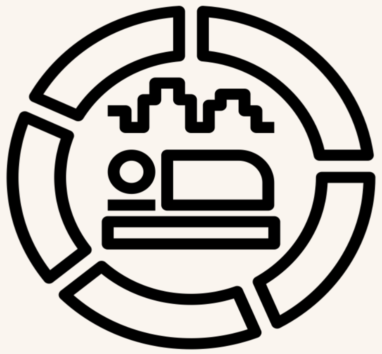
Methods

Literature Review

CONNECTED TO
T8, H3, G2, C5

AUTHORS
CHI-CHI FANG

HUMAN FACTORS



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from Noun Project

H1

CHRONOTYPE LINKED TO PERFORMANCE AND WASTE PRODUCTION AMONG ASSEMBLY WORKERS

PEOPLE WITH EARLY CHRONOTYPE ARE MORE LIKELY TO EXPERIENCE FATIGUE DURING NIGHTSHIFTS AND VICE VERSA. FURTHERMORE, IF THEY ARE FACED WITH A PHYSICALLY OR MENTALLY DEMANDING TASK IN SUCH SHIFTS MISTAKES, ACCIDENTS AND WASTEFUL PRODUCT CREATION ARE MORE LIKELY TO HAPPEN.

Theoretical Background

Our circadian rhythm is a pattern driven by our internal biological clock that operates on an approximately 24-hour cycle. During this period, our physiological parameters, performance, behaviour, and cognitive functions vary.All this entails that, peak performance hours differ from person to person, which can challenge the productivity of shiftwork, alongside raising concerns to safety and risks to errors. When such issues occur during a certain shift, it is often the result of fatigue. Mental fatigue – also known as cognitive fatigue – is characterised by inefficient levels of energy, subjective tiredness, impaired thinking, and concentration

Recommendations

- Education of employes and managers around the topic.
- Effectively schedule breaks during shifts .
- Recommend the usage of smartwatches that have inbuilt sensors and alarms notifying the owner when fatigue indicators are low or high.

References

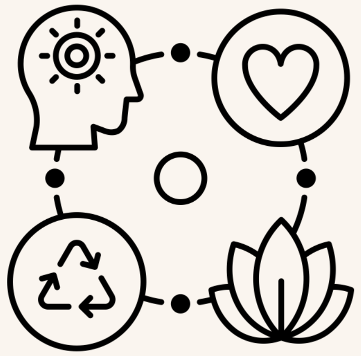
Lee, Gan & Christopoulo, 2021

Methods

Literature Review

CONNECTED TO
G3, H2, H4, T3

AUTHORS
MELÁNIA MOLNÁR



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H2

LIFESTYLE IN RELATION TO ACCIDENTS AND MISTAKES DURING SHIFTWORK IN ASSEMBLY

BIOCOMPOSITES ENABLE MATERIAL RECYCLING, REDUCING EMISSIONS AND AIDING IN ACHIEVING 2050 ZERO-EMISSION TARGETS FOR AVIATION.

Theoretical Background

This study assessed the relationships among chronic fatigue, psychological variables, lifestyle factors, and coping behaviors in shift-worker nurses. Using an exploratory design with 111 eldercare shift-worker nurses who completed self-administered questionnaires in 2006, the study found that mood disturbance, locus of control, and trait anxiety significantly predict chronic fatigue. Poor sleep quality was the strongest lifestyle predictor, followed by higher workload perception, lack of exercise, and lack of support. Problem-focused coping behaviors were not linked to fatigue, but coping strategies involving alcohol use, emotional release, and avoidance were significant predictors.

Recommendations

- Educational workshops for employees about fatigue management through lifestyle interventions.
- The study suggest that improving fatigue outcomes requires identifying high risk profiles and integrating these insights into a comprehensive fatigue management program.

References

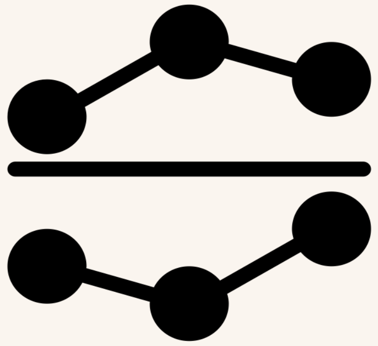
Samaha, Lal, Samaha & Wyndham, 2007

Methods

Literature Review, Prospective Life Cycle Assessment (pLCA)

CONNECTED TO
H1

AUTHORS
MELÁNIA MOLNÁR



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H3

VISUALISING DATA HAS POSITIVE IMPACT ON UNDERSTANDING

USING A KNOWLEDGE GRAPH VISUALISATION WILL ALLOW USERS TO SEE THE MOST RELIED-UPON INPUTS AT A GLANCE, AND READ THE CERTAINTY OF THESE VALUES BASED ON THEIR DESCRIPTIONS. THE USER CAN MORE EASILY INTERPRET THE ACCURACY OF AN ANALYSIS USING GRAPHICS RATHER THAN SPREADSHEET.

Theoretical Background

The hypothesis is based on work showing that visualisations are used to enhance inference, judgement, and decision making. Visualising data improves comprehension and requires less cognitive effort for interpretation compared to textual alternatives. Based on this, a knowledge graph web application that converts simple cost-benefit analyses from spreadsheet to fully interconnected dashboard layout was created. A pilot test was conducted using validated questionnaires.

A positive link was once again established between the readability of data and its visual representation.

Recommendations

Visualising economic models allows decision makers to better understand the data on their own without reliance on external parties. This effectively removes an additional layer of interpretive bias. With this information, any kind of analysis could potentially benefit from the removal of a layer of interpretive bias. This includes LCAs, supply chains, CBAs, CUAs etc.

The recommendation is for corporations and governments to visualise data for ease of readability.

References

Alhadad, 2018
Eberhard, 2021
Stevens, 2023

Methods

Literature Review, Validated Questionnaires

CONNECTED TO
H5, T3, C1, H4, T8, T9

AUTHORS
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Created by MUHAMMAT SUKIRMAN
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H4

RESEARCH INTEGRITY IS BEING THREATENED

PAPERS BEING PUBLISHED ARE FULL OF ACADEMIC FRAUD, INCORRECT CLAIMS, INCORRECT CITATIONS, AND AI GENERATED CONTENT. THIS MEANS THAT ANY CITATION IS SUSPECT AND YOU SHOULD NEVER TAKE CLAIMS AT FACE VALUE.

Theoretical Background

In today's scientific literature, justification for nearly every belief can be found. This includes contradicting beliefs. The current peer review process is insufficient to catch errors and the majority of academic authors favour expediency over understanding; reading just the abstract or conclusion of a paper and citing it based on that.

An example relevant to the lab would be the claim that hydrogen combustion reduces NOx pollution in jet propulsion, which, based on peer reviewed literature is both justifiably correct and incorrect.

Recommendations

A straight forward solution would be a more rigorous understanding of the sources being cited and the claims being made. This requires significantly more investment than simply citing a source based on track record of trust or the esteem of an institution. Researchers must critically assess the methodologies, context, and relevance of their sources, verify claims through cross-referencing multiple reliable sources, and transparently document their evaluation processes.

References

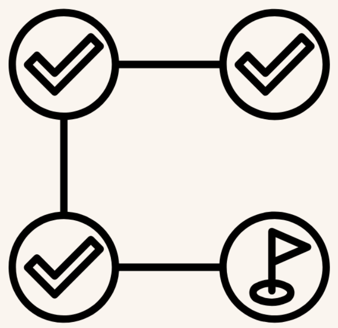
Del-becq, Fontane, Gourdain, Mugnier et al., 2022
Goldmeer, 2021

Methods

Literature Review

CONNECTED TO
G3

AUTHORS
JENS VAN DEN BERG



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H5

ANALOGIES FOR SUSTAINABLE MATERIAL INNOVATION

ADAPTING SUSTAINABLE MATERIALS IN THE AIRCRAFT INDUSTRY BY DRAWING INSPIRATION, IDENTIFYING SIMILARITIES, AND SYNTHESIZING PRACTICES FROM OTHER INDUSTRIES AS A WAY TO APPROACH AIRCRAFT MATERIAL INNOVATION.

Theoretical Background

Analogies not only explain new ideas but can also inspire innovative solutions by highlighting structural similarities across domains. This dual role of analogies in explaining and inspiring underscores the utility in scientific discovery and problem-solving. The similarities can be at product level, feature level, manufacturing level or at the Business level. By leveraging existing solutions, companies can significantly cut down the time needed for research and development. This speedier process helps in getting products to market faster without risk.

Recommendations

- Identifying parallels with the architectural and automotive industries.
- Taking insights from material selection processes such as New material selection process by Mike Ashby and Karan Johnson.
- Drawing inspiration from art galleries and artworks.

References

Chou & Shu, 2015
Gassmann & Zeschky, 2008

Methods

Literature Review

CONNECTED TO
T1, T5, B3, G3, H3

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NEW BUSINESS MODELS

Created by Naya Putri
from Noun Project

B1

COST-BENEFIT ANALYSIS IS (STILL) A USEFUL TOOL FOR TRANSPARENT DECISION MAKING

COST-BENEFIT ANALYSIS (CBA) IS A ROBUST AND RELIABLE FRAMEWORK FOR ECONOMIC DECISION-MAKING. IT STANDARDIZES ECONOMIC MODELING BY USING MONETARY METRICS, ALLOWING FOR DIRECT COMPARABILITY BETWEEN REPORTS. THIS CONSISTENCY ENABLES THE INTEGRATION AND INTERCHANGEABILITY OF DIFFERENT ANALYSES, ENHANCING THE OVERALL RELIABILITY OF THE SYSTEM AS COMPARED TO HETERODOX METHODS.

Theoretical Background

CBA provides a standardized framework using monetary metrics, which allows for comparability and integration across various analyses. However, CBA's focus on quantifiable financial data often overlooks non-monetary costs and benefits, such as environmental impact, social welfare, and long-term sustainability. Critics argue that this narrow focus can lead to incomplete or skewed conclusions.

Recommendations

The solution is not to discard CBA in favour of entirely different economic models, but to complement it with additional methods that account for these broader impacts. By acknowledging the limitations and integrating other perspectives, policymakers and economists can enhance the robustness of their analyses and make more informed decisions.

Incorporating tools like Multi-Criteria Analysis (MCA) or Cost-Effectiveness Analysis (CEA) alongside CBA can provide a more comprehensive view. These tools can address the qualitative and less tangible aspects that CBA might miss, offering a fuller picture of the potential impacts of a decision.

References

Beria, Maltese & Mariotti, 2012
James & Predo, 2015

Methods

Literature Review

CONNECTED TO
C1, T1, C2

AUTHORS
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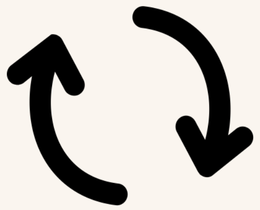

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B2

CIRCULAR BUSINESS MODELS SHOULD FOCUS ON REUSING MATERIALS OR COMPONENTS

CIRCULAR BUSINESS MODELS (CBM) THAT FOCUS ON REUSING MATERIALS OR COMPONENTS, WITH AS LITTLE ADAPTATION/PROCESSING AS POSSIBLE, ARE PREFERRED SINCE THEY ALLOW FOR MINIMAL LOSS OF QUALITY AND PREVENT DOWNCYCLING.

Theoretical Background

Currently, there is a high focus on recycling materials as part of a circularity strategy (round-table discussion). However, in the 10R strategy designed by Potting et al (2017), which is an expansion of the R framework, recycling should not be the highest priority to achieve circularity. First, reducing the amount of product/material should be prioritized, but also the reuse of materials and products or remanufacturing. Recycling is low on the list because it usually requires high energy use to accomplish and can potentially lead to a loss of quality in materials and resources.

Recommendations

CBM should focus on reusing materials in their original state as much as possible, which allows for minimal resource use in between uses of the product/materials. This also means that for new products, this reuse should be kept in mind in the design process, so they can be reused with minimal adaptations. Recycling should only be used if the products cannot be reused or remanufactured, to keep the value of the materials. Additionally, it is important to mention that downcycling should be prevented as much as possible.

References

Potting, Hekkert, Worrell & Hanemaaijer, 2017

Methods

Literature Review, Semi-Structured Interviews

CONNECTED TO
B3, T2, T3, T4, G1, C3

AUTHORS
CHRISTEL DONKER

B3

IMPROVING END OF LIFECYCLE OF AIRCRAFT INTERIOR PARTS

Created by tezar tantular
from Noun Project

BIO-BASED MATERIALS OFTEN OFFER A RANGE OF DISPOSAL OPTIONS, INCLUDING COMPOSTING, ANAEROBIC DIGESTION, AND RECYCLING. THIS FLEXIBILITY CAN ENHANCE WASTE MANAGEMENT PRACTICES OF AIRCRAFT INTERIORS.

Theoretical Background

Airbus, in its Global Market Forecast (GMF) for the period 2023-2042, has established a view of future air traffic and fleet evolutions. Nearly 40000 new aircrafts will be introduced by 2042. A plane's exterior may age gracefully and remain structurally sound. But airline interiors don't stay factory fresh for long and needs to be changed every 3-7 years.Today, a new class of highly performant materials bio-composites are emerging to offer more exciting possibilities for improved environmental performance as engineers aim to unlock their potential for use in future aircraft. Increasingly used in industrial applications due to their numerous advantages, bio-composites are lightweight, flexible, cost-effective, and recyclable. (Airbus, 2022)

Recommendations

1. Material Selection: Opt for environmentally friendly materials with lower carbon footprints, with reduced environmental impact.
2. Weight Reduction: Explore Bio based materials promise to be lightweight without compromising safety.
3. Lifecycle Assessment: Conduct a comprehensive lifecycle assessment to identify environmental hotspots and areas for improvement throughout the entire lifecycle of the interior components.
4. Collaboration and Innovation: Collaborate with manufacturers and designers to explore innovative solutions and technologies that promote sustainability in aircraft interior design.

References

GMF, 2023

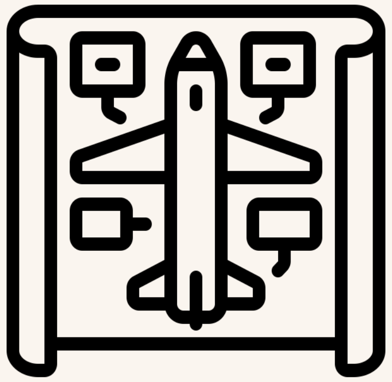
Methods

Literature Review

CONNECTED TO
C1, T4, H3, H5, B2, C4,T8, G2, T2, G3, G1

AUTHORS
CHINMAYI NARASIMHA

GOVERNANCE



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from Noun Project

G1

LACK OF END-OF-LIFE REGULATIONS FOR AIRCRAFT

THE LACK OF REGULATION REGARDING END OF LIFE OF AIRCRAFT PROVIDES AN OPPORTUNITY FOR MANUFACTURERS TO VOLUNTARILY IMPLEMENT NEW PRACTICES REGARDING THE END-OF-LIFE OF AIRCRAFT.

Theoretical Background

Aircraft design must be safe for public use. In the EU, the European Union Aviation Safety Agency (EASA) ensures high, uniform civil aviation safety (Regulation (EU) 2018/1139). To be considered safe, an aircraft design must comply with Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (CS-25), particularly Subpart D. This section mandates that the aircraft "may not have design features or details that experience has shown to be hazardous or unreliable" (CS 25.601 General). Therefore, manufacturers do not need to consider the aircraft's End-of-Life during design due to no legal obligation. Upon retirement, airworthy parts are recovered, and the rest are reused, recycled, or sent to landfills (EASA, 2022).

Recommendations

Even though there is no legal obligation to design an aircraft with consideration for its End-of-Life, it is estimated that in the next decade, more than 11,000 aircraft will be retired (IATA, n.d.), thus, developing voluntary guidelines for dismantling information to be handed over to the customer or the disassembly company will be useful at the time of the aircraft's decommissioning. This information will help the scrapper optimise the use of materials contained in the aircraft for recycling.

References

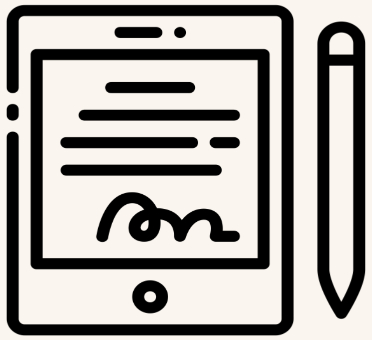
European Union Aviation Safety Agency, 2020
International Air Transport Association, n.d.

Methods

Literature Review

CONNECTED TO
C2, B3, B2, T3, T8, C4

AUTHORS
MARCELO TALIA MORENO



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G2

CONTRACTUAL CLAUSES IN THE CHAINS OF ACTIVITIES

THE INTRODUCTION OF NEW CONTRACTUAL CLAUSES WICH OBLIGE THE SUPPLIER TO UTILISE NEW TECHNOLOGIES IN THE SUPPLY CHAIN WILL PROMOTE THE ADOPTION OF MEASURES REQUIRED TO COMPLY WITH HUMAN RIGHTS AND ENVIRONMENTAL LAWS.

Theoretical Background

Manufacturers rely on information from their suppliers, often shared through paperwork, which increases costs and limits information availability and accessibility. Digitalization allows real-time customer access (Muduli et al., 2022). The Corporate Sustainability Due Diligence Directive (CS3D) mandates that companies address human rights and environmental impacts in their operations and those of subsidiaries and business partners. Article 10 of CS3D requires companies to seek contractual assurances from direct business partners to ensure compliance with the company's code of conduct. Thus, companies must include new contractual obligations with suppliers to align their operations with the company's code of conduct.

Recommendations

Since the manufacturing process requires a lot of raw materials that need to be extracted, such extractions must be done with accordance to the law. The company can implement new provisions in their contracts with their suppliers regarding the documentations they have to hand over to the company to prove compliance with the CS3D. To do so, the supplier can utilise new technologies that are ready available in the market to provide all the detailed information required to comply with the provisions of the new CS3D by the time it will be implemented. Moreover, if the supplier is a small or medium-sized enterprise (SME), following article 10(2) (e) of the CS3D, the company shall provide assistance to the SME in order to comply with their obligations.

References

Muduli, Raut, Narkhede & Shee, 2022
European Parliament, 2024

Methods

Literature Review

CONNECTED TO
T8, C5, B3, T9

AUTHORS
MARCELO TALIA MORENO

Created by Nithinan Tatah
from Noun Project

G3

COLLABORATION BETWEEN COMPANIES AND RESEARCH INSTITUTIONS

OPENLY SHARING DATA AND RESEARCH FINDINGS ON SUSTAINABILITY PROJECTS WILL ACCELERATE THE RESEARCH PROCESS FOR STUDENTS.

Theoretical Background

Organizational cultures between universities and industry can pose significant barriers to collaboration. Universities often prioritize academic research and publication, while industry focuses on commercialization and profit, leading to misalignment of goals and values. Unclear ownership rights and complex licensing agreements may discourage companies from investing in collaborative research projects with universities.

Recommendations

1. Establishing transparent and equitable intellectual property policies that clarify ownership rights and confidentiality in a fast manner.
2. Sharing datasets publicly available through online repositories or platforms to facilitate knowledge exchange and collaboration among stakeholders.

References

Rothaermel, Hitt & Tyler, 2001
Boardman & Bozeman, 2007
Ratinho, Henriques & Muñoz, 2018

Methods

Literature Review, Stakeholder Interview

CONNECTED TO
B3, H5, H4, C3, H1, C5

AUTHORS
CHINMAYI NARASIMHA

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