

Circular Economy with a Sustainable Supply Chain for the Aerospace Industry

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<p>When communicating about sustainability topics and the current environmental and social problems, global warming, soil erosion, inequality, water, air, and land pollution, authors might get caught in their perceptions by reflecting on their communication style concerning the issue. Therefore, it is important to write about the climate crisis accurately and impartially through effective climate communications to avoid writing about how one emotionally sees climate change and begin to address the problem and criteria for solutions objectively.</p> <p>Validity, relevance, and reliability in research methods are key to beginning a credible source of information when communicating about climate change to regard it as fact and not a matter of opinion or a document that attempts to persuade or popularize a topic. Nevertheless, rather in great detail and analysis to inform and develop scientific research regarding the issue.</p> <p>Aerospace vehicle manufacturing is a highly technical and quality demanding industry. A systemic approach to achieving dynamic and structural change must begin with tactical level tools and criteria to identify, analyze, and validate design principles fit for a value-added transformation. To ensure sufficiency of resources, environmental boundaries being respected, and social well-being, The aerospace industry must collaborate with multiple partners and implement innovative design frameworks and integration of knowledge, resources, and instruments that have a systemic and surrounding conscious perspective.</p> <p>Instruments, guidelines, and perspectives are the foundation upon which this research achieves behavioral change through regenerating ecosystems impacted by rotorcraft vehicle components.</p> <p>A product lifecycle assessment is in a systemic perspective with its respective logistics and supply chain applications in how it is made for main rotor blades and its relationship to the reaches of a circular economy.</p> <p>The supply chain's environmental, social, and economic sustainability, challenges, and opportunities can be overcome and develop a more sustainable chain of supplies.</p> <p>Causal loop diagram, its relationship to the circular economy, and how it can build the foundation upon which the tactical levels of the circular economy are transformed into dynamic and even structural changes.</p> <p>Planet, people, and profit strategy origins and reasons for the strategy, the benefits and financial opportunities within carbon accounting, and market trade.</p>	
Keywords Circular Economy, Green Supply Chain, Systems Change, Aerospace	

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1 Introduction

This document is a research-based bachelor thesis for the Degree Programme in International Business in the major specialization of Supply Chain Management at the Haaga-Helia University of Applied Sciences. This chapter is intended to introduce the thesis document, and readers can expect a description of the problem setting, objectives, delimitation, and concepts of the project.

This chapter is intended to be a general introduction to the publication. This thesis aims to develop a public written document in the field of study within an academic thesis structure of project planning developed for a third-party commissioning company.

The thesis document also contains a small research component using qualitative analysis methods to implement the research.

1.1 Background of the study

Acknowledging global warming is not a matter of belief anymore. It has been proven by scientific research and consensus time and time again how humans have been the main cause of the rising temperatures in the past millennium and how the measurements of CO₂ in the atmosphere have correlated to the mean temperature during the increase and decrease of the interglacial periods. Source: (Lüthi et al., 2008).

Even though correlation in graph data does not mean causation, the current scientific data clearly illustrates how the main cause of global warming is harmful gas emissions from burning fossil fuels (GHG) caused by business and human activity, which heat the atmosphere by 1.5 degrees more than its existence. (Migliozzi & Roston, 2015).

Because the CO₂ and temperature mechanisms are directly related to light's physical properties, when light from solar rays reaches the earth, two things occur: it bounces back into outer space, and the second is it is absorbed. The earth is warmed, emitting back the infrared spectrum of light. Nevertheless, CO₂ and other compounds such as methane and water vapor suspended in the atmosphere let light through but capture and absorb infrared radiation, making the molecule vibrate and create heat. The heat supposed to leave the earth is now trapped, generating what is known as the GHG effect, which is the natural self temperature regulating system that prevents the earth from freezing completely from the lack of heat in outer space Source: (Lindsey, 2009), which is a form of a reinforcing feedback loop of a stock and a flow.

The claim that the GHG increase is due to human activity is the different carbon isotopes present in the atmosphere, carbon-12, carbon-13, and carbon-14. Each one has a different weight, the first of which, carbon-12, is produced by living organisms and is found predominantly in the atmosphere, compared to the other two. Because carbon-14 decays quicker than the other carbon isotopes, Carbon-14 is more abundantly present in young organic matter than in older organic matter that lacks this isotope. Because of this, carbon-14 is practically inexistent in fossil fuels. Source: (Lindsey, 2020).

Recent atmospheric measurements of carbon isotopes have shown the ratio from carbon-13 to carbon-12 to be decreasing, meaning there has been a recent spike in a source that is rich in carbon-12. Moreover, because carbon-13 predominantly comes from volcanic eruptions, the increase can only come from a source, so carbon-14 is depleted that any carbon-14 it once contained has been reduced to undetectable levels Source: (Lindsey, 2021). Alternatively, in other words, pointing to fossil fuels. This way, it can be certified and guaranteed through the isotopic fingerprint of the carbon composition in the atmosphere that global warming is manufactured. Source: (Lindsey, 2020).

To counter this environmental crisis, achieve net-zero anthropogenic gas emissions and carbon neutrality by 2030. Eight years will require efforts towards sourcing transparency and current assessment of the abuses of the carbon and other biogeochemical cycles with a systemic shift towards renewable resources and modes of transportation.

A group of ecological economists has estimated that it would cost USD thirty-three trillion a year to replace what nature does for nothing in exchange. Source: (Costanza .et.al, 1997) Current economic thought does not take into account what nature as a productive system with its own needs and right generates for humanity, but rather view it as means to make production feasible.

Nowadays, businesses should re-evaluate their current production and waste management model to understand the climate crisis as a shared systemic phenomenon or product of a certain system and its connection. The problem must be viewed holistically by identifying its elements and their relationships.

The objective of this thesis is to develop a circular economy strategy for an aircraft engine and improve its supply chain sustainably through systems change perspective for a commissioning company in the aerospace technology industry in need of understanding how to transition their product life cycle from a linear production model to a circular economy model as an approach for sustainable growth.

While improving the management of material and information flow with the cooperation among companies along the chain of supplies while targeting goals in three dimensions of corporate sustainability development in their logistics; social, environmental, and economical, with the stakeholders' requirements into account. Source: (Editorial / Journal of Cleaner Production 16 (2008) 1545-1551).

The purpose of the circular economy model is regenerative and restorative to design out waste, as the only way to ensure sufficiency of resources is by reducing consumption through creating closed-loop material cycles.

Achieving a circular economy requires new thinking and operating models with a reorientation of previous business activities that abused the carbon cycles. Redesigning the take, make, waste approach to reduce, reuse, and recycle as much as possible to avoid landfills at all costs.

Many multinational companies have increased environmental action by setting environmental and social sustainability compliance standards for their suppliers in the past couple of years. Source: (Gioia & Villena, 2020).

1.2 Thesis Objective and Publication

This thesis aims to develop a written legacy document that serves as a frame of reference that demonstrates how to develop an environmentally sensible project in the industrial maximization of resource use and minimization of waste, known as the circular economy, with a supply chain sustainability improvement through the use of systems thinking perspective for change in the life-limited parts from helicopter main rotor blades.

While maintaining accordance with their stakeholders' sustainable objectives by viewing them from a socio-economic systemically sensible perspective.

1.3 Research Question

The research question (RQ) of this thesis was: How can a circular economy with a sustainable supply chain be sensibly developed for rotorcraft blades while using a systems change perspective for the aerospace industry?. The research question was divided into investigative questions as follows:

IQ 1: What is Sensible a Theoretical Framework for the Project?

IQ 2: What Are the Current Material Sourcing and Consumption Standards?

IQ 3: How To Develop a Product Life Cycle Assesment (LCA)?

IQ 4: What Are the Current Supply Chain Environmental Impact & Objectives?

IQ 5: How to Draw a Causal Loop Diagram on Current System Structure?

IQ 6: What Should the People, Planet & Profit Strategy Be in SCM Activities?

Table 1 below presents the investigative questions, theoretical framework components, research methods, and results for each chapter.

Table 1. Overlay Matrix

Investigative Questions (IQs)	Theoretical Framework	Research Methods	Results (chapter)
IQ 1. What is sensible a theoretical framework for the project?	Double diamond framework for innovation	Categorization	Project theoretical framework figure
IQ 2. What is the current material sourcing and consumption standards?	Qualitative research	Desktop research and Supplier code of conduct	Description of sourcing and consumption process
IQ 3. How to develop a product Life Cycle Assesment (LCA)?	Product LCA ISO14040 ISO14044	Vensim Diagram and Graph	Product LCA
IQ 4. What are the current supply chain	Qualitative analysis	Qualitative thematic analysis	Description of current SCM

environmental impact & objectives?			methods and challenges
IQ 5. How to draw a causal loop diagram on current system structure?	CDL layout	Vensim diagram	Causal Loop Diagram
IQ 6. What should be the people, planet & profit strategy in SCM activities?	Tripple P function to cost diagram	MS office chart	GRI

1.4 Scope

This thesis will only solve the research question of the reusability, recyclability, and remanufacture input and output inventory of life-limited parts of the helicopter blades to its respective product lifecycle assessment, supply chain sustainability recommendations, and systemic structure change design.

The project scope will define the system boundaries for the systemic structure model.

1.5 Demarcation

This thesis will not research or question the applicability or feasibility of the circular economy model as a proven concept. It will not experiment or dispute the sustainable supply chain methodology and its applicability to successful business practices.

Moreover, this document will not investigate the systems thinking methodology for change as a scientific framework to understand relationships and causalities between elements and their impact.

This thesis will also not propose or entertain the idea of completely prohibiting plastic production or use, but rather research and suggest a sensible use of plastic materials in all their forms, with their respective discarding methods to avoid the materials ending up in landfills, seas or oceans.

This thesis will only research how to apply the circular economy life cycle assessment of one product component from an individual commissioning company and its respective supply chain impact with recommendations through systems thinking perspective to reduce unmeasured resource extraction, inadequate waste disposal, and greenhouse gas emissions gasses footprint.

The main title will not include systems thinking & intelligence for change will not be included in the main title. However, it is a part of the investigative question because systemic thinking is already within the requirements and key concepts of a circular economy and is advised to think in these terms to understand the nature of the constituents and connections that define the structure of the issue.

The Double Diamond Framework for Innovation will also not be included in the main title even though it is researched in the empirical part. Nonetheless, it is a project design tool that is especially useful when building future developments in a reasonable frame of reference.

1.6 International Aspects

The international cooperation in sourcing and procurement for materials to manufacture flight vehicles is directly influenced by planetary boundary wellbeing. Transport and logistics also require strong international cooperation for the social, political, and environmental wellbeing of the countries of origin, transit, and destination. Company X has a global supply repository of over 1200 direct suppliers in over 180 locations worldwide.

Company X has international clients who benefit from its business, governmental, civilian, and paramedic market products. Furthermore, their intake order services include a vehicle care contract from the National Aeronautics and Space Administration (NASA) to contribute to the fleet.

1.7 Benefits

Company X, their plant logistics, materials, and operations department staff, its global clients along with their partners as well as their police, emergency rescue, and technology stakeholders, would ensure the sufficiency of natural resources by the efficient use of raw materials by reducing the need for virgin natural resources and valuable material extraction.

Implementing sustainability practices in operations will act as risk mitigation by anticipating possible political and legislative uncertainty as a proactive approach in provisional strategy. They would also mitigate supply chain risk in legislation that might shift in the coming years. Practices that were allowed before might become sanctioned in the near future.

Company X and its joint venture partners would be recognized as a groundbreaker for creating new opportunities in the aerospace industry as a response to the largest global challenges such as global warming, depletion of natural resources, and loss of diversity.

This project would develop knowledge and network growth in the industry and specialization field to set a precedent for future generations inspired by social and environmental consciousness for sustainable business.

1.8 Key Concepts

Circular Economy where the existing natural resources take, make, and discard linear model is being redesigned into a counter economy that prevents waste from being formed in the first place. The circular economy is founded on three principles: reducing waste, circulating high-value products and materials, and renewing nature.

Thanks to a transition to renewable energy and materials to separate economic activity from limited resources. It is a robust structure that benefits business, society, and the environment. (Ellen MacArthur Foundation, n.d.).

Biological & Technical cycles are nutrient-based and technology-based products and materials sequenced through the economic system. Each has its own specific set of characteristics, requirements, and constraints (Ellen MacArthur Foundation, 2013).

The Double Diamond Framework for Innovation is a tool that assists both designers and non-designers in addressing complex social, economic, and environmental issues. It also contains a set of basic premises, methodological guidelines, and the safe working culture needed to produce long-term beneficial transformation. Source: (Design Council, 2022).

Green Supply Chain integrates environmental thinking into product design, material sourcing and selection, manufacturing processes, delivery of the final product to the customer, and end-of-life management of the product after its useful life Source: (Srivastava, 2007; 54-55). While Identifying hazards and opportunities in the value chain

to leverage risk mitigation, process optimization, savings in resource use, generate innovation, and promote corporate values.

Systems Thinking is a scientific approach to understanding how things are related to each other and why these relationships matter in the real world by understanding the meaningful consequences of certain individuals and groups of people bound to the rest of the shared world.

Every change to the supply chain reacts. Therefore an effective system intelligence perspective must be put in place to analyze the current dynamism of the extent of the relationships that links to other people, technologies, species, and environments.

Furthermore, the Ellen MacArthur foundation instructs businesses to think in terms of 'systems' to have the ability to understand how individual parts influence one another within an ensemble and the relationship of the entirety to the parts as key to unlocking an effective circular economy model Source: (Ellen MacArthur Foundation, 2013).

1.9 Commissioning Company

The commissioning company will be referred to as Company X throughout this document, research, and analysis for this project.

Company X is a global commercial aircraft, helicopter, defense intelligence, telecommunications, navigation, equipment, and security provider with headquarters in Netherlands and head offices located in France. It is currently operating in Europe, the Americas, Asia-Pacific, Africa, and the Middle East with 180 locations worldwide, 1200 direct suppliers across the globe, over 130,000 employees, and more than 100 nationalities between them.

Company X is purposely committed to creating sustainable business towards net-zero emissions, clean aerospace, safety, and quality and climate change mitigation in their activities through a sustainability strategy that targets these issues through the United Nations Global Compact Sustainability Development Objectives, a topic which is detailed further in the investigative question and subchapter 3.4 What is the current supply chain environmental impact & objectives? Moreover, the subchapter 3.6.1, Established stakeholder key performance indicators.

2 Theoretical Framework

Key concepts presented in this report are basic and academic terms that must be used in order to be able to properly describe the thesis topic, objective, and phenomena being studied. These are Circular Economy, Green Supply Chain, Double Diamond, and Systems.

2.1 Categorization of Information

The theoretical framework uses the design council's double diamond framework for innovation within as theoretical framework in the empirical part to answer the thesis research question. It also encompasses all three individual parts of the project scope that make up the thesis research sensibly through a scientific approach to systems thinking & intelligence philosophy.

2.2 Demarcation

Each part is insufficient to properly address the circular economy purpose with a sustainable supply chain. It requires aligning these objectives with stakeholder interests to an effective cost structure in the triple bottom line diagram by redefining objectives in a double diamond framework for innovation.

2.3 Conceptual Structure

This figure is a tool that helps visualize the relationships between concepts and the order in detail in which they should be discussed in the thesis report.

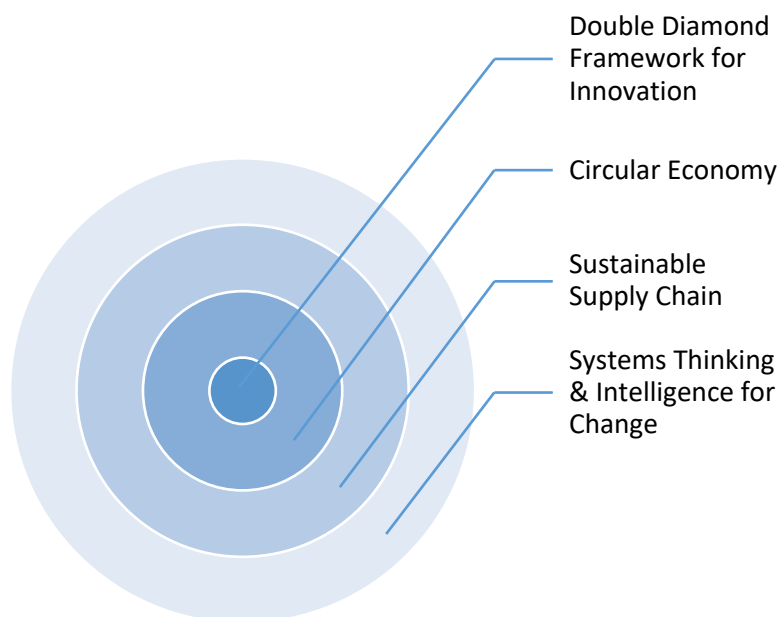


Figure 1. The Theoretical Framework – Model for a Circular economy with a Sustainable Supply Chain

2.4 The Industry

The Aerospace Industry shares a broad spectrum of products and services related to the atmosphere, airspace, and outer space. These organizations design, investigate, produce, assemble, maintain and service vehicles, equipment, and software from commercial aircraft to telecommunication services. Source: (Cranfield University, 2022)

Aerospace components and vehicle manufacturing are highly technological in the diverse production of vehicles, military equipment, defense & rescue vehicles, spacecraft, propulsion, satellites, aircraft engines, and rotorcraft. Source: (United States Bureau of Labour Statistics, 2013.)

2.4.1 Technology

Technology implemented in the aerospace industry requires the latest innovations in components, materials, aviation fuel, and computer programs to ensure the best possible operations and delivery of products and services.

Advanced analytics and artificial intelligence are examples of the latest software advancements for data in the aircraft operational and performance implementations of the 4.0 industry for customers and suppliers.

Biomimicry is when the design and material used for future component or vehicle manufacturing tries to simulate plants and animals' physical capabilities and physical substances. It is currently also one of the sustainable approaches to aircraft material design at Company X.

2.4.2 Challenges

Achieving high quality in materials that can be recycled, repaired, and remanufactured for an industry that demands the best production and control standards. Moreover, being able to involve those materials back into product manufacturing

Maintaining clean aerospace when merchandise shipping, passenger air travel, and mobility have been continuously growing before COVID-19 and is currently regaining momentum as the restrictions are lifted. Environmentally friendly aviation fuel and a form to recover and reuse resources and valuable material from vehicle components that are no longer in use must be put in place to preserve a clean earth atmosphere and buffer the impacts from raw material extraction.

Zero emissions are key for the aerospace industry, as kerosene or jet fuel is a petroleum-based fuel used to combust aircraft engines. However, the byproduct of combustion is always carbon dioxide (CO₂) and others such as Carbon Monoxide (CO). The industry has developed hydrogen-powered engines as a more sustainable alternative. Even though these are completely free and net-zero for CO₂ as a byproduct, they are not exempt from releasing hydrogen oxide or NO_x pollution, a harmful greenhouse gas (GHG).

A sustainable supply chain is an increasing requirement for all industries; however, this is especially evident for aerospace manufacturing because of the complexity of its supplier network and technological resource demand. An effective supplier code of conduct with sustainability key performance indicators (KPIs) as filters for supplier compliance is essential to building a more sustainable supply chain.

Helicopter sound footprint and noise pollution are other emissions that must be taken into account when monitoring environmental impacts from products. The next generation of helicopters made by Company X is developing urban air mobility vehicle solutions certified by the European Union Aviation Safety Agency's Special Conditions for Vertical Take-Off and Landing (EASA SC-VTOL). besides being an electrically powered helicopter, it targets below 65 dB(A) decibels on the flyover and 70 dB(A) while landing.

2.4.3 The specific situation in the commissioning organization

Company X has committed to creating a path towards net-zero and sustainable aviation. Currently, Company X has developed the first helicopter, which functions with one hundred percent sustainable aviation fuel (SAF), as well as the reduction of noise from rotorcraft, and is beginning the implementation of innovative materials in the development of helicopter design with less raw materials and therefore more sustainable.

3 How Can Circular Economy with a Sustainable Supply Chain Be Sensibly Developed for Main Rotor Blades?

Main rotor blades are life-limited parts that, at the end of their functional lifecycle, need to be broken down into components and then into materials for suitable disposal and potential remanufacture, reusability or recycling in order to reduce valuable resource extraction.

First, designating a theoretical framework that allows combining concepts, sustainability objectives, and stakeholder key performance indicators with the ability to be in constant self-renewal is the beginning of a long-lasting, relevant impact in innovation.

Identifying and detailing the current sourcing and consumption practices is the following step to create a systemic perspective and build upon the areas of opportunity that will strengthen supplier relationships, client needs to be met and cultural transparency.

Reporting and analyzing the different origins, sources and conditions through its lifetime with tools such as product lifecycle assessment can help identify all sorts of emissions, origin, sources, impact, and waste generated in each production unit stage from the beginning of the manufacturing cycle and the end of products end of practical use or life as well as from the transport activities involved in an ordered manner.

According to professor Esa Saarinen, systems intelligence is a philosophy that allows us to “articulate a crucial competence we have as human beings as we orient ourselves through action, situations, and surroundings” Source: (Climate University, 2020). Systems thinking is a scientific methodology to explain how everything in the world is connected and how every action in industrial operations affects the earth’s system science.

Closing matter and energy loops for the repair, remanufacture, and recycling of materials in technical cycles to avoid contact with nature’s biological cycles, analyze the existing supply chain environmental impacts, and assess how to take measures that alleviate the damage.

Developing a detailed sustainability strategy for supply chain operations reduces operational costs and increases commitment, attraction, and motivation for emerging talent. Criteria available, such as the Global Reporting Initiative (GRI), allow corporations to recognize and improve sustainability standards for products and services.

Carbon bonuses and the carbon market are an economic opportunity for any company from any industry to obtain remuneration for their environmental emission reduction compliance. It also allows for improvement by trading with companies worldwide in the futures contracts market if emission reduction targets cannot be met. Proactive involvement and public transparency build an organizational reputation with customers and the world by taking mitigation measures to climate change.

3.1 What Is a Sensible Theoretical Framework for the Project?

First and foremost, any plans in the future must be founded upon a conceptual tool that allows analyzing simultaneously the project's several fluctuations and conditions involving development towards the objective, which can be implemented in various complex scenarios and structures of work.

Theoretical frameworks help organize and designate limits, influence, and responsibilities in a context where these factors are of utmost importance when creating a sensibly designated project which considers its negative and positive impact on both planet and people concerning expected profit obtained. A practical, consequence-conscious frame of reference must be put in place to address these matters and achieve optimal results.

Adding value in the 21st century has become more intricate than lowering costs or increasing production cycles. Every endeavor that aims to bring society into the future must be aware of its impact on its surroundings and how its economic objectives are directly related to its environmental change. It must now consider ethical principles that challenge the current social and environmental crisis affected by its consumption and production in economic activities all along the value chain.

Combining large scale and small theories in an abstract representation designed for the project's desired objective while being interconnected to the activities directly impacting areas of influence through values and moral standards forms a reasonable theoretical basis for the plan of action.

3.2 Design council

Design Council is an international organization from 1944 established by Winston Churchill's government as The Council of Industrial Design in charge of Britain's economic recovery during wartime through the industrial design improvement of the products manufactured in the UK Source: (Design Council, 2022)

Nowadays, its purpose has progressed towards meeting the needs of the economy and society of today by addressing the contemporary complex socio-economic problems through design and the ability it has to allow for a change in the lives of people and the planet. Since 2010 it has helped over 10,000 businesses access its full capabilities and research institutions to commercialize its projects. Source: (Design Council, 2022)

The organization is fully ISO9001:2015 registered and has received Creative Review's Best in Book award in 2014 for its National Health Service (NHS), 'A Better A&E' solution for violence and aggression towards frontline medics which costs the NHS more than GBP 60m a year Source: (Design Council, 2022)

The council's central motive for existence is to improve lives through design, Working closely with the government by creating projects, research, and influencing policy. Their projects include the built environment, public sector design, and social and business innovation. They are connected through more than 450 partners within the design economy, meaning they impartially and inclusively create spaces to solve intricate difficulties through strategic advice, programs, research, and insight. Source: (Design Council, 2022)

Their strategy for 2020-2024 is to ensure the design is utilized as a force that drives change in society's lives to solve some of the most complicated economic problems in the United Kingdom and the world. Their key priorities for this strategy are "improving health and wellbeing, enabling sustainable living and increasing design skills" Source: (Design Council, 2022)

Design for them is a mindset and skillset which combines critical thinking and creativity at its core values. It tackles distress head-on towards problem-solving in developing the ability to visualize and conceptually understand the intangibility of the immaterial. It is humanly oriented at its core, through the fondness and curiosity for creating solutions that improve the lives and well-being suitable for people and ecosystems. Furthermore, it implements practical design skills through the technical abilities to achieve the final objective Source: (Design Council, 2020).

3.2.1 Double diamond framework for innovation

The Design Council's theoretical framework for innovation in project design may be adopted for designers and non-designers to construct the foundations upon which every new project can be aligned with the necessary principles to achieve the long-term positive impact required to lead the organization towards meaningful transformation with the earth

and people into account through the application of its conceptual methodology. Source: (Design Council, 2019)

It comprises design principles, a non-linear process for using the framework, a design methodology bank, and corporate culture to reflect upon the aspects of the project and organization that can be adapted toward its specific needs and requirements.

The Double Diamond is a guideline which any project can be developed to create a positive impact on their economy, social wellbeing, or any sustainability Key Performance Indicator (KPIs) and turn objectives into reality through design for the project in a sensible application of values and moral principles embodied into humane economic activity.

The following figure is Design Council's Double Diamond Framework for Innovation as a visual representation intended to be a template that brings together all the necessary elements to create a restructuring project.

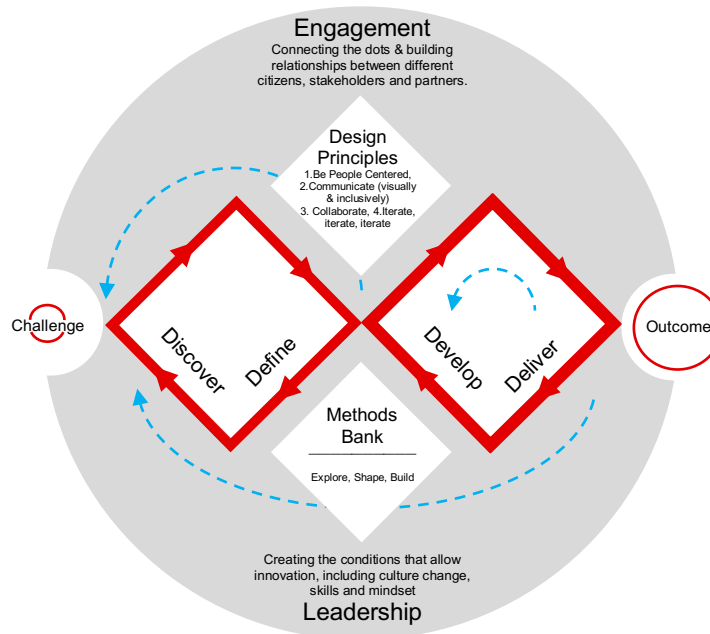


Figure 2. Design Council's Double Diamond Framework for Innovation Source: (Design Council, 2019).

3.2.2 Conceptual structure process of the innovation framework

The conceptual framework is structured in a non-linear manner by following the dotted arrows in the figure. Every time the organization discovers something new about the issue being studied or developed, it can begin by including that new factor. Testing new ideas can be done early in the idea generation process, which discovers new factors in the issue by getting feedback on its behaviors. Source: (Design Council, 2019).

The first process for this is thinking differently about the issue in the discovery and definition phase and then taking concentrated action in the developing and delivering phase to explore the matter more broadly and profoundly. Source: (Design Council, 2019).

3.2.3 Framework principles & components for rotary blades

The The framework details four central principles for problem-solving:

- “Put people first:” Begin thinking about users' needs, strong points, and objectives. Source: (Design Council, 2019).
- “Communicate visually and inclusively:” Allow for a clear visual understanding of the ideas and challenges. Source: (Design Council, 2019).
- “Collaborate and co-create:” Collaborate and connect with partners who share their passion for innovation. Source: (Design Council, 2019).
- “Iterate, iterate, iterate:” Constantly doing this allows for problems to be identified early in every step of the process Source: (Design Council, 2019).

Methods bank

- Explore the challenges for the aerospace industry, such as high-quality material is required. Maintaining clean aerospace. Being able to use net-zero transportation solutions. Potential risks in human right violations in transport and logistics.
- Shape: Using recycled materials that use cutting-edge technology in remanufacturing to achieve aerospace quality control standards. Biomimicry. Working with the market in favor of society and the environment. Knowledge and know-how integration.
- Build Life cycle assessments for products. Carbon accounting. Material circularity.

Design Process

1. Discover: the first part allows people to grasp concepts and get visibility and understanding of the problem by getting to know the people involved, talking with them, and attuning to their situation.
2. Define: The understanding collected from the previous experience will help determine the problem differently.
3. Develop: the second part of the double diamond inspires people to propose their idea solutions for the previously established problem
4. Deliver: Implement the different solutions at a smaller scale and discard the ones that do not work while improving those that do.

3.3 What Are the Current Material Sourcing and Consumption Standards?

Life-limited parts are product components that cannot be repaired or refurbished and therefore require to be removed and replaced in their entirety. These products often contain materials that can be recycled upon their end-of-life period. If they cannot be recycled, they can be repurposed for different purposes other than the initial reason they intended. Giving the material a second life or a redefined purpose to avoid the landfill at all costs.

For the aerospace industry, some of the life-limited parts in-flight vehicles are Helicopter Main Rotor Blades, and Tail Rotor Blades made out of Composite Carbon Fiber with titanium reinforcement. These components contain plastic polymers, which are harmful to the earth's soil if they were to be discarded in a land plot or end in seas and oceans, as well as scarce underground resources which through the mining infrastructure and land involved in the extraction of raw materials create immense destruction of entire hectares ecosystems and wildlife hectares.

For the circular economy, material sourcing should be from recycled materials, halting the need to extract raw materials and the incorrect disposal of such. Furthermore, material consumption should involve the utilization of goods and then the disposal of them in an environmentally appropriate way which allows for its material components to be broken down to their original raw state to be used again or repurposed for a different product. or

3.3.1 Management research process

Precise data for materials, manufacturing, and logistics information is mostly hard to acquire and is regarded as confidential or business secret. Therefore, most information came from the commissioning company's online websites and university research papers.

Especially due to Company X information protection requirements for both internal and suppliers alike detailed in their supplier code of conduct, guarantee to protect against sensitive, confidential and proprietary information, making it inaccessible to the public. Including product names, materials, trademarks, and other publicly available content.

However, common material qualities, sourcing and consumption, manufacturing, market structures, statistics, and environmental impacts are available online for desktop research through university research, scientific papers, government legislations, material supplier company websites, and environmental studies.

Desktop research is a project management method tool that involves the investigation of relevant articles, research papers, government legislations, studies, manuals, and frameworks available on the internet. This method was specifically used for most of the research regarding explicit materials, processes, and solutions specific to the case company and industry and its sustainability implications.

3.3.2 Material sourcing

Composite Carbon Fibre (CCF) consists of thin carbon strands of organic polymer strings of molecules bonded together by carbon atoms. Source: (Johnson, 2020), (Jennings, 2015). There are two main types of carbon fibers used in automotive and aeronautic industries: filament and staple. The aerospace industry uses the first one, dry fiber, or resin pre-impregnated fiber, mostly used for manufacturing vehicle body frames and other components. (The Japan Carbon, n.d.).

The Aerospace industry demands the highest quality and grade of over 600 GPa carbon fiber, known as ultra-high-modulus composite carbon fibers. The composite carbon fiber is made of polyacrylonitrile (PAN). It is regarded as the most resource-intensive industry for this raw material averaging prices between USD 85,000 and USD 220,000. Source: (Morabito, 2020).

Completing carbon fiber manufacturing is begun is pyrolysis, which is a heat treatment process by burning the material in a vacuum seal. A process also used in the disposal and recycling method for automobile tires. These methods are explained and detailed in the material consumption subchapter 3.2.3.

Even though fiberglass can be made from silica sand, most commercially sold fiberglass is mixed with these chemicals to make it more heat resistant when manufacturing. Fiberglass is made from silica sand (SiO_2) which is mixed with other ingredients in a process known as batching, where aluminum oxide (Al_2O_3), calcium oxide or lime (CaO), magnesium oxide (MgO), and boron oxide (B_2O_3) is added, which is in turn melted and then extruded and drawn to form the fiber Source: (Gardiner, 2009).

Silica sand comes from mining which significantly deteriorates land. By degrading it through excavation, the natural water drainage is interfered creating soil erosion and, in turn, the loss of regional biodiversity. Furthermore, silica refining is highly water-intensive due to the washing required, and the extraction availability of this resource is reduced. Source: (Mishra, 2015).

Suspended Particle Matter (SPM) pollution is also a concern for silica mining as plants' photosynthetic and respiratory activity is interrupted due to the accumulation of dust in their leaves as well as bringing water transmitted illnesses due to contamination of the water source for the surrounding population Source: (Mishra, 2015).

Titanium in its raw form is called titanium ore when it is just extracted from the ground from mining titanium-bearing sands. Aerospace is the most titanium-intensive market in the world. Source: (Froes, 2015). It must go through a complex and costly refining method known as the Kroll process to make it into an aerospace-grade material. The titanium ore is thermally and chemically treated to become a pure titanium Source: (ElKhalloufi & Drevelle, & Soucy, 2021). Because titanium is hard to buy and recycling of the metal scraps is hard to find in Europe, most raw material is purchased from the United States or Russia and given when the industry needs to get rid of the scraps Source: (Knight, 2018).

Aluminum does not occur in a natural state. The most available source of aluminum comes from Bauxite which is a clayey rock or the commercial ore of aluminum, mostly surface-mined in West Africa and South America and has been economically calculated for reserves to last another 100 years of supply at current demand Source: (International Aluminium Institute, 2018). The land must be cleared from every tree and vegetation for mining to commence. Creating significant deterioration of soil and water quality and loss of habitat and species. Source: (Lad & Samant, 2012).

After it has been mined, Bauxite is then passed through a clay removal process called beneficiation Source: (The International Aluminium Institute, 2018). It also must be atomically separated by a chemical process known as electrolysis, where the oxygen aluminum atoms held together by oxygen are separated through an electric current.

It has recently been announced that several companies in the aerospace industry, with an investment firm, jointly secured a purchase of a mining company. This strategy reduces risk and uncertainty for raw material bottlenecks or shortages in the industry and strengthens a direct supply of the metal resource for complex supply chains Source: (Global News Wire, 2022). The company has publically disclosed a project partnership with a metal scrap recycling company detailed further in the following subchapter 3.2.3 material consumption.

Company X counts with a supplier code of conduct enforced for all companies who wish to become a part of their material providing solutions. Measures such as these enforce a binding contractual relationship with every company wishing to do business with them.

The code provides a legislative framework for supplier sustainability and ensures the implementation of best practices, responsibility, and ethical compliance across their third and fourth-tier supply chain. The code of conduct details cannot be reproduced within this document and are regarded as private information.

Even though most of this subchapter is dedicated to the main component materials of the helicopter rotor blades, it is important to analyze and detail the sourcing and procurement of consumables and non-consumables such as drills, polishers, chemicals, plastics, fuels, oils, water, and energy consumption used in upstream and downstream activities as well as for every unit production stage of manufacturing. These factors are detailed further in the subchapter 3.4, how to develop a product lifecycle assessment (LCA), and subchapters 3.4.2, Product LCA inventory analysis.

3.3.3 Material consumption

When Life-limited parts such as helicopter blades are damaged or discarded because of their lifespan. The materials that conform to the blade components must be properly discarded to reuse scarce materials and prevent them from ending up hurting ecosystems.

Fortunately, the same process by which composite carbon fiber is begun is also how it can be recycled. However, there are three main methods to recover the material, which are divided by thermal, chemical, and mechanical. Only the first two methods allow for about 70% tensile strength retention compared to the virgin material and allow the remanufacture of high-grade composite parts Source: (Hadigheh & WeiS. & Kashi 2021).

There has been a recent development made in the last year, where the recycling method for Carbon fiber reinforced polymers (CFRP) is improved since the fiber properties during pyrolysis depend on specific variable parameters, the material can retain its quality properties and high grade by up to 90% than other methods Sources: (Yip et al., 2002), (Pimenta & Pinho, 2011). using pyrolysis in an optimization technique that is energy efficient and cost reductive while improving the surface quality of recycled fibers. Source: (Hadigheh & WeiS. & Kashi 2021)

Fiberglass is perhaps the most difficult component material to recycle. The material can be repurposed and remanufactured with different methods such as grinding, incineration, and pyrolysis. Fiberglass can be broken down into three different recoverable substances through pyro-gas, which can be sold as a natural gas replacement through pyrolysis.

Pyro-oil is similar to heavy crude oil, which can be repurposed for asphalt or mixed with other oils to make fuel. Source: (Designed Conscious, n.d.)

General Electric (GE) has partnered in a long-term effort to recycle wind turbine blades with the main component, fiberglass. Even though this does not directly generate income for GE, it shows responsibility for the final form in the lifetime of their products. Source: (Designed Conscious, n.d.)

Titanium is not scarce, but it is a valuable metal. Its strength and non-corrosive properties are especially useful in medical, maritime, and aerospace applications. After its disposal and scrap, it can be recycled through a process developed by the French company EcoTitanium. Metal recycling requires less energy and creates fewer emissions than refining titanium ore. Using plasma furnace technology to melt the metal with heated gas and air vacuum furnaces to prevent polluting elements from escaping. It is expected to prevent 100,000 tons of CO₂ a year from being released into the atmosphere Source: (Knight, 2018)

Titanium is expensive because it is difficult to refine by using the Kroll process. EcoTitanium turns aerospace quality titanium cheaper, easier to source, and less wasteful than virgin titanium Source: (Knight, 2018).

The process for recycling aluminum is simple if the material has been properly discarded and shredded. An advantage of aluminum is that it does not corrode like other metals, making it easier to recycle. Aluminum can be recycled through a simple melting and subsequent casting of the metal, which can ultimately be made into any production form Source: (Husband, 2012).

Company X counts on care contracts with international government institutions. They disclose full Environmental Management Systems (EMS) in their service and repair facilities for each helicopter product.

An Environmental Management System (EMS), according to the US Environmental Protection Agency (EPA), is a framework of processes and practices that help reduce environmental impact and improve operational efficiency. In order to optimize sustainability operational performance, environmental capabilities should be reviewed, reported on, and regularly evaluated. Source: (EPA, 2021).

Basic EMS elements according to EPA: Source: (EPA, 2021).

- Reviewing corporate environmental objectives.
- Analysing environmental impacts and legal compliance requirements.
- Framing environmental targets for environmental impacts
- Designating programs to meet objectives and targets.
- Measuring advancement in objective achievements.
- Guaranteeing employee environmental competence and awareness,
- EMS progress review and improvement achievements.

The following figure is a design visualisation of an EMS.

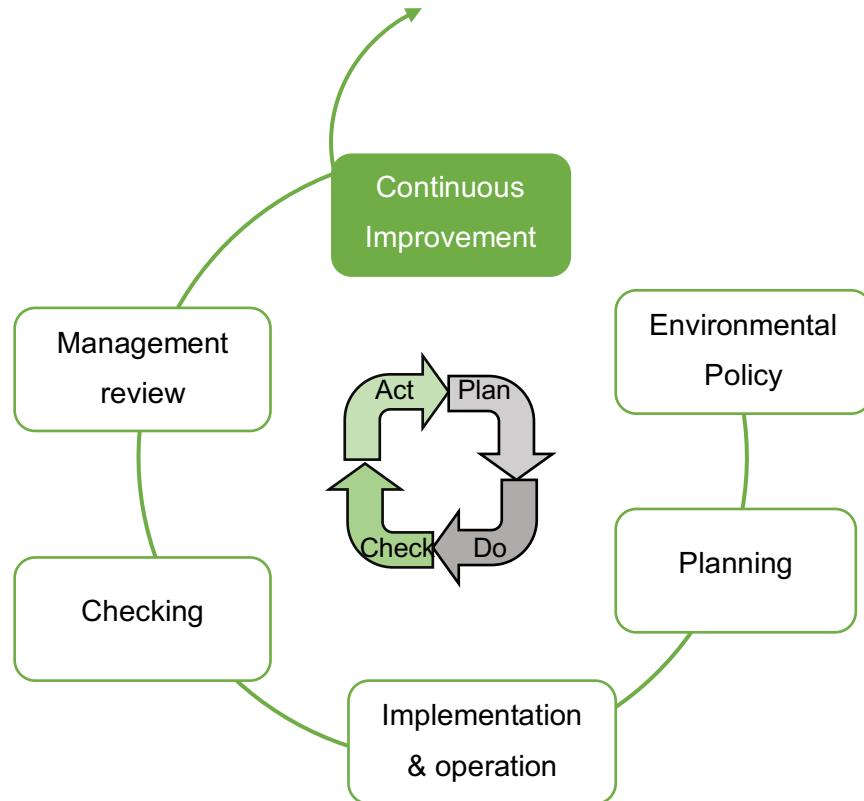


Figure 3. Continuous improvement cycle. Source: (Lehtinen, 2021).

The green arrow pointing outwards of the circle refers to a new cycle after management has reviewed performance as part of a continued improved cycle. The continuous improvement cycle is supposed to be constantly renewed and improved after every completion of the cycle and when reaching the evaluation stage. The first stage begins with commitment and policy regulations. It later uses that policy to develop an environmental impact mitigation plan. Source: (EPA, 2021).

The following step is to implement the plan. Afterward, a management evaluation must be made regarding the effectiveness of the plan's performance regarding the environmental targets. If they are off track, corrections must be made to improve environmental management. Source: (EPA, 2021).

3.4 How To Develop a Product Life Cycle Assessment (LCA)

A life cycle assessment (LCA) evaluates the input and output flows of materials and energy involved in the lifespan of a product through the recording and interpretation of environmental impact factors such as emissions, waste generation, energy, and material consumption. It is important to mention that a product LCA is only an instrument and criteria that enable industries and business units to evaluate and begin to reduce the emissions hopefully involved in the product's entire lifetime and, therefore, move forward in their corporate sustainability practices. Moreover, it should not be the end goal of a sustainability strategy. A product LCA is just a tactical forcing to move a critical systemic threshold in the short term. Creating dynamic forcings and even structural changes in the system requires profound cooperation from governments, businesses, and society.

An LCA allows business units to identify opportunities for environmental performance improvement of products at different stages of their useful lifetime. Inform decision-makers and stakeholders in government and non-government organizations, industry leaders, and employees to plan policy, product, or manufacturing process design strategically. Selecting performance indicators for environmental priorities such as measurements and calculations on public product marketing declarations.

The figure below details the visualization of a Product LCA principles and framework.

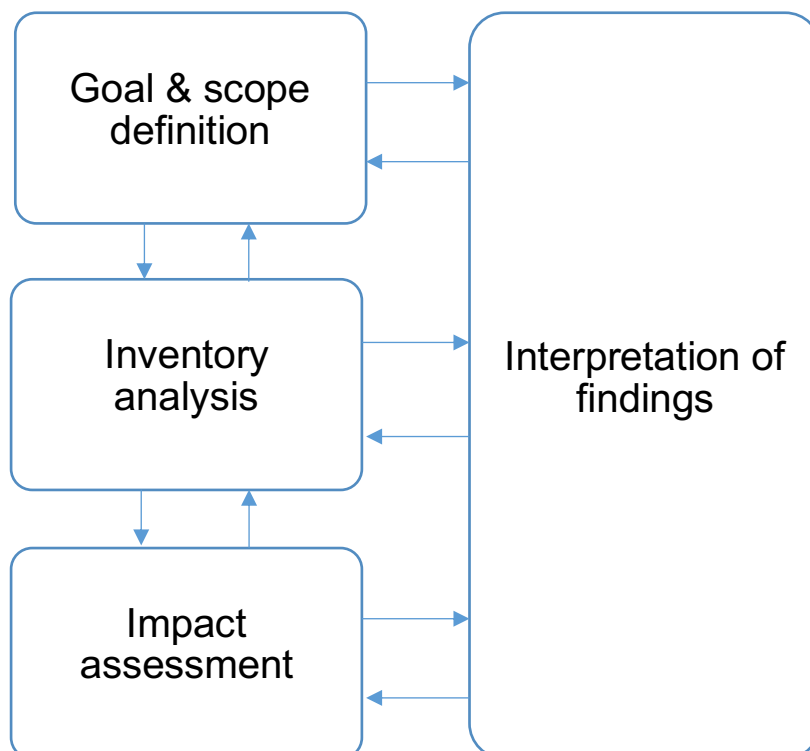


Figure 4. ISO14040:2006. Environmental management. Life cycle assessment. Principles

and framework. 2006 Source: ISO 14040:2006 - Environmental management – Life cycle assessment – Principles and framework, 2006)

The phases of the LCA in order are the phase of goal and scope definition, phase of inventory analysis, phase of impact assessment, and phase of interpretation of findings..

3.4.1 Product LCA Goal and scope definition

The goal of a product lifecycle assessment is defined by the intended application it has regarding the production system being studied, the reasons for developing the assessment, the audience intended with whom the findings and results will be shared and communicated with as well as if the study will be publically disclosed or used in terms of declarations of comparison Source: (ISO 14040:2006 - Environmental management – Life cycle assessment – Principles and framework, 2006).

The following figure is the design of a lifecycle assessment.

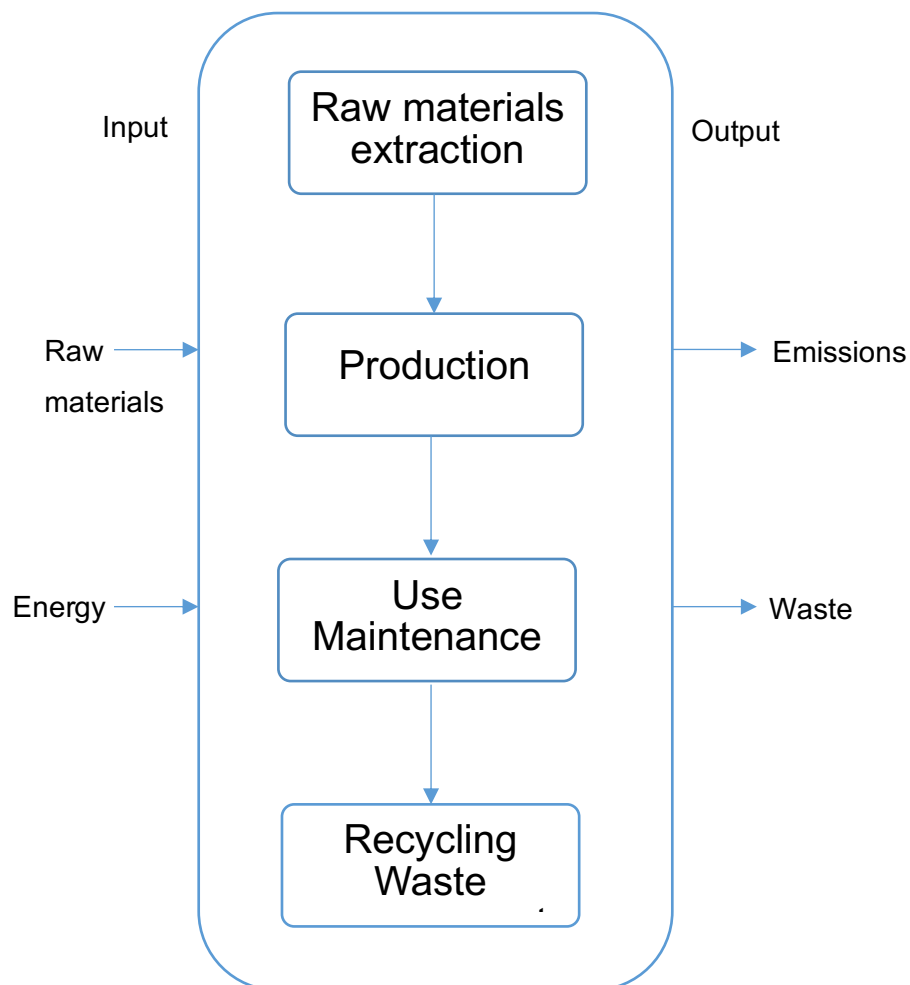


Figure 5. Life cycle assessment Source: (Lehtinen, 2021).

The reason for developing a product LCA is to identify and understand the flows of matter and energy implicated in the product, material, manufacturing process, packaging, and several other processes and find out the environmentally detrimental points and prevent or remove them using replacement materials or systems.

A product LCA scope must include according to ISO14040:2006:

- Product system being studied.
- Functions of the product system or systems depending on if the study is being compared to other systems.
- Units of measurement quantification for the system inputs and outputs being recorded.
- Systemic boundary.
- Allocation strategy.
- Categories of impact.
- Requirements for data.
- Assumptions.
- Limitations.
- Initial qualitative data requirements.
- Critical review type.
- Format of the required report for the study.

Source: (ISO 14040:2006 - Environmental management – Life cycle assessment – Principles and framework, 2006).

The scope defines the systemic boundary, which will also determine the system boundaries in the causal loop diagram.

3.4.2 Product LCA inventory analysis

Product LCA inventory analysis collects and quantifies factors that accumulate inputs and outputs of relevant emissions in a product system. Because the data collection process is through repetition, the continuation of learning about the product system or new issues may occur in the process. The sampling procedures must be updated to fit the scope and objectives of the assessment. Source: (ISO 14040:2006 - Environmental management – Life cycle assessment – Principles and framework, 2006).

Data collection tables come from the ISO14044:2006, and even though it is a different standard has been regarded as a compliment to the ISO14040:2006 standard because tables are not included in these guidelines. For data collection purposes, they serve as basic templates and guides to begin recording process inputs and outputs material, emissions, water, and energy consumption.

The following tables are input and output data collection, emissions, and releases to the environment references.

Table 2. Input, Consumption and Output Data for Unit Manufacturing Process #1 Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Material inputs	Units	Quantity	Sampling procedure description:	Origin Location
Water consumption	Units	Quantity	Sampling procedure description:	Origin
Energy inputs	Units	Quantity	Sampling procedure description:	Origin
Material outputs	Units	Quantity	Sampling procedure description:	Destination

The table must include information that allows the evaluation to identify the unit process being recorded, such as process ID, process description, the location where it was collected, dates regarding the yearly period, the month when the record was begun, and the month when it was ended.

Afterward, the material inputs such as quantity, respective units, the sampling process description, and location of origin can be collected. The same can be made for material outputs, including its products, the only difference being the destination where it is headed. According to the standard, “The figures in this data collection sheet refer to all inputs and outputs not yet allocated during a specified period” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Water consumption can be “the amount of water used in manufacturing processes, surface water or drinking water” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006). Energy inputs must be recorded: “heavy, medium or light oil, gasoline, aviation kerosene, natural gas, propane, coal, biomass, grid electricity” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Material inputs may be the raw materials transformed in each unit process along with manufacturing. These material inputs could be, for example the carbon fiber is

impregnated by resin, assembly bonding of the shells, filament and tape winding Source: (National Research Council, 1991).

A separate table is used to collect data on water, air, land, and other emissions allocated in each product's manufacturing process.

Table 3. Emissions Data Collection for Unit Manufacturing Process #1 Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Air Pollutants	Units	Quantity	Sampling procedure description:
Water Pollutants	Units	Quantity	Sampling procedure description:
Land Pollutants	Units	Quantity	Sampling procedure description:
Other pollutants or releases	Units	Quantity	Sampling procedure description:

The emissions data collection table is a quantitative recording method for detailing and organizing air, water, land, and other emissions generated by input or output during each unit manufacturing process.

The same unit process identification and location of the report must be included in the data collection. It must not be overlooked to describe any distinctive calculations, data collection, sampling, or variations from any unit process operations Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Emissions to the air may be "For example inorganics: chlorine (CL₂), carbon monoxide (CO), carbon dioxide (CO₂), dust/particulates, fluorine (F₂), hydrogen sulfide (H₂S), sulfuric acid (H₂SO₄), hydrogen chloride (HCl), hydrogen fluoride (HF), nitrous oxide (N₂O), ammonia (NH₃), nitrogen oxides (NO_x), sulfur dioxide (SO_x); and organics: hydrocarbons, polychlorinated biphenyls (PCB), dioxins, phenols; metals: mercury (Hg), lead (Pb), chromium (Cr), iron (Fe), zinc (Zn), nickel (Ni)" Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Water emissions can be recorded as microplastics, microorganisms, bacteria or viruses, particulate matter, “ biochemical oxygen demand (BOD), chemical oxygen demand (COD), acids, chlorine gas (Cl₂), CN₂–, detergents/oils, dissolved organics, Fluorine (F–), iron (Fe) ions, Mercury (Hg) ions, hydrocarbons, sodium(Na⁺), ammonium (NH₄⁺), nitrite (NO₃–), organochlorides, other metals, other nitrogen compounds, phenols, phosphates, sulfate (SO₄²⁻), or other suspended solids” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Land releases of waste and emissions include “mineral waste, mixed industrial waste, municipal solid waste, toxic wastes and any other compounds included in this category” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Other emissions or releases, for instance, “noise, radiation, vibration, odor, waste heat” Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

3.4.3 Product LCA impact assessment

Analysis can be made quantitatively or qualitatively. In quantitative analysis, air, water, and soil emissions are calculated in a specific system ISO14040:2006. In the qualitative analysis, assessment can be made upon environmental impacts in the upper lever and verbally any calculations such as waste management, transport, and storage.

Its purpose is to objectively evaluate the impact on environmental matters generated by the life cycle inventory (LCI) results. This process is made by equating the inventory data collected results with certain environmental elements and characteristics into ecosystemic categories to understand the impact created by the product Source: (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Additionally, the software used in drawing the causal loop diagram on current system modeling (Vensim) can create graphs by registering the quantitative input values that pass through the system’s feedback loops and quantify the amount of GHG emissions, discarded or recycled in a plotted graphical visualization.

3.5 What Is the Current Supply Chain Environmental Impact & Objectives.

As described in subchapter 3.2.2, Material sourcing is the impact of purchasing goods and materials from industries that deplete the earth's natural resources and deteriorate the surrounding communities' systems. Company X has committed to alleviating the impact created by its supply chain requirements and building a more sustainable supply chain in its product line by enforcing a thorough supplier code of conduct in which they demand every company which wishes to do business with company x to uphold and implement environmental and social sustainability practices detailed in the document within their logistics, sourcing and procurement solutions providers.

Apart from that, company x enforces standards for the safe handling of toxic chemicals and regulated materials and substances, of which government institutions are regulating approximately 1,700 substances. These vary from surface treatments, paints, fire protection, cleaners, and sealants. Now, Company X expects each of its suppliers to satisfy regulations such as the Toxic Substances Control Act (TSCA), Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH), Ozone Depleting Substances (ODS), and Fluorinated Greenhouse Gases (F-GHG).

Company X respects people working for them as employees and in their business operations and supply chain to uphold human rights. Because creating a safe and respectful place of work, diversity and inclusion are at their core strategy for business prosperity.

The United Nations (UN) Global Compact is a voluntary, non-binding agreement to set goals towards humanitarian labor, environmental and anti-corruption business practices, and product manufacturing and service operations policies through their set of seventeen individual and inconsecutive Sustainability Development Objectives. Businesses can adopt these goals to mold and conform these corporate sustainability objectives to their corporate value system Source (UN Global Compact, n.d.)

Company X publically shares that they have adopted and committed to the UN Global Compact Sustainable Development Objectives for their supply chain. Some of them are numbers: #9 Industry innovation, #12 responsible consumption and production, #13 climate action, and #17 partnership for the goals. These matters are detailed in further depth in the subchapter 3.7.1. What are the established stakeholder key performance indicators (KPIs)

3.5.1 Documentary analysis of supply chain impact

ISO14044:2006 standard has frameworks for the data collection of emissions from several modes of transportation by recording the types of raw material, the transport load capacity and the actual load of raw material transported, and whether the mode of transportation returned empty.

Table 4. Data Collection for Upstream Road Transportation (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Name of raw material	Road Transport			
	Distance (km)	Transport load capacity (tonnes)	Actual load transported (tonnes)	Empty haul back (yes/no)

The table can record the intermediate material used in each production unit for manufacturing, such as carbon fiber, fiberglass, titanium, aluminum, and others. Its respective transported load by material, the distance it traveled through that mode of transportation, and whether the load capacity returned empty, otherwise known as haul back.

Table 5. Data Collection for Upstream Water Transportation (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Name of raw material	Water Transport			
	Distance (km)	Transport load capacity (tonnes)	Actual load transported (tonnes)	Empty haul back (yes/no)

The same can be made for the upstream water transportation activity. If the intermediate material traveled outside a container, the total load quantity in tonnes might be recorded.

Table 6. Data Collection for Upstream Rail Transportation (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Name of raw material	Rail Transport			
	Distance (km)	Transport load capacity (tonnes)	Actual load transported (tonnes)	Empty haul back (yes/no)

If the material transported through rail infrastructure was not allocated inside a container, the actual load could be recorded in tonnes.

Table 7. Data for Internal Transport in a Plant & Air Transportation (ISO 14044:2006 - Environmental management – Life cycle assessment – Requirements and guidelines, 2006).

Fuel type	Total amount of input transported	Total fuel consumption

Table 7 is for data collection of intermediate materials transported inside the manufacturing plant. The total input of material transported must be recorded with its respective type of fuel consumed in the transportation may be diesel oil, gasoline, kerosene, liquid petroleum gas (LPG), and other fuels, and a total amount of fuel used in such.

3.5.2 Sustainable logistics operations process and effects

Consultancy services McKinsey & Company advisor Peter Spiller has written about Supply chain decarbonization by pointing out the Greenhouse Gas Protocol (GHG) Scope 3 emissions which come from downstream activities such as transportation and distribution, processing of sold products, use of sold products, end of life treatment of sold products, investments, and other instruments. Source: (GHG Protocol, 2011).

For scope three, emissions have been reported to be at least 80% of the overall climate impact of the business emissions. For resource and energy-intensive companies in heavy industry, this represents a complex challenge that will require carbon traceability and assurance by working closely with suppliers, customers, and industry organizations through actively maintaining decision-makers and stakeholders involved in a long-term effort. These system solutions for carbon tracking are discussed in subchapter 3.6.3 Carbon bonuses. Source: (Sipller, 2021).

Scope 1 and scope two emissions can be reduced by business units in the internal company. Scope 3, however, requires collaboration and partnership with both external customers and both third and fourth-tier suppliers. Recording and traceability for emission accountability are of utmost importance to decarbonization in all three scopes. Source: (Sipller, 2021).

There are still five big challenges that come between a path towards full decarbonization and business value chains which Spiller points out:

Table 8. Five challenges stand between businesses and net-zero value chains Source: (Spiller, 2021).

Challenge	Solution
1. Poor or inexistent carbon accounting	Setting baselines for scope three emissions and quantification of value at stake for achieving or not achieving objectives
2. Overrelying on secondary source data for scope three emission accountability	
3. Uncertainty on cost and technological feasibility of carbon reduction solutions.	Set a cost curve for decarbonization and prioritize according to targets.
4. Industry wide collaboration is required to reduce multiple emission sources.	Implement and trace decarbonization. Create synergies.
5. Constant involvement from internal and external stakeholders in a long-term endeavor.	

The path towards net-zero is rooted in the ability of each company and its partners to address and reduce scope three emissions. If organizations want to make a meaningful impact in their value chains, they must tackle the five main problems of decarbonization.

Net-zero can mean a big opportunity to take ownership in solving a problem that many other external parties will benefit from for some industry players. Others might want to partner with research institutes, universities, governments, and industrial corporations to develop a shared solution. Furthermore, there might be the mindset to wait patiently for others to bring about the solution, which will avoid overcommitting even though it might mean another expense.

Each decision with its degree of risk. Some might view the leadership decided to set a precedent and roll out large profits from commercializing the solution. Others might view the partnership decision to strengthen public and corporate relationships. Others might think that waiting might be the best decision because it does not represent much responsibility.

Decarbonization opportunities by sector according to Spiller:

Table 9. Choices by different sector and by factors including state of technological development Source: (Spiller, 2021).

Choice	Action	Aluminium Industry Example
Pursuing: leverages that are being developed by other leaders in the industry.	Wait patiently for industry leaders to develop the decarbonizing technology to implement a change in the supply chain.	Inert-anode electrolysis, when sold, reduces carbon offsets and costs. Strategically source from suppliers in the cutting edge of environmentally responsible technology.
Sharing: Leverage which is excessively large for individual actors to achieve differentiation.	Sharing knowledge and resources to collaborate with suppliers and customers for decarbonization in the value chain.	Closing open loops through the recycling of materials. Creating a shared strategy to generate exosystemic end-of-life for materials and products.
Leading: Leverage strategic solutions for a competitive advantage	Directly investing in net-zero solutions and lead decarbonisation in the value chain	Increase the use of recycled aluminium, creating a business with strategic suppliers to increase its use in high-end products.

Realizing the appropriate balance between company expectations and sources of change is increasing. Actors should evaluate each decarbonization decision and whether they should create and lead the transformation themselves, collaborate with other partners who may solve the problem, or wait for the new technologies to be developed by other companies. Source: (Spiller, 2021).

3.5.3 Sourcing & procurement

Sustainable sourcing begins with effective supplier engagement. In order to create a more sustainable supply chain, according to Harvard Business Review writers Gioia and Villena, it is necessary to evaluate supplier sustainability compliance across every

material sourced from direct suppliers or the suppliers' supply chain, which is known as third-tier suppliers and fourth tier suppliers.

This measure means taking into account their material sourcing standards, whether they purchase raw materials or use recycled goods, how they manage plastic and toxic waste in each of their production units, if they implement an environmental management system for their supply chain, fair labor and wage conditions for employees and if they are in continuous compliance of their sustainability objectives specific for their entire product line with accordance and cooperation from business partner organizations.

Recognizing areas of opportunity is crucial for companies who wish to take sustainability measures and develop long-term business relationships with suppliers who align with the organization's sustainability goals and third-party providers for materials or components Source: (Gioia & Villena, 2020).

Third-tier suppliers provide materials and resources to the sourcing units for component manufacturing. For example, in the aerospace industry production of main rotor blades, the titanium sourced third tier supplier is the company that refines and casts the titanium into sheets. Fourth tier suppliers would be the mining companies that extract the resource from the ground.

Company X has publically stated that complying with their supplier code of conduct is a mandatory requirement for every supplier who aspires to become a part of their procurement solutions and expects the sustainability regulations and objectives to be enforced in their code of conduct and operations for the suppliers' organization and across their supplier repository.

This measure guarantees a sustainable, ethical, and moral code of conduct for third-tier and fourth-tier suppliers, enabling Company X to have a third-tier supplier and fourth-tier supplier sustainability guarantee across their supply chain for each production unit.

However, some suppliers do not require the same standards as their suppliers. It is important to study the supply chain in greater depth to analyze the sustainability standards for sourcing and procurement from lower tiers which often do not have the resources or expertise to implement sustainability practices in their supply chain operations, or they may not be aware of social, economic, and environmental legislation Source: (Gioia & Villena, 2020).

Harvard business review points out four best practices for social and environmental sustainability:

- Suppliers have established long-term sustainability goals.
- First-tier suppliers are also required to establish long term sustainability goals.
- Low-tier suppliers are included within the sustainability strategy.
- A task person of staff is appointed to include the sustainability goals towards first-tier and lower-tier suppliers. Source: (Gioia & Villena, 2020).

3.5.4 Sustainable shipping

Using effective fuel consumption systems can help lower GHG emissions and reduce the necessity for crude oil extraction from the earth. Sustainable fuel is also being developed for cruise ships by companies in the energy efficiency industry, leading to decarbonization solutions for net-zero operations with nitrogen combined with captured CO₂ as a sustainable fuel for any transport mode.

Oils, grease, and filters used in the ship's operation must be properly discarded when the utilized material is no longer functional for the engine and other machines and ship equipment. The waste can be deposited and collected at ports of destinations that count with Association of Maritime Services contracts for the collection of ship-generated waste Source: (Port of Rotterdam, 2022).

Transshipment or transport freight of liquid or dry cargo residue that remains after the unloading of the merchandise is the responsibility of the consignee or recipient of the cargo to pay the cleaning costs and waste handling costs after the merchandise has been unloaded from the ship as well as indicate what will the respective cleaning method or waste disposal instructions Source: (Port of Rotterdam, 2022)

For upstream main rotor blade freight of materials such as composite carbon fiber, it may come in as rolls of fabric packaged either in pallets or crates with special protective foam or low-density polyethylene (LDPE) bubble wrap. These industrial forms of waste can be recycled in a special facility because recycling LDPE is more complex than other forms of plastic waste.

In the case of downstream helicopter freight, special wooden crates are used to handle the shipment of the blades and generate no waste other than additional plastic packaging such as protective bubble wrap. Styrofoam is used to secure each helicopter blade inside of the crate because each one costs over USD 200,000. The wooden crate left behind

after it has been discarded can be reused several times for other finished product shipments. Source: (Smithsonian Channel, 2017).

Water must be efficiently used in the ship, and water management systems are available for the ship's operative functions. Besides, water used in the engine room, converted to bilge water, is regarded as waste and must also be discarded at collection centers in the destination port and cannot be deposited into the sea or ocean. GHG exhaust gas control systems also monitor and control exhaust gasses emitted during the voyage. Benzene gasses generated in operation are also required to be degassed at ports that have a vapor processing system Source: (Port of Rotterdam, 2022).

Marine mammals, especially whales. Which migrate in seas and oceans using their bio-sonar, which allows them to navigate through the water, locate potential predators or prey, and communicate with other whales and members of their pod. When large cargo shipping cruisers pass close by, with their large and noisy engines, they disturb the whale's sensitive sonar system, which can cause them to become disoriented, making them lose their sense of perception and bump into cargo ships often killing them.

Active Sonar from communication transmission systems in cargo ships has also been proven to deteriorate whales' biological changes, such as disruptions in their feeding patterns, mass whale strandings, and mating opportunities. Because their natural Sonar is such an inherent part of the whale's ability to function, the noise and sonar pollution emitted from cruise ships endanger the nourishment and capacities of these marine mammals. Source: (Morell, 2015).

Phthalates are potentially the most dangerous polluting element in seas and oceans, not only for marine biology but also for human health. Phthalates are pieces of plastic that have reduced to millimetric or microscopic size and therefore are virtually undetectable at first glance. These pollutants become dissolved in the water and consequently introduced into the fish for human consumption.

Medical examinations have recently discovered that the first trace of microplastics was present in a human blood sample in March 2022. Even though most of the plastics found in the ocean are pneumatic tires, fishing nets, and abandoned fishing equipment, this does not mean that all sorts of plastic items end up polluting the marine ecosystem and should be deposited in such. (Leslie, et al. 2022).

Maritime freight shipping has made humpback whales an endangered species in most regions. Commercial ships have been responsible for some of the whale numbers depleting. Some measures are available to mitigate this detrimental impact on the ocean, such as fish finding systems to locate whales and other large marine mammals in the vicinity. (Jepson, et al. 2003)

3.5.5 Greenhouse Gasses (GHG) emissions and material data

GHG emissions generated either in the first protocol for Greenhouse Gas (GHG) scope one direct reporting company business unit emissions from company facilities and company vehicles (which are the emissions generated by shipping activities) and scope 2, indirect upstream emissions from purchased energy such as electricity, steam heating, cooling for personal use and scope three upstream and downstream emissions Source: (GHG Protocol, 2011).

IPCC shared economic pathways scenarios are a range of different sequences of events and models developed by climate scientists, economists, and energy system modelers which through the assumption of shared global socio-economic measures for environmental sustainability in which society, demographics, and economics are examined in their global progress over the next century.

There are currently five main pathway scenarios in place, which are:

- IPCC scenario 1: Sustainability, where environmental boundaries are respected. There is an emphasis on economic growth directed to human well-being & inequality reduction. Decreased energy, resource, and material consumption.
- IPCC scenario 2: Middle of the road, where there is uneven income growth and infrastructure development. Slow process to achieve sustainable development goals. Continuation of the deterioration of environmental systems. Consumption was only slightly reduced.
- IPCC scenario 3: Regional rivalry, where the domestic focus is increased. Persisting or worsening inequalities. Investments in technological developments and education are declining. Some regions are strongly environmentally degraded.
- IPCC scenario 4: Inequality, where there is an increase in inequalities across and within several countries. Conflicts are becoming increasingly common. The energy sector is diversifying. Environmental policies are focused only on local problematics in high-income areas.
- IPCC scenario 5: Rapid growth, where faith in competitive markets and innovation with increasingly integrated global markets. Strong investment in social capital continues. Lifestyles around the world are highly energy-intensive. Geo-engineering if it becomes necessary.

Source: (Riahi et al, 2017).

The threat to global security is real, and it is no longer a matter of debate. It is now a matter of how fast the catastrophic events caused by the global warming problem be avoided.

3.6 How to Draw a Causal Loop Diagram on Current System Structure

According to Checkland and Scholes, authors of the soft systems methodology in action book said, it is helpful to choose to think about the world in terms of systems, but arguing the world is a system is a position to knowledge that no human being can achieve.

Source: (Checkland & Scholes, 1990).

A Causal Loop Diagram (CDL) is a tool that, by mapping the elements and relationships between them that conform to a system structure, allows us to grasp systemic behavior concepts visually to gain a broader understanding of the problem.

To draw a (CDL), one must begin by identifying elements and their relationships to identify variables and dynamics within the established boundaries. We could begin by listing the factors which influence a specific product's component conditions for repair and whether the (+) variables change in the same direction (increment-increment or decrement-decrement); (-) variables change in the opposite direction (increment-decrement or decrement-increment).

With that identified, we can then begin establishing boundaries by the extent of the scope that individual elements and relationships have. It is essentially drawing limits that define the extent of the system of interest and provide a clear point to understand when more connections are added are not significant for the study. For this document, we will stop adding new elements when they do not directly influence the company's logistics and environmental impact on its product lifecycle. These limitations will draw the system boundaries.

3.6.1 Elements

Elements inside and outside the observed system boundaries such as: Raw material extraction, production, use, repair, recycling, waste management, transportation, energy inputs, economic growth, employment, installation, fossil fuel use, land use change, GHG emissions, surface ozone layer, precipitation, Ph at surface, mean temperature, sea ice concentration, sea level rise.

3.6.2 Relationships

The complexity of the adaptive system (CAS) as an eco-social system is defined by systems with a certain capacity to adjust to variations in their input and output needs. Corporations can remember and learn responses to different arrangements in their previous experiences to create a different possible future path. The company that repairs the main rotor blade components can develop an emissions mitigation and resource efficiency project in response to emerging environmental legislation forbidding corporations to abuse fossil fuel use and inadequately dispose of waste.

These affect planetary boundaries by pushing the limits upon critical thresholds and forcing past stability attractors for systemic equilibrium in the impact factors values. In the case of the aerospace industry, life-limited parts cannot be reused or repaired by the product servicing company. This connotation means they must be thrown away as waste and often in landfill areas, which creates incentives for hectares of land-use change by increasing the necessity for mining and waste dumps, which create a loss of biodiversity at a great scale.

The human systems in eco-social activity can define the relationship between human economic activity within climate change. These involve agency, power relations, and responsibility within interdependent relationships for economic growth. For example, in the case of this research, the agency is any individual or entity that has a direct decision-making position that has an impact that causes the degradation of the environmental conditions due to main rotor blade component logistics and repair.

The power relations are the differences in the access to information, resources, and social capital within society. The responsibility lies on the decision-makers and stakeholders that choose to create and sustain such systems for the future regardless of how they affect the world.

3.6.3 Current system modelling: Causal Loop Diagram (CDL)

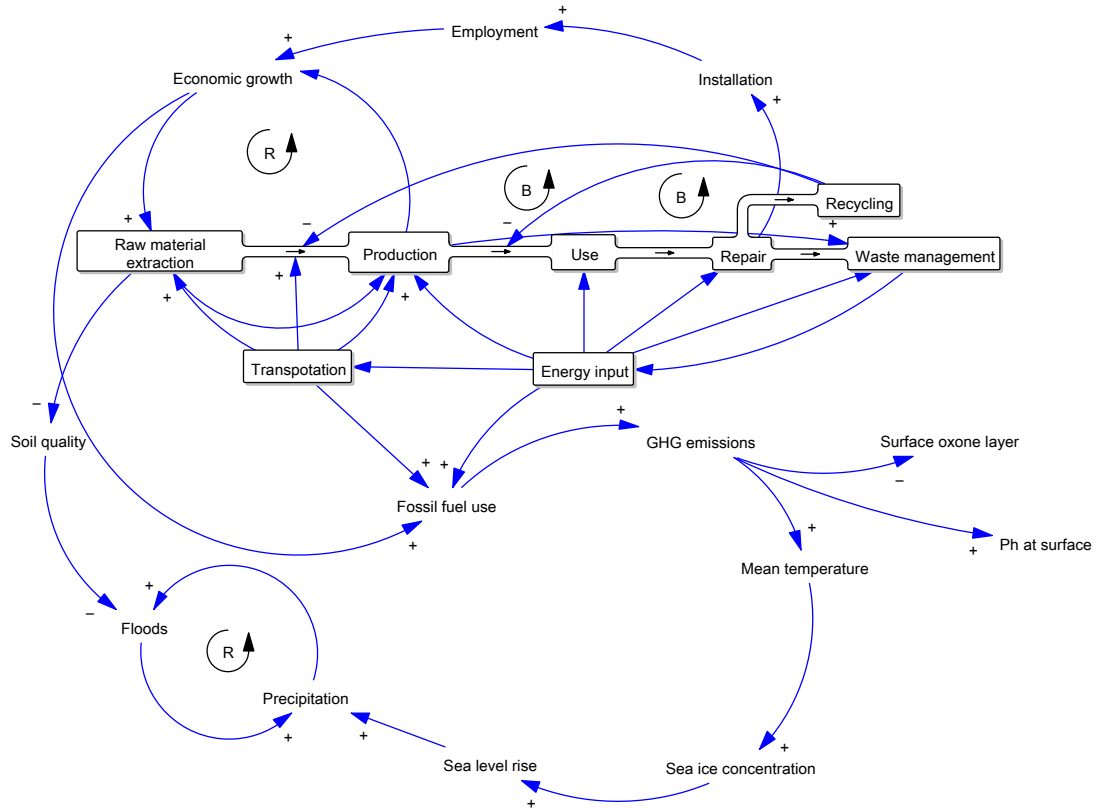


Figure 4. Causal loop diagram of current system structure.

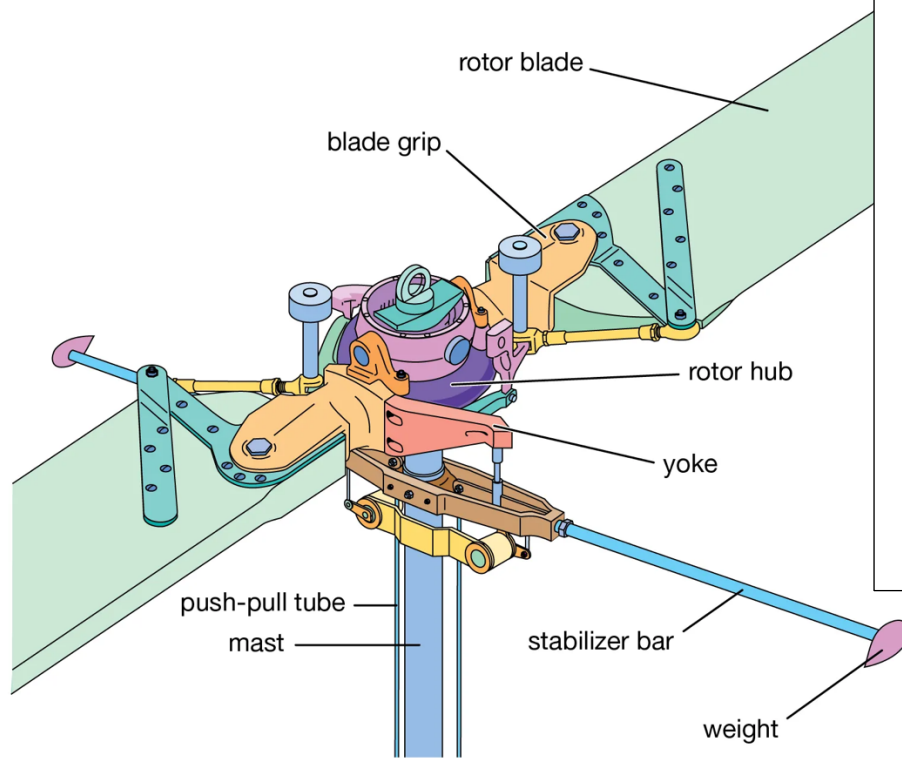
The black arrows represent the input and output movement of flows such as materials and energy along with the system, and the white boxes represent stocks that accumulate those flows.

The R in a counterclockwise circle represents a reinforcing feedback loop, meaning the increased flow (+) in the variable stock relationship to the impacted variable stock causes it to increase, augmenting the stock of that variable.

A balancing feedback loop, the counterclockwise circles with a capital B inside, work by identifying the actual situation of the objective and implementing corrective actions in response to the inconsistency of the two variables.

3.6.4 Parts and impact drivers

Parts of the main rotor



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Figure 6. Parts of main rotor. Source: (Encyclopædia Britannica, 2011).

Strategies:

- Statistically track material optimisation
- Partnership with specialised recycling facilities
- Appeal to an environmentally conscious market
- Encourage purchasing through strategic recycling plans.
- Care and repair incentive

Concerns:

- Helicopters are not currently popular or widespread
- Civilians do not normally purchase helicopters

Assumptions:

- Half of broken rotor blades will be remanufactured in EMS facilities
- Helicopter users will purchase for government or paramedic activity
- Helicopters can be leased at a lower price
- Rotor blades weigh about less than 5000kg

Company X rotorcraft vehicle products are not the same as the figure above. This image only serves as a frame of reference to show which are the components being researched and studied and their relationship to the concepts discussed in this thesis.

Table 10. "Impact drivers" environmental impacts of a main rotor blade.

Materials	Upstream transportation of raw materials	Building materials:	Transportation to disposal facility
Tail, spar, honeycomb, balance tube, erosion shield. (materials and manufacturing)	Globally to manufacturing facility (transportation)	titanium, aluminum, carbon fiber, fiberglass (use)	Recycled. Remanufactured. Incinerated. Landfill (Disposal)

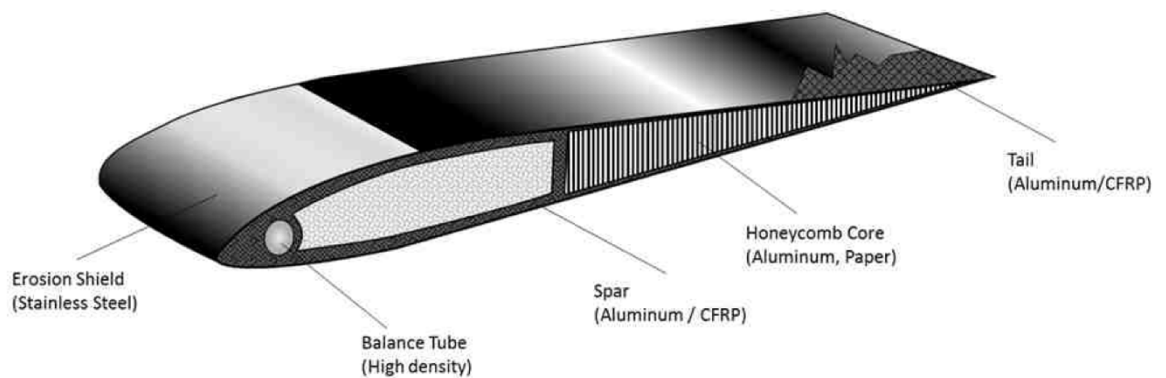


Figure 7. Cross section of a helicopter rotor blade. Source: (Krumm et al., 2019).

Company X does not disclose the use of paper or similarity in the structure of their main rotor blades; however, all the other materials used to maintain a relation to the figure above.

Closing material and energy loops by first illustrating the life cycle of a product and assessing the importance of the product detailing the flow of manufacturing stages when it was made, then assessing the environmental impacts of that product in every stage of its life cycle flow. Where can environmental impact be improved, and how can end of life be managed?

3.7 What Should the People, Planet & Profit Strategy Be for Eco-socially Concious SCM Activities.

Human beings unconsciously seek two main decision factors that define all our behaviors. The first one is love, and the second one is security. From the first time, a child

demonstrates these two factors, whether by displays of affection or in material objects in any shape or form, through the social acceptance by consensus, whether through familial relationships, films, or any other form of social interaction. This exposure creates a cultural frame of reference that those praxes are the way they can fulfill these desires.

A young human being consciously registers that those activities or articles will offer love or security and then begins to build upon a behavior pattern that will compel the rationalization to obtain those things by any means necessary. Consequently, the world has offered a socio-economic context where physical pleasure or power, no matter what, will satisfy these desires for love and security.

This world sold us the rhetoric that to earn respect or safety, one must subordinate external entities to be above someone else by putting someone down. In an industrial society, this has been manifested as the accumulation of tangible or intangible wealth and the disparity across all regions. In economics, wealth is defined as “an accumulated store of possessions and financial claims. It may be given a monetary value if prices can be determined for each possession.” Source: (Enciclopedia Britannica, 2020).

For human society to achieve these desires regardless of the cost or consequences, humanity has mutually created a culture of consumption and disposal that has no regard for the already inhabited surroundings. Investigation reports have proven that truckloads of plastic waste are being dumped in landfills and the ocean every thirty-eight seconds. (Clunies-Ross, 2019).

Capitalism has proven to be a flawed system, but that does not mean it should be completely discarded or does not have the potential to alleviate the climate crisis or potentially solve it. Industries and consumers alike must deploy themselves in the sustainable production, use, and disposal of manufactured units. The objective is to form a major shift in the culture to depart from consumerism and incorrect garbage disposal at a structural scale, even though this change begins personally.

The profit motive is not inherently bad, it can be used in favor when the means are moral and ethical, and the objectives are aligned with long-term impacts on social and environmental well-being. Using the profit motive and incentives in favor of generating positive change on our planet will create a major shift in industrial productivity and consumption culture.

It is important to recognize how every industry has been subsidized by nature. Once the earth system's critical threshold boundaries in this case, finite resources have been depleted, the system's basin of attraction will go past its tipping point, causing a new system behavior. Everyone is responsible for the product bought, the culture which wants things right now is unsustainable.

Bring about an eco-socially conscious SCM because we are all connected to supply chains. Whether we're consumers, suppliers, manufacturers or any other, directly or indirectly benefited from the value chain.

A paradigm means thinking, mindset, how matters are being processed. Principles come with established parameters or standards, boundaries and limitations for protection.

It is necessary for people and management in for-profit organizations alike to restructure unconscious materialistic and consumerist desires by replacing them with a conscious decision to pursue a path guided by ethics and morals within each of our actions to shift the power dynamics in industry and trade culture.

The Global Reporting Initiative or (GRI) is a reporting method to disclose and identify sustainability. It is one of many but the most popular nonetheless because, European Union (EU) parliament directive 2014/95/EU law requires certain companies to report their emissions, social and environmental impact. It also allows for the company who reports the initiative to bring transparency to stakeholders.

3.7.1 Established stakeholder key performance indicators (KPIs)

The complete list of UN Global Compact SDG which Company X is committing to are:

- #4 Quality education
- #5 Gender equality
- #8 Decent work and economic growth
- #9 Industry innovation
- #12 Responsible consumption and production
- #13 Climate action
- #16 Peace, justice and strong institutions
- #17 Partnership for the goals.

Some of the UN's global compact sustainability development objectives have been made to be interrelated through positive interconnections and synergies. Alternatively, negative interconnections are known as trade-offs. However, the UN Global Compact SDG chosen by Company X does not positively connect with other SDGs in synergies.

3.7.2 Tripple bottom line diagram and strategy

The figure below is a triple bottom line or 3P venn diagram for social, environmental and economic activites where capital assets are allocated.

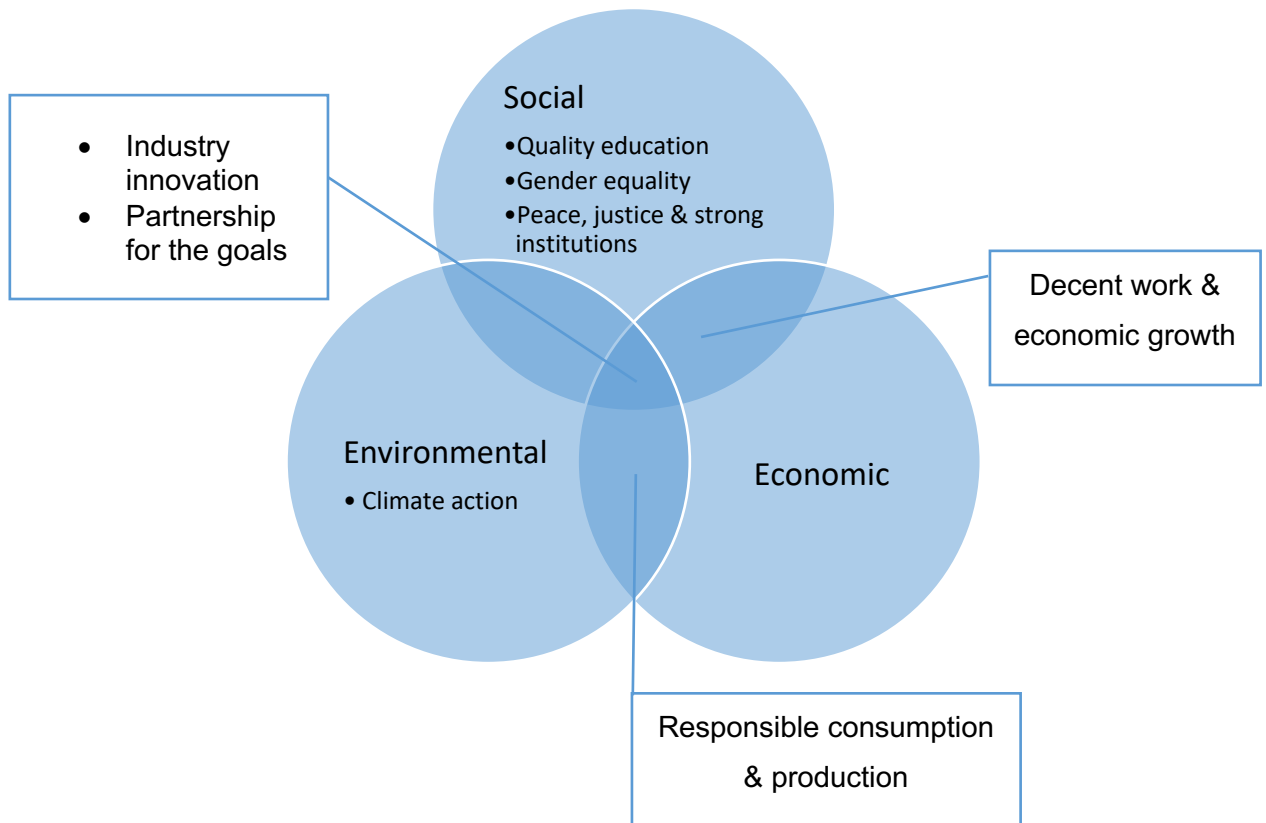


Figure 8. Triple bottom line diagram in Company X UN Global Compact SDG

The Tripple bottom line diagram is a term created by business writer John Elkington And it serves as a visualization of financial investments reflected in the company's bottom line to alleviate the impacts and connections their business activities have to the three dimensions, environmental, social, and economical.

3.7.3 Carbon bonuses

Carbon Bonuses are positive monetary incentive credits issued by cap-and-trade programs in countries that can be exchanged in the futures contract market, working as a corporate allowance for emissions. Carbon offsets traded in Europe are traded in the European Union Allowance (EUA) financial institution in the mandatory compliance carbon market. One EUA is equal to one ton of CO₂ or CO₂ gas equivalency allowed to emit by the futures contract holder Source: (Carbon Credits, 2022)

Carbon credits are worth "the average price paid for a tonne of carbon removed from the atmosphere" However, the price can vary between the quality and type of carbon offset project, validity, additional benefits created by the carbon offset program, waste-to-energy, renewable energy, and many more factors. According to the Carbon Credits website, in 2019

There are two main carbon offset markets: mandatory (compliance) and voluntary carbon markets (VCM). The mandatory (compliance) carbon market is governed by national, regional, or provincial law and obliges sources of emissions to conform to GHG emission reduction objectives. Source: (Carbon Credits, 2022)

The voluntary Carbon Market (VCM) aims to reduce emissions as lucrative monetary incentives. If a corporation exceeds its GHG emissions, it can purchase carbon credits from the carbon market to comply with its government's GHG regulatory parameters. Source: (Carbon Credits, 2022)

GEO contracts follow strict COIRSA standards from the International Civil Aviation Organisation. These carbon offsets come from the American Carbon Registry, Climate Action Reserve, a high-quality carbon offset that complies with international aviation industry regulations or emission offsetting. They are referred to as "Aviation Industry Carbon Offsets" Source: (Carbon Credits, 2022).

3.7.4 Function to cost structure

The sustainability strategy would function to costs with the financial leverage generated by the monetary value in implementing a systemically earth-centered product LCA for its manufacture and supply chain offset strategy added carbon bonuses. These, in turn, would create a financial cushion upon which to lay the costs of the triple bottom line and sustainability strategy implementation.

There is also financial risk analysis, such as the Task Force on Climate-related Financial Disclosures (TCFD), founded by the Financial Stability Board, allowing companies to protect themselves from systemic risks implicated with climate change financially. TCFD provides insights and financial recommendations for all market players on future physical and transition climate change risks such as droughts or sea-level rise through published information about the financial opportunities and uncertainties by setting a 2°C pathway scenario as the target objective with financial analytics to accurately price and value assets and therefore make better investment decisions with visibility into the future of climate change-related events. (S&P Global, 2022).

4 Research Methods

4.1 Key Findings

Desktop research is limited due to unavailable precise emissions disclosure from the industry studied, being regarded as business secrets.

Material data can be found on university research and project papers even though not the exact companies the study is based on, the processes and quality specifications are the same.

Legislative requirements on environmental matters are found on government website entries such as the United States Environmental Protection Agency and the European Commission.

Data on carbon offset credits was different because there is not a single centralized institution dedicated on providing information on carbon credits, it can be collected by third party organisations such as CDP or Carbon Credits website.

4.2 Population and Sample

The qualitative data sample specific to the main rotor blade materials and manufacturing details came from an individually high-level contact person who prefers to remain anonymous at Company X's international factory facilities.

4.3 Data Collection

The data collection methods came from a mix of desktop research and qualitative and quantitative data gathering from Company X organisation website and publically disclosed documents and reports.

Most confidential information is hard to obtain and disclose on a university institution published document. Nonetheless, desktop research included university research papers, government institution webpages, aviation industry webpages, sustainability websites, sustainable business consultancy reports and commissioning company public website documents and reports.

University research papers were used to gather information on materials and consumption process, sustainability practices, and aviation vehicle component technical details.

Government institution websites were accessed to obtain information not only on industry insights but also on environmental regulations and scientific paradigms.

Aviation industry webpages were used to obtain data on the material component data and the nature of the products related to this thesis research question.

Youtube videos were used to explain first what the systems philosophy is and on the shipping process for helicopter main rotor blades.

Sustainability websites were accessed to gather information on recycling processes and innovations on material recycling facilities.

Consultancy companies publicly disclosed documents and research was used to obtain information on sustainable supply chain practices as well as the outlook on future sustainability trends for logistics, sourcing and operations.

4.4 Reliability, Validity and Relevance

The data was analysed prior to incorporating it into the thesis through research. Most of the information detailed in this document has less than 10 to 15 years of antiquity. The core concepts of the thesis are somewhat older such as circular economy and decarbonisation however, the challenges, standards, legislations and material reports used are not older than 15 years some have been published within the last year.

The data collected online was the closest approximation to Company X process and requirements for the manufacturing of helicopter main rotor blades.

4.5 Data Analysis

The data obtained was necessary to investigate the different requirements for building a circular economy with a sustainable supply chain for a helicopter's main rotor blades. Even though some of the specific data for Company X was not able to be included in this thesis document. The closest available data online was collected to fit the research question.

5 Data and Results

The qualitative interview question answers used to implement in this thesis cannot be included in their entirety because they were expressly requested not to be disclosed on the thesis document on behalf of the commissioning company. They can only serve as a frame of reference to guide the research and answer questions directly related to the manufacturing and materials used on the main rotor blades.

6 Conclusions

6.1 Key Findings

Sourcing and procurement of aerospace materials is complex due to the high demand standards for aerospace grade quality resistance properties, often times requiring only virgin materials.

Key challenges for supply chain decarbonization are cooperation between several supplier tiers, net-zero transportation services, and carbon accounting for logistics operations.

The aerospace industry's product supply chain system is an intricate global network of multiple supplier tiers that must enforce the most scrutinous environmental impact management standards for their operations to comply with laws and legislations and be a part of the global supplier repository for aerospace companies.

Achieving a circular economy for helicopter main rotor blades can be achieved through partnership and collaboration with the latest technologies for recycling carbon fiber, fiberglass, aluminum, and titanium.

However, achieving a systemic forcing in the attractor's basin for a structural change that achieves broader and far-reaching sustainability objectives such as regenerating ecosystems will depend on collaboration between sectors and industries to create a new constant basis for the business involved in sustainable innovation.

6.2 Recommendations

A major initiative from the industry players must be initiated on the road toward structural sustainability to shift the power dynamics. It begins with a cultural change in corporations that will bring about society to shift their cultural perspectives on environmental coexistence with economic development. They will begin to view their role in the world as one who matters for the benefit of the community.

Designing for the availability for reuse, repair, and remanufacture is key to reducing the demand for resource extraction. On financial matters, the TCFD does not report on abrupt changes such as if the currently used fuels or materials should one day not be available

for the company or if countries were not able to provide them; therefore, it is important to develop a tool that anticipates what to in such cases.

Because of the arguments against a circular economy in the potential increase of emissions generated by transportation in the recovery of materials, the recommendation is that the circular economy must have sustainable logistics and transportation infrastructure in place which monitors and takes advantage of sustainable fuel options or at the very least respects the current legislation for their vehicle emission regulation. Fortunately, crates, pallets, and containers can be leased and returned to the leaseholder depending on the type of contract and its requirements.

6.3 Reliability, Validity and Relevance

Validation in a causal loop diagram is made by comparing the conceptual model with the real-world system to see if we have included all the meaningful aspects of the system in the model. Validating this research's conceptual model by seeing if the IPCC shared socio-economic pathway scenario conditions align with the industry KPIs for sustainability and waste management, which are the real-world conditioned actions companies take to mitigate the impact upon the earth system boundaries, whether they have significant relevance to such.

Verify the study by determining the closeness of the simulated behavior compared to the real system behavior. This verification can be made by looking at the IPCC WGI Interactive Atlas: Regional Information simulation model numerical values and statistical tendencies compared to the stock and flow input and output graphed tendencies through sensitivity analysis by changing some of the parameters to look at the dynamics in the system behavior.

Changes can be represented as separate scenarios for analysis. For example, the sensitivity analysis can reveal how the CO₂ emissions perform when the input variables for fossil fuel use are duplicated. In this case, leverage points such as carbon buffers and stock and flow structures in waste disposal networks can create different scenarios for feasibility study, especially before being implemented in practice.

The topic of global warming is a relevant trend that has to be constantly addressed to develop the culmination of multiple decision-makers and stakeholders to solve the problem for future generations collectively.

6.4 Further Research

Power to x technology is a sustainability strategy where fossil fuels are replaced by sustainable energy by Capturing CO₂ from the air and storing the excess power generated by fluctuations that make supply exceed demand. Source: (Byfield & Vetter, 2016). An example of this could be Sustainable Aviation Fuel (SAF) which comes from organic cellulose mixed from discarded clothes, grass cuttings, and other organic materials mixed with other fuels. As they are not extracting more oil but replacing it with existing emissions, the fuel is considered net-zero due to its carbon footprint balance.

There has also been a claim against the circular economy, arguing that only residues generated in the future will be recycled, and the residue left in landfills will not be managed. It is a different challenge from manufacturing but must be addressed by land conservation associations or government plans for land restoration to achieve a higher level objective in the circular economy route.

The core source of the global warming problem is not waste, resource depletion, or toxic emissions. Those are only symptoms or collateral damages of the main problem. The main cause is the thought culture of compulsive consumerism as accepted behavior. Source: (Hartmann, 2009).

6.5 Reflection on Learning

Conducting this research was a valuable insight into an industry that demands the highest standards and quality. It was challenging to find appropriate solutions and criteria to a global challenge. Moreover, the experience of developing this thesis document provided me with more insights and abilities into developing circular economy achievement levels and sustainable supply chains in an industry that is constantly evolving.

A product LCA is the only criteria and tool for business units to generate accountability for the emissions generated by the product's material sourcing, production, manufacturing, transport, use, and disposal. An LCA by itself will not suffice as a long-term objective of the circular economy if it is not partnered with a strategy that fits natural ecosystem cycles.

Systemic change can only be brought about with the cooperation of multiple actors to create a new basin of the attractor to generate a forcing in the system dynamics and go past the tipping point from the critical threshold and generate new structural change for a new way of creating eco-social value.

Reducing several emissions such as chemical is the tactical tool and criteria that allows aerospace industry companies to achieve short-term objectives; however, multiple partnerships are required in creating conditions for change to achieve a dynamic level of the circular economy.

The environmental impact of ineffective waste management goes beyond the depletion of natural resources. It is all the different changes to everyday human life and the person's well-being that will change if a transcendent view is in places such as the redefinition of activities which impact common activities, functions, and abilities that will be lost due to a tipping point forcing in our ecosystem's critical threshold which causes a new system behavior, dynamics, and structure..

7 Discussion

The challenges in sustainability for aerospace industry to reach a circular economy dynamic and in hopefully a near future at structural level change for long-term wellbeing such as healthy ecosystems, environmental and social planetary boundaries being respected, begins with tactical

It has been argued that reverse logistics would increase and sometimes even double emission offsets because the recovered material haul back shipping would generate a second need for transportation in place from the different recovery locations.

It was presented in the introduction of this thesis document that each part is not enough for achieving what the circular economy searches to obtain as goals for dynamic and structural levels that the circular economy cannot be made without a sustainable supply chain.

The challenge is not really regulated, one must set targets but not everyone is at the same place. Risk assessing the cost of opportunity in not meeting these criteria.

The question remains which decisions will the industry take in the technical and dynamic reaches of the circular economy, such as tools, key processes, criteria, and conditions both listed in this thesis and available elsewhere to obtain a unique strategy to obtain the level of reach of structural change in the system behavior.

We are all connected to supply chains, whether we are employees of a business or individual consumers. The problem of environmental impact on global warming, ecosystem deterioration, resource depletion, and cultural consumerism is larger than turning off the tap on fossil fuels. It needs the technological infrastructure for a regenerative change.

It is important to see the traceability of where waste and emissions come from and how they are generated and to talk with several business units involved to review and assess the applied due diligence. A higher level of achievement in the circular economy can be obtained if these recycling processes can be implemented together with net-zero transportation and logistics.

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Appendices

Appendix 1. Causal loop diagram of current system structure.

