Design for Repurposing
Of Composite Products

Appendices

Master Thesis | Parshva Mehta

ECOBULK

TUDelft

Master Thesis

July 2021

Author

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Msc. Integrated Product Design,
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Delft University of Technology

Chair

Erik Tempelman

Faculty of Industrial Design Engineering
Delft University of Technology

External Mentor

Irene Fernandez Villegas

Faculty of Aerospace Engineering
Delft University of Technology

Mentor

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Faculty of Industrial Design Engineering
Delft University of Technology

Project EcoBulk

European Union's Horizon 2020

Research and innovation program
Grant agreement No 730456

TU Delft

ECOBULK

Table of Content

A.1 Project brief

IDE Master Graduation

Project team, Procedural checks and personal Project brief

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

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

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

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

family name: Mehta
initials: PK given name: Parshva
student number: 5000610
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ○ DfI ○ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ○ Honours Programme Master
specialisation / annotation: ○ Medisign ○ Tech. in Sustainable Design ○ Entrepeneurship

SUPERVISORY TEAM **

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

** chair: Erik Tempelman dept. / section: SDE/ MM
** mentor: Jelle Joustra dept. / section: SDE/ CPD
2nd mentor: Irene fernandez villegas
organisation: Faculty of Aerospace Engineering
city: Delft country: Netherlands

comments (optional): Role of the Prof. Irene is tc provide the required perspective and connection relating to the composite products used in Aviation.

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

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

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

APPROVAL PROJECT BRIEF

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

chair Erik Tempelman date 01 - 03 - 2021 signature _____

CHECK STUDY PROGRESS

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

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

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

YES all 1st year master courses passed

NO missing 1st year master courses are:

name _____ date - - signature _____

FORMAL APPROVAL GRADUATION PROJECT

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

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name _____ date - - signature _____

Initials & Name PK Mehta Student number 5000610

Title of Project Design for re-purposing of composite materials

TU Delft

Design for re-purposing of composite materials

project title

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

start date 08 - 02 - 2021 22 - 07 - 2021 end date

INTRODUCTION **

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

Since their introduction in the 1950s, fibre-reinforced polymers, also known as composites, have steadily been growing in importance. Recent "breakthrough applications" include the BWM i3 city car, the Boeing 787 Dreamliner aircraft, and less well known but equally impressive in its market – The Velosione e-bike.

A key drawback of these materials is their inherently reduced recyclability as compared to homogeneous materials, such as metals, plastics, and glass. At lab scale (and occasionally, in the real world), composite waste generated during manufacturing can be recycled quite well, but always with significant performance and value loss due to the inevitable fibre break-up, which holds equally for thermoplastic and thermosetting composites. Although Considering the end of life material waste, recycling is still under investigation. One way around this problem is repurposing: here, the aim is to keep the material intact and basically reuse its shape and remaining strength for a different, new product. At the end of the first life, there are still potential left in the composite product, sufficient enough for the other products. This comparatively new route will be explored in this MSc graduation project. The focus will be on thermoplastic composites, as these can be reshaped (e.g. with over-moulding techniques) to unlock new possibilities.

To allow upscaling, the additional issue of logistics demands, the availability of materials in the value chain must be tracked, including material types, shapes and sizes, and condition. One promising way to do this is by using existing PLM software (from "product life-cycle management").This topic will, therefore, also feature in this MSc project. The result of the graduation project will be shared with the Eco-bulk EU-funded research programme. The project's mentor Jelle Joustra, himself active in this programme as part of his PhD work on composite recycling, will ensure the link to Eco-bulk. Furthermore, the project's chair Erik Tempelman brings along his know-how and know-who of this topic, as well as PLM contacts that are ready for use.

This topic will, therefore, also feature in this MSc project. The result of the graduation project will be shared with the Eco-bulk EU-funded research programme. The project's mentor Jelle Joustra, himself active in this programme as part of his PhD work on composite recycling, will ensure the link to Eco-bulk. Furthermore, the project's chair Erik Tempelman brings along his know-how and know-who of this topic, as well as PLM contacts that are ready for use.

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introduction (continued): space for images

Emerging use of composite material in transportation sector

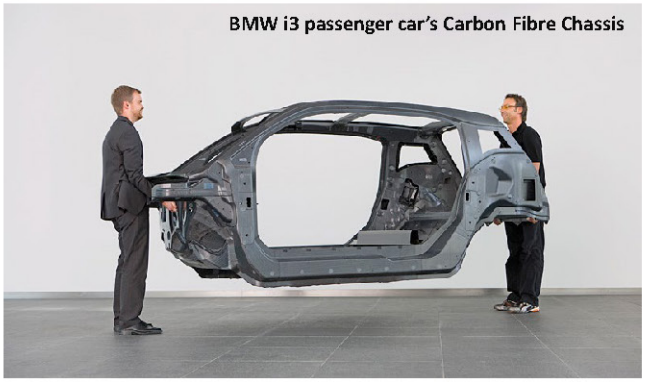


image / figure 1: Stakeholders & LifeCycle of Airoplane

image / figure 2: Aeroplane: End of life

PROBLEM DEFINITION **

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

With no concrete regulation on end-of-life waste management in the Aviation sector, the composite material waste from decommissioned aircraft goes into the incineration process or land filling. Due to high-quality demand in airlines, the discarded composite material used in parts has still the potential left to serve an additional life. With a new generation of aircraft using more than 50 % of material from polymer composite material, it is necessary to look for an approach to utilise the material to its full potential using a repurposing approach.

For sustainable end-of-life treatment, it is crucial to have the composite material status during the decommissioning stage. As passenger Aircraft goes through multiple stakeholders in its 20-30 years, there is a need for a material passport to document the vital information such as type of material, manufacturing, service, and maintenance throughout its life. With the intense competition and legal issues in the aviation industry, there is a need for an integrated approach where the platform can be designed to improve the inefficient end of the life process.

For this graduation project, research and result will be focused on the thermoplastic polymer composite. Additionally, with one of the largest consumer of composite material, the Aviation industry will be the focus of the project to demonstrate the case study.

ASSIGNMENT **

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

The primary goal of this graduation is to design the process that can take advantage of repurposed polymer composite material originated from decommissioned products. This process's focus will be to provide a design solution that should be scalable enough to compensate for the amount of massive waste predicted in the future.

The project will be initiated with the literature study on polymer composite and the various products using it. Later, Stakeholder interviews will be conducted to understand the current scenario and their concern. These tasks will provide a foundation for the solution and further steps to be taken. Additionally, a demonstration of the case study will be prepared using PLM software showcasing data input during the various stages of the product during its initial life. This aims to provide the required data to End-of-life solution providers for efficient and hassle-free repurposing of composite material.

After observing composite aircraft parts, physical properties (strength, shape and structure) will be evaluated, with conclusions to find the possible repurposed solution. A small case study will be prepared to demonstrate the process of repurposing the decommissioned products and using their material and shape characteristics to replace parts/materials in existing products (e.g. using the decommissioned CFRP panels from aircraft for over-bridge flooring). The case study will be evaluated (Desirability, viability & Feasibility) at a later stage during the co-creation session(s) with several experts and stakeholders from multiple industries. As a final deliverable, guidelines will be formulated with a similar process, including various enablers to implement the repurposing of products made out of polymer composite material at the scalable market.

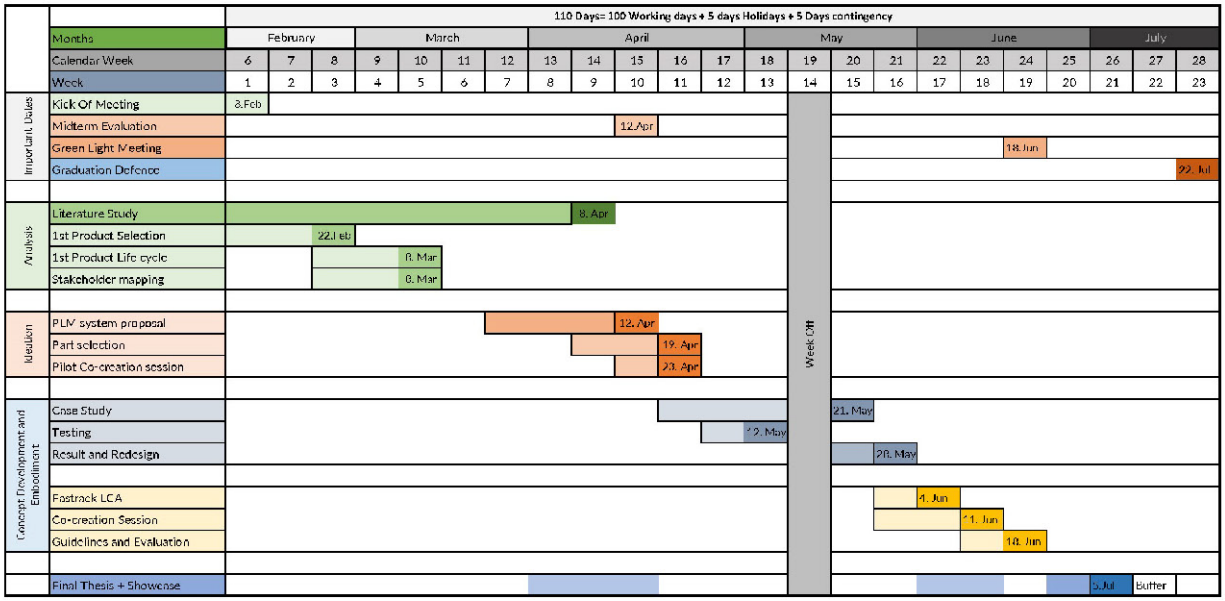
Initials & Name PK Mehta Student number 5000610

Title of Project Design for re-purposing of composite materials

PLANNING AND APPROACH **

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

start date 8 - 2 - 2021 22 - 7 - 2021 end date



Project Duration= 08/02/2021 to 22/07/2021
110 Days= 100 Working days + 5 days Holidays + 5 Days contingency

The above plan illustrates the various phases and deliverables in the project. Phases are divided into weeks which contains activities depending on the deliverables. The plan will be modified as the project will proceed with results obtained at each stage.

Every week meetings will be planned to update the progress of the graduation project with the supervisory team. Additionally to provide necessary insights from Aerospace Sector, Prof Irene fernandez villegas from faculty of Aerospace Engineering will be consulted regularly.

The tentative dates:

Kick off meeting: 8th Feb. 2021
Midterm evaluation: 12th April 2021
Green Light Meeting: 18th Jun 2021
The graduation defence: 22nd July 2021.

Initials & Name PK Mehta Student number 5000610

Title of Project Design for re-purposing of composite materials

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Coming from India and with a Mechanical engineering background, I have a different perspective on manufacturing and recycling. With minimal development in sustainability in manufacturing, I have seen landfill and poor waste management, making these project very attached to my cultural vision.

Through the last six projects in TU Delft, I have tried to choose the project that will improve the current situation employing design and technology. I want to work with these problems through the Graduation project on a larger scale where the issues are tangled with numerous sub-problems. In the future, I want to be a part of an organisation where I can use my multidisciplinary background in engineering and design. As the manufacturing and recycling process of composite material is complex and requires more resources, I find this graduation project a platform to implement my knowledge from a Mechanical Engineering background and Industrial Design engineering knowledge.

During the graduation project, I also want to enhance my project management and service design skills. Along with that, I would like to broaden my experience in designing and prototyping with composite materials.

FINAL COMMENTS

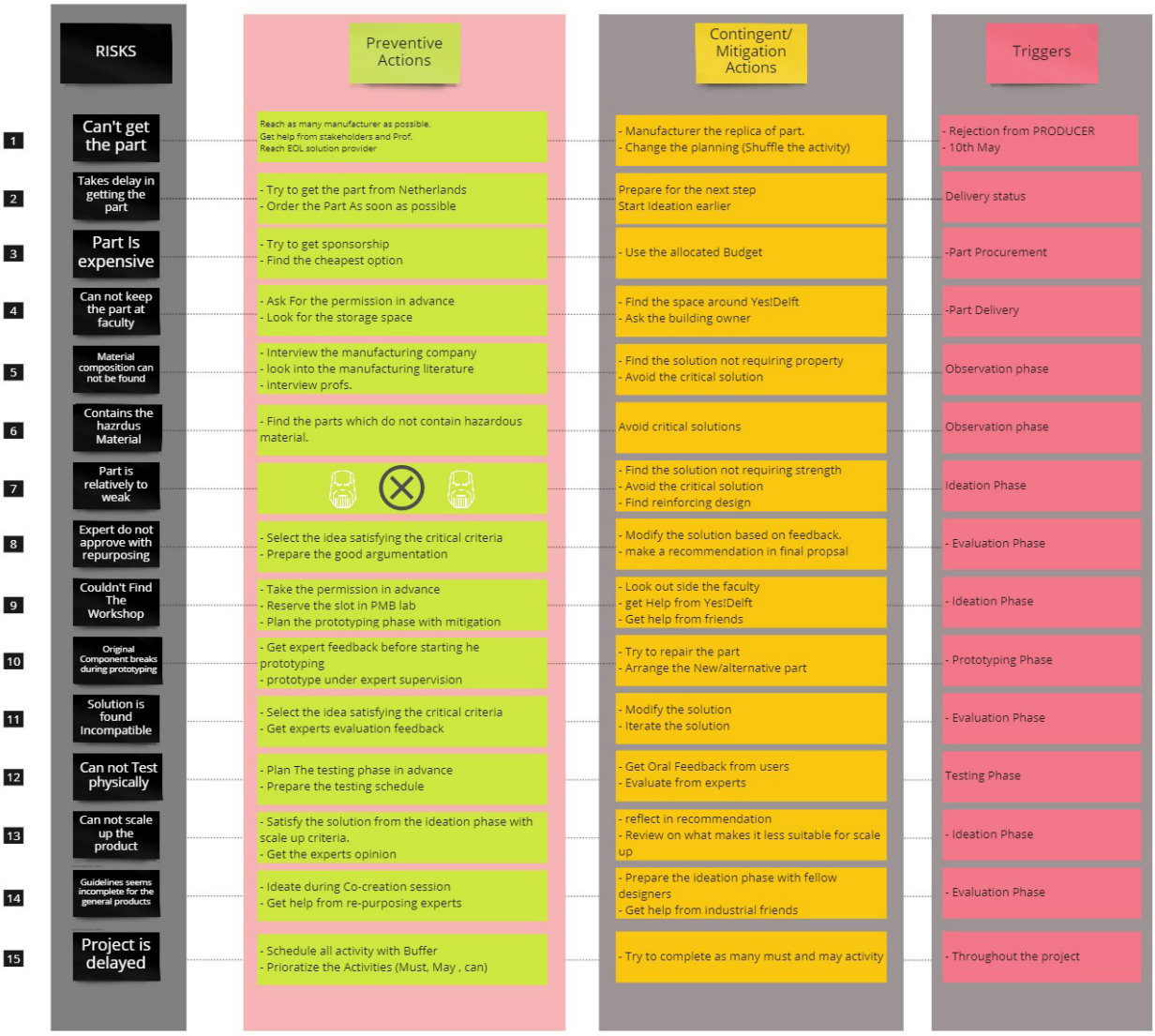
In case your project brief needs final comments, please add any information you think is relevant.

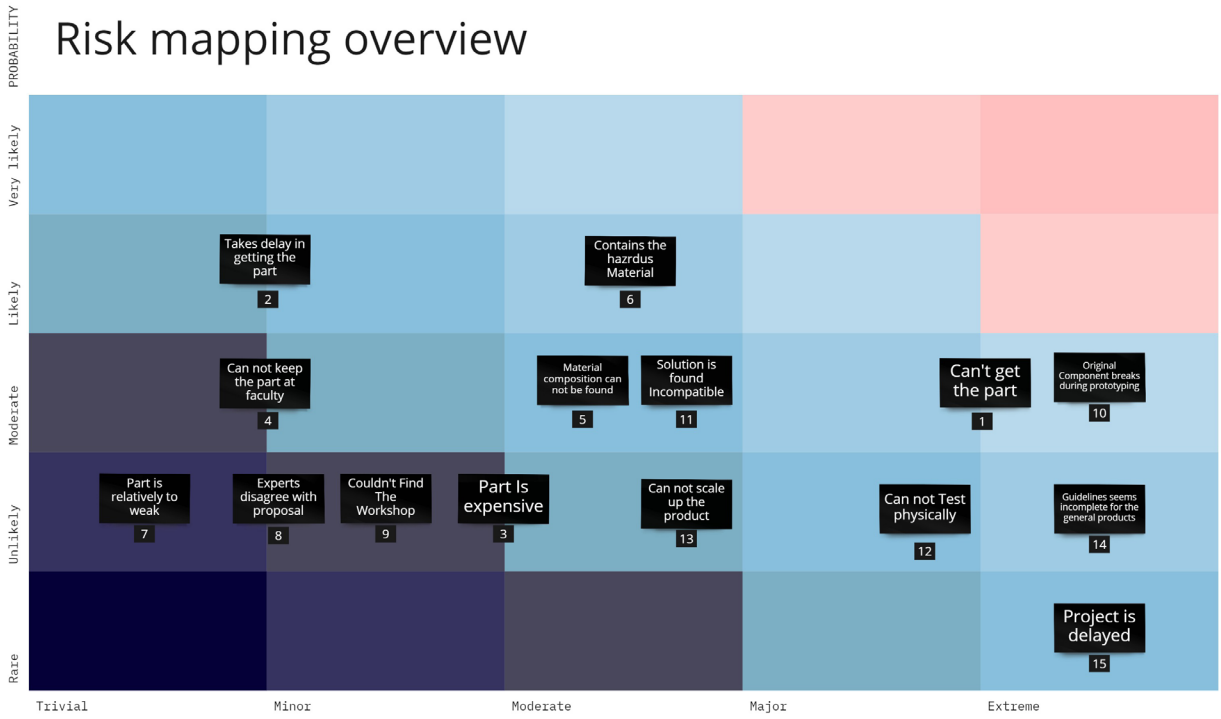
Initials & Name PK Mehta Student number 5000610

Title of Project Design for re-purposing of composite materials

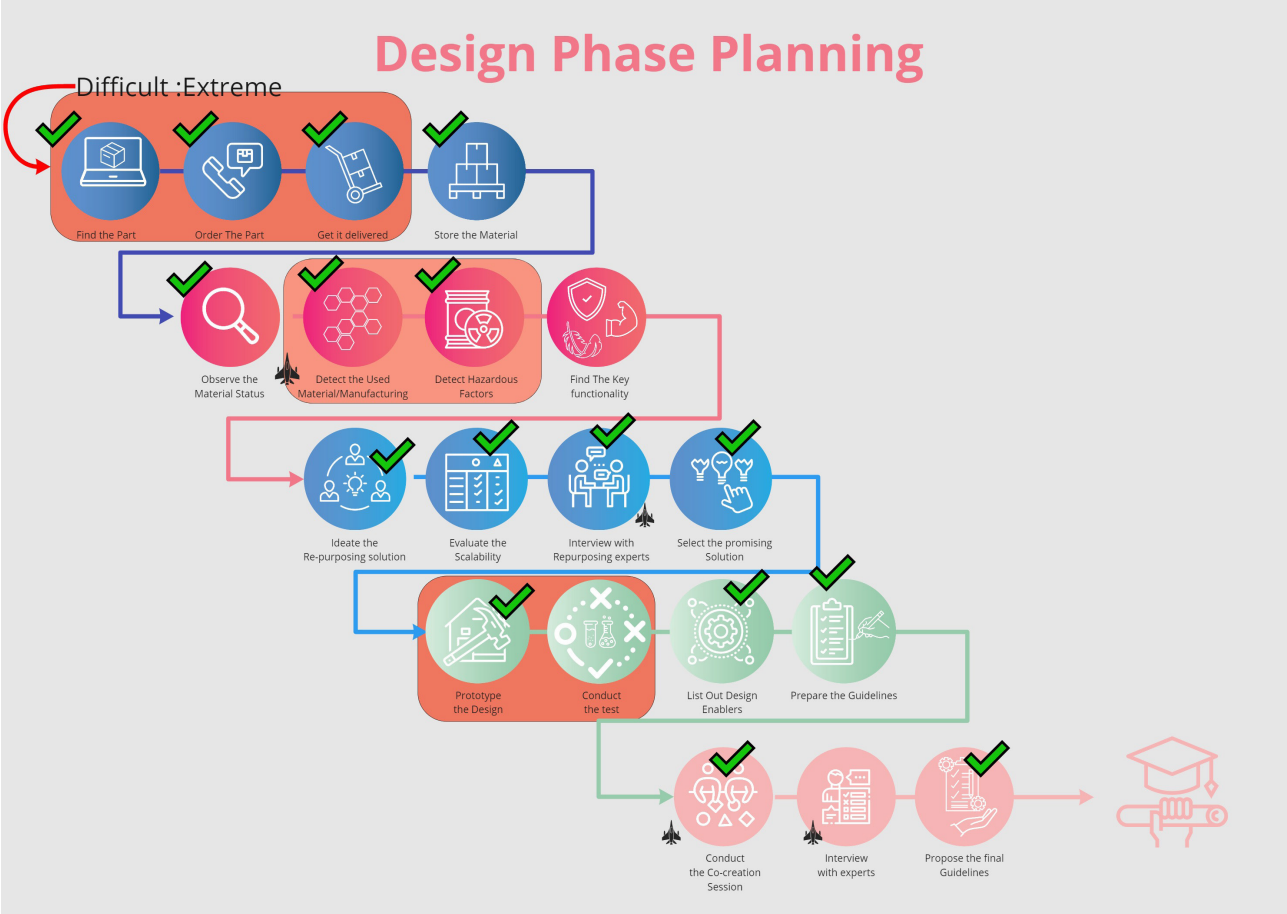
A.2 Project Planning

Risk mapping





Project Planning



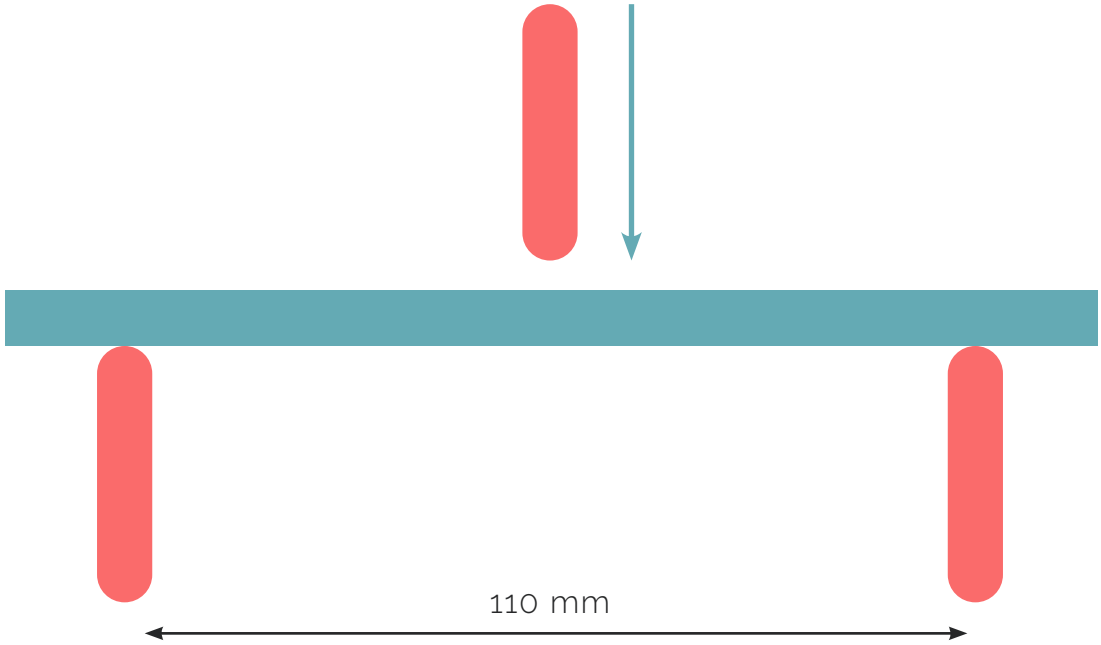
A.3 Case Study

A.3.1 Adhesive remova through heat gun

https://youtu.be/2XrFUw-ailg

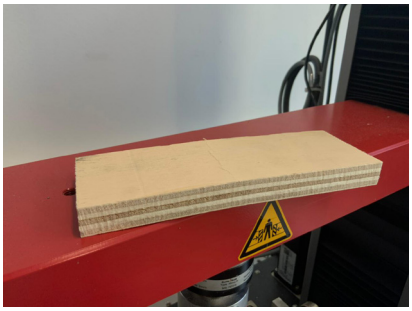
A.3.2 Material Testing

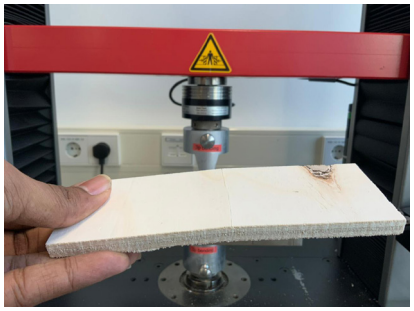
Test Standard: ATSM 3939
Setup

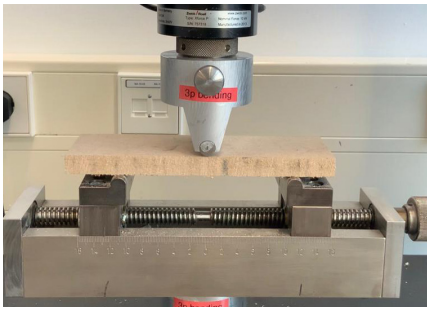


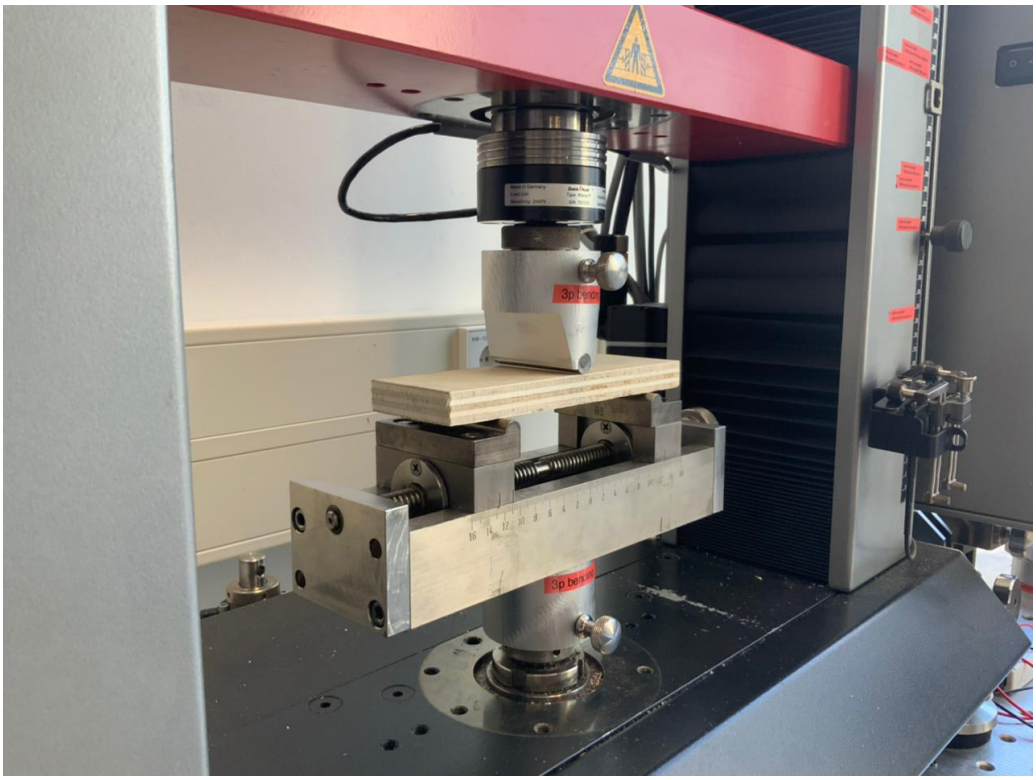
width of coupon: 60 mm

Wooden Samples:



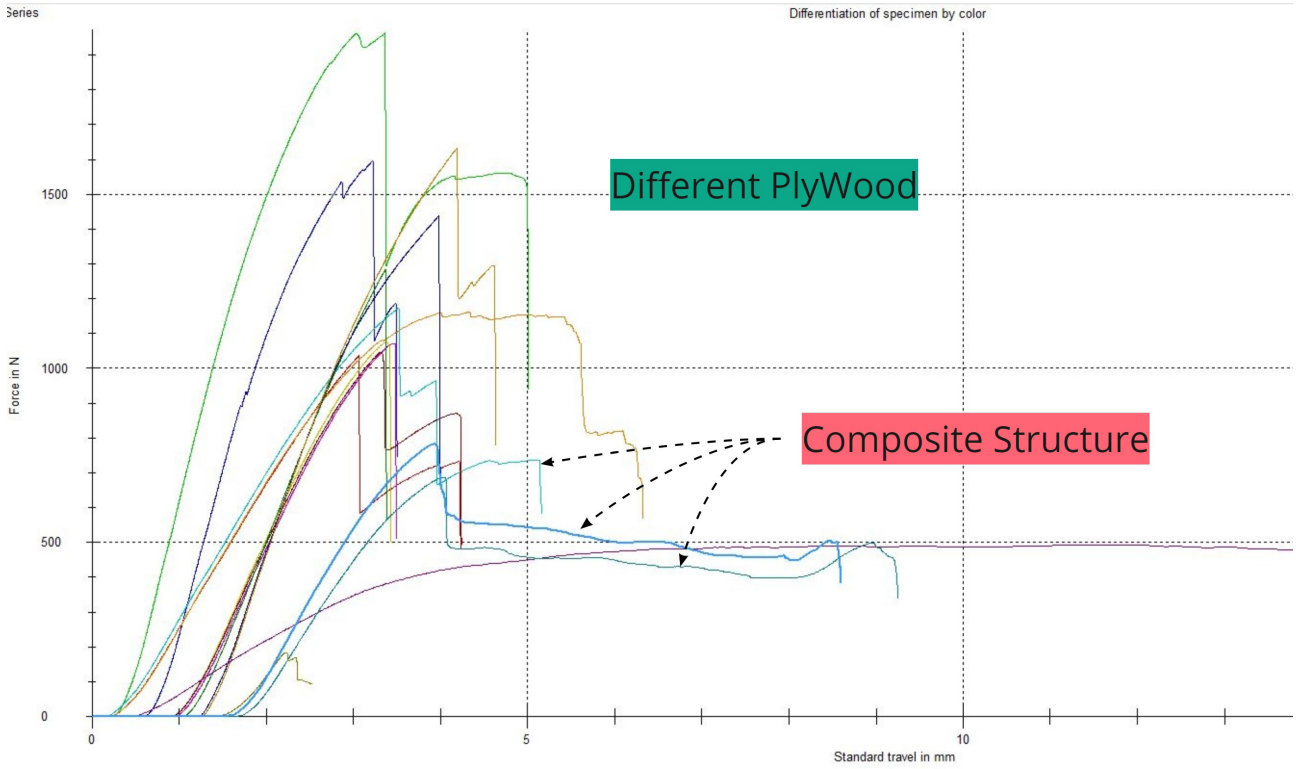






Test setup

Broken sample


Series
Differentiation of specimen by color
Different PlyWood
Composite Structure
Force in N
1500
1000
500
0
0
5
10
Standard travel in mm

Test result

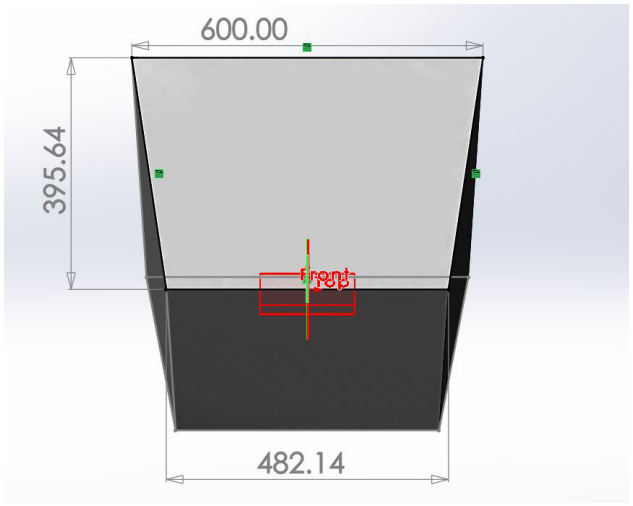
A.3.3 Prototyping

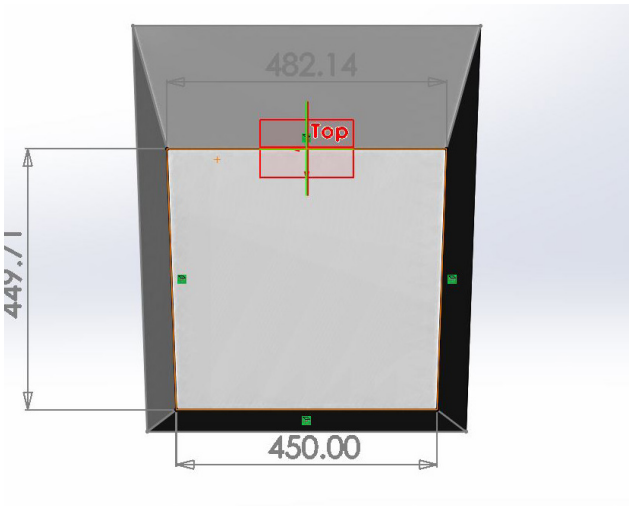
Reference

Reference bike

Reference bike

Cad model



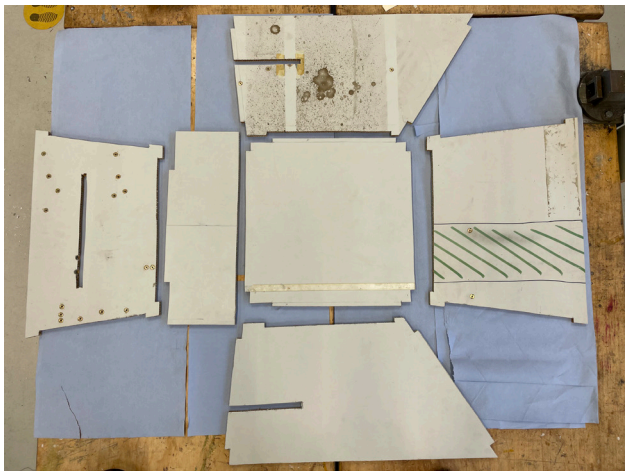


CAD model from actual bike

building the final cart

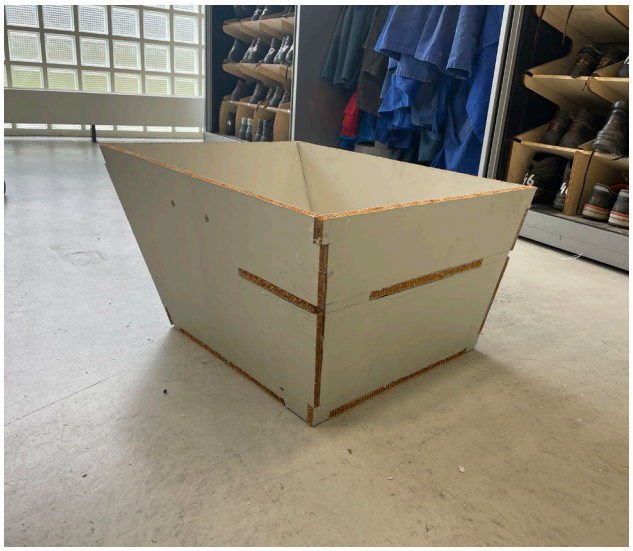
Band Saw

Poly Max clear adhesive



Sepererated panels

Applying adhesive



Bonded cover

Branding

A.4 Cocreation session

A4.1 Participants

Attendees of co-creation session

Erik Tempelman:
Associate professor at Faculty of Industrial Designer Engineering, TU Delft

Erik has experience in innovation, research and education at the crossroads of design, materials, sustainability, and manufacturing. With his expertise in design, manufacturing and Sustainability, Erik is the Chair of the supervisory committee of this graduation project.

Irene Fernandes Villagas:

Associate professor at Faculty of Aerospace Engineering, TU Delft.

Irene has 18 years of experience in polymer composite welding technology and is the mentor of this graduation project

David Peck:
Associate professor at faculty of Architecture and building technology.

David's years of experience covers Sustainability challenges, Critical product design and Governmental policy. David has also experience working as a project manager at Lucas Aerospace

Bart Mooij:
Senior Material and Process Expert at Safran Cabin
Being a sponsor of the aircraft galley for the project, Bart was invited to the session as a Stakeholder representing the composite manufacturer.
Eduard Eijkman and Dragos Dascalu:
Industry process consultants at Dassault,

Working with several industries to implement Dassault's PLM software, Eduard and Dragos have experience with implementing the upcycling program assisted by PLM software.

Arun Junai:
European Research and Innovation Professional
Working with European Affairs to formulate strategy, prepare program/ technology roadmaps, and propose proposals, Arun provided the project with insight needed to make it feasible and viable for implementation.

Naga Gautham:
Masters Student, industrial Ecology, TU Delft and University Leiden

Naga is working on his master's project focusing on Industrial ecology and circular economy with experience in Industrial engineering.

Pranav Gawde, Atula Jadhav, Thomas Kandavil Abraham
Master's Student, Faculty of industrial design Engineering, TU Delft

Pranav, Atula and Thomas were invited to the co-creation session as Industrial designer representing the primary users of the repurposing guidelines.

Pranav Gawde, Atula Jadhav, Thomas Kandavil Abraham
Master's Student, Faculty of industrial design Engineering, TU Delft

Pranav, Atula and Thomas were invited to the co-creation session as Industrial designer representing the primary users of the repurposing guidelines.

A4.2 Link to miro Board

https://miro.com/welcomeonboard/VjR0NXRDbUZrOEEzWDJtZ2kxWTF-PU1N0alJYRG9nTTUwY1dRVFVwVjhHaTM4emxMTUR6SnU4NUVPeVlGbkxDY-3wzMDc0NDU3MzQ3NzU1MzMxNzgw

A4.3 Activity

Activity 1: Evaluate the repurposing guidelines with all the participating stakeholders

Activities:

00-05 mins:
A brief introduction to the project by Erik and introducing participants, facilitator and co-facilitator.

05-15 mins
Introduction and presentation to the graduation project and description of activities.

15-25 mins
Ice breaker session to get the participant comfortable in using the miro board and kickstarting the session with interacting activity such that later participant can easily communicate with Miro board platform

25-45 min
Reviewing the draft guidelines:
Participants were asked to go through the guidelines considering themselves as a stakeholder and give feedback by writing the feedback on Miro board or opening the discussion, Aim of the activity was to get the review from the potential user of this guidelines. Later, Industrial designers were asked to give their opinion on guideline after the workshop.

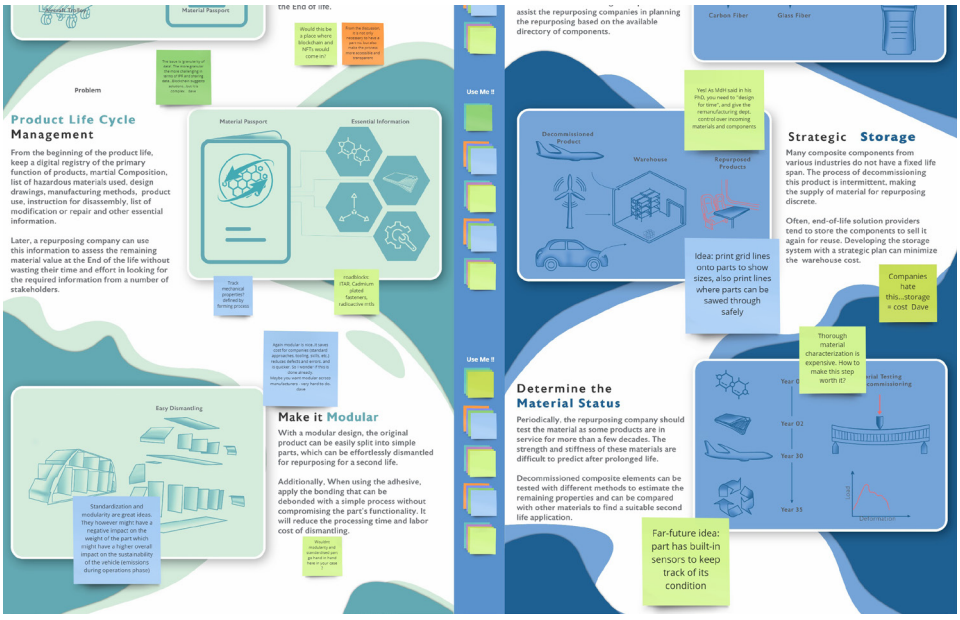


Fig 4.2 Guideline review during co-creation session

Outcome

The activity was concluded with constructive feedback (Fig. 4.2) from the participants. One of the major discussion that getting everyone's attention was guidelines focusing on the design phase regarding the standardization of parts. Concerns were raised about the impact of standardization and modularity on high-performance composite products in aircraft composite having a complex shape. The part identification was related to blockchain and NFT. One of the positive impact mentioned in identification guidelines were making the process more transparent and accessible with PLM software. Further, participants asked for clarification on a clear separation between key players involved in the process.

As expected some of the participants also mentioned few automation processes which can accelerate the transition phase such as using virtual reality for dismantling process or creating a process which can assist the workers. Some of the stakeholders also indicated their concern regarding the economical side of the repurposing and marketing plan. Arun Junai also mentioned some of the new guidelines which should be added focusing on the consumer perspective such as aesthetics and expectation of consumers.

45-50 mins

Participants were then given 5 min break to refresh them-self and prepare for the next activity.

50-80 mins

Participants were divided into two teams, stakeholders and design engineer. 1st team involves the participant having experience working with composite material, PLM software and Circular economyand were asked the following questions.

1. To make effortless repurposing of the Aircraft composite Galley for Industrial designer, What kind of information will you seek from the various product life cycle stages?

This question aimed to collect the opinion of stakeholders regarding the PLM software and the information they find essential from initial product life.

Outcome:
In addition to the required information mentioned in the PLM chapter, participants suggested including skills which are required by the decommissioning worker to dismantle the entire composite product after the end of the life. The other important element discussed during this activity was the inclusion of Product weight which can provide information concerning sustainability.

2. What repurposing application or sector will be best suited for composite panels?

The goal of this activity was to observe if Industrial designers can remember the information provided to them from guidelines.

Outcome:
As a positive outcome, participants suggested the application from the automobile sector, transportation and temporary film sets where such products are continuously moved from location to location. This show that, by keeping the guidelines, Designers can find the application which will take advantage of high strength to weigh the property of composite material..

3. To repurpose a product out of the galley, we have to disassemble the original galley. The galley contains a bonded panel and many hidden inserts. Usually, it takes a working day to dismantle it. To maintain the economic value, we have to find the application/ process which can create higher value than disassembly and processing cost.

By solving this design task, the co-creation session can prove that designer can determine the strategy to keep the economical value of repurposed product high enough to market the product.

Fig 4.3 Co-creation activity 2

Outcome:
Few of the strategy provided by industrial designers were as follow:

1. By providing carbon credits for the manufacturing industry for repurposing their products.
2. Finding the application with a very long life to utilize the maximum potential by repurposing.
3. Creating an emotional value to market the repurposing product.

80-90 mins

Participants were asked to write a quote about the concept of repurposing composite material and what are their opinion . Based on this quote, the participant will be contacted post-co-creation session to discuss the final outcome of the project if it can solve their concern.

Erik

"We do this not because it is easy but because it is hard!"

Irene

"The impact of repurposing on the sustainability (e.g. emissions during operations of the original vehicle) needs to be monitored to make proper decisions."

David

"I am not convinced the business model in terms of costs and revenues stack up. The hope of policymakers and regulators forcing a change on the scale wanted won't happen in the short term. I think the value in the research lies in understand the financial 'gap'"

Bart

"A phased approach starting with the reuse of industrial byproduct and ending would be a good way to get manufacturers on board. The end goal is to repurpose end-of-life components."

Eduard

"getting the right (materials) data in *the right from the start of the design by PLM and use this data over the full lifecycle including repurposing."*

Dracos

"Combining financial incentives with environmental responsibility will provide the necessary pressure for such repurposed programs to start."

Pranav:

"The application sector to target needs to be capable enough to sink in a large amount of repurposed composite materials."

Atula

"Telling the story is key to an interactive marketplace."

Thomas:

"The focus at this stage is more to involve all stakeholders in a system that engulfs all. "

Master Thesis | Parshva Mehta