A REFERENCE MODEL FOR DECARBONISING THE PASSENGER AVIATION ECOSYSTEM

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A Reference Model for Decarbonising the Passenger Aviation Ecosystem

by

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Preface

When I was in high school, I majored in Architecture and I was considering following a career as an architect. However, technology has always played an essential role in my life, and I was always eager to learn more about the latest innovations and developments. For a long time, I was looking for a way to combine both my passion for structural design and technological development.

A few years ago, when I was finishing my bachelor's degree, I found out about Enterprise Architecture as a professional path. I have decided to focus my master's on Enterprise Architecture and I am sure it was the best decision for me. During my master's study, I have realised that thinking from an architectural perspective encourages design thinking and enables problem-solving in a structured manner.

As I am a strong believer that using an architectural approach can help overcome any challenge, during my master's thesis I have decided to focus on one current problem which is very close to my heart, sustainability. This research has been carried out within 8 months, where I managed to improve my ecosystem architecture skills, as well as learn a lot about decarbonisation and the aviation industry. With the help of many, this research become what it is today and aims to shine a light on Climate Change by emphasizing the impacts ecosystem architecture can bring.

Along my journey, I have received enormous support from a number of people. Firstly, I would like to thank Maria Iacob and Marten van Sinderen, my University of Twente supervisors, for providing support throughout my entire study and guiding me during the path of my thesis. Secondly, I would like to thank my Deloitte supervisors, Laleh Jalali Khalilabadi and Paul Verhoeven, for being there every step of the way during my thesis. Lastly, I would like to thank all the experts who have taken part in this research and have provided valuable information along the way. Without the support of all these people, the research would have looked a lot different than it does today.

Special thanks to Deloitte and the other companies that took part during the interview and validation sessions. As well as a lot of appreciation to the university staff for helping me during the process.

I would like to end by thanking my family and friends for their constant support during this research, and throughout my entire study path. It was a long path and I am happy I did not have to walk it alone.

I truly hope that you will enjoy reading this research.

Ioana Miu
Enschede, April 2022

Executive Summary

Currently, Greenhouse Gas (GHG) emissions are one of the biggest threats to the environment. The aviation industry currently contributes over 3% to global CO_2 emissions and is considered the most unsustainable mode of transport currently available [1]. Additionally, passenger travel is accountable for 81% of the overall aviation emissions. Therefore, the industry must reduce its current emissions and the enterprises active within the industry must improve their current business model.

A Digital Business Ecosystem (DBE) aims to create an environment that fosters the economical development of businesses and facilitates the interaction between enterprises, governments, research and innovation [2]. The proposed perspective of reinventing the industry and making it ready to face the incoming emission reduction standards by using a DBE was due to the alignment of the aim of a DBE with the goal of this research. This can enable the industry to connect and collaborate with other stakeholders inside the industry and strategically align their business to reach their decarbonisation goals. The aim of the research is also reflected in the main research question of this research, as shown below.
"How can ecosystem architecture improve the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?"

A literature review was conducted to establish the state of the art literature regarding the aviation industry-wide decarbonisation approaches, and create an overview of the existing DBE architectures which aim to solve decarbonisation issues in the aviation industry. Due to a shortage of literature, a preliminary series of nine interviews have been conducted. During these interviews, the capabilities needed for reducing the industry's emissions were defined and a capability map which provides the foundation for the reference model was designed. Additionally, the second round consists of six sessions, each focused on a different sector (Ground Operations, Flight Operations, Aircraft Design, Fuel Management, Ecosystem Management for Flights Improvement, and Ecosystem Management for Flights Reduction). For each value chain within the aviation industry, architectural models have been designed in collaboration with the experts. This technique was used to define the main common capabilities and understand how each value chain needs to be integrated into the ecosystem model.

According to the opinion of the experts, a centralized Ecosystem Core model was needed to assure the collaboration of all parties into one decarbonisation ecosystem. Moreover, a reference model for decarbonising the aviation industry through an ecosystem approach has been designed. Additionally, during the research, a novel approach to the use of DBEs for the purpose of decarbonisation has been developed. The findings presented in this research directly contribute to the research and to the practice of DBE, as well as the current knowledge concerning the correlations between DBEs and decarbonisation. Lastly, this research has resulted in a new way of perceiving Aviation as more than a classical industry, but as a DBE.

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Abbreviations

APU	Auxiliary Power Unit
ATFM	Air Traffic Flow Management
CDA	Continuous Descent Approach
CORSIA	Carbon Offsetting and Reduction Scheme in International Aviation
DBE	Nationally Determined Contribution
DSM	Design Science Methodology
EA	Enterprise Architecture
GHG	Greenhouse Gases
HCD	Human-Center-Design
IATTA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILR	Integrative Literature Review
LNG	Liquefied Natural Gas
LR	Literature Review
MFFCS	Multi Functional Fuel Cell System
MFHE	Multi-Fuel Hybrid Engine
NECP	Integrated National Energy and Climate Plan
NSCs	Nationally Determined Contribution
ODSs	Ozone Depleting Substances
RCSFPAT	Requirements for Communication Systems in Future Passenger Air Transportation
RQ	Research Question
SLR	Systematic Literature Review
SPs	Sustainability Principles
TEAM	The Ecosystem Architecture Management
UAM	Urban Air Mobility
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1

Introduction

In this section, an introduction to this research is provided, together with all background information needed to understand the research. Furthermore, the research method selected, in this case, Design Science Methodology, is presented in-depth. Lastly, the research problem and objectives, as well as, the research questions, are described.

1.1 Introduction

Currently, Greenhouse Gas (GHG) emissions appear to be one of the biggest threats to the environment. Especially, CO_2 emission resulting from Oil and Gas based energy production, distribution and utilization primarily contribute to the problem [18]. According to literature, Climate Change is one of the major issues society is dealing with at the moment [19]. However, despite the gravity of the problem, the current initiatives aiming to provide a feasible solution are limited.

The necessity of reducing Carbon Dioxide (CO_2) emissions in the energy production, distribution and usage industries is a currently known fact [19], which implies that changes need to be made for all emissions Scopes. This research will focus in particular on Scope 3 emissions, as they define the category of emissions that occurs from sources which are not owned or controlled by the company.

The aviation industry currently contributes over 3% to CO_2 emissions and Climate Change and is considered the most unsustainable mode of transport currently available [1]. Additionally, passenger travel is accountable 81% of the overall aviation emissions. In Europe, the reasoning for the low sustainability of aviation is considered to be the rapid expansion and estimated future growth of the sector [20]. Factors such as increasing GDP, globalization and liberalisation of the air transport market in combination with the current technological level of the industry and the low fares business models; are considered to be the reasons behind the high emissions in the sector [20].

When it comes to ecosystem modelling in the Aviation Industry, models have been built to show how current technologies such as Carbon Capturing and Storage, as well as the integration of reusable energy resources, can reduce emissions. The current state of the art literature, despite providing models which incorporates decarbonisation capabilities for the aviation sector, is primarily focusing on singular changes.

Based on a preliminary review of the aviation industry, it become clear that there is a large diversity of stakeholders (the government, the regulatory institutions, the airlines, the airports, the aircraft manufacturers, the fuel suppliers, the customers etc.) involved, as well as a lot of interconnected processes [21]. As a result, an ecosystem approach has been found appropriate for this research and is proposed as a solution for tackling the current CO_2 emissions increase from the aviation industry.

This research aims to create a reference ecosystem model for the passenger travel aviation industry, including emission reduction capabilities and decarbonisation as the main focus.

1.2 Background

This section contains background information regarding the topics further discussed in this research.

Firstly, the main sustainability-related taxonomy used during the research will be presented to provide the basic terminology expected for understanding this research. The sustainability-related explanations can be found in Section 1.2.1.

Secondly, the current CO_2 emission agreements and targets will be discussed. The international agreements and the targets will be summarised with a focus on the Netherlands. A specific country had to be chosen to narrow down the scope of the research and enable the focus on more specific information. The in-depth information regarding agreements and targets can be found in Section 1.2.2.

Thirdly, the terminology required before collecting all information needed for constructing the capability model as an artifact is provided in Section 1.2.3.

1.2.1 CO_2 Emission Taxonomy

In this section, the main sustainability-related taxonomy, with a direct focus on decarbonisation, will be presented.

1.2.1.1 CO_2 Emission Terminology

To better understand the CO_2 emission quota, it is necessary to acknowledge the diversity in the terminology used to describe the CO_2 emission in the distinct context of the articles and journals analysed. Although the Carbon Dioxide (CO_2) emission is the focus of this research, there are diverse terminologies found to have a similar contextual meaning such as:

Terminology	**Source**
Greenhouse Gas	The Paris Agreement
Greenhouse Gas Emission Inventories	The Kyoto Protocol
Decarbonisation	The Kyoto Protocol
Decarbonising the economy	The Kyoto Protocol in the EU
Carbon Stock	The Paris Agreement
Net Zero Target	The Paris Agreement

TABLE 1.1: Distinct CO_2 Emission Related Terminologies

Table 1.1 shows a list of the most used terminologies and the sources from which they have been retrieved. To familiarize the reader with these terms, the definitions of each term are provided.

Greenhouse Gas (GHG) Greenhouse Gas is one of the terminologies used for the gases which emit and absorb radiant energy, within the thermal inflated range, causing the greenhouse effect. According to the Kyoto Protocol [19], these are the following Greenhouse Gases considered, given that the Ozone Depleting Substances (ODSs) are already controlled by the Montreal Protocol [19]:

- Carbon dioxide (C02)
- Methane (CH4)
- Nitrous oxide (N20)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF6)

Greenhouse Gas Emission Inventories Greenhouse Gas Emission Inventories refer to creating more standardised "reporting, reviewing and compliance procedures related to the reporting of Greenhouse Gas (GHG) emission inventories and accounting of assigned amount" [19].

Decarbonisation Decarbonisation is a term used by many scholars when referring to reducing, and even removing the CO_2 emission from the atmosphere [22]. Despite the uncertain origin of this term, this explanation was found numerous times during the literature research. The oldest source mentioning the term "decarbonisation" found during the Systematic Literature Review (SLR) was The Kyoto Protocol [19]. For this research, the following definition of decarbonisation has been used: "Decarbonisation is the term used for removal or reduction of carbon dioxide (CO_2) output into the atmosphere. Decarbonisation is about reducing CO_2 emissions resulting from human activity, with the eventual goal of eliminating them." [22].

Decarbonising the economy Decarbonising the economy is also a common goal presented in most of the International targets, which also applies to the Netherlands. This term refers to reducing the output of GHG emissions and building an economy based on low-carbon energy sources. Moreover, this term is closely related to the Kyoto Protocol, since it is one of the targets aimed to be reached by following the protocol [23].

Net Zero Targets Net Zero Targets is a terminology, often used in the Paris Agreement proceedings, which refers to reducing the CO_2 emission to zero. This target was globally set for 2050, to limit the global warming process [24]. However, according to the agreement, each country can independently determine their strategical contribution under the Paris Agreement [25].

Energy Value Chain When it comes to the energy value chain, it is needed to define the boundaries of Integrated Oil and Gas processes which in this case represent the majority of the value chain.

For this research, the value chain was considered from the initial stage of Exploitation, until the final stage of Retail. To better understand the boundaries and layers of the energy value chain, the "Simplified illustration of accounting of product transfers along the value chain" design by Siveter et. al can be found in the Appendix, in Figure 1.1 [3].

Figure 1.1 shows the 3 steps in the energy value chain: Exploitation and Production, Refinement, and Retail [3]. However, depending on the specific value chain, extra stages can be added, such as: "Exploration and production; Oil sands and heavy oil upgrading; Coal bed methane production; Gas processing; Carbon capture and geological storage; Natural gas storage and (liquified natural gas) LNG operations; Liquid transportation and distribution; Natural gas transmission and distribution; Refining; Petrochemical manufacturing; Minerals and mining operations; Retail and marketing; and Energy generation (including electricity, heat/steam, and cooling)" [8].

Additionally, it is important to understand that each layer of the value chain can be managed by a distinct company [21]. There are situations in which one company can internally operate throughout the entire value chain. However, in most situations, the value chain acts as a non-linear ecosystem.

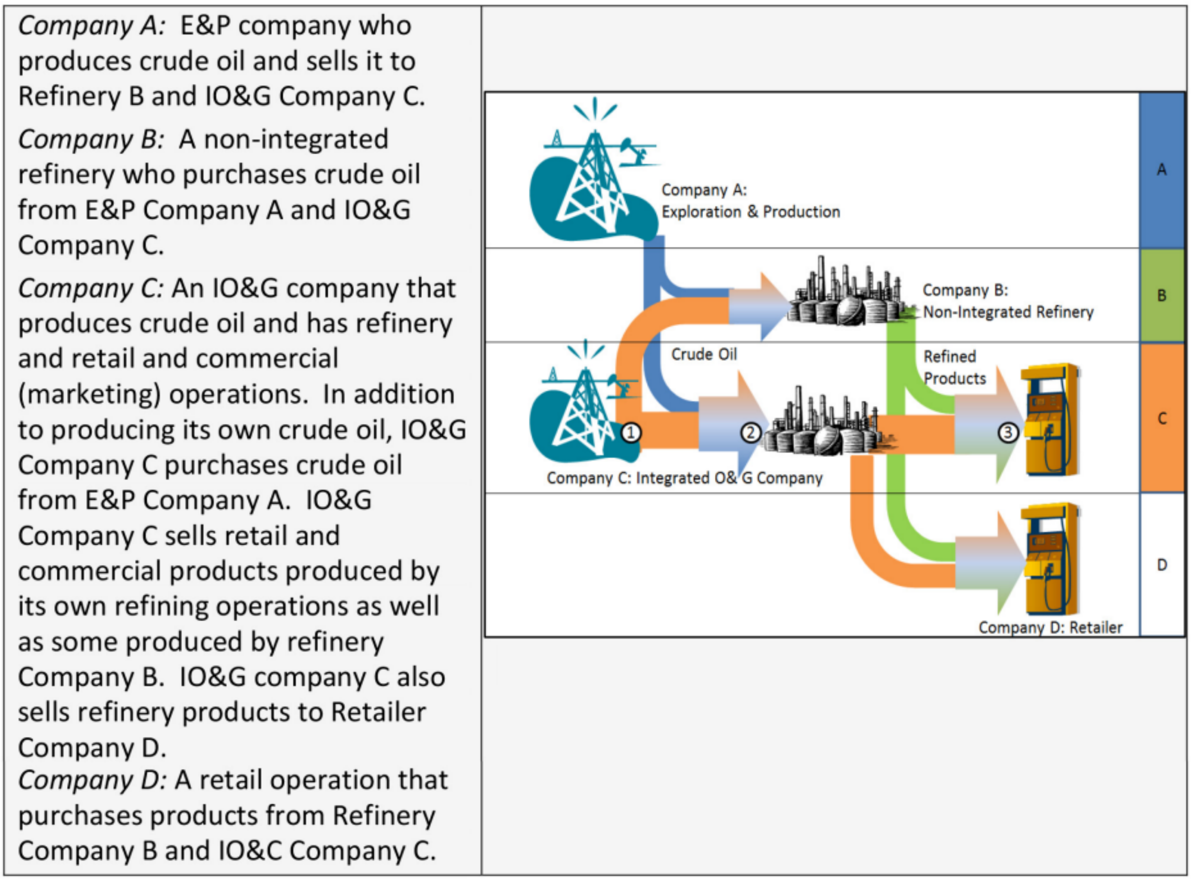

FIGURE 1.1: Simplifies illustration of accounting of product transfers along the value chain [3]

Although the value chain can be seen as an entity, it can involve numerous actors, processes and technology layers. Due to the level of interoperability of the value chain, it can be considered an ecosystem in itself.

1.2.1.2 Upstream and Downstream

Another way of structuring the industry based on value chain instances of CO_2 emission is by using the upstream and downstream operations [3]. "In the context of future GHG regulations, significant GHG emissions in a company's value chain may result in increased costs (upstream) or reduced sales (downstream), even if the company itself is not directly subject to regulations. Thus investors may view significant indirect emissions upstream or downstream of a company's operations as potential liabilities that need to be managed and reduced"[26]. The representations of Upstream and Downstream can be also observed in Figure 1.2.

Upstream Refers to "Indirect GHG emission related to the purchased or acquired goods and services" [3]. Upstream emissions are classified to be generated from cradle to gate. The upstream emission averages 4 times the operational emission, so they have a huge impact on climate change [27]. "Supply chains can include tens of thousands of suppliers, many of them small and medium-sized enterprises with limited resources. Reducing upstream emissions necessitates actively and effectively engaging the supply chain" [27].

Downstream Describes the "Indirect GHG emission related to sold goods and services" [3]. "Downstream emissions are emitted after a product or service leaves the company's control/ownership" [27]. Additionally, downstream interventions are mainly affected by product design and behaviour change [27].

1.2.1.3 Emission Scope

To better distinguish the differences between direct and indirect emission, the term "scope" was attributed to better define the GHG reporting processes [3]. The GHG gas emission is divided into 3 scopes, in order to improve emission transparency and to centralize the reporting terminology [26]. Scope 1, 2 and 3 are mutually exclusive in any given context and by combining Scope 1, 2 and 3 for one company, one can estimate the total GHG emission of one company throughout the value chain [3]. Figure 1.2 provides a clear visualisation of the 3 Scopes and their relations to the value chain.

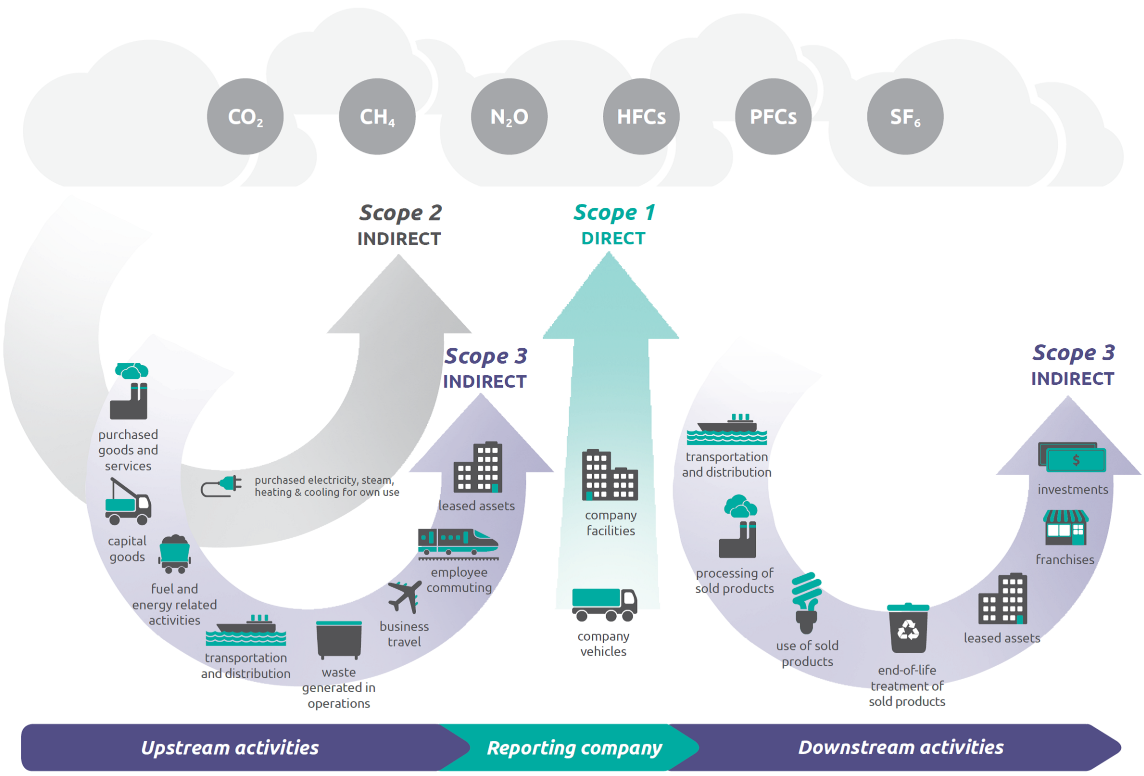

FIGURE 1.2: GHG Protocol scopes and emission across the value chain [3]

Scope 1 Describes direct GHG emissions resulting from sources which belong directly to the company (such as emissions produced by company-owned vehicles or technological machinery, or emissions from combustion in owned or controlled boilers). Scope 1 emission refers only to the list of GHG mentioned by the Kyoto Protocol [26].

Scope 2 Refers to indirect GHG emissions originating from electricity. This emission results from the externally provided electricity which is being used by the company. Scope 2 emissions are accounted for at the facility where electricity is generated [26].

Scope 3 Aims to cover the remaining indirect GHG emissions which did not belong to either of the previous scopes [3]. Scope 3 emissions define the category of energy emissions that occur from sources which are not owned or controlled by the company. A good example of this applying to the energy distribution industry is the context of transportation of fuels which have not been produced by the distribution company [26]. Traditionally, Scope 3 emission is dived into two categories, Upstream and Downstream; these categories have been described in-depth in Section 1.2.1.2 and can also be visualised in Figure 1.2.

1.2.2 Agreements and Targets

This section describes the main agreements currently setting the targets and designing strategies regarding CO_2 emission reduction. Additionally, the main Dutch targets for reducing the CO_2 emission will be collected and presented in an orderly manner.

1.2.2.1 Agreements

When it comes to documentation regarding the CO_2 emission targets worldwide, two agreements are setting the targets and designing strategies regarding CO_2 emissions. The Paris Agreement regarding Climate Change of 2015 and the Kyoto Protocol of 1992, are the principal findings of the literature review. Although neither of these agreements appeared as primary sources, the sources collected regarding CO_2 emission and Greenhouse Gas targets have been built upon these two agreements.

The Paris Climate Agreement The Paris Climate Agreement of 2015, effective starting from 2021, aims to set a global framework which helps diminish the climate variations. This agreement is currently the guideline when it comes to reducing GHG emissions, especially Carbon Dioxide emissions. Additionally, the policies agreed upon, have as a goal, reaching the Net Zero target and climate-neutrality [24].

Although this agreement has an international orientation, the objective of the agreement is that each participating country has a Nationally Determined Contribution (NSCs) [24]. This contribution implies that each particular country will create a National Climate Action Plan where it will provide the particular goals and strategies. Moreover, the governments agreed that these contributions will be finalized and updated within 5 years following the signing of the Paris Agreement [25].

The European Union has submitted their contribution regarding Article 20(3) of the Paris Agreement and has fixated a list of four objectives, which need to be implemented in the contribution of each member country [25]. The four fundamental objectives are as follows:

- preserving, protecting and improving the quality of the environment;
- protecting human health;
- prudent and rational utilisation of natural resources;
- promoting measures at the international level to deal with regional or worldwide environmental problems, and in particular combating climate change.

Aside from the above mentioned, the Netherlands has not yet made available its NSC details in line with the Paris Agreement. However, a public declaration has been released confirming the involvement of the Netherlands in the Paris Agreement. The following declaration has been found in an accredited source which is directly related to the Paris Agreement, however, it was not a part of the SLR: "The Kingdom of the Netherlands, for the European part of the Netherlands, declares under Article 14, paragraph 2, of the United Nations Framework Convention on Climate Change in conjunction with Article 24 of the Paris Agreement, that it accepts both means of dispute settlement referred to in that paragraph as compulsory in relation to any Party accepting one or both means of dispute settlement" [28].

Kyoto Protocol The Kyoto Protocol which came as an addition to the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, is the predecessor of the Paris Climate Agreement. The Kyoto Protocol is focused on two strategical points: I. "global warming is occurring" and II. "human-made CO_2 emissions are driving it" [19].

Although the protocol became effective in 2005 and the strategically set time-frames, including the time extension, for both stages have ended in 2020, its objectives are still referenced as the focuses of today's documentation. Moreover, one of the documents found during the SLR is an actual Journal Article reviewing the implications of implementing the Kyoto Protocol [29].

Given that the Kyoto protocol did not manage to reach the relevant targets detailed upfront, many considered the Paris Climate Agreement to be an improved continuation of the Kyoto Protocol. Additionally, the objectives of the Kyoto Protocol have been reused, by the European Union, as the objectives each member state should focus on when creating the national contributions for the Paris Agreement. The objective list can be found in the above paragraph regarding the Paris Agreement.

Lastly, unlike the Paris Agreement which aims to achieve its goal by motivating each nation, in particular, to participate with a national contribution internally defined, the Kyoto Protocol had a set of clear targets applying to each of the countries involved [19].

1.2.2.2 Targets

To better understand the Dutch targets for reducing the CO_2 emission, this section provides a structured table including the current targets resulting from the research. The information presented in the table was collected from the Integrated National Energy and Climate Plan (NECP) for 2021-2030, which is the official Dutch document, created as a proceeding to the termination of the Kyoto Protocol. This also partially defines the national contributions regarding the Paris Climate Agreement [4].

Additionally, the Kyoto Protocol has defined a list of targets which apply to the Netherlands, and which have not yet been met during the protocol. One of these targets was to reduce the GHG emission by 8%, however, during its effective time frame, the Netherlands has only reached a 6% reduction [19]. For this reason, the Netherlands has created the Integrated National Energy and Climate Plan for 2021-2030, which has been delivered in 2019. This aims to show the Dutch contribution to the global movements [4].

This Integrated National Climate Plan of the Netherlands contains an adaptation of the targets set by the Paris Climate Agreement, directly designed at a national level. Although it is not directly equivalent to the Nationally Determined Contribution (NCS) of the Netherlands, it is the only current documentation which defines clear national targets to reach the goals proposed by the Paris Climate Agreement [4]. This document is used to show a national representation of the targets, as the official NCS has not been publicly submitted yet.

For this research, the main targets presented in the Integrated National Climate Plan of the Netherlands, have been summarised, classified and presented in the form of a table. The extensive table of Dutch national targets for CO_2 emission can be found in Figure 1.3.

1.2.3 Ecosystem Taxonomy

In this section, the main ecosystem related taxonomy will be presented. As the term ecosystem has multiple meanings differing from one context to another, the definitions which refer to the current context will be provided.

Current Dutch national targets in sustainability		
Target	**Year**	**Reasoning**
1.5% a year average saving on final energy consumption		The Energy Agreement for sustainable growth (2013)
Energy savings of 100 petajoules in the Netherlands' final energy consumption, compared with 2012	2020	The Energy Agreement for sustainable growth (2013)
14% increase in the share of renewable energy generation (over 4 % in 2013)	2020	The Energy Agreement for sustainable growth (2013)
100% reduction in gas extraction in Groningen	2022	Paris Agreement (2016)
49% reduction in greenhouse gas emissions, compared with 1990	2030	Paris Agreement (2016)
27% share of renewable energy	2030	Paris Agreement (2016)
Max 1,950 petajoules in primary energy consumption (excluding use for non-energy purposes)	2030	Paris Agreement (2016)
100% zero emissions for newly sold cars	2030	Coalition Agreement (2017)
100% reduction of the nuclear energy production in the Netherlands	2033	The closure of the nuclear power plant in Borssele
70% of total electricity will consist of renewable electricity	2030	National Plan (2019) - Electricity Sector
Generating circa 49 TWh wind energy offshore	2030	National Plan (2019) - Electricity Sector
Generating 35 TWh of renewable energy (wind energy and solar power) on land	2030	National Plan (2019) - Electricity Sector
Small-scale generation of renewable electricity from, for example, private solar panels, good for circa 10 TWh.	2030	National Plan (2019) - Electricity Sector
1.5 million homes and other buildings will be natural gas-free	2030	Paris Agreement (2016)
3.4 Mton of additional CO2 reduction	2030	Climate Agreement (2017)
Climate-neutral society	2050	Coalition Agreement (2017)
Reliable, affordable, secure and low CO2 energy supply	2050	Coalition Agreement (2017)
Reduced greenhouse gas emissions by 95% compared with 1990	2050	Paris Agreement (2016) & Climate Agreement (2017)
Electricity generation must be 100% CO2	2050	Paris Agreement (2016)

FIGURE 1.3: Current Dutch national targets in sustainability. (Adapted from [4])

Ecosystem The term ecosystem has a large variety of meanings and can change its significance based on the context. To better understand the focus of this research, it is of utmost importance to be able to provide, based on the literature studied, a definition which describes the meaning of "ecosystem" in the current context.

Initially, the term ecosystem was used in the business context as an ecological metaphor for the natural ecosystem, since it explains the complex and dynamic characteristics that can be found currently in the business context [30].

Additionally, the term "ecosystem" is used in the sense of a Digital Business Ecosystem (DBE). This term was originally used in Europe as the European Union aimed to help Small and Medium Enterprises implement ICT technologies to improve productivity [2].

This perspective of an ecosystem provides a more technologically oriented structure of the business context.

As the focus of this SLR is placed on architecture and technology with a business-wide context of the energy industry, the most relevant meaning of ecosystem is Digital Business Ecosystem.

Moreover, the initial meaning of a Digital Business Ecosystem is to create an environment that fosters the economical development of businesses and facilitates the interaction between enterprises, governments, research and innovation [2]. This definition aligns with the goal of this research, which is to understand how the capabilities of the ecosystem can help improve sustainability at an industry level.

Enterprise Architecture Enterprise Architecture (EA) is the management and technology practice that aims to reach business development through business architecture, enterprise structure, process modelling and performance management. This discipline aims to guide the Strategy, the Business and the Technology of an enterprise [31].

EA provides more than a way of structuring an enterprise, changes made in the company architecture directly affect the organization's business model [32]. EA focuses on the enterprise, so the capabilities are considered to have a focus on the progress of the internal organisation, while also considering the position of the organisation in the market [31].

Although this approach offers good insights at an organisational level, in this research the aim is on the progress of the entire industry environment, rather than placing the organisation as a central focus.

Ecosystem Architecture Ecosystem Architecture is fundamental for this research as it refers to an architectural way of thinking beyond organisational boundaries. Given that this research does not limit to only one company or only one value chain, the ecosystem architecture perspective appears to be the best way of understanding the technological structure at an industry level.

Additionally, structures such as The Ecosystem Architecture Management (TEAM) framework have been created to guide the designing and evaluation process of an ecosystem architecture [33]. Generally, applicable frameworks can help assure the applicability and relevancy of any model despite the context. Having clear modelling standards can help assure the proper application of CO_2 emission reduction techniques.

Capabilities According to the literature, a capability "is defined as the ability (of a static structure element, e.g., actor, application component, etc.) to employ resources to achieve some goal. This definition indicates that capability (similarly to a resource) can be seen as an abstraction of some behaviour of the static structure element. Also, capability assumes the ability to employ (i.e., configure, integrate, etc.) resources" [34]. This can be summarized as an "organization's ability to appropriately assemble, adapt, integrate, reconfigure and deploy valued resources, usually, in combination or co-presence" [35] [36].

Despite the definition of capabilities used from an Enterprise Architecture perspective, the meaning does not alter when thinking of an ecosystem. The paper by Linde et al. explains how "firms can develop dynamic capabilities to orchestrate ecosystem innovation and, thus, gain from it." [5]. Understating that the benefits of using capabilities can go further than one singular company and can have ecosystem-wide effects is important for this research. To visualise the benefits of using capabilities at an ecosystem level, Figure 1.4 provides a visualisation of the effects of dynamic capabilities on ecosystem innovation. When thinking of reducing the Climate Change impact, decarbonisation should be not only an organisational goal but an ecosystem goal. Enterprises should work together to reach the Net Zero target.

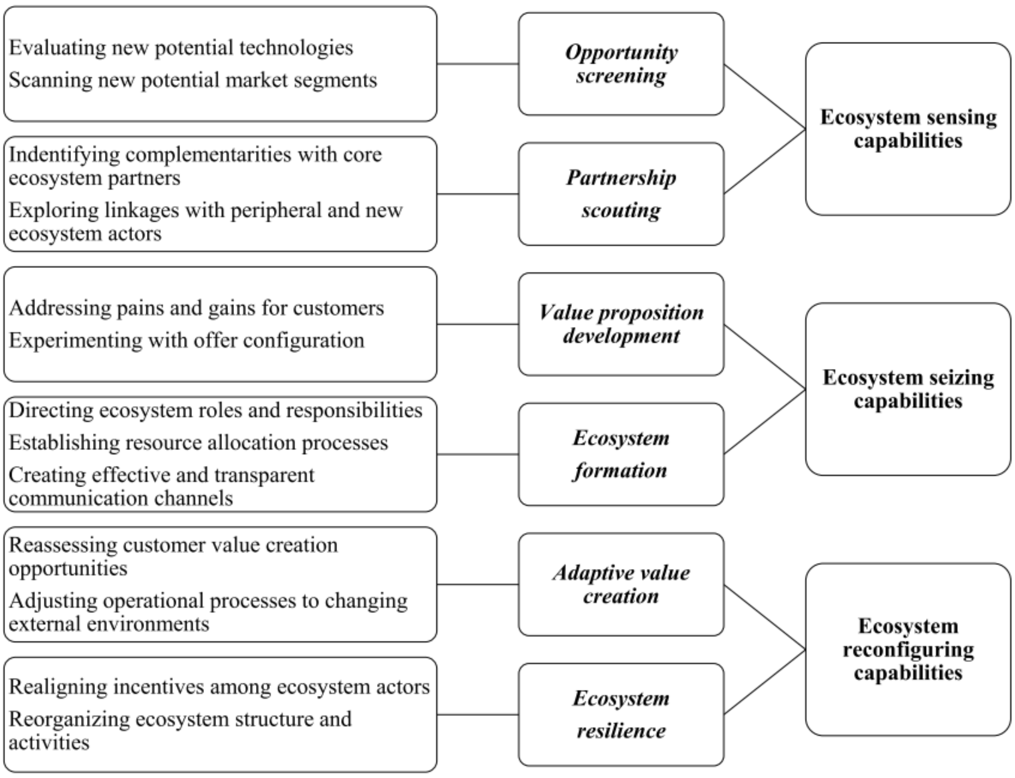

FIGURE 1.4: Data structure: dynamic capabilities for ecosystem innovation [5]

Capability Mapping "A Capability map is a map of the enterprise that visualizes its capabilities in a particular state, for example, current capabilities and their current maturity level, or required capabilities in a future state" [6]. A capability map is also an approach to managing the capability requirements and the relations between capabilities by mapping matrix-es which show associations between entities [37].

In order to better map capabilities, the following steps need to be taken:

- Identifying Capabilities

- Linking Capabilities

The main Capability Map model offered by academic literature is the ArchiMate Enterprise Capability Model which can be found in Figure 1.5.

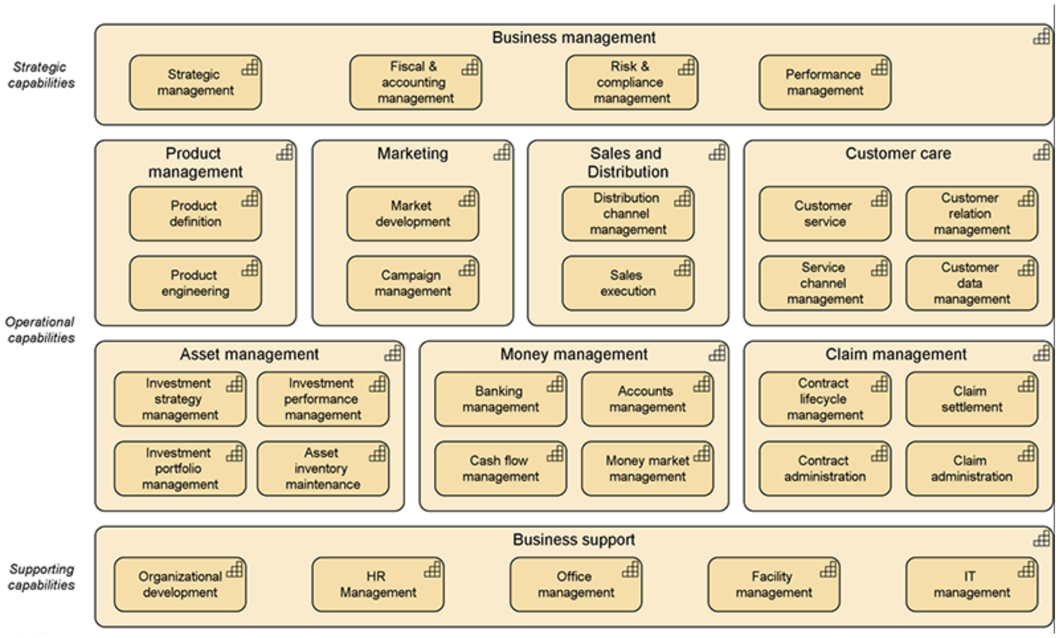

FIGURE 1.5: Capability Map [6]

1.3 Research Design

This section describes how this particular research is designed. Firstly, the problem statement is formulated and consequently, a research objective and scope are being defined. Furthermore, clear research questions are being formulated. Additionally, the process and the structure of the research are described in depth.

1.3.1 Problem Statement

Current global efforts are aiming to reduce CO_2 emissions resulting from energy-related industries, in particular, caused by fossil fuel combustion [18]. Although there exist worldwide initiatives aiming to motivate and reinforce the CO_2 emission reductions, many parties fail to consider the CO_2 emission implication in their sector. The lack of word-wide awareness related to CO_2 emission effects on the Climate Change appears to be a contemporary problem.

In 2007, the aviation industry contributed about 3% to CO_2 emissions and subsequently affect the Climate Change, and these numbers have been considerably growing since then [1]. These numbers consist of both passenger travel (81%) and freight travel (19%).

Moreover, aviation is considered the most unsustainable mode of transport currently available [1].

Reducing the CO_2 emission from the aviation industry is a problem that has further implications. Looking at this problem from the perspective of a person, an enterprise or even a singular country provides a limited perspective.

1.3.2 Research Objective

Based on the problem statement described in the previous section, it becomes clear that although enterprises play an important role in the aviation industry, there are many distinct stakeholders (the government, the regulatory institutions, the airlines, the airports, the aircraft manufacturers, the fuel suppliers, the customers etc.) and subsequently multiple processes taking place [21].

For this reason, an ecosystem perspective might be a more appropriate way to investigate and attempt to solve such a large scale problem.

The main objective, as well as the sub-objectives of this research, have been listed below.

Main Research Objective
The objective of this thesis is to help the passenger travel aviation industry to become more sustainable by lowering its environmental footprint. The direct aim of this research is to design a reference ecosystem architecture incorporating emission reduction capabilities which will enable the emission reduction. Ultimately, this research could result in reducing Scope 3 CO_2 emissions for oil and gas resulting from the passenger travel aviation industry.

Sub-Objectives

1. Review the state of the art literature regarding Scope 3 CO_2 emission and the architectural ecosystem modelling for CO_2 emission reduction in the aviation industry.

2. Define, categorise and map the main capabilities related to CO_2 emission reduction in the current aviation ecosystem.

3. Design a capability model of the passenger travel aviation ecosystem incorporating the CO_2 emission reduction capabilities previously defined.

1.3.3 Research Method

The research method used for this paper is Design Science Methodology (DSM) as presented by Wieringa [7]. Based on this methodology, to conduct research following the DSM technique, the main component needed is an artifact. This artifact operates in the context defined by the research target and has a goal to solve the given problem defined by the research.

According to this methodology, the process starts by formulating a design problem. The design problem includes a problem context, based on which we design an artifact. This artifact needs to satisfy some requirements and ultimately achieve the goals set. For this, the following template introduced by Wieringa [7], will be used.

Improve	*a problem context*
by	*(re)designing an artifact*
that	*satisfies some requirements*
in order to	*help stakeholders achieve some goals*

To define the design problem for the particular context of this research, the above template was filled in:

Reduce	*Scope 3 CO_2 emissions for oil and gas resulting from passenger travel in the aviation industry*
by	*designing a reference ecosystem architecture incorporating emission reduction capabilities*
that	*enhances the current ecosystem architecture by incorporating the key capabilities needed to reduce CO_2 emissions*
in order to	*become more sustainable by lowering environmental footprint*

1.3.4 Research Scope

With the increase in Climate Change caused by carbon emissions, there is a clear need for further research related to decarbonisation actions. Given the situation, the present study analyzes the role of defining decarbonisation as a goal when designing the reference ecosystem model. The focus is on implementing decarbonisation capabilities in the current ecosystem architecture and validating the results. The scope of the study is restricted to the aviation ecosystem as ecosystem architectures differ radically based on the industry focus. Moreover, the study focused on reducing CO_2 emission and has considered the emission of other GHG out of scope. Furthermore, the study uses academic literature and the information gathered from other sources has been included at the recommendation of the experts being interviewed.

1.3.5 Research Questions

To reach the research objective, the following research questions were formulated. These questions aim to describe the sustainability quota in Scope 3 CO_2 emission from oil and gas resulting from passenger travel in the aviation industry.

Main Research Question
How can ecosystem architecture improve the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?

Sub-Questions

1. How are the current Scope 3 targets of CO_2 emission represented in the passenger travel in the aviation industry according to the literature?

    - How is Scope 3 CO_2 emission currently represented in the energy ecosystem architectures according to literature?

2. What are the ecosystem capabilities which affect the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?

    - What are the types of ecosystem capabilities which affect the Scope 3 CO_2 emission in the aviation industry?

    - How can these capabilities be better represented in an ecosystem architecture of the passenger travel in the aviation industry?

3. How can designing a reference ecosystem architecture based on the defined capabilities can facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?

    - What architectural requirements should be considered when building a reference ecosystem architecture aiming reduction Scope 3 CO_2 emission in the passenger travel aviation industry?

4. How can an ecosystem architecture be validated to facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?

The relationship between the research questions can be visualised in Figure 1.7. Moreover, a more in-depth structure counting the research methods used for each research question can be found in Figure 1.9.

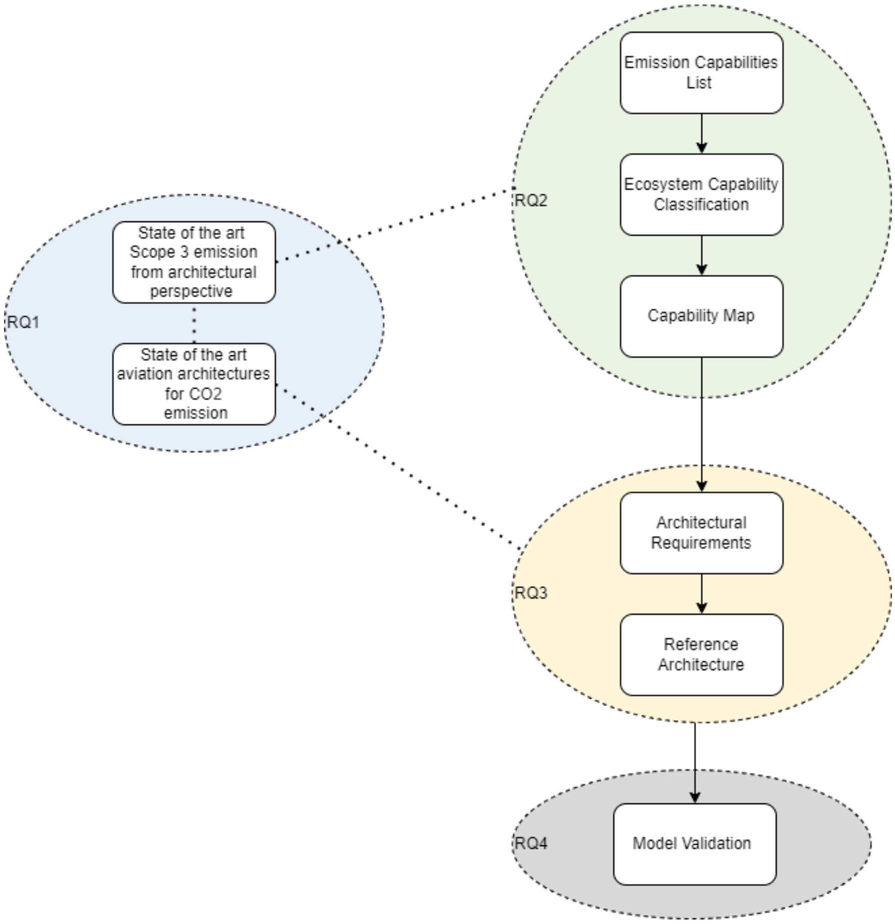

Figure 1.6: Research Questions Relations

1.3.6 Research Relevance

Due to the increasing impact of Climate Change on Earth, sustainability, especially decarbonisation, is becoming a topic of high importance in most industries. The current effects caused by GHG emissions involve all organizations and emphasize the importance of change and progress.

The aviation industry especially contributes around 3% to the total annual emission, out of which 80% results directly from passenger travel. These facts, in combination with the current Climate Change effects, emphasize the necessity of research in the area.

This research contributes to the current knowledge on the topic by studying the problem from an ecosystem perspective. Additionally, it considers the state of the art information available regarding CO_2 emissions reduction in aviation and uses it as a base for further development. Additionally, this research provides a novel viewpoint by using the perspective of enterprise architecture and transposing it into ecosystem architecture to formulate a model to better facilitate aviation decarbonisation.

1.3.7 Research Process

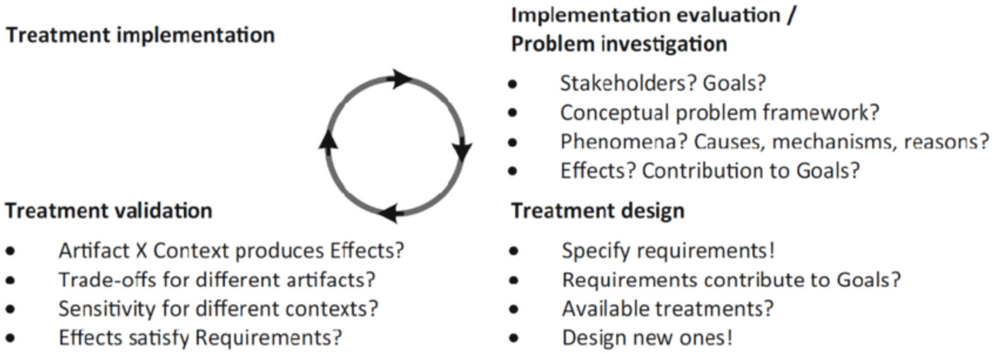

FIGURE 1.7: The Engineering Cycle [7]

To solve the above-defined design problem, we will follow the Design Cycle methodology by Wieringa [7]. This method provides a structured process approach throughout the research, starting with the problem investigation stage, and ending with the design and validation of an artifact. The Design Cycle is part of the Engineering Cycle and consists of 4 stages: the Implementation evaluation /Problem investigation, Treatment design, Treatment validation and Treatment implementation. However, for this research, the Treatment implementation and Implementation evaluation stages will be considered out of scope. The adapted model can be found in Figure 1.7.

Despite the circular nature of the processes based on the engineering cycle found in Figure A.3, this particular research implies a linear process, due to the exclusion of the Treatment Implementation stage. Although in a real business context this step is of utmost importance since it offers the actual results, for the purpose of theoretical research, the other 3 steps are being prioritized. However, by removing one step the circle cannot anymore be closed, so a new linear adaptation of this process is being used. The linear process used for this research can be found in Figure 1.8.

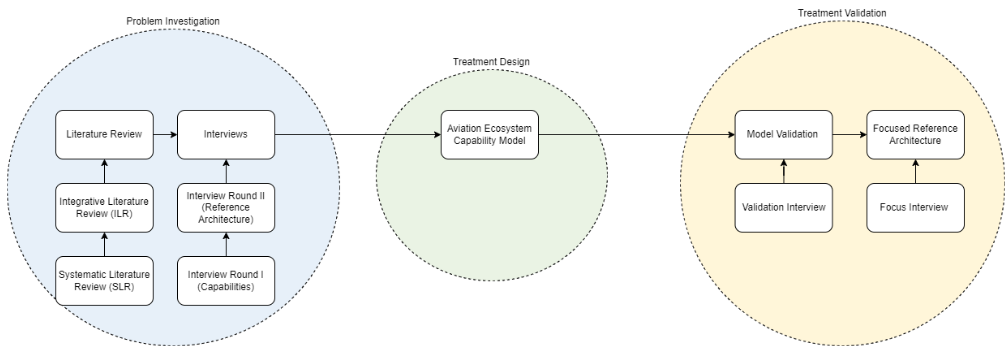

FIGURE 1.8: Design Science Methodology Research Process (Adapted after [7])

Problem Investigation The Problem Investigation stage consists of two main data collection techniques, Literature Review and Interviews.

- **The Literature Review** stage consists of two different types of research have been conducted: an SLR and an Integrated Literature Review (ILR). The SLR focuses more on obtaining the background information and assuring the need for the research, while though the ILR the information needed during the research was collected.

- **The Interviews** stage takes place subsequently to the Literature Review (LR) and makes use of most information gathered during the LR. This stage consists of two distinct interview rounds. Interview Round I focuses on defining and categorising the emission reduction capabilities found in the aviation industry. Interview Round II uses the information gathered during the first interview round to create a capability model for the aviation ecosystem.

Treatment Design stage focuses on building the artifact which aims to solve the problem defined by the research. During this stage, two distinct artifacts are being constructed: a Capability Map and a Capability Model.

- **The Capability Map** includes all decarbonisation capabilities collected from both literature and interviews and structures them based on the goals they aim to achieve. The capability map serves to build the capability model.
- **The Capability Model** provides the business layer of the reference architecture of the entire ecosystem.

Treatment Validation stage focuses on validating the results of the Treatment Design stage. For this reason, the Capability models for each of the ecosystem focuses will be reviewed, together with the general integrated model. The integrated Capability Model, which is the main artifact of the research will be validated based on a business case.

1.3.8 Research Overview

To better visualise the process of this research, Figure 1.9 provides an overview of the research questions. Additionally, the methods used for answering each research question are mentioned, together with the expected outcome.

1.3.9 Document Structure

This research has been structured into 8 chapters. Chapter 1 provides an introduction and the method of the research, as well as the background information needed to better understand the topic. Chapter 2 describes the literature research conducted for this study and strictly presents the results obtained during the literature review. Chapter 3 subsequently provides a description of all research methods used for this study, aside from the literature review. Chapter 4 provides the results obtained from the two sets of

Research Questions	Methodology	Desired Result
CURRENT STATE OF THE ART		
1. How are the current Scope 3 targets of CO2 emission represented in the passenger travel in the aviation industry according to the literature?	Literature Review	Models overview
1.1 How is Scope 3 CO2 emission currently represented in the energy ecosystem architectures according to literature?	Literature Review	Scope 3 overview
CAPABILITIES AND CAPABILITY MAPPING		
2. What are the ecosystem capabilities which affect the Scope 3 CO2 emission for oil and gas resulting from passenger travel in the aviation industry?	Literature Review + Modeling + Expert Interviews	Capability list
2.1 What are the types of ecosystem capabilities which affect the Scope 3 CO$_2$ emission in the aviation industry?		Components/ layers
2.2 How can these capabilities be better represented in an ecosystem architecture of the passenger travel in the aviation industry?		Capability map/ layers
REFERENCE ARCHITECTURE MODELING		
3. How can designing a reference ecosystem architecture based on the defined capabilities can facilitate the reduction Scope 3 CO2 emission in the passenger travel aviation industry?	Literature Review + Modeling + Expert Interviews	Reference architecture
3.1 What architectural requirements should be considered when building a reference ecosystem architecture aiming reduction Scope 3 CO2 emission in the passenger travel aviation industry?		Requirement's list
RESERCH VALIDATION		
4. How can an ecosystem architecture be validated to facilitate the reduction Scope 3 CO2emission in the passenger travel aviation industry?	Validation Interviews	Reference analysis

FIGURE 1.9: Research Overview

interviews conducted. Chapter 5 provides a visualisation of the finally designed capability model together with an explanation of the new model and subsequently, Chapter 6 studies the validity of the model. Lastly, Chapter 7 contains the discussion based on the research; while the conclusion is available in Chapter 8, which prospects this entire study.

Chapter 2

Literature Review

This chapter describes the required literature review conducted for this research. Starting with the Review Methodology, Section 2.1, provides a clear categorisation of two different search types that have been conducted. Followed by the Research Process, Section 2.2, which presents a summary of the search results. In the last section of this chapter, a detailed answer is provided for each of the corresponding research questions.

2.1 Review Methodology

This section describes the methodology of the literature review used in this research. This section is divided into two main parts a Systematic Literature Review and an Integrative Literature Review. Given that two distinct literature reviews were conducted for this study, providing the methodology for each of the processes separately assures the professionalism and validity of the literature used.

2.1.1 Systematic Literature Review

A Systematic Literature Review (SLR) was conducted to serve the Research Topics module. The Research Topics aimed to obtain clear background information about the topic, together with providing reasoning for the need for this research. This information serves as a preceding to the Thesis Research by creating a solid base of information. In the case of the background research, an SLR was found to be an appropriate method due to the limited literature available. Using the SLR method helps ensure that all relevant and available research is identified, as well as, provides a clear corresponding answer for the research questions mentioned in the Research Topics [15].

The extensive information regarding the SLR structure, strategy and process can be found in Appendix A.1. The process of this SLR was based on the study of Torres-Carrión et al. [15]. Additionally, the following supporting concepts were used: Gall et al. [38] provided a clear review structuring and strategical goal formulation advice, and Hart et al. [39] showed a clear way of motivating the need for the research.

The information gathered during the SLR has been used in this research for multiple purposes. Firstly, it served to explain and emphasize the need for this research. Secondly, it provided a review of the currently used terminology, which is presented in the Background Section 1.2. Lastly, it provided an answer to Research Question 1.1 "How is Scope 3 CO_2 emission currently represented in the energy ecosystem architectures according to literature?". Aside from the mentioned purpose, the information found during the SLR was the main source used for writing the Introduction Chapter 1.1 of this paper.

To guide the search for proper literature, search terms were developed based on keywords derived from the research questions. The following list presents the search terms that have been used in the SLR.

- greenhouse gas protocol Netherlands
- CO_2 emission targets Netherlands
- energy production ecosystem Netherlands
- energy distribution ecosystem Netherlands
- energy ecosystem architecture
- energy ecosystem artifacts
- CO_2 and Enterprise Architecture
- CO_2 and Digital Ecosystem Platforms
- Energy value chain and emission scopes

For more detailed information regarding the SLR, please refer to Appendix A.1.

2.1.2 Integrative Literature Review

As mentioned in the Introduction 1.1, an additional Literature Review (LR) was conducted for this research. The goal of this part of the research is to provide more information related to the topic. The primary objective is to propose a reference ecosystem architecture incorporating emission reduction capabilities in order to reduce Scope 3 CO_2 emissions from oil and gas resulting from passenger travel in the aviation industry. Additionally, through this LR, the identified information provides the context for describing, elaborating, and evaluating the new artifact [40]. As previously mentioned, in the context of this paper, the new artifact is a reference architecture for the aviation ecosystem which emphasises CO_2 emission reduction.

Given the before mentioned research goal, an Integrative Literature Review (ILR) was found as an appropriate method of collecting information. ILR was selected as the literature research method due to the support this method confers to novel topics, as well as its focus on creating preliminary conceptualizations and theoretical models [41]. In this particular situation, the goal is to create a preliminary reference architecture of the passenger travel aviation ecosystem which considers Scope 3 emission as a principal design characteristic.

The other research methods considered for obtaining the needed literature background were LR and SLR. However, both methods exclude Grey Literature, which was shown to be an important information source during the background research due to the novelty of the topic. Moreover, since the purpose was not to obtain all available information, but relevant information for building the new artifact, the SLR method was not taken into consideration [15]. Lastly, a classic LR was not used for this paper because it allows selection bias, as well as it can cause the disregard of valid literature [42].

The ILR method was used since the purpose was not to cover all articles ever published on the topic but rather to combine perspectives and insights from different fields of research types [41]. For this reason, an initial key term based research was conducted on a defined set of databases, which can be found in Appendix A.2.4.3. However, aside from the key term based search, additional literature was consulted based on the recommendation of the experts being interviewed. In addition to the key term based literature search, additional literature has been identified utilizing the semi-structured interviews which have been conducted at a later stage of this research, as can be found in the following subsection 2.1.2.1. This additional way of collecting sources provides a guided strategy for obtaining appropriate Grey Literature, as well as clearly defined business cases.

Additional information on the applied ILR strategy can be found in Appendix A.2. The process of this ILR was based on the study by Whittemore et al. [43]. Additionally, the following supporting concepts were used: Baumeister et al. [41], Snyder [40], Cooper [44], and Oxman [45].

The information gathered during the ILR has been used in this research for multiple purposes. Firstly, it served to provide an answer for Research Question (RQ) 1. Additionally, it was used to provide a base for RQ 2, RQ 3 and RQ 4. Lastly, it helped to obtain all available information in order to build a novel theoretical model and validate its functionalities.

To guide the initial search for proper literature, search terms were developed based on keywords derived from the research questions. The following list presents the search terms that have been used in the ILR.

- scope 3 emission AND aviation
- CO_2 emission modelling AND aviation
- aviation ecosystem architecture
- passenger travel aviation architecture
- process capabilities of aviation industry
- CO_2 emission capabilities
- requirements for ecosystem architectural reference models
- standards for ecosystem architectural reference models

For more detailed information regarding the ILR, please consult Appendix A.1.

2.1.2.1 Literature Obtained though Interviews

During the first round of interviews, the experts were requested to suggest appropriate literature which can provide further information for this research, especially which contains capabilities. The literature recommended can be academic, grey literature, as well as business cases. The references of the sources obtained from this literature review selection method were not considered for the research.

2.2 Research Process

The two literature review processes used for this paper, the SLR and ILR have been summarized in a simple visualisation found in Figure 2.1, respectively Figure 2.2. Moreover, the in-depth information regarding each step of the process can be found in Appendix A.

For the purpose of this research two independent searches have been conducted. An initial SLR was conducted during the Research Topics stage which provides all the background information for this thesis, as well as additional information proving the need for this particular research topic.

During the SLR, 119 studies have been defined based on the search-term literature revision. Out of the 119 papers initially selected, 70 have been removed do the inclusion and exclusion criteria A.1.5. Although the search terms have been chosen to fit the topic specifically, many of the papers found did not fully fit the purpose of the research and have been discredited based on the specific exclusion criteria A.1.5.2.

Consequently to the first revision, 49 papers have been searched in-depth regarding both presented content and references used. Based on this 101 papers have been considered as either Primary or Secondary literature. A final number of 17 sources has been quoted in the Research Topics. Additionally, the same sources have been used in the background chapter of this paper. The visualisation of the source selection process based on the SLR can be found in Figure 2.1.

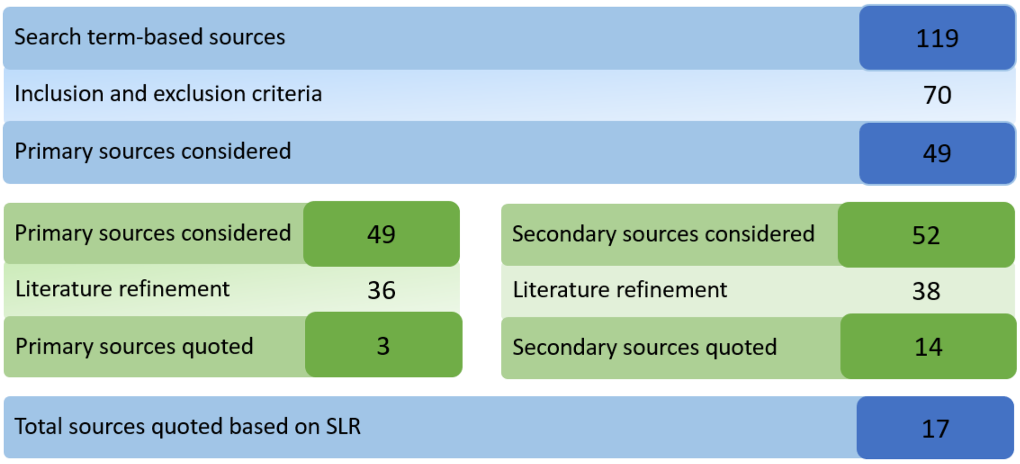

FIGURE 2.1: SLR Results Overview

The second independent search method used for the purpose of this paper is ILR. The ILR was conducted in order to collect the literature needed to support this research. Through the ILR, the answer for question 1 as well as the theoretical background for questions 2 and 3.1 were composed. The results of questions 2 and 3.1 consists of both information from academic literature, and information gathered from expert interviews and grey literature.

During the ILR, 51 studies have been defined based on the search-term literature revision. Out of the 51 papers initially selected, 16 have been removed do the inclusion and exclusion criteria A.1.5. The summarised process of the ILR can be found in Figure 2.2.

Consequently to the first revision, 35 papers have been searched in-depth and categorised based on the research question to which they can provide backing information.

Since the ILR method allows the addition of sources based on the recommendation of the experts interviewed, during Interview Round I, all interviewees were asked to recommend literature sources that they consider appropriate for finding decarbonisation capabilities for the aviation industry.

During the interviews, five literature sources have been recommended by the experts. All these sources have been searched in-depth and two have been excluded since they presented the same capabilities mentioned by the experts. Lastly, the remaining three sources have been used for answering the second research question. The sources have

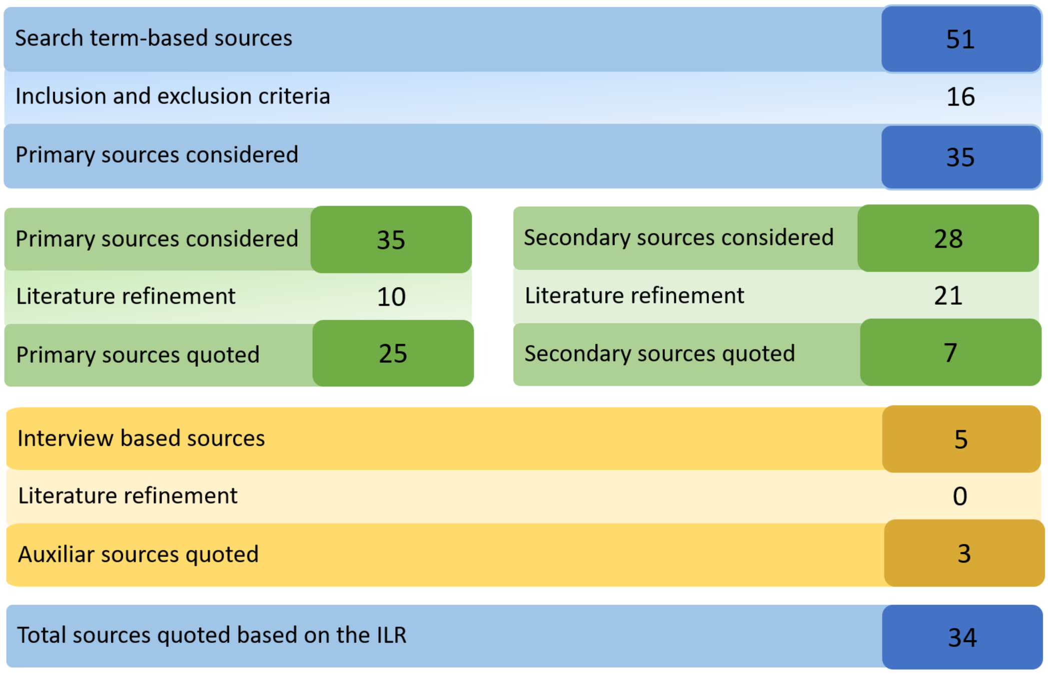

FIGURE 2.2: ILR Results Overview

provided a list of 10 capabilities in total, while the last one provided The Open Group Architectural Model for Commercial Aviation. The list of sources obtained through interviews can be found in detail in Appendix D, Section D.3. These sources obtained from expert interviews were also included in Figure 2.2.

2.3 Results

This section presents the results obtained through the literature review. The first research question is answered by explaining what Scope 3 means and what is its role in an ecosystem 2.3.1. Subsequently, it presents in-depth the CO_2 aware architectural models of the aviation ecosystem found in literature 2.3.2. Lastly, this section focuses on defining the main decarbonisation capabilities for aviation found in literature 2.3.3.

2.3.1 Ecosystem architecture of Scope 3 emission

"How are the current Scope 3 targets of CO_2 emission represented in the energy ecosystems architecture?"

The aim of this section is to provide an answer to the research question based on the findings provided by the SLR.

In this section, there will be an in-depth definition of what Scope 3 emission means, which will provide a more elaborate description than the one used in the Background section 1.2.

Although many perspectives describe Scope 3 emission as an external part of the Oil and Gas industry value chain, the Oil and Natural Gas Industry Schematic, found in Figure 2.3 also models it as the "Retail and Marketing" step [8].

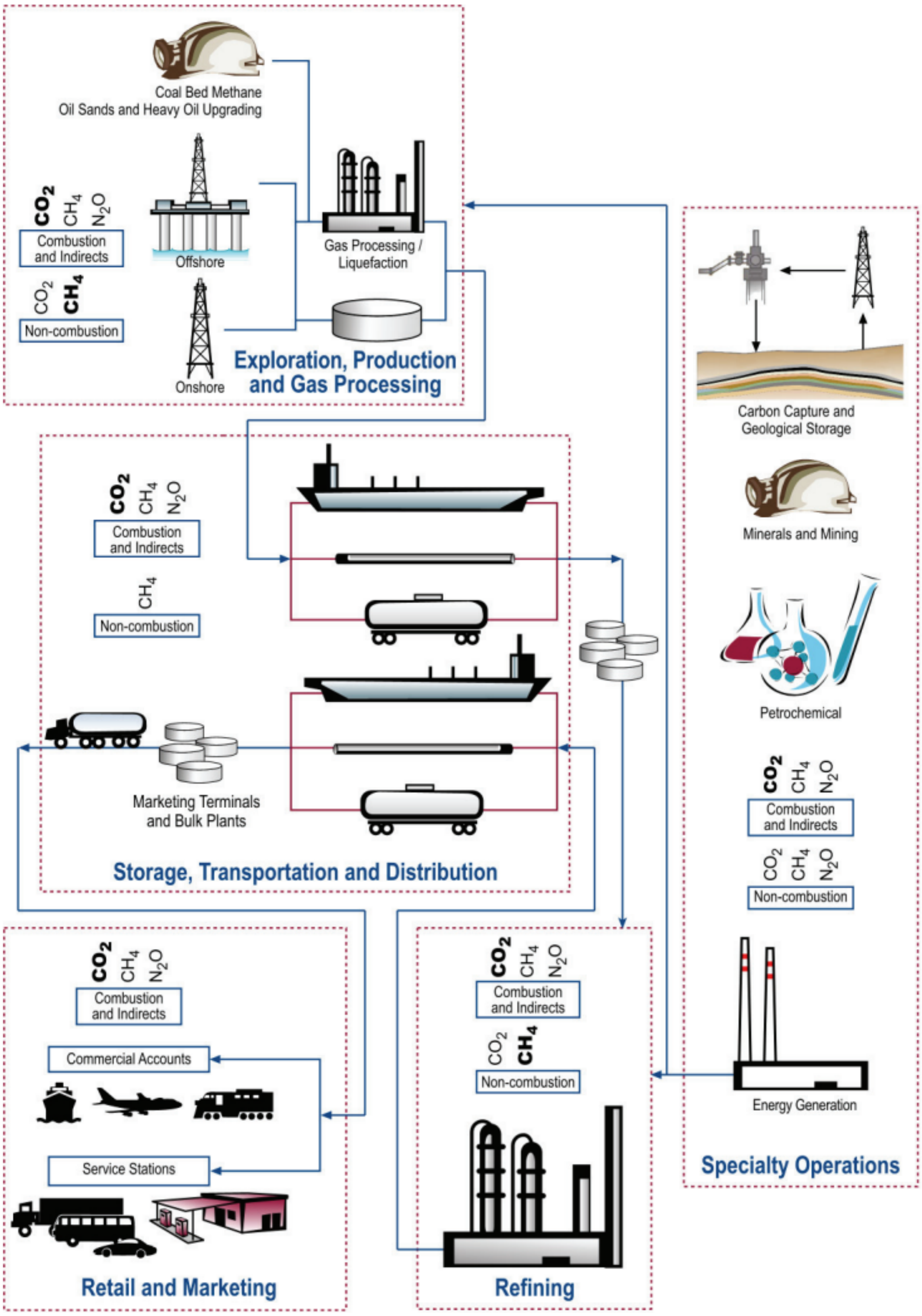

FIGURE 2.3: Oil and Natural Gas Industry Schematic of GHG Emissions [8]

Defining what Scope 3 emission exactly entails has been challenging, so the following table was used to show exactly which categories have to be considered for Scope 3 emission in this research, based on the Corporate Value Chain (Scope 3) Accounting and Reporting Standard [16]. Moreover, Table 2.1 underlines the Upstream and Downstream nature of each category, to better define its meaning.

When looking at Scope 3 emission only, the Upstream activities refer to the goods and services purchased, while the Downstream refer to the goods and services sold [3]. Although there is a similarity with the meaning of Upstream and Downstream used for the entire value chain, it is important to understand the specific meaning in the context of Scope 3.

Scope 3 emission category
Upstream scope 3 emissions
1. Purchased goods and services
2. Capital goods
3. Fuel- and energy-related activities (not included in scope 1 or scope 2)
4. Upstream transportation and distribution
5. Waste generated in operations
6. Business travel
7. Employee commuting
8. Upstream leased assets
Downstream scope 3 emissions
9. Downstream transportation and distribution
10. Processing of sold products
11. Use of sold products
12. End-of-life treatment of sold products
13. Downstream leased assets
14. Franchises
15. Investments

TABLE 2.1: List of Scope 3 Categories (Adapted from [16])

Based on this information, it is clear that Scope 3 emission comes from a wider and more diverse line of processes. As shown in Table 2.1, the sources of Scope 3 emission originate from a multitude of industries [16].

2.3.2 Ecosystem architecture of Scope 3 emission in aviation industry

"How are the current Scope 3 targets of CO_2 emission represented in the passenger travel in the aviation industry?"

This section provides an overview of the architectural models found in during the literature research phase. Although a variety of models were found, the majority did not align with the focus of this research.

Based on the literature review, six papers have been initially considered. These papers were selected since they provided a visual model of structurally improving the CO_2 emission inside the aviation industry. However, since this research is focused on finding ecosystem-level solutions, only two of the papers identified provided multi-focus, ecosystem-like, models. The remaining four papers have been excluded from this research since they focus on one unique process, or include only one singular strategy of CO_2 emission reduction.

The two models further analyzed are:

- Causal loop diagram of emission from a commercial aviation industry [9] (Available in Figure 2.4.)
- The causal loop diagram [10] (Available in Figure 2.5).
- The stock-flow diagram [10] (Available in Figure 2.6).

2.3.2.1 Causal Loop Diagrams

In this subsection, the two causal loop diagrams discovered during the literature review are presented and analysed. Causal loop diagrams consist of "variables connected via arrows that explain the causal influences between the connected variables. Each causal link has an appropriate polarity as per the nature of change experienced by the dependent variable, especially when there's a change in the independent variable. The (+) sign signifies that a dependent variable would move in the same direction as the independent variable, while a () sign suggests the change in dependent variable opposite to that of the independent variable."[10].

Causal Loop Diagram I The "Causal loop diagram of emission from a commercial aviation industry" [9], Figure 2.4, will be firstly discussed since it provides a high-level model. The Causal loop model presented by Tan et al. was created to predict total aviation industry emissions in Malaysia, however, its applicability does not resume to a singular context. This model includes the main side (or sub-) systems which affect the CO_2 emission. The model shows the relations between different systems, as well as the type of impact they have on CO_2 emission [9].

The following list includes the systems and sub-systems included in the causal loop diagram 2.4:

- Policy Program
- Aircraft Design and Technology
- Aircraft Travelled

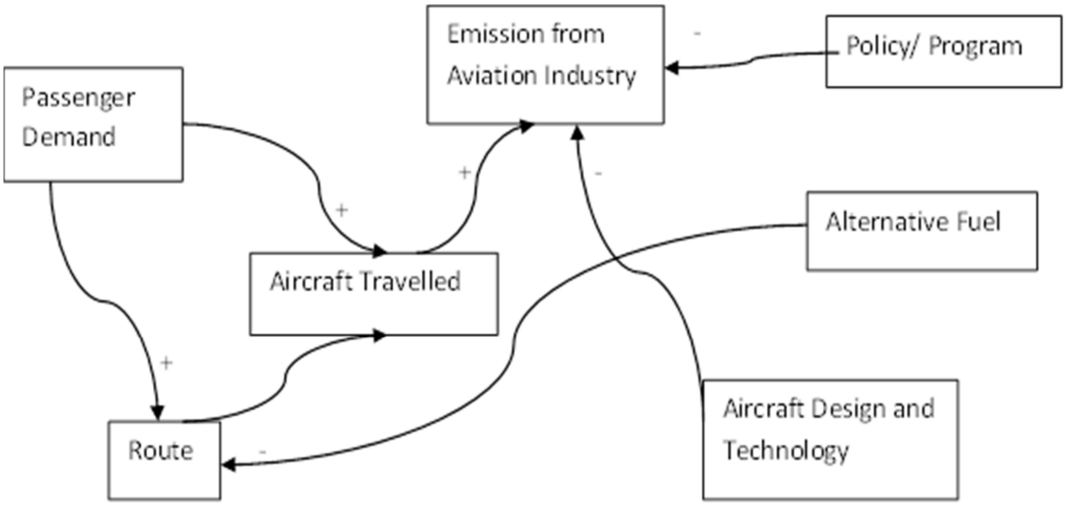

FIGURE 2.4: Causal loop diagram of emission from a commercial aviation industry [9]

  - Passenger Demand
  - Route
    * Passenger Demand
    * Alternative Fuel

In their paper, Tan et al. use the causal loop model as a first step of the system dynamics modelling. The research uses the following four steps of creating a system dynamics model: identifying issue and objective, generating causal loop diagrams, generating stock and flow diagrams and validating results [9]. However, the stock and flow diagrams presented in the study by Tan are case and scenario-specific, so they do not provide an industry ecosystem overview, but rather describe an individual case. For this reason, they will not be considered for this research.

Causal Loop Diagram II "The causal loop diagram" [10], found Figure 2.5, provides a more in-depth modelling of aviation decarbonisation. The Causal loop model presented by Sharma et al. was created based on the Carbon Offsetting and Reduction Scheme in International Aviation (CORSIA) targets [10]. In their paper, Sharma et al. focus on four emission reduction ways based on the CORSIA policy framework. Moreover, they use the four ways stated in the Environmental Defense Fund [46]. These four approaches are:

1. flying fuel-efficient aircraft
2. using new technologies to choose flight paths (network aspect)
3. using sustainable alternative bio-fuels
4. investing in carbon offsets towards green projects to reduce carbon footprints

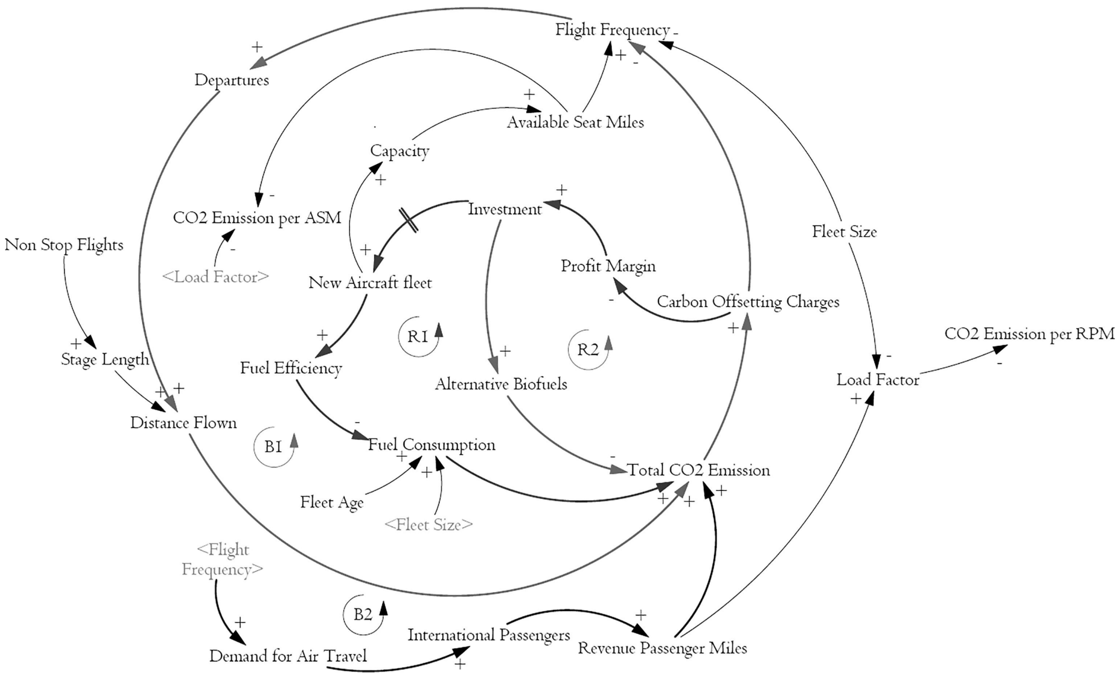

FIGURE 2.5: The causal loop diagram [10]

The above concepts have been modelled in a causal loop diagram, found in Figure 2.5. In this specific model, key loops are highlighted using loop identifiers. "A loop identifier suggests the nature of the feedback. A positive feedback is denoted by a reinforcing (R) sign and a negative feedback is denoted using balancing (B) sign. ...The arrow surrounds the loop identifier suggests the direction of flow of the loop." [10].

Despite providing a model which incorporates decarbonisation capabilities for the aviation sector, the causal loop diagrams cannot be considered ecosystem architectures.

2.3.2.2 stock-flow Diagram

This subsection contains an analysis of the stock-flow diagram found during the literature review. This particular diagram is created by the authors, Sharma et al. [10] based on the causal loop diagram previously discussed 2.4. This model is the most elaborate visualisation found during the literature review considering the impact of CO_2 emission in the aviation industry.

The stock-flow diagram 2.6 was created based on the relationships shown by the causal loop 2.4 with create a system dynamics model [10].

A stock-flow diagram visualises the main two components of a system dynamics model: the stocks and the flow. "Stocks are the accumulations in a system; they are the entities that give inertia to the modelled system, serving as the system's memory. ... Flows, on the other hand, are the auxiliary variables that have a rate of change. In general, flows are the functions of stock and other variables in the system." [10].

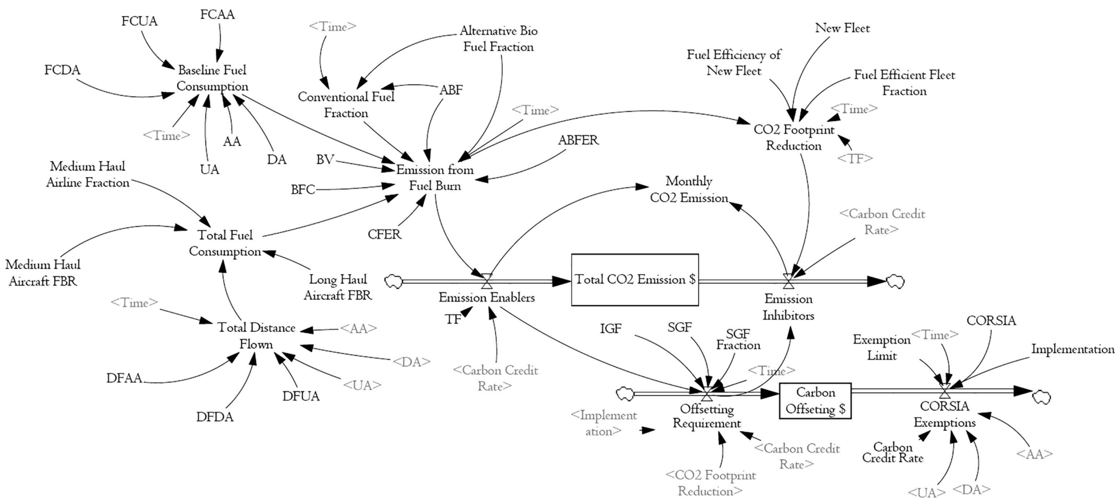

FIGURE 2.6: The stock-flow diagram [10]

The paper uses the stock-flow diagram to develop an equation which aims to calculate the "Total CO_2 Emission ", as well as calculate the emission costs and the total "Carbon Offsetting". The purpose of these calculations in this research by Sharma et al. is to provide a clear cost overview which will subsequently help the CO_2 emission reduction [10].

Despite the variety in models analysed, it appears that the inclusive ecosystem models currently available in the literature are made from the perspective of system dynamics. The reasoning for using system dynamics in this context was due to the nonlinear behaviour of complex aviation system [9] and the ongoing motion of the system described by its dynamic nature [10].

2.3.3 Ecosystem capabilities for aviation industry

"What are the ecosystem capabilities which affect the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?"

This section provides an analysis of the CO_2 emission reduction capabilities found during the literature review. Although there is a lot of diversity in the capabilities found, every single capability considered describes a strategy which can enable the CO_2 emission reduction. Despite the difference in approach, all these capabilities serve the same goal, which is to reduce the CO_2 emission in the aviation industry.

Table 2.3.3 will present a list of all capabilities found during the literature review, together with the sources from which they have been extracted.

The following list will provide an overview of the literature review results in terms of the capabilities mentioned. For this reason, both the terminology used to describe the capability and a short definition are presented in the following paragraphs.

Capability	Source
Aircraft Routing Optimization	[47]
Fleet Planning Optimization	[48]
Formation Flights Development	[49]
Climate-Optimized Trajectories	[50]
Fuel Optimization	[51][52]
Legislative Measures Development	[53][24]
Aircraft Engine Design Optimization	[54]
Agreements and Targets Development	[55][24][19]
Air Traffic Flow Management	[56]
Fuel Cell System Optimization	[57]
Replacing Flights with Alternative Transportation	[58]
Aviation Regulatory Capabilities	[59]
Dynamic Flight Trajectories Implementation	[60]
Box-wing Aircraft Design Optimization	[61]
Energy Transition Leadership	[62]
Electric Propulsion Implementation	[63]
Business and Educational Travelling Management	[64]
Aero-structural Design Optimization	[38]
Holiday Travelling Management	[65]
Data Model Implementation	[66]
Communication System Improvement	[67]
Travelling Behaviour Management	[68]

Table 2.2: Capabilities extracted from literature review

Aircraft Routing Optimization
Despite the general negative effects of CO_2 emission, the emission location and time can also influence its impact on the climate. "Emission in certain locations (or times) can lead to a greater climate impact (even on the global average) than the same emission in other locations (or times)." [47].

In the study, Grewe et al., uses "a multi-step modelling approach, starting with the simulation of the fate of emissions released at a certain location and time (time-region grid points)" [47]. This capability of reducing the emission and its effects by using aircraft routing can make use of distinct technologies. However, in the specific study consulted, the technology used a series of models (the chemistry–climate model EMAC, AIRTRAC (V1.0) and CONTRAIL (V1.0)) and calculation tools (air traffic simulator (SAAM) coupled to an emission tool (AEM)) in order to reduce CO_2 emission [47].

Fleet Planning Optimization The article by Cheng et al. considers carbon emission the key factor when distributing aircrafts in airways and planning the structure of the fleet. Currently, "the fleet planning and en-route airway allocation are mostly depending on the cost model" [48].

Aside from explaining how the fleet planning process can be optimized to reduce the CO_2 emission on a flight, the paper looks at how this optimisation can have positive long-term effects. The strategy proposed combines the airway operating cost model with the airline fleet planning, "in order to solve the problem of the fleet planning of airlines in long term as well as the problems of allocations of airways in the short term, both within the constraints of Carbon Emission Constraint" [48].

Formation Flights Development This capability explains how CO_2 emission can be reduced by flying in aerodynamic formation. Formation flying is a strategy already used in military aviation and refers to the method of flying multiple objects in a coordinated order [69]. This strategy is inspired by migrant birds, "who fly in formation to save energy" [49]. Furthermore, "Observation of close-formation flight of migratory birds has therefore motivated aerospace engineers to look closely at similar flight configurations of multiple aircraft for possible energy savings" [70].

The study explains how flying in aerodynamic formation can positively impact the climate impact. "When this operational measure is adapted to commercial aircraft it saves fuel and is, therefore, expected to reduce the climate impact of aviation" [49]. This capability does not only aim to reduce the CO_2 emissions but also NO_X and H_2O emissions [49].

Climate-Optimized Trajectories The study by Matthes et al. shows that the aviation sector can reduce its climate impact by "controlling its CO_2-emission and non-CO_2 effects, e.g., aviation-induced contrail-cirrus and ozone caused by nitrogen oxide emissions" [50]. The study discusses not only emission reduction but strategic emission points in order to reduce the environmental impact. "The impact of aviation on the environment can be reduced by adopting climate-optimized aircraft trajectories, which preferentially fly in regions where aviation emissions have lower climate impact, so-called green trajectories"[50].

Though implementing "operational measures that aim to avoid those atmospheric regions that are in particular sensitive to non-CO_2 aviation effects" [50]. Although this study does not directly relate to reducing CO_2 emission, it provides a capability of reaching the predefined goal of making aviation more sustainable by lowering its environmental footprint.

Fuel Optimization New technologies aim to redesign the current perception of fuels to make them CO_2 neutral. Technologies such as direct air capture of CO_2 are already being commercialised [51].

In his paper, Goede explains how combing air-captured carbon or nitrogen with water, "it creates a liquid fuel with greatly enhanced energy density, such as kerosene or ammonia, or gaseous fuel like methane which can replace natural gas in the existing gas network" [51].

Another way of looking into fuel development is based on Biodiesel fuels. Biodiesel fuels are currently the most important renewable energy source for diesel engines, and they manage to reduce the carbon footprint of a vehicle without implying technical changes to the vehicle [52].

Although Biodiesel reduces the SO_2 , CO_2, HC and PM emissions, it appears to increase the NO_X emissions. The study by Yamik et al. compares the advantages and disadvantages of Biodiesel and provides methods of mitigating the NO_X emissions [52].

Legislative Measures Development In his paper, Scheelhaasea et al. explain the impact of legislative regulations regarding CO_2 emission on the aviation industry. The paper describes the EU Directive 2009/29 EC, which implies that from 2012, all flights starting from or landing at European airports are subject to the EU ETS, which implies clear yearly CO_2 reduction targets [53].

Aircraft Engine Design Optimization In his paper, Yin et al. assess the performance of a novel turbofan engine using two energy sources: Liquid Natural Gas (LNG) and kerosene, called Multi-Fuel Hybrid Engine (MFHE) [54].

Based on the study, the novel turbofan engine "reduces the CO_2 emission by about 27% and the energy consumption by 12% compared to the current state-of-the-art turbofan engine" [54].

Agreements and Targets Development The paper by Ternoire et al. provides a description of the importance of the Paris Agreement [24], while also defining its direct implications on the aviation sector [55]. Additionally, it uses calculations to show the effect of CO_2 emission on long and short terms, as well as the impact of legislative measures on emission [55].

Although this paper describes only the Paris Agreement, multiple measures have been mentioned 1.2, such as the Kyoto Protocol [19].

Air Traffic Flow Management In his paper, Hamdan studies the effects of air traffic flow management(ATFM) through an "ATFM bi-objective mathematical model that minimizes the total delay cost and the total CO_2 emissions" [56]. The model considers factors such as "ground delay, air delay, flight rerouting, speed controls, and CO_2 emissions and is solved using the weighted comprehensive criterion method" [56]. The research illustrates by better managing delays, one can reduce CO_2 emissions by an average of 0.07% [56].

Fuel Cell System Optimization The study by Lucken explains how through the replacement of the conventional auxiliary power unit (APU) with a multi-functional fuel cell system (MFFCS), one can reduce the emission of carbon dioxide [57]. The paper also provides methods of managing the fact that "current system dynamics are higher than currently available fuel cell systems can provide" [57].

Replacing Flights with Alternative Transportation The study by Armstrong presents the system used by the Federal Aviation Administration in the US to provide an analysis of the life cycle costs and emissions reduction of the motor vehicle fleet [58]. This research shows how using alternatives to low-speed electric vehicles, can reduce the CO_2 emission [58].

Aviation Regulatory Capabilities The paper by Mayer discusses the impact of aviation regulatory agencies' regulations. It also analyses the effect of the increasing focus on aircraft fuel consumption and emissions assessments [59].

Dynamic Flight Trajectories Implementation Improving the flight process strategy can improve the CO_2 emission. The classical Continuous Descent Approach (CDA) approach implies that the trajectory is usually fixed and pre-planned before the horizontal path is planned. Current optimizations are focusing on the vertical section direction. However, it is clear that "the advantages of CDA procedure have not been fully excavated and used" [60].

The paper by Fengxun et al. explains how "the dynamic continuous descent approach (CDA) trajectory is chosen through comparison and analysis of the way points restrictions, which has the minimum total CO and CO_2 emissions" [60].

Box-wing Aircraft Design Optimization Many studies consider the improvement of the aircraft design as a solution for improving fuel efficiency and reducing the carbon footprint. The study by Frediani et al. explains the benefits of a conceptual aircraft design called "PrandtlPlane" [61]. "PrandtlPlane indicates an aircraft configuration based on a box-like lifting system in the front view" [71]. This configuration allows one to conceive many different air crafts for both passenger and freighter aviation, ranging in size and increasing the flight sustainability [61].

Energy Transition Leadership The paper by Devold et al. explains the purpose of digitization in the new energy landscape. Additionally, it emphasizes how important is for a company to create a robust digital strategy to assure a successful energy transition [62]. The success of the transition depends on a good strategy, and without a successful transition, there will be no positive effect on the environmental impact.

Electric Propulsion Implementation Electric Propulsion is already used on a small scale in the aviation industry [63]. The paper by Hermetz et al. explains how the concept of electric propulsion can be scaled up in the aviation industry to reduce the noise pollution as well as CO_2 emission occurring during departure [63].

Business and Educational Travelling Management Aside from making flights more sustainable, lowering the demand for flying is also a considered method of reducing the carbon footprint of the aviation sector. The paper by Davis et al. discusses the effects of purposeful travelling on the ecosystems, the responsibility attribution and the need for considering distinct strategies and transportation means [64]. Although the study focuses on a specific group of educational travelling, this applicability transcends to business travelling as well.

Aero-structural Design Optimization Global aero-structural wing optimizations help achieve the optimum trade-off between the aerodynamic performance and the wing mass [72]. In the paper, Wunderlich et al. explain how "the comparison of the optimized wings in terms of cruise flight performance and wing mass allows the quantification of potential reduction of CO_2 emissions per passenger kilometer" [72]. Additionally, the research provides explanations of how aero-structural wing optimizations can be measured in terms of energy and emission reduction [72].

Holiday Travelling Management As previously mentioned, lowering the demand for flying is also a considered method of reducing the carbon footprint of the aviation sector. However, despite the big impact of educational and business travelling, holiday travelling also plays an important part in the increasing demand for flights. "The footprint of tourism through travel is contributing significantly to the accumulation of human-made CO_2" [65].

The study by Kapeller et al. uses a "combination of two software models, a social-economic individual-based model to simulate the decision processes of holiday travel and an emission calculation model to estimate single travel-based CO_2 emissions" [65]. This method of calculation defined the impact of passenger behaviour on the CO_2 emission.

Data Model Implementation Considering the upcoming developments of the aviation ecosystem, concepts such as Urban Air Mobility (UAM) vehicles should be considered as they may have a future impact on CO_2 emission [66]. The paper by Tuchen explains how data models can help keep track of the urban air traffic as well as account for the carbon footprint created [66].

Communication System Improvement The research by Zambrano et al. explains the Requirements for Communication Systems in Future Passenger Air Transportation (RCSFPAT) based on current data and several forecasts. It also presents a solution based on SDR multi-mode which can help improve the current scenario, in which "the communication systems for passenger air transportation are developed", by considering the "capacity requirements provide an appropriate communication infrastructure supporting future air communication systems growth" [67].

Travelling Behaviour Management The paper by Coehn et al. builds on the assumption that "technology and management will not be sufficient to achieve even modest absolute emission reductions" [73]. Moreover, the focus is placed on how can public behaviour be influenced. The paper explains two main factors influencing public behaviour in the aviation sector as follows: "(a) support the efforts of individuals/consumers to respond to the emission reduction challenge, and (b) conflate the onus of responsibility (and the anxieties of consumption fuelled climate change) from the level of the individual, to the collective levels of government, industry and economy" [68].

To summarise and better visualise the above-mentioned capabilities, Figure 2.7 provides a clear overview of the entire capability list obtained through the ILR.

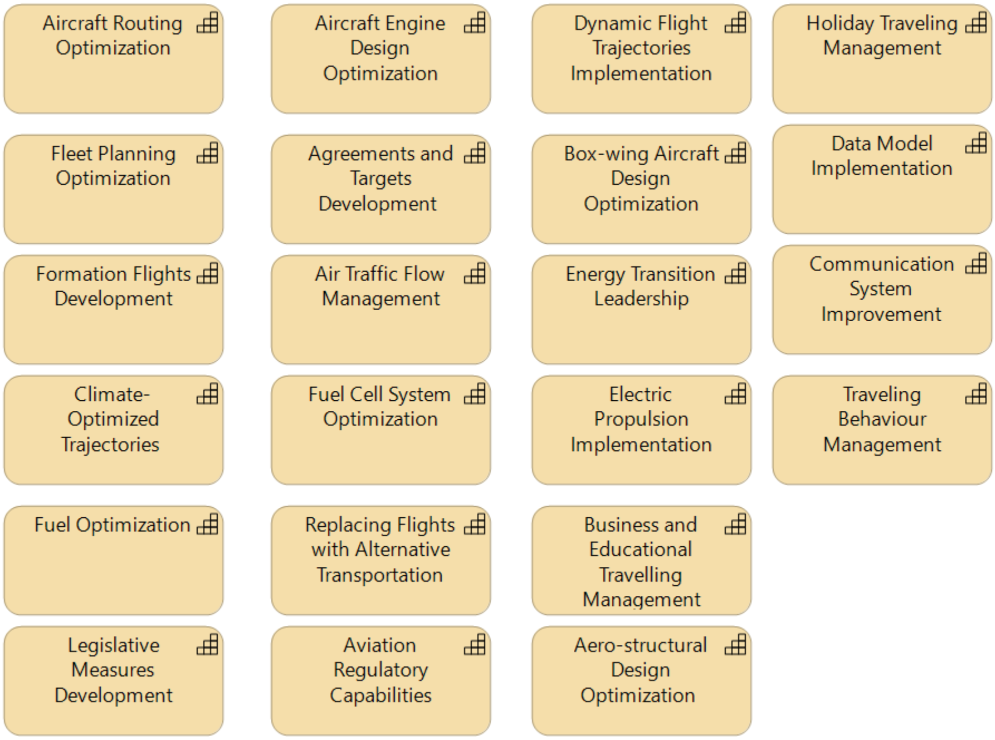

FIGURE 2.7: Capabilities obtain though ILR

2.3.4 Types of Ecosystem Capabilities for aviation industry

"What are the types of ecosystem capabilities which affect the Scope 3 CO_2 emission in the aviation industry?"

In the previous section, the capabilities gathered through literature research have been presented. Even though all considered capabilities have the reducing CO_2 emission as the main goal, there is a large variety in their approach.

After reviewing the information gathered from the literature, it became clear that the capabilities mentioned can be classified into two main categories based on the goals:

1. Reducing the number of flights
2. Making flights more sustainable

Although most papers reviewed looked into the way of improving the sustainability of flights by improving the aircraft design, improving the flight process or the fuel; making flights more sustainable is only one approach to reducing CO_2 emission from aviation.

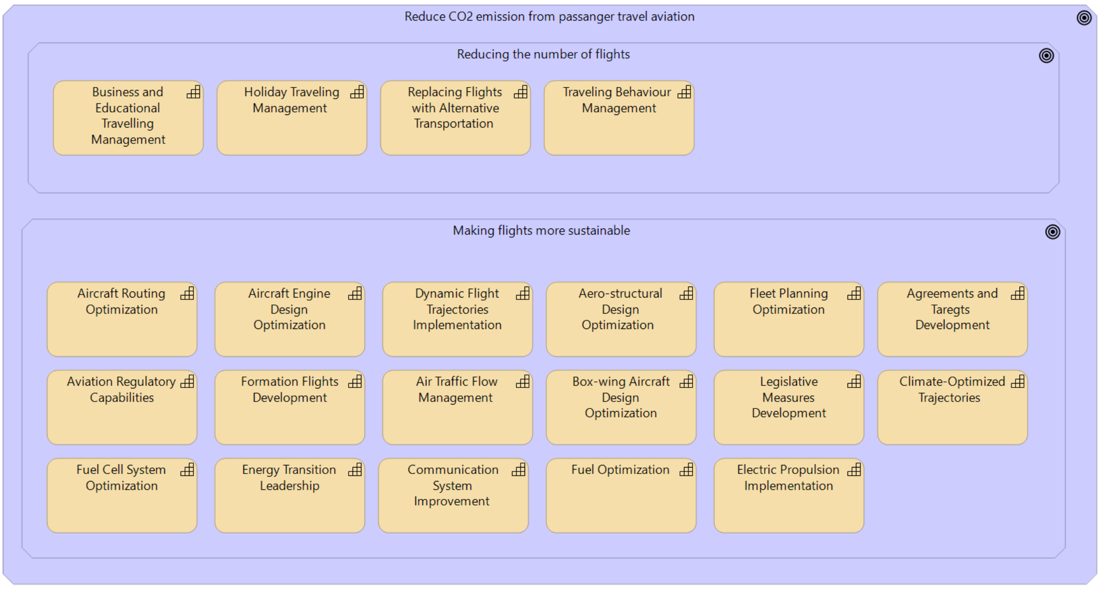

FIGURE 2.8: Capabilities Categorised by Goals

Based on the research of Gössling et al. social and behavioural change are also necessary to achieve a climatically sustainable tourism [73]. For this reason, in this particular research, both capabilities related to flights reduction and flight sustainability improvement will be taken into consideration. The capabilities gathered during the literature review have been classified based on the categories, the model containing the classification can be found in Figure 2.8. Additionally, the capabilities can also be further grouped based on the commune sub-goals they help achieve. The sub-goal categorisation will be created once the final list of capabilities will be determined, after the interviews.

Despite this logical categorisation of the capabilities made based on the papers studied, a more clear classification needs to be defined before building a capability map.

Since the end goal of this research question is to build a capability map which can be later on used as the foundation for the new ecosystem architecture, the Capability Map model of ArchiMate was used as a reference [6]. The Capability Map model can be found in Figure 1.5.

Additionally, based on this model, the main types of capabilities considered in this research have been defined as:

1. Strategic capabilities
2. Operational capabilities
3. Support capabilities

These three types of capabilities have been defined based on the ArchiMate Capability

Map 1.5 and will be used to categorise the capabilities during the first round of interviews. The final list of capabilities does not resume to only the capabilities found during the literature research but is a combination based on the information gathered during the literature review and the information gathered during the first round of interviews.

The final capability list will be classified based on the three categories mentioned above and will be used when modelling the capability map of this research.

Chapter 3

Research Method

This chapter describes the research method used for this study. As the main way of collecting data in addition to the literature review is expert interviews, the process of the interviews is explained during this chapter. Two distinct interview rounds have been conducted during the data collection process.

3.1 Interviews

The results obtained through the literature review have significantly contributed to this research by presenting and discussing the current state of the art implications of CO_2 emission targets on ecosystem architectures. Moreover, using the findings obtained in the ILR, an initial list of CO_2 emission reduction capabilities has been created. The capabilities in this list served as the basis for proposed categories and classification options. Lastly, the literature review provided potential architectural requirements which have to be considered when building a reference architecture. Nevertheless, due to the novelty of the topic, reviewing the literature fails to provide the level of industry applicability needed to create a reference model. The information collected only from the literature review provided very conceptual and academic-oriented information, so an additional way of collecting information was needed to assure the business applicability of the research.

Although interviews are commonly used in qualitative research, there exist numerous other scientific methods for collecting data. For this reason, the following paragraph will explain the choice of using interviews for this research. "The purpose of the qualitative research interview is to contribute to a body of knowledge that is conceptual and theoretical and is based on the meanings that life experiences hold for the interviewees" [74]. This aims to provide not only clearly defined answers to specific questions but to encourage the party being interviewed to share their knowledge and interact with the researcher. This type of interaction can not be obtained through other methods, such as surveys [75]. Additionally, the target audience was too small for surveying as all people targeted as interview participants have already established expertise in the topic. Furthermore, given the novelty of the topic, a lot of introductory information was needed and most situations require to follow up questions or explanations of the terminology. Lastly, the conversational manner of interviews encourages the interviewee to provide information and can help collect relevant research sources.

Moreover, in this specific context, the decision of conducting a series of expert interviews has been influenced by the need for industry applicability targeted by this research. The goal of this research is to build a capability model which can provide guidance in a real business context and which can be validated for an actual business case. This goal implies the need for a business component in the data collection method which cannot be satisfied just by academic literature.

During the interviewing phase, the goal is to collect relevant information from industry experts regarding their vision on CO_2 emission reduction capabilities, as well as the contextual business perspective defining the need or the lack of need for a reference architecture.

Since the type of information aimed to be collected from the experts is qualitative, interviews provided the best approach to collecting the data needed [43]. Additionally, interviews were chosen as a method because they help not only obtain a review of the information collected but also gain knowledge of different data that the experts find relevant [42]. In the particular situation of RQ2, the purpose of the interviews is not only to model the capabilities with an informed party but to review the current capabilities, by removing the irrelevant ones, adding new ones and finally modelling the remaining ones.

3.2 Interview Design

Interviews are generally used to provide in-depth information on participants' experiences and viewpoints on about particular topic [76]. The data collected during the interviews, together with the data gathered through the literature review, serve as the main information resources for this paper.

Based on the research of D. Turner [76], there are three distinct interview designs recommended when conducting qualitative research. The first one is an informal conversational interview, which does not require a lot of structuring and which implies that there are no formulated questions. Although these types of interviews offer a lot of freedom, the results collected fail to provide non-arbitrary and structured answers [38]. As for this research experts from a lot of different industries as well as with different areas of expertise are being interviewed, the research needs to be able to structure and generalize the information collected. An informal conversation results in a vast variety of data which is almost impossible to process promptly, thus a more structured approach is needed.

The second type is general interviews. This type implies the use of questions prepared in advance, though the formulation of each question can differ from one interview to another [38]. However, in situations when exists a clear diversity between the people being interviewed, this method can show clear bias.

Lastly, the most used method is the one of a standardised open-ended interview. This method will also be used for this research given that it implies clearly defined questions, which will be asked similarly to all parties being interviewed. This standardised strategy aims to provide clear answers in line with the research, as well as to reduce the bias between different sources [38]. For this type of research, where a lot of distinct experts are interviewed with very different opinions, is very important to treat all interviews in the same matter.

Additionally, the exact type of interviews used can also be described as semi-structured interviews. Semi-structured interviews have been considered appropriate for this research as they provide a clear structure, while still allowing for some flexibility by using additional sub-questions or prompts to ensure that all questions will be sufficiently answered [42]. This technique assures that all predefined questions will be asked in the same manner to all interviewees, while additional questions can be added if needed.

To design the interview process and prepare for the interviews, the three steps by Creswell [11] have been followed. These steps can be found in Figure 3.2, and have been elaborated further in this chapter.

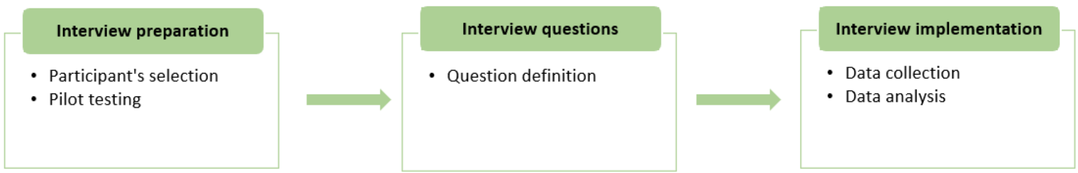

FIGURE 3.1: Interview Design Process Phases (Adapted from [11])

For this research, two different series of interviews will be conducted at two distinct moments of the study. To better define each interview series and to provide clear references in the text, from this point onward be referred to as Interview Round I and Interview Round II.

Interview Round I provides data regarding RQ 2. During this interview round, the focus will be on defining the capabilities, categorising them and modelling them inside a capability map and a first draft version of this capability map you have already created as part of your ILR, and will serve as the basis. The information obtained through

Interviews I, together with the data extracted during the literature review, will provide the basis for Interview Round II.

Interview Round II provides data regarding RQ 3. During this interview round, the focus will be to integrate the capability map previously determined and implement it inside the ecosystem architecture. The reface ecosystem architecture will have as based on The Open Group reference architecture of the aviation industry. The final goal of this interview round is to have a clear reference ecosystem architecture which considers the importance of CO_2 emission reduction capabilities by incorporating them into the current ecosystem architecture.

3.2.1 Interview Preparation

During the preparation stage which occurs right before the start of each interview, the following principles designed by McNamara [77] have been followed.

- explain the purpose of the interview;
- address terms of confidentiality;
- explain the format of the interview;
- indicate how long the interview usually takes;
- tell them how to get in touch with you later if they want to;
- ask them if they have any questions before you both get started with the interview;
- don't count on your memory to recall their answers

3.2.1.1 Participant selection

The two different rounds of interviews will be conducted with distinctly different goals and will have a complementary relation. The first round of interviews aims to consult industry experts to review the current capabilities, by removing the irrelevant ones, adding new ones and finally modelling the remaining ones in a capability map. The second round of interviews uses the information collected and processed based on the first round and aims to consult the same experts from an architecture perspective to design the best ecosystem capability model which includes the capabilities defined in Interview Round I.

3.2.1.2 Pilot testing

Pilot interviews are essential before interacting with "real" participants. This type of preparation helps the interviewer understand how different approaches can influence the data obtained helps improve the confidence of the interviewer, and prepares the interviewer to create a relationship with the participants [75].

Lastly, trial interviews also support the improvement of the interview structure and interview questions [75]. In the particular situation of this research, two trial interviews have been conducted for Interview Round I.

The two trial interviews have been conducted with relevant industry experts, to assure the effectiveness from both an experience and content perspective. However, the parties being interviewed in this context have been aware and in close connection with the research along the way, so they could not be included in the actual interview sessions due to potential bias. Nevertheless, for the trial, assuring that the experts are informed about the topic and understand the goal of the research, helps certify the reliability of the interview questions. The results of the pilot interviews can be found in the Appendix, in Section D.3.

Due to the extended series of interviews imposed by this research, together with the time contaminants of the graduation project, no pilot sessions were conducted for the second interview session. Therefore, the case interview guide has been reviewed in an informal round-table session with two enterprise architects.

3.2.2 Interview Questions

Given that the interviews used for this research will be standardised open-ended interviews, defining the interview questions is a crucial step. Before formulating the interview questions, the following steps recommended by McNamara [77] have been considered:

- wording should be open-ended (respondents should be able to choose their terms when answering questions);
- questions should be as neutral as possible (avoid wording that might influence answers, e.g., evocative, judgmental wording);
- questions should be asked one at a time
- questions should be worded clearly (this includes knowing any terms particular to the program or the respondents' culture);

3.2.2.1 Question definition

Since two different rounds of interviews will be conducted for this research, two distinct sets of interview questions have been formulated. The first round of interviews questions has been designed before Interview I, while the second round has been designed prior to Interview Round II. The interview rounds were not designed simultaneously since Interview Round II depends on the findings of Interview Round I.

The questions for Interview Round I can be found in the Interview Protocol in Section C.1. The questions for Interview Round II can be found respectively in section C.2.

3.2.3 Interview implementation

The interview implementation section provides a short description of the ways data has been collected and analysed in a non-biased manner. During this section, the strategy used for each interview of collecting necessary data for this study, as well as the way the data has been processed and transposed into the report is summarised.

3.2.3.1 Data Collection

For all interviews performed a predefined interview structure was followed. The structure of Interview Round I can be found in Section C.1.3 and respectively for Interview Round II in Section C.2.3. Depending on the background knowledge of the interviewee, in some cases, the extended explanations and definitions were skipped and the interview shortlists transposed in PowerPoint presentations were solely used. However, despite the minor variations of the protocol, the questions used for the interviews were not modified. All interviews took place in an online setting and, with the permission of the party interviewed, were recorded for improving the interview notes quality.

Interview Round I
The interview structure for the first interview round can be summarised as follows:

- The interview starts with a short introduction of the researcher and the research. Subsequently, the interviewee is asked to introduce themselves and will be asked a few general questions. These questions can be found in the Appendix C.1.3.
- The main focus of the interview will be on CO_2 emission reduction capabilities available, so the interviewee discussed the capabilities found in literature, removes the ones that appear irrelevant and provides additional capabilities, as well as provide a rationale for all decisions taken. Moreover, the interviewee is asked to provide literature input if any comes to mind.

- Lastly the final list of capabilities is structured by the interviewee based on the capability types described inside the Capability Map.

For a more extensive description of Interview Round I, please refer to Appendix C.1.

Interview Round II The interview structure for the second interview round can be summarised as follows:

- The introduction round is skipped given that the group of experts interviewed is the same as in the first round. At the beginning of the interview, the progress since the first interview will be discussed. This part will focus on validating the capability map.
- The main focus of the interview will be on mapping CO_2 emissions reduction capabilities collected during the research together with the capabilities presented in the capability map proposed by The Open Group.
- Lastly the interviewee will be asked to add processes and relations to the capability map and turn it into a diagram. This will also take into account the capability diagram proposed by The Open Group.

For a more extensive description of Interview Round II, please refer to Appendix C.2.

3.2.3.2 Data Analysis

The interview data will be analysed based on the interview notes. To support the privacy of the interviewee and to manage the time constraints implied by a thesis study, interview notes are used instead of interview transcripts for the data analyses. Additionally, due to the interactive manner of the interviews and the visual component provided by the Miro boards, the interview notes will contain information supporting the board visualisation together with the image of each board after the interview.

Lastly, the advantage of using note writing is that it facilitates the analysis process by having the data collected in an already structured manner. This assures that the "information is already classified into appropriate response categories by the interviewer" [78], and it is readily accessible.

To assure the quality and objectivity of the interview notes, the following list of methods collected by Muswazi et al. has been followed [79]:

- Include the topic, complete bibliographic information and summary [80]. You cannot always be assured to find the sources of the information you obtained some time ago e.g. from the internet as it may be removed by the time you go back to it so, the advice to include bibliographic information, for instance, should be taken seriously [79].

- Even if you are not able to make complete field notes right away, you should at least try to write a summary of the sequence of events and noteworthy statements [79].
- You can use this summary to stimulate your writing of a more extensive set of notes [79]. Skim the reference source before taking any notes so that you can decide what materials to take down [81].
- Be sure that notes are complete and understandable for they are not likely to be used for some time after they have been taken [79].

Additionally, to assure the quality of the notes and to reduce the disturbance during the interview, interviews have been recorded. One of the disadvantages of interview note writing is that it may interrupt the communication flow between interviewer and respondents and the omissions of detail that can occur [79]. For this reason, video recordings have been used to consolidate the information [82]. Given that all interviews took place in an online setting, the recording was facilitated by the video call system in a very easy manner.

Interview Round I
For the first round of interviews, notes were taken based on 3 main focuses: Capabilities, Literature Recommendation and Capability Classification.

1. **Capabilities** As most of the interview focuses on the decarbonisation capabilities, clear notes will be taken with regards of:

   - Notes regarding whether or not the expert finds the capability list obtained through literature relevant.
   - Notes about the capabilities the expert wants to remove from the list and reasoning for each capability removed.
   - Notes about the capabilities the expert wants to add to the list and explanation of each capability added.
   - The notes include a visual representation of the Miro Board Capabilities after each interview

   Literature Recommendation The notes contain information regarding whether or not the expert has proposed any literature. The literature name and citation of the literature remanded were added in the notes. The research presented in the notes goes one step further by reviewing the literature recommended and extracting a list of capabilities together with the definition of each capability.

2. **Capability Classification** Lastly, the notes include a visual representation of the Miro Board Capability Types after each interview

The complete notes of the interview can be found in the Appendix, in Section D.3.

Interview Round II
For the second round of interviews, notes were taken based on 2 main focuses: Capability Mapping and Capability Processes.

1. **Capability Mapping** As half of the interview was focused on the Capability Mapping, clear notes will be taken with regards of:

    - Notes regarding the relevance of the current capability map.
    - Notes regarding the combination of the capability map proposed by this research and the industry capability map proposed by Open Group.
    - Notes about the relationships between capabilities.
    - The notes include a visual representation of the Miro Board after each interview.

2. **Capability Processes** As the other half of the interview was focuses on the Capability Processes, clear notes will be taken with regards of:

    - Notes about the processes associated with each of the capabilities mentioned.
    - Notes about the relationships types between capabilities and their processes.
    - Notes regarding the combination of the capability diagram created during the interview and the industry capability diagram proposed by Open Group.
    - The notes include a visual representation of the Miro Board after each interview.

The complete notes of the interview can be found in the Appendix, in Section D.3.

3.2.4 Interview Data Validity

Validating data from qualitative interviewees has always been a challenge as the data cannot be summarised in a mathematical formula. In his paper, Sandelowski stated that "a research instrument is valid when there is confidence that it measures what it was intended to measure" [83]. Guba and Lincoln suggest that the "truth value" of a qualitative study should be evaluated based on credibility and not on internal validity.

They also mentioned that in order to check the validity of the data after being processed, it needs to be validated by the same sources as it was extracted [84].

Validating the interview data is a top priority since it reduces the risk of basing decisions on data which is to represent the current business ecosystem accurately. For this reason, an entire chapter has been attributed to the validation of the study, see Chapter 6.

Chapter 4

Interview Results

This chapter describes provides the results obtained through the expert interviews. Initially, a concise Interviews Overview 4.1 is provided, followed by the summarized results of both interview rounds.

4.1 Interviews Overview

To better visualise the overview of interview participants, organisations and industry specialization, Table 4.1 provides a clear overview of Interview Round I and Table 4.1 provides a clear overview of Interview Round II.

	Length	**Organisation**	**Role**	**Industry**
1	1:30:36	A	Assistant professor of Aerospace Management and Operations	Academia
2	1:33:08	B	Enterprise Architecture Analyst on Decarbonisation Projects	Technology Services
3	1:32:21	C	Sustainability Expert in Airport Mobility	Airport Industry
4	1:09:45	D	Lead Enterprise Architect	Energy
5	0:42:59	E	Energy Strategy Expert	Energy Services
6	1:01:08	E	Sustainability Expert	Energy Services
7	1:11:43	A	Sustainability and Supply Chain Researcher	Academia
8	0:27:36	E	Leader in Strategy Consulting in Aviation	Aviation Services
9	0:46:20	G	Sustainability Lead	Arline Industry

Table 4.1: Interview Respondents Overview - Round I

	Length	Org.	Roles	Industries
1	1:22:38	C	Sustainability Expert in Airport Mobility	Airport Industry
2	0:33:65	G	Sustainability Lead	Arline Industry
3	1:03:46	A	Assistant professor of Aerospace Management and Operations	Academia
4	0:19:47	E	Energy Strategy Expert, Leader in Strategy Consulting in Aviation	Energy Services, Aviation Services
5	1:09:39	B, D	Enterprise Architecture Analyst on Decarbonisation Projects, Lead Enterprise Architect	Technology Services, Energy
6	0:59:19	E	Sustainability Expert	Energy Services

Table 4.2: Interview Respondents Overview - Round II

4.1.1 Respondents Role

Given that most interview respondents have taken part in both interview sessions, the information regarding the respondents will be presented together. During the interviews, several participants with distinct backgrounds have been consulted. The roles of each interviewee will be presented and described in this section, in order to emphasize the expertise of each respondent. All participants interviewed are experts in their field and have a primary background in either decarbonisation, the aviation industry or ecosystem architecture. However, most participants have gained experience in all three topics throughout their careers. Additionally, most participants have an explicit understanding of digital business ecosystems and information systems.

Respondent 1 The first expert interviewed is an Assistant Professor of the Aerospace Management Operations program at organization Organisation A. The expert is valuable due to the extensive knowledge in the aviation industry from a theoretical perspective, as well as hisher background in Operation Research. Moreover, this particular expert has a broad understating of Business Information Systems. The results collected during this interview can be found in Section D.3.1.

Respondent 2 The second expert interviewed is an Enterprise Architecture Analyst with a background in sustainability, especially decarbonisation. The expert is valuable due to their extensive knowledge of digital business ecosystems, as well as hisher background in decarbonisation. Moreover, this particular respondent has vast theoretical knowledge and experience in the energy sector, especially oil and gas. The results collected during this interview can be found in Section D.3.2.

Respondent 3 The third party being interviewed is a Sustainability Expert in Airport Mobility with a background in Industrial Engineering with experience in Aeronautical

Engineering. The expert is valuable due to their extensive knowledge in optimizing airport sustainability, as well as hisher passion for aviation. The results collected during this interview can be found in Section D.3.3.

Respondent 4 The fourth party being interviewed is a Lead Enterprise Architect in a large energy company focused on oil and has transitioned with experience in decarbonisation. The expert is valuable due to their extensive knowledge in ecosystem architecture, as well as hisher passion for improvement and optimization. The results collected during this interview can be found in Section D.3.4.

Respondent 5 The fifth party being interviewed is an Energy Strategy Expert in a large consultancy company focused on the energy sector. The expert is valuable due to their extensive knowledge in the decarbonisation of the energy sector, as well as hisexperience with large-scale production, storage and transmission of green hydrogen. The results collected during this interview can be found in Section D.3.5.

Respondent 6 The sixth party being interviewed is an expert in Sustainability and Enterprise Architecture in a large consultancy company focused on the energy sector. The expert is valuable due to their extensive knowledge in decarbonisation, as well as hiseducational background in aerospace engineering. The results collected during this interview can be found in Section D.3.6.

Respondent 7 The seventh expert interviewed is a researcher in Sustainability and Supply Chain at Organisation A. The expert is valuable due to the extensive knowledge of the best practices of decarbonising the supply chain from a theoretical perspective, as well as hisher doctorate research in sustainable sourcing. Moreover, this particular expert has a broad understating of Information Systems Management. The results collected during this interview can be found in Section D.3.7.

Respondent 8 The eighth party being interviewed is an expert in Strategy Consulting in Aviation from a large consultancy company focused on ecosystem strategy. The expert is valuable due to the extensive knowledge in decarbonising the aviation landscape as well as other landscapes. The results collected during this interview can be found in Section D.3.8.

Respondent 9 The last party being interviewed is an expert in Sustainability and is working together with his/hers team to build and implement new sustainability strategies. The expert is valuable due to their extensive knowledge in aviation sustainability, as well as hiseducational background in aerospace engineering. The results collected during this interview can be found in Section D.3.9.

4.1.2 Organisations Overview

In this section, the organisation where the experts have gained their experience will be presented. Additionally, the industry where they operate is also mentioned.

Organisation A The first organisation is a prestigious theoretical university in the Netherlands. The party interviewed from this organization was used to provide a digital ecosystem transformation perspective.

Organisation B The second organisation is a multinational technology corporation. The party interviewed from this organization was used to provide formal and non-bias expertise.

Organisation C The third organisation is an international airport located inside the European Union territory. The party interviewed from this organization was used to discuss decarbonisation from the perspective of ground operations.

Organisation D The fourth organisation is historically known as a multinational oil and gas company currently transitioning to the extended energy industry. The parties interviewed from this organization were used to discuss decarbonisation from the perspective of the energy industry.

Organisation E The fifth organisation is a multinational professional services network with a focus on the energy industry. The parties interviewed from this organization were used to discuss the decarbonisation of fuel from a non-bias ecosystem perspective.

Organisation G The last organisation is a very large airline and also the flag carrier for one European country. The parties interviewed from this organization were used to discuss the decarbonisation plans from the perspective of an airline.

4.1.3 Interview Round II Focuses Overview

In this section, the six main focuses of the second round of interviews will be presented, together with the respondents participating in each interview session.

Capability	**Source**	**Respondents**
1	Ground Operations	3
2	Flight Operations	9
3	Aircraft Design	1
4	Fuel Management	5,8
5	Ecosystem Management for Flights Improvement	2,4
6	Ecosystem Management for Flights Reduction	6

Table 4.3: Capabilities extracted from literature recommended though interviews

4.2 Interview Round I Results

The first round of interviews had three focus points: updating the capability list, gathering additional recommended literature and categorising the capability list based on the Capability Map 1.5.

Expert based capabilities list During the interview, the expert is asked to review the capability list gathered from the literature. The interviewee is encouraged to remove the capabilities that he/she finds irrelevant and add new capabilities that he/she finds missing from the original list. The list of newly added capabilities can be found in Figure 4.1. Since no references have been removed, there is no list available of removed capabilities. Finally, the detailed list of capabilities obtained through each interview can be found in Appendix D.

Expert-recommended literature During this part of the interview, the data collected from the expert is a list of recommended literature containing potential decarbonisation capabilities for the passenger travel aviation industry. This list can include both academic and grey literature, as well as business cases. The final list of capabilities collected from expert-recommended literature can be found in Figure 4.2 while the extended reference list is available in Table B.2.

Interview Round I Capabilities Overview To emphasize the methodological process of collecting all these capabilities, Figure 2.3.3, the list of capabilities obtained during the expert interviews can be found in Table D.1 and the list of capabilities obtained from expert-recommended literature can be found in Table 4.3.

Expert based capabilities categorisation The last step of the interview requires the interviewee to categorise the capability list based on their personal opinion into three categories: Strategical, Operation and Supporting. Figure 4.4 provides a visualisation of the collective classification and emphasizes how often each capability was mapped in which section.

4.3 Interview Round II Results

The second round of interviews had three focus points: validating the capability list, incorporating The Open Group capability model into the capability model created in this research and defining the capability model for this research.

Interview Round II Capabilities Overview To emphasize the methodological process of collecting all these capabilities, Figure 4.5 provides a summary of the capable collection and validation methods.

Capability Map Validation During the second round of interviews, the complete Capability Map realized based on Interview Round I has been presented in each session.

FIGURE 4.1: Capabilities extracted from expert interviews

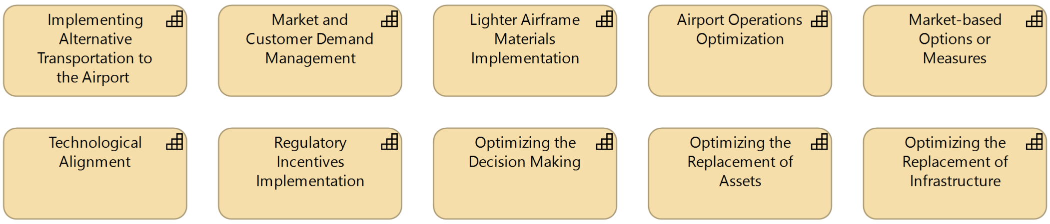

FIGURE 4.2: Capabilities extracted from literature recommended though interviews

FIGURE 4.3: Overview of Capability Sources

All experts interviewed have considered the map very helpful and they found the goal structuring a very appropriate approach for the context and goal of the research. One expert has mentioned that the map also has the characteristics of a Goal Hierarchy.

Incorporated Capability Maps Subsequently to the second round of interviews, the final capability maps have been visualised. The following visualisation contains all incorporated capability maps and unites them into one final capability map. This map can be found in Treatment Design, in Figure 5.3. The maps for each focus designed during the interview in the Miro Boards can be found in Figure D.4, in the Appendix.

Capability Models Based on the models created during the second round of interviews, six distinct capability models have been constructed in ArchiMate. The models can be visualised as follows.

Capabilities	Strategic	Operational	Supporting
Aero-structural Design Optimization			
Agreements and Targets Development			
Air Traffic Flow Management			
Aircraft Engine Design Optimization			
Aircraft Routing Optimization			
Aviation Regulatory Capabilities			
Box-wing Aircraft Design Optimization			
Business and Educational Travelling Management			
Climate-Optimized Trajectories			
Communication System Improvement			
Data Model Implementation			
Dynamic Flight Trajectories Implementation			
Electric Propulsion Implementation			
Energy Transition Leadership			
Fleet Planning Optimization			
Formation Flights Development			
Fuel Cell System Optimization			
Fuel Optimization			
Holiday Travelling Management			
Legislative Measures Development			
Replacing Flights with Alternative Transportation			
Traveling Behavior Management			

FIGURE 4.4: Overview of Capability Classification

Capabilities obtained though LR	22
Capabilities added during Expert Interviews Round I	+ 59
Capabilities removed during Expert Interviews Round I	0
Capabilities obtained from expert recommended literature	+ 10
Capabilities removed due to repetition	- 3
Capabilities added during Expert Interviews Round II	+ 59
Capabilities removed during Expert Interviews Round II	- 3
Total Capabilities	99

FIGURE 4.5: Overview of Capability Sources

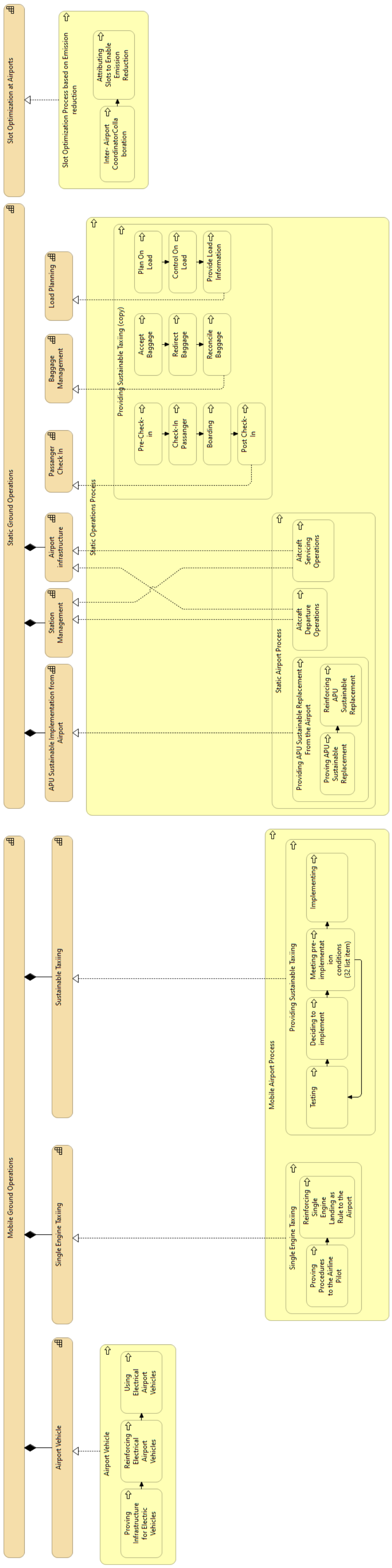

Figure 4.6: Capability Model: Ground Operation

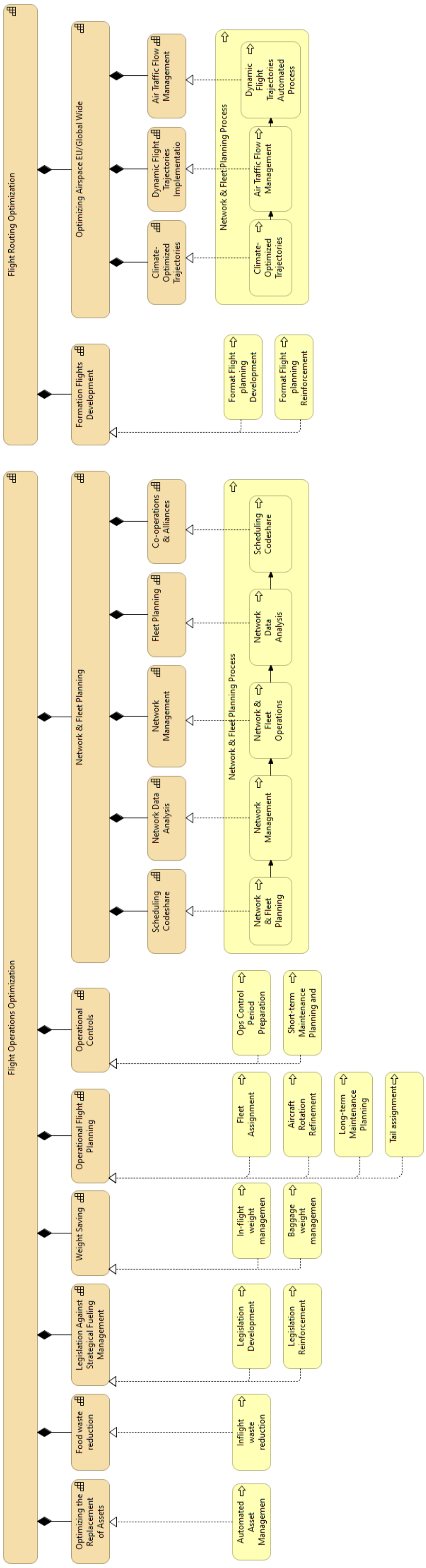

Figure 4.7: Capability Model: Flight Operation

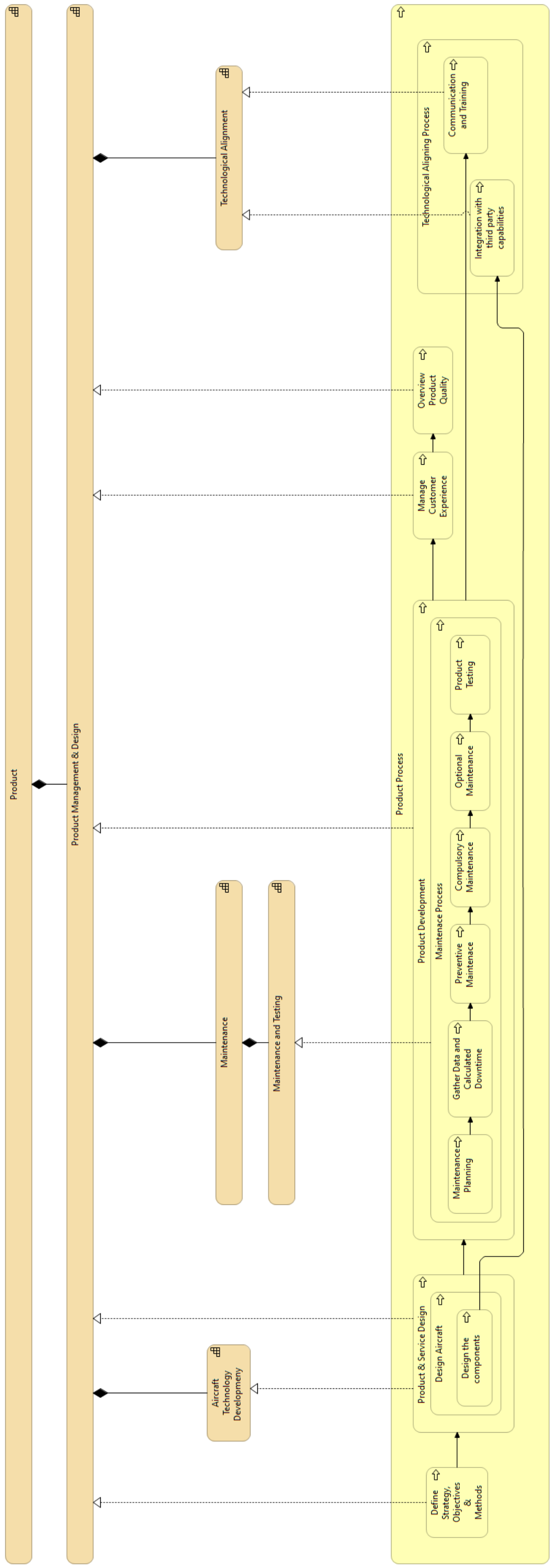

Figure 4.8: Capability Model: Aircraft Design

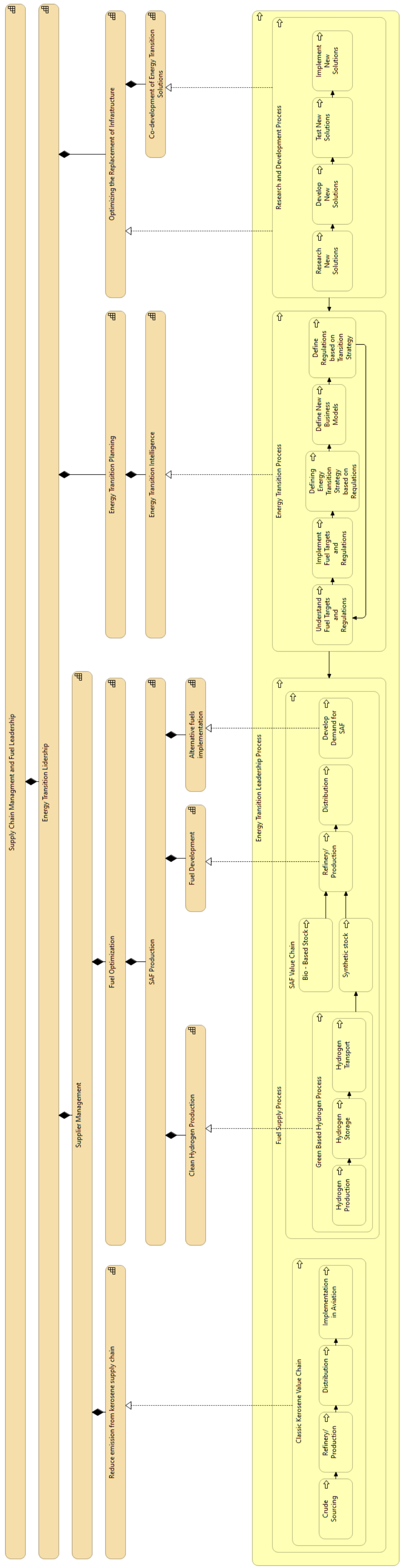

FIGURE 4.9: Capability Model: Fuel Management

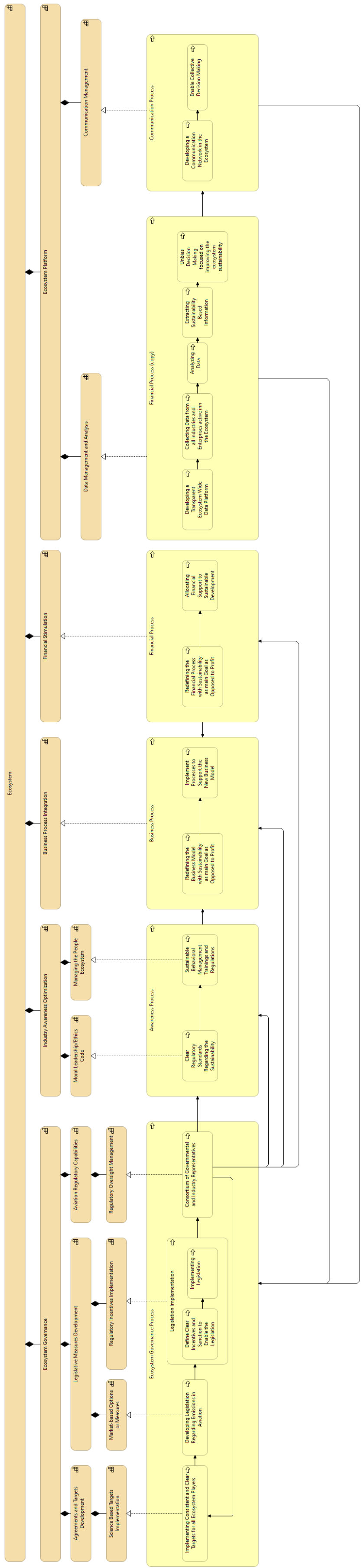

FIGURE 4.10: Capability Model: Ecosystem Management for Flights Improvement

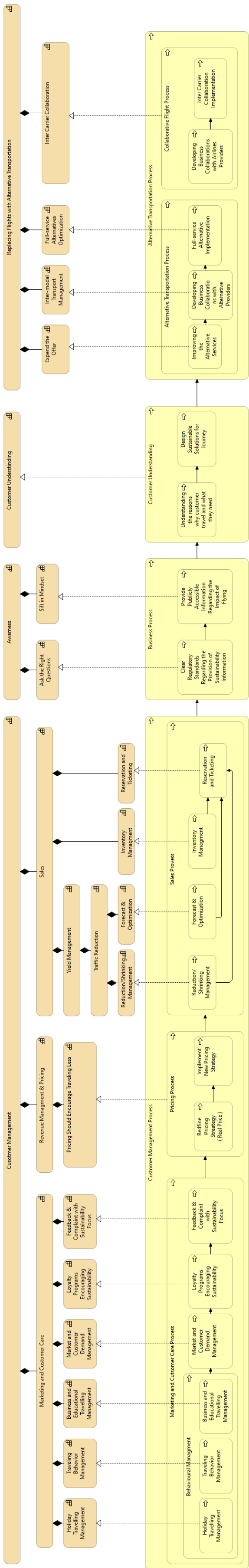

FIGURE 4.11: Capability Model: Ecosystem Management for Flights Reduction

Subsequently to the second round of interviews, the final capability models have been visualised. The following visualisation contains all incorporated capability models and unites them into one final capability reference architecture. This map can be found in Treatment Design, in Figure 5.3. The maps for each focus designed during the interview in the Miro Boards can be found in Figure D.4, in the Appendix.

Chapter 5

Treatment Design

This chapter describes the treatment design part of the research. Starting with the initial Capability Map 5.1 section, which provides a clear mapping of the capabilities gathered from literature and during the first round of interviews. Followed by the Integrated Capability Map 5.2.1 section, which presents the final version of the capability map which integrates The Open Group Capability Map. In the last section of this chapter, the final artifact of this research is presented. The final artifact consists of the Capability Model 5.2.2.

5.1 Capability Map

In order to design a new artifact and resolve the problem tackled by this research, a few sub-steps have to be considered. The need for designing a Reference Architecture of the aviation ecosystem which has a decarbonisation focal point has been established. However, the process of realising this architecture implies defining the capability map.

The following list mentions all steps that will be taken in order to define the capability map for the aviation ecosystem which will be the foundation of the new reference architecture.

1. Clarifying which unique decarbonisation capabilities will be considered
2. Structuring the capabilities by the domains and sub-domains they correspond to
3. Clarifying the hierarchy and the relation between the capabilities inside a domain
4. Design the capability map

5.1.1 Final Decarbonisation Capability List

After collecting capabilities from both literature and expert interviews, the final list contains 91 decarbonisation capabilities for aviation. However, before defining the hierarchy and relations between these capabilities, it is important to remove the repetitive capabilities and create the final list of unique capabilities.

Based on the current capabilities names each capability is unique, in some situations, the experts used distinct names to express the same capability. For this reason, three capabilities have been removed. The three capabilities removed are:

1. **Implementing Fly Tax.** This capability has been removed since the definition provided by the expert is equivalent to the explanation provided by another expert for "CO_2 Emission Tax Implementation". The latter one was included in the final capability list.

2. **Energy Transition Strategy Planning.** This capability has been removed since the definition provided by the expert is equivalent to the explanation provided by another expert for "Energy Transition Planning". The latter one was included in the final capability list.

3. **Collaborate.** This capability has been removed since the definition provided by the expert is equivalent to the explanation provided by another expert for "Integrated Value Chain Collaboration". The latter one was included in the final capability list.

After removing the previously mentioned capabilities, the final list contains 87 unique capabilities. All these capabilities have been mapped in the final capability map.

5.1.2 Capability Classification by Domains and Sub-domains

Based on the interview results shown in Figure 4.4, it became clear that distinct parties had completely different experts on how capabilities should be categorised based on the classical Capability Map 1.5. The most relevant explanation for this result is that the classical Capability Map used was built from the perspective of an enterprise rather than an ecosystem, while the capabilities collected for this research were not restricted by one specific enterprise or industry.

As suggested by one of the experts, The Open Group resources have been consulted. These resources contain the standard Commercial Aviation Reference Architecture is the model proposed by The Open Group as a Preliminary Standard for the industry [12]. This model "describes a reference architecture that can be used to provide a common taxonomy and basis for Enterprise Architecture for the commercial aviation industry" [12].

Although this model still focuses on industry architecture rather than ecosystem architecture, it still provides a multi-focal view of the aviation industry. The architecture presented in the document focuses on 10 main capability domains (Product, Sales, Network Fleet Planning, Ground Operations, Revenue Management Pricing, Flight Operations, Marketing Customer Care, Cargo, Maintenance and Support). These domains can be better visualised in Figure 5.1.

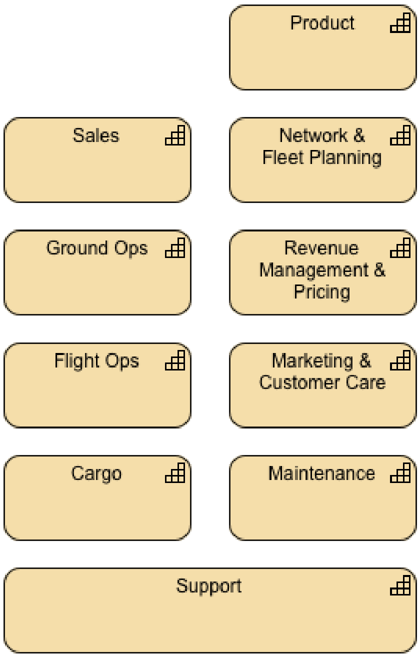

FIGURE 5.1: Domains of the aviation industry [12])

To define the capability map for this research, the first step taken was to look over all capabilities collected and classify them based on the main goals they help reach. Based on the initial capability classification, two capabilities were classified based on two main goals: "Reducing the number of flights" and "Making flights more sustainable", as shown in Figure 2.8. During the interviews, one additional major goal was added, in order to match all capabilities collected. The added main goal is "Compensate elsewhere for the emission produced".

Additionally, multiple sub-goals have been defined based on the collected capability in order to better structure the final list of capabilities. These sub-goals and sub-sub-goals aim to provide a clear structure of the in-depth implications of placing decarbonisation at the core of the aviation ecosystem architecture. The goal classification is structured as follows:

- Reducing the number of flights

  - Making aircrafts more sustainable
  - Making ground operations more sustainability
  - Making flight process more sustainable
  - Making Fuel Management more sustainable
  - Enhancing ecosystem efficiency and sustainability
    * Improve decision making
    * Improve ecosystem governance
    * Improve ecosystem communication
    * Increase stakeholder awareness
    * Provide financial incentives

- Making flights more sustainable
- Compensate else-were for the emission produced

Aside from the logical goal classification, the domains used by The Open Group were also considered. Although these 10 domains provide a clear way of structuring the aviation industry, this research focuses on the entire aviation ecosystem, so distinct industries included in the aviation ecosystem also play important roles. The main classification used for organizing the capability map was based on goals. However, in a later stage of the research, The Open Group capability maps will be integrated into the capability map proposed by this research. The integration of the two maps can be found in Section 5.2.1

Based on the domains mentioned by The Open Group and the goals gathered in this research, 7 distinct capabilities domains have been defined (Ground Operations, Flight Operations, Aircraft Design Optimisation, Fuel Management Management Optimisation, Ecosystem Management for Flights Improvement Optimisation, Ecosystem Management for Flights Reduction). Each of these domains has a commune goal and contains multiple capabilities.

5.1.3 Capability Map

Although when talking about capability mapping the main Capability Map model is still the ArchiMate one found in Figure 1.5, The Open Group Model appears to be more appropriate for this research. Unlike the general model, The Open Group Model for commercial aviation was designed especially for the case of the aviation industry and it aims to show the perspective of the entire industry ecosystem rather than an enterprise view[12].

The Open Group Model includes more domains than Strategic, Operational and Supportive since it aims to provide a more granular perspective. Unfortunately, the high granularity of this perspective was not advantageous for the first round of interviews, when most of the subjects were getting accustomed to the research topic. However, during the Capability Categorisation part of Interview Round I, it was observed a high discrepancy between the perspectives of each expert 4.4. For this reason, the final capability map will be constructed by the researcher prior to the second round of interviews and will be validated during the interviews.

The final capability map has been structured into 6 focus points (Ground Operations, Flight Operations, Aircraft Design Optimisation, Fuel Management Optimisation, Ecosystem Management for Flights Improvement, Ecosystem Management for Flights Reduction). These focus points have been defined by considering The Open Group aviation model and focusing on the goal categorisation made based on the capabilities collected through this research. The final capability map can be visualised in Figure 5.2.

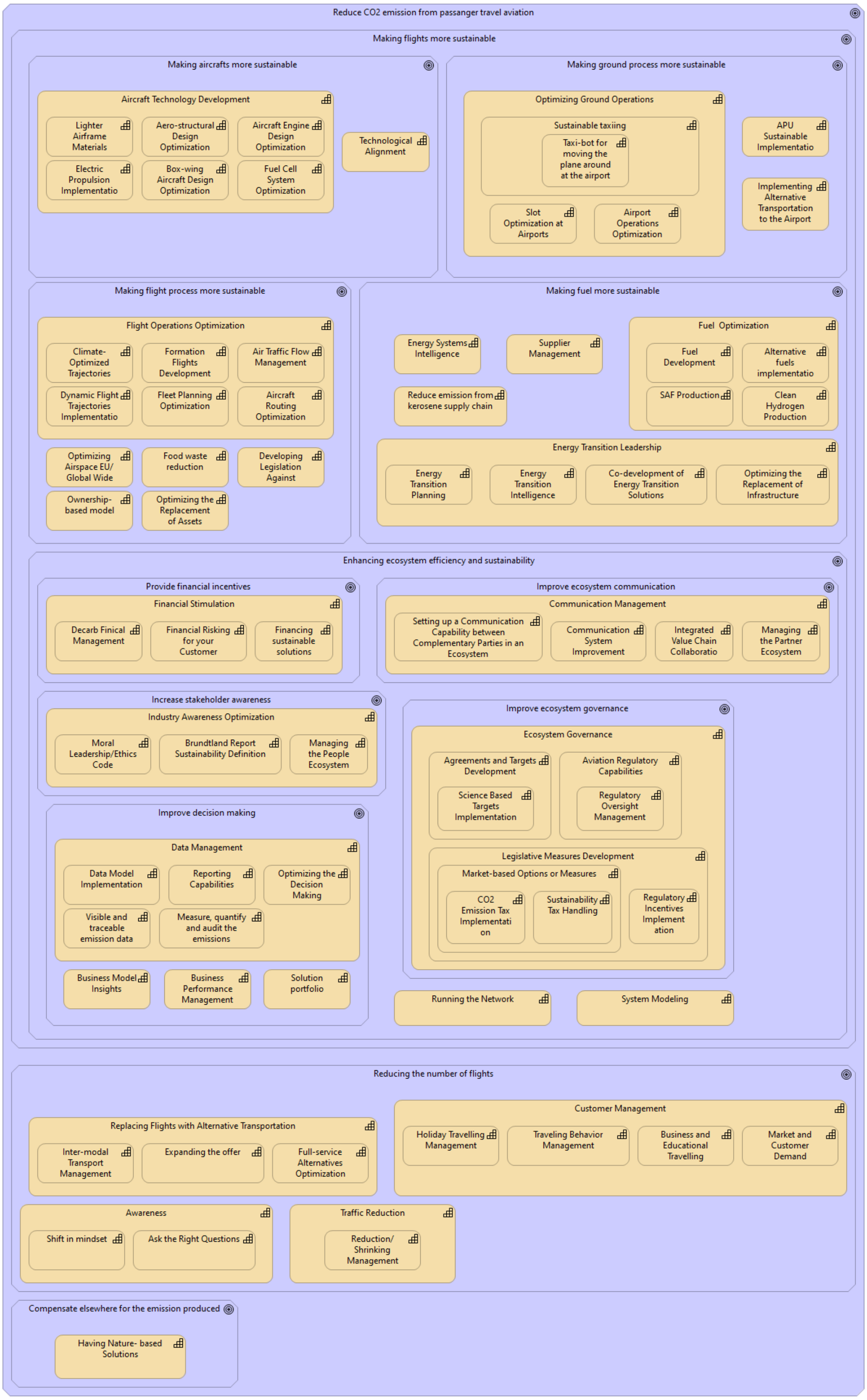

Figure 5.2: Capability Map for Decarbonising the Aviation Ecosystem

5.2 Capability Model

The Capability Map for Decarbonising the Aviation Ecosystem, constructed based on the TOGAF model, has been used during Interview Round II as a basis for creating the Capability Model [85]. The following list mentions all steps that will be taken in order to define the capability model for the aviation ecosystem which will be the foundation with sustainability at its core.
1. Define the final capability map by integrating The Open Group's proposed capability maps in the current model obtained through the conducted interviews
2. Clarify the processes supporting all capabilities included in the map
3. Design the capability model as part of this research, which consists of a capability diagram, including capabilities and processes

5.2.1 Integrated Capability Map

In order to integrate the two capability maps, each map has been defined from multiple views as explained earlier in this chapter. Lastly, Table 5.1 shows the clear correlations decisions made during this research during the capability maps integration phase. These correlations have been made based on the capabilities contained in each capability map provided by The Open Group in relation to the capabilities contained in the capability map developed by this research.

Capability Categories from this Research	**Open Group Capability Categories**
Ground Operations	Ground Operations
Flight Operations	Flight Operations, Network and Fleet Planning
Aircraft Design	Product, Maintenance
Fuel Management	-
Ecosystem Management for Flights Improvement	Support
Ecosystem Management for Flights Reduction	Marketing and Customer Care, Revenue Management and Pricing and Sales

TABLE 5.1: Co-relations between the Capability Map and The Open Group Model

The Final Capability Map, incorporating both the capabilities gathered in this research and the ones proposed by The Open Group has been created based on the second round of interviews. The following visualisation contains all of the incorporated capability maps designed during the second round of interviews and unites them into one Final Capability Map. This map can be found in Figure 5.3.

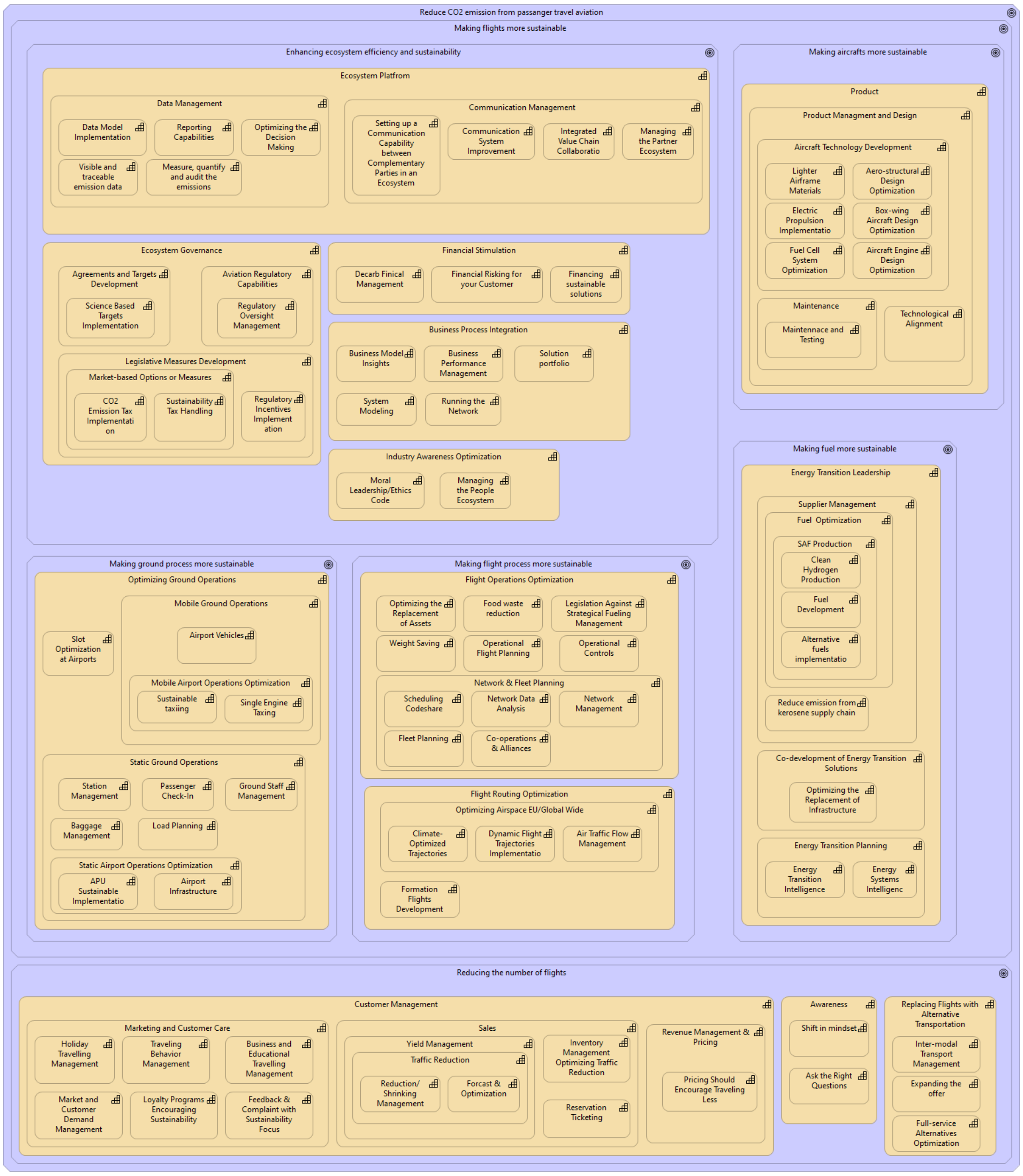

FIGURE 5.3: Final Capability Map

5.2.2 Capability Model

Based on the second round of interviews, for each of the 6 focus areas defined for this research, a separate model has been detailed (Ground Operations, Flight Operations, Aircraft Design Optimisation, Fuel Management Optimisation, Ecosystem Management for Flights Improvement, Ecosystem Management for Flights Reduction). These models are visualised in Section 4.3. However, all models provide extensive information about sub-capabilities and sub-processes. Given the complexity of the previously mentioned visuals, simplified versions have also been created for a better business context understanding.

Additionally, an Integrated Capability Model for decarbonising the aviation ecosystem is a reference model which provides an overview of the capabilities and processes in the ecosystem. This implies that the main focus is visualising the ecosystem as a whole and the interaction inside, rather than focusing on extensive parts of sub-capabilities and sub-processes. An Integrated Capability Model refers to the integration of all sub-models and focuses on process centralization.

All experts consulted during the interviews agreed on the need for clear integrated ecosystem management, both for governing the ecosystem and aligning all current strategies towards decarbonisation. Moreover, it was underlined in the interview results that integrated ecosystem management capabilities should be at the core of the ecosystem. The current problem mentioned by the experts was that all actions designed and taken by the organisations they represent, aim to affect only that same organization. So the focus is on their core business, internally, rather than external. The only collaborations currently created are decentralized, they occur at a smaller level between partners. This results in limited effects on the overall ecosystem.

Despite the openness of the players to communicate and work together, currently, there is no management, communication or data exchanged widely throughout the ecosystem. As collaboration is lacking, they impede each other from reaching progress together.

Based on the interview results, the ecosystem model consists of two layers: the Ecosystem Core and the Ecosystem. These layers can be visualised in the Simplified Ecosystem Model 5.4. This model was designed based on the interview results and has as its goal the integration of all models.

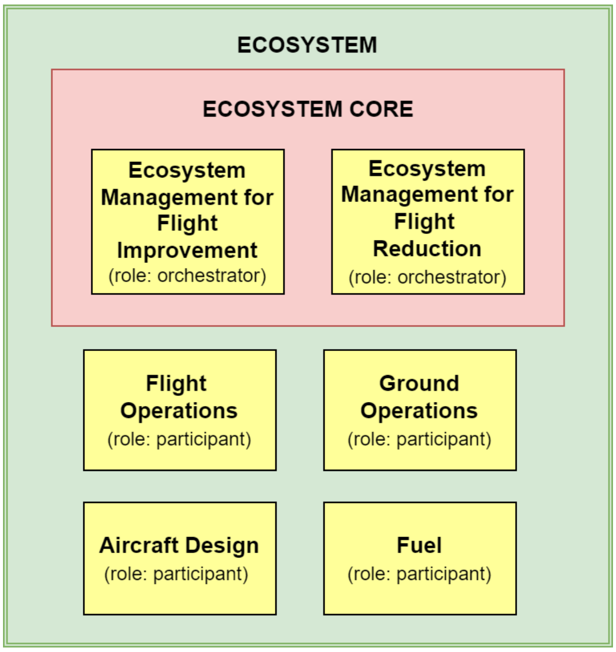

FIGURE 5.4: Simplified Ecosystem Model

According to the experts, the Ecosystem Management for Flights Improvement and

Ecosystem Management for Flights Reduction capabilities consist of the Ecosystem Core and emphasise the need for an integrated management system to run the ecosystem. The Flight Operations, the Ground Operations, the Fuel Management and the Aircraft Design capabilities and processes have been considered part of the Ecosystem since they affect and are affected by the Ecosystem Core. The Flight Operations and Ground Operations support the Arline, Airport and Air Traffic Data Management, while Fuel Management supports the Fuel Management Data Management Process and Aircraft Design supports Aircraft Design Data Management Process. Additionally, the Centralized Business Process directly affects all specific processes.

All layers of the ecosystem together with the main focuses associated with each level can be visualised in Figure 5.4. The names given to each layer were given with an analogy to the natural ecosystem in order to ease the understanding of the figure.

As previously mentioned, all experts interviewed have agreed with the need of operating as an ecosystem. Despite working for an airline, an airport, air traffic control, an aircraft manufacturer or even fuel suppliers, all experts agreed that for reaching the current decarbonisation targets, all measures are inter-depended and cannot be solved singularly by one organization or even one industry. Moreover, some of the experts interviewed admitted that currently most decarbonisation actions are taken at an enterprise level and they fail to reach the targeted goals, as the goals are defined for an industry level.

For this reason, the Ecosystem Core focuses on Ecosystem Management for Flights Improvement, for both improving the flights and reducing the number of flights. Basic modules found in current digital ecosystems, such as the Ecosystem Board, have been implemented, together with a simplified version of the capabilities and processes provided in Results. These capabilities and processes aim to create centralised ecosystem management and an integrated way of work across all involved parties. The Integrated Model can be visualised in the Appendix, in Figure E.1.

However, due to the extensiveness of this model, an even more simplified model has been designed to be used in a business context. This model aims to show the main processes and capabilities without providing in-depth information. This model will be used for the Business Case based Validation. Based on the information obtained during the interviews, it was found that it is important to have a simplified view that can help decision-makers, who do not have an architectural background, understand the model. This is the reason why the simplified view will be used for the validation session. The Simplified Ecosystem Core view can be found in Figure 5.5.

The Simplified Ecosystem Core Model contains all core capabilities and processes defined by this research as needed for managing the ecosystem as a whole. However, the models obtained during the second round of interviews for Ground Operations 4.6, Flight Operations 4.7, Aircraft Design 4.8 and Fuel Management 4.9 also contain managerial capabilities, as they reflect industry-wide improvements.

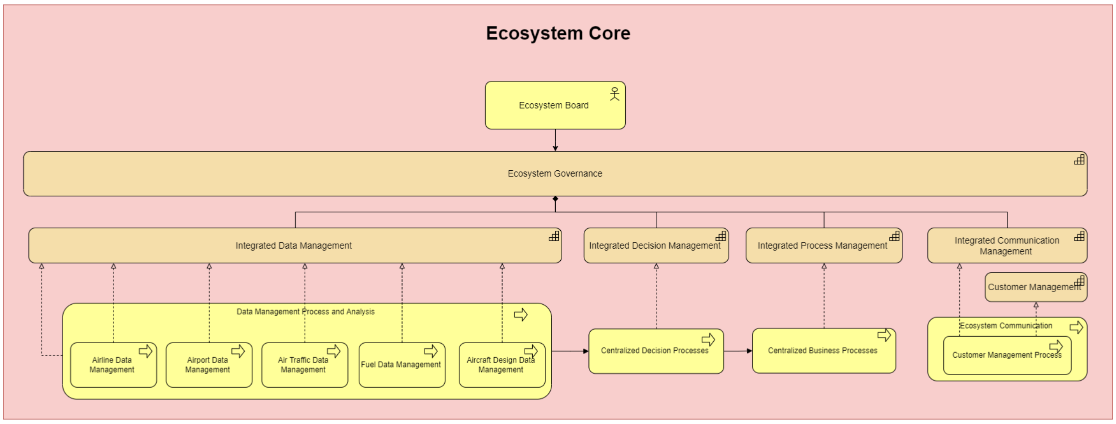

FIGURE 5.5: Simplified Ecosystem Core Model

During Interview Round II, the need for centralised ecosystem management was emphasised, and the model for the Ecosystem Core 5.5 has been created, the models for each industry, in particular, have been adapted in order to function under the general ecosystem management.

Each of the four models has been reconstructed to integrate the Ecosystem Governance Capability which consists of Integrated Data Management, Integrated Decision Management, Integrated Process Management and Integrated Communication Management. Additionally, by integrating the core ecosystem capabilities and processes, some of the industry-focused capabilities and processes have been removed, as they have been replaced by the ecosystem core ones.

The models containing the integration of the Ecosystem Core capabilities and processes can be visualised in Appendix E. A visualisation of each of the four models is provided (Ground Operations E.2, Flight Operations E.3, Aircraft Design E.4 and Fuel Management E.5). These visualisations consist of a simplified version of the model which integrates Ecosystem Core capabilities and processes. The Ecosystem Core capabilities and processes have been underlined in pink rectangles, so that it is easier for the viewer to differentiate the capabilities and processes that play a role in the Ecosystem Core, from the industry-specific ones.

The importance of clear simplified visualisation was previously emphasized. The models integrating the Ecosystem Core for each of the four industry focuses have been further summarized, showing only the processes left outside the core of the ecosystem. These processes tend to have a more operational focus and, based on expert opinion, are mainly controlled locally by the industry. Nevertheless, all these capabilities and processes still play an important part in the ecosystem. The visualisation of the simplified industry-specific models can be found below (Ground Operations 5.6, Flight Operations 5.7, Aircraft Design 5.8 and Fuel Management 5.9).

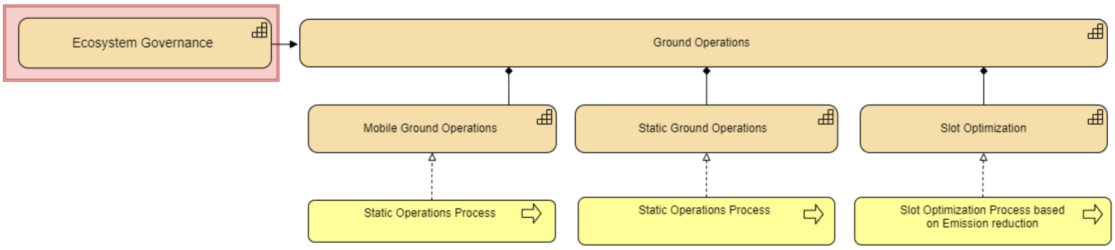

FIGURE 5.6: Integrated Ground Operations

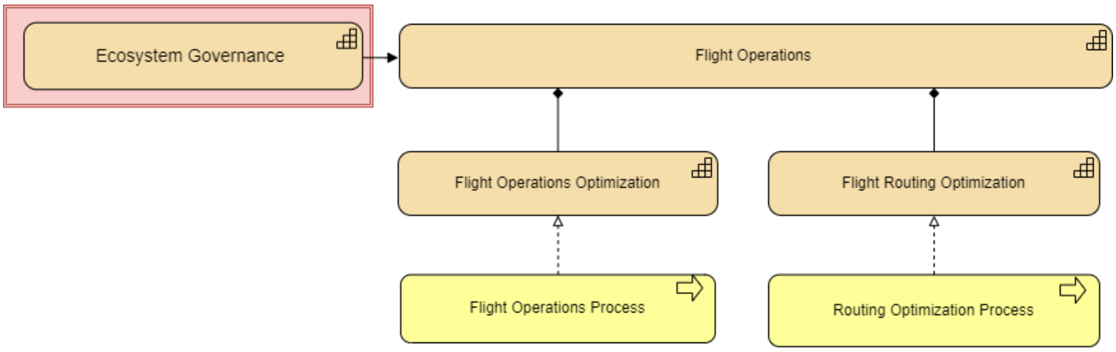

FIGURE 5.7: Integrated Ground Operations Flight Operation

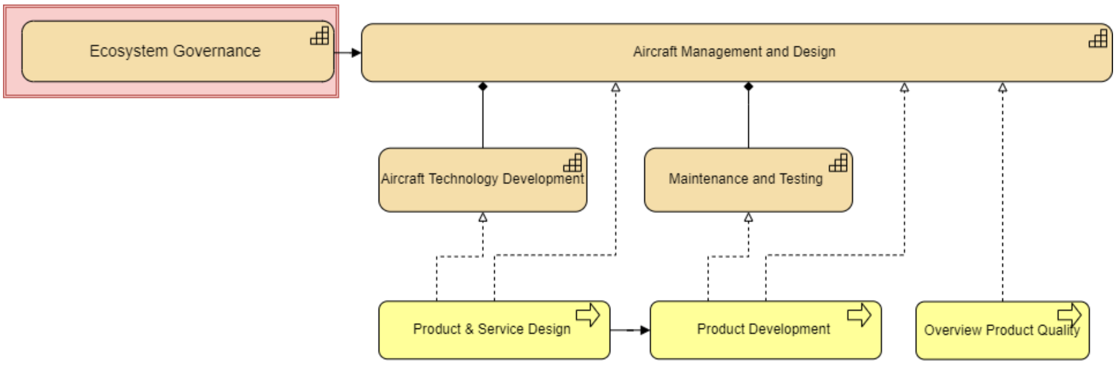

FIGURE 5.8: Integrated Aircraft Design

Lastly, in order to reflect the ecosystem as a whole, The Reference Model of the Aviation Ecosystem has been created. This model can be found in Figure 5.10 and provides all layers of the ecosystem and the connections between all elements.

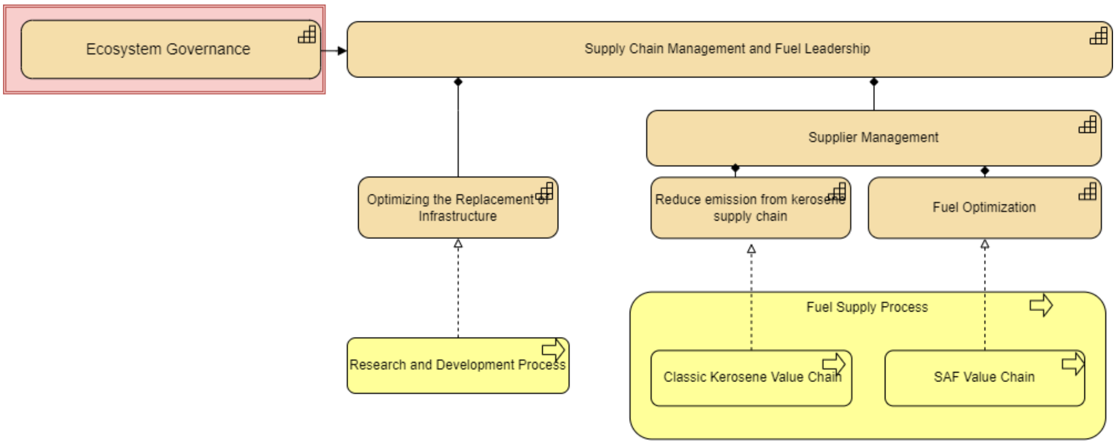

FIGURE 5.9: Integrated Fuel Management

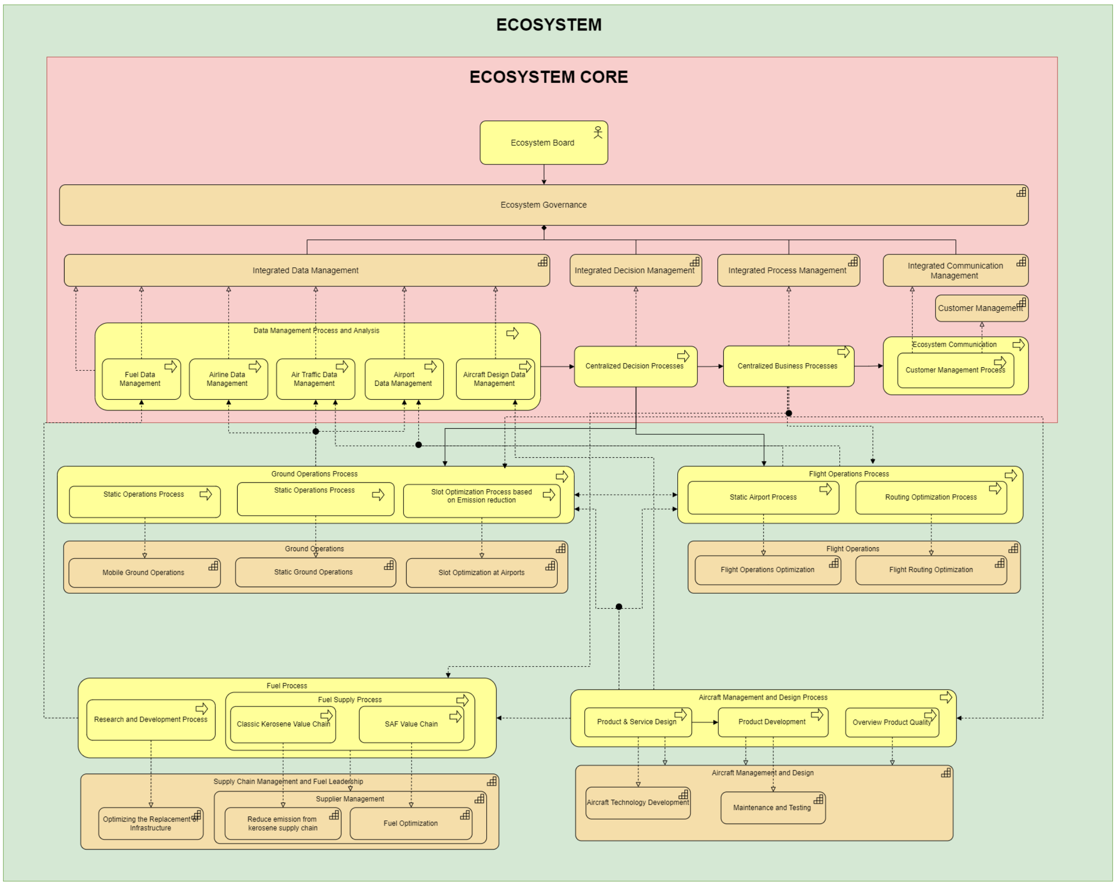

FIGURE 5.10: The Reference Model of the Aviation Ecosystem

Chapter 6

Treatment Validation

In this chapter, the treatment validation process is presented. The validation process is structured based on the two core questions of a validation defined by R. Wieringa, "What will be the effects of the artifact in a problem context?" and "How well will these effects satisfy the criteria?" [86]. With these questions as a focus, the artifact will be first evaluated based on a case study. The first validation session has two core purposes based on the previously quoted questions. The purpose is to validate the integrated model based on a business case, to see the effects of the artifact in a defined problem context. The second purpose is to validate each model in particular, to define the depth to which each model satisfies the criteria.

Additionally, the Desired applicability of the artifact and the actual need for the artifact will be discussed. This discussion will be based on the following questions, "How does this treatment perform compare to other possible treatments?" and "Would the treatment still be effective and useful if the problem changes?" [86].

In order to answer the question "How does this treatment perform compare to other possible treatments?" [86], a clear comparison was made by evaluating both the integrated versions of the treatment and each model in particular. Furthermore, the existing treatments have been considered and discussed during the validation session. More information regarding the first validation session can be found in 6.3.

Moreover, a second iteration of the validation session was designed to validate the changes made based on the first validation session. The second validation iteration can be found in Section 6.4.

Lastly, the background, goals, process and resources for the validation sessions can be found in the Appendix, in Chapter F.

6.1 Participant Selection

For the first iteration of validation, two experts originating from two different companies have been included. All experts have a background in the Oil and Gas sector, as well as decarbonisation. Despite the expertise in the Oil and Gas industry, two distinct types of experts have been participating in the first validation session.

The first expert focuses on aviation Decarbonisation and has a background in projects regarding aviation decarbonisation from the Oil and Gas industry perspective.

The second expert is an Architecture expert with a background in Oil and Gas, as well as experience with projects related to decarbonisation.

Moreover, the Business Case selected has a direct connection with the roles of the experts. The information regarding the roles and the organizations of each expert can be found 6.1. The organisation deceptions can be found in Section 4.1.2.

The third expert was chosen to validate the changes made based on the feedback collected from the first validation iteration. As the focus of the changes was Ground Operation, the third expert is an Airport Mobility Product Owner, with background experience in decarbonisation.

Expert	**Organization**	**Role**
Expert 1	D	Decarbonisation Manager for Aviation Industry from Oil and Gas perspective
Expert 2	E	Enterprise Architecture Senior Manager working in Oil and Gas Decarbonisation project for company D
Expert 3	C	Airport Mobility Product Owner

Table 6.1: Validation Interview Respondents Overview

6.2 Evaluation Session

Due to the extended series of interviews conducted for this research, together with the time constraints of the graduation project, no pilot sessions were conducted for the validation case study. Therefore, similar to the approach of the second round of interviews, the case study guide has been reviewed in an informal session.

The feedback collected through this session can be summarized as follow:

- The structure of the validation session is appropriate to the research and clearly defined

- The name of the Ecosystem Management capabilities needs to be changed so that they make sense more intuitively
- The Ecosystem Core model is very accurate as a base model but is interesting to think how this model can be extended for the future research
- The models are very clear, especially the simplified version can be very useful in the real business context
- The idea of a certification possessed by all the ecosystem members can help involve enough parties in the ecosystem to get it started

6.3 Case Study Validation

In this section, the case study selected is being introduced. The first part explains the case study selection process. The second part describes the feedback received during the first validation session.

6.3.1 Case Selection

Several informal meetings have been conducted with distinct stakeholders of the aviation industry, aside from the experts taking part in the interviews, to find the most appropriate business case for the validation session.

Initially, four business cases have been considered. However, three of them lacked the collaboration view implied by this research and had a more particular industry focus. The final case selection was based on the applicability of the case to the context of this research. Lastly, although the selected case originates in the Oil and Gas industry, it has further ecosystem implications, as it affects all players considered in this research (Airlines, Airports, Air Traffic Control, Aircraft Manufacturers and Fuel Providers).

6.3.2 Case Description

All companies and experts consulted during the interviews underlined the importance of working together, especially for reducing Scope 2 and Scope 3 emissions, as those depend on multiple players. For this reason, the case selected focuses on reducing Scope 3 emissions from an Oil and Gas company perspective.

Based on a recent legal decision, a major Oil and Gas company is expected to have drastic emission reduction by 2030, in line with the Paris Agreement targets. However, aside from the reduction of Scope 1 and Scope 2 emissions, to reach the set targets, the company must consider also Scope 3 emissions. For the Oil and Gas company, Scope 3 emissions represent the emissions produced by the companies that purchase their fuel.

In this particular situation, the aviation industry is one of the main customers of the Oil and Gas company presented. Subsequently, a major part of the Scope 3 emissions of the Oil and Gas company result from the aviation industry. Together with the fuel improvements, the company has prioritised the service of providing decarbonisation advice for the aviation industry.

Lastly, a specialized department was created inside the company and resources were invested in order to help the aviation industry reduce emissions from all perspectives. For this reason, one party involved in this specific team is taking part in the validation session where the applicability of this research to the problem context and the business case will be discussed.

6.3.3 Case Study Validation Results

The first goal of the validation session was to validate the adaptability of the models in the context of the case study. As one of the experts taking part in the validation session is working in the exact situation described by the case study, the applicability of the research to the case study can be determined. The questions asked based on the case study can be found in Figure F.1 and the summarized answers can be found in G.4.

In this section, the information gathered during the validation session for the business case is discussed.

Ecosystem
Both experts have agreed on the high importance ecosystems play in aviation. Moreover, the need for the ecosystem approach was confirmed in the context of decarbonisation. The summarised results from the questions can be visualised in Figure G.1.

Expert 1, who is working in the context of the business case described, admitted that the concept of digital ecosystems is not very familiar with the current strategy. However, the expert explained that the current approach is of creating connection and communication platforms including all parties of the value chain, which decibels a very similar view to the one presented in this research. From the feedback, it become very clear that ecosystems are found very useful, but there is a need for clarifying definitions and modelling standards before adopting the research results.

Expert 2, who has an architecture background has confirmed and emphasized the need for an ecosystem approach. However, although the current models of this paper were found extremely effective, the need for looking more in-depth was expressed. The expert mentioned that the business layer was a very good approach and needs to be integrated into the business case and clear reasons for the case for the need of working as an ecosystem. On the other hand, the expert stated that application and technology layers are required in order to implement the ecosystem approach in the business case. The main feedback was focused on extending the model for all TOGAF lawyers.

Lastly, both experts agreed that together with standard measuring methods, the ecosystem can provide a clear overview of the emissions produced in the industry. This feedback related to the usage of models for calculation purposes as a next step will be further discussed in Chapter 7, Section 7.3.

Industry Specific Models
When it comes to industry-specific models, the relevance of these models was confirmed by both experts. The summarised results from the questions can be found in Figure G.2.

Expert 1 has found the models presented of vital importance and has confirmed the need for each of the value chain models before building an ecosystem model. Moreover, from the Oil and Gas industry perspective, the expert has rated the relevance of each value chain from the perspective of their decarbonisation abilities. The expert has rated Fuel Management with a 5 (highest score) since based on knowledge of the expert in the industry that can decarbonise the most (up to 65%). The second highest score was a 4 for Aircraft Design, as the expert considers that to have the second most powerful influence in industry decarbonisation. Lastly, Flight Operations was allocated a 3 and Ground Operation a 2, based on their relevance to the decarbonisation process. Together with these results, the expert also emphasised that this research has taken a correct approach by inducing all 4 parts inside the ecosystem, as most current researches leave out Fuel Management and Aircraft Design, which have been rated as the most relevant players. Nevertheless, the expert mentioned that looking at Scope 3 from Oil and Gas for Aviation is a very efficient way of looking outside in and managing to include all ecosystem players.

Expert 2 has confirmed that when looking to build a digital ecosystem, it is vital to understand all parts of the process from the perspective of all players. For this reason, modelling all value chains for each industry is a clear step which needs to be taken before modelling the ecosystem. Additionally having a clear architectural model of each industry before and after the integration into the ecosystem is needed to assure the correct integration of the ecosystem model by all parties. For this reason, the expert emphasized again the need for developing more in-depth models containing all TOGAF layers. Moreover, it was mentioned that such models need to be firstly created for the current state of each value chain, followed by the desired state of each value chain before determining the ecosystem core in-depth model.

6.4 Future Research Validation

Based on the feedback received during the validation session, the development of more layers for the model was considered the first next step to be taken. As modelling the application and technology layers of the ecosystem core and for the separate industries was not feasible for this research, this section provides the first next step to be taken towards a complete model.

In this section, an approach to in-depth future work is provided and validated by an industry expert. The focus is placed on validating the need for the ecosystem approach from the perspective of a singular industry. From the 4 industry focuses defined (Flight Operations, Ground Operations, Fuel Management and Aircraft Design), Ground Operations was selected as a prototype industry for which the current model and the future model will be created and validated by an industry specialist.

The industry focus models proposed by this research have been designed in order to show the desired business layer for the aviation ecosystem. However, a complete architecture based on the TOGAF should also contain the Data layer, the Application layer and the Technology layer [85]. However, due to the time limitations of this research, the focus of the artifact was placed only on the Business Layer.

For this part of the research, the Ground Operations model is extended with the Application layer, to show a future first step approach toward a complete architecture. All models can be extended with all layers, nevertheless, this section only provides a suggestion for one industry focus, which can be later applied for all industry focuses and for all layers. Additionally, an in-depth architecture with all layers should be created in future research for the Ecosystem Core.

6.4.1 Ground Operations In-depth Models

The initial Ground Operation model has been created based on The Open Group Aviation Model during the expert interviews. For this reason, when developing the Ground Operation Architecture (including the Application layer), the original Open Group Model will be considered. However, as mentioned before in the paper, The Open Group Model focuses mainly on the airline perspective. The Open Group Ground Operations Architecture provides a clear visualisation of the business and application layer of the current industry state. This model can be found in Figure 6.1.

Having The Open Group Ground Operations Architecture as a visualisation of the current state of the art, a new Ground Operation Architecture was created to represent the desired state. This architecture has been based on the Ground Operation Capability Model 4.6 and extends this model by looking in-depth into the applications needed for fulfilling the desired processes. This architecture provides the visualisation of the future

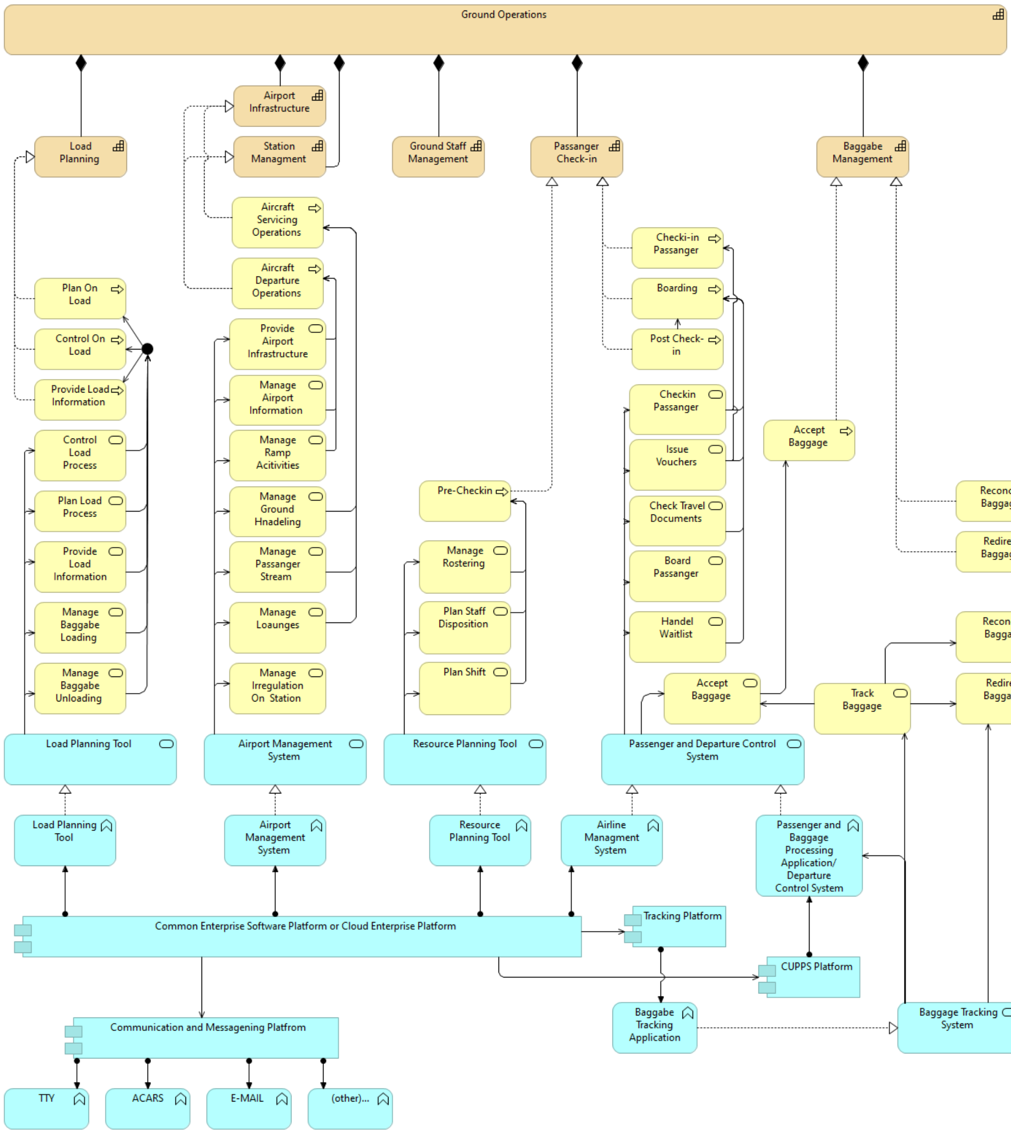

FIGURE 6.1: The Open Group Architecture for Ground Operations [12]

state with the decarbonisation goals in mind. The Future Ground Operations Architecture was created based on The Open Group Model and the information collected during Interviews Round II.

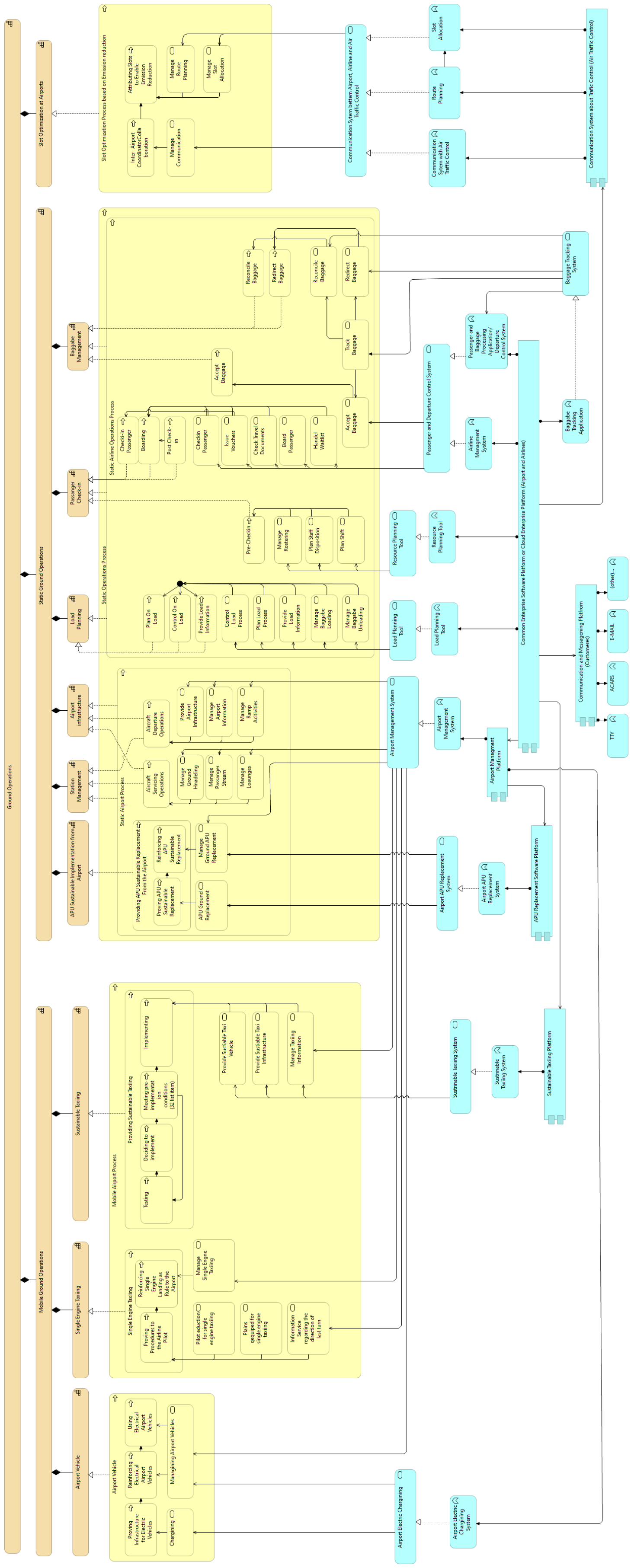

FIGURE 6.2: The Desired Ground Operations Architecture

The Desired Ground Operations Architecture contains the Business and Application layers for Ground Operation, including the perspectives of the Airline, the Airport and Air Traffic Control. This model is designed to show all the applications needed by each party in order to implement the decarbonization strategies designed in the business layer and to reach the desired decarbonisation state. Also, the decarbonisation additions made in the desired model can be found G.2. Based on the connections created in-between the application, the need for intercommunication between all parties is emphasized. The Desired Ground Operations Architecture can be visualised in Figure 6.2.

Moreover, the need for designing a simplified model for business understating purposes was considered. The Desired Ground Operations Architecture Simplified 6.3 provides a visualisation of the desired state of Ground Operation based on an ecosystem perspective.

Lastly, this architecture will be validated in Ground Operations Validation Interview F.2 and can be visualised in Figure 6.3

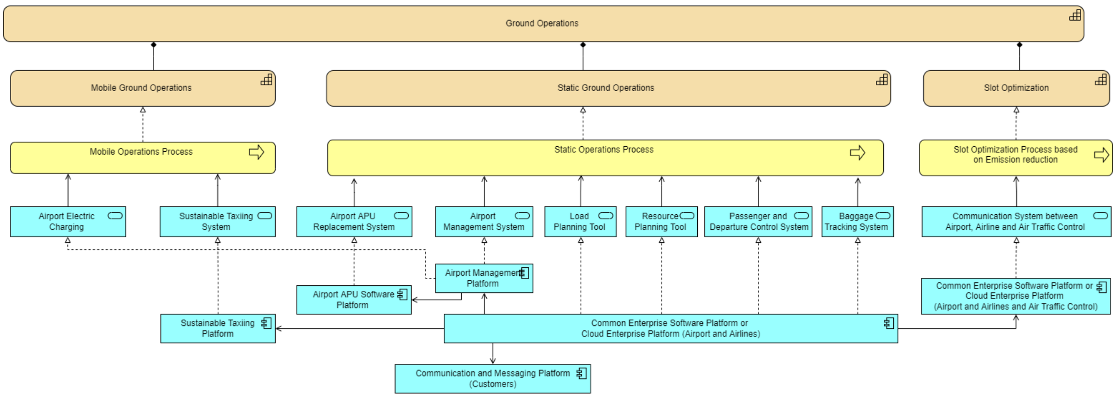

FIGURE 6.3: The Desired Ground Operations Architecture Simplified

6.4.2 Ground Operations In-depth Models Validation Results

After applying the feedback collected during the first validation session, a second validation iteration has been conducted for this research. The second validation iteration has as its main goal the validation of the Ground Operation model in a real business context by consulting with an expert from the specific business context. Moreover, the need for a digital ecosystem was validated from the Ground Operations as well as the application layer of the model.

The expert interviewed has direct experience with decarbonising ground operations from the perspective of the Airport industry. Expert 3 has found the research very innovative and very useful in a real work context. The models presented were clear for the experts and the information presented was in line with the current approach of the airport. The summarised results can be found in Figure G.4.

When it comes to the current application of architecture in the industry, the expert admitted that there is no such an equivalent. However, the enterprise the expert represents has a defined Net Zero target for 2030, as well as a clear road-map for reaching the Net Zero goal. The road-map provides a structured overview of the emission reduction points and targets as well as operational suggestions. The current road-map can be easily transposed into an architecture based on the information gathered in the interview. Having an architectural model together with the road-map appeared to be an interesting approach for the expert.

Additionally, when looking at the ecosystem perspective, the expert has explained that there is no ecosystem in place from the perspective of a digital ecosystem platform, at the moment. However, there is a clear communication structure and ongoing communication channels with all parties involved in the ground operations, including Airlines, Air Traffic Control, Handlers and Fuel Suppliers. Despite having the communication points clearly defined, currently, the communication is taking place in person and there is no systematic data and communication platform.

The expert has found the use of an ecosystem very interesting as it makes communication much more efficient and easy. Since now the data transfer and communication processes take a lot of ongoing effort, an ecosystem platform was found very helpful by the expert and was considered a good next step for the industry. The expert showed interest in this research and mentioned that this approach will be considered by the enterprise.

Chapter 7

Discussion

In this section, the results of this research are being discussed, together with the decisions taken to design the ecosystem model. This section aims to explain the findings and the reasoning behind these results and the limitations. Additionally, the contextual validity and extensive applicability of the research are discussed. Lastly, general recommendations are made as well as future research suggestions.

7.1 Capability Map

The first step toward a reference model for the aviation ecosystem included defining a list of decarbonisation capabilities, from both literature and expert opinion. Based on these capabilities, a goal-oriented capability map has been defined to conceptually visualise the construct and provide the basis for designing the reference model.

7.1.1 Capabilities Identification

All capabilities collected have as an aim the completion of the central goal of this research: "Reduce CO_2 emission from passenger travel aviation". The use of goals and capabilities for designing a business layer architecture was decided based on the TOGAF model guiltiness [85].

A list of 22 unique capabilities has been collected based on the academic literature review. The translation of the data collected from the literature into capabilities can leave room for interpretation. For this reason, all capabilities collected during the literature review have been validated by experts during the first round of interviews. Interestingly, all capabilities collected during the literature review have been considered relevant by the experts, so none of the initial capabilities was removed.

Additionally, 59 more capabilities have been added during the expert interviews based on the recommendations of the experts. Each expert was asked to review the capabilities obtained from literature and add the missing capabilities, based on their expertise. An unexpected observation was that during Interview Round I, most experts added capabilities which refer to a different part of the value chain than their expertise. Although this showed the clear interoperability inside the industry, it created the need for a second interview iteration, where each expert can focus solely on their area of expertise.

Lastly, based on the ILR method, literature could be considered at the suggestion of the experts interviewed. This method was used to include Grey Literature in a non-bias way. As there was a lot of non-academic information available online, the researcher used the ILR method in order to access non-academic sources in a non-bias way. Gathering expert based sources proved to be an effective method as 10 more capabilities were added based on the literature recommended by the experts.

A total of 91 capabilities were defined during the literature review and the first round of interviews. However, when reviewing the list of all capabilities 3 pairs of equivalent capabilities have been identified and so 3 capabilities have been removed. The identification was made based on the definitions provided by the experts for each of the capabilities. The capability definitions can be found in Section 2.3.3 (for the literature-based capabilities) and Section D.3 (for the capabilities obtained during the interviews and based on literature recommended during the interviews).

7.1.2 Construct Design

Based on the literature review and the first round of interviews, a final list of 87 unique capabilities has been defined. This list has been structured into a capability map based on defining logical goals and which divided the capability list into 6 clear areas of interest (Ground Operations, Flight Operations, Aircraft Design Optimisation, Fuel Management Optimisation, Ecosystem Management for Flights Improvement, Ecosystem Management for Flights Reduction). Since during the first interview round the experts focused on the whole industry, during Interview Round II, focus expert sessions were designed for each area of expertise. This approach aimed to validate each capability focus with an expert from that specific area.

Based on the second interview iteration, the final capability map, focused on 6 distinct sub-goals, was designed. This map consists of 119 capabilities and sub-capabilities. The sub-goals were defined both based on the capabilities collected and The Open Group Model for Aviation Industry. For more details, the capability collection and validation process can be visualised in Figure 4.5.

Out of the 6 sub-goals, two focus on creating an ecosystem way of work for both improving the sustainability of flights and reducing the number of flights. The other sub-goal section represents capabilities needed on each part of the value chain for decarbonisation. This approach of diving into the construct in 6 distinct focuses provided an effective way of collecting all information needed to build the final integrated model.

Consequently, a final based capability map was designed to conceptually visualise the capabilities collected and provide a basis for designing the reference model. This map contains the final list of capabilities collected from both literature and Interview Round I, reviewed and validated by focus expert sessions during Interview Round II. This map can be visualised in figure 5.3.

7.1.3 Relations inside the Capability Map

The capability map has been designed to provide order and structure to the data collected from both the literature review and the expertise of the interview participants. Aside from this map, during the interviews, multiple relations between the capabilities have been defined, both inside a sub-goal and in-between sub-goals. The capability map does not provide the information flow between capabilities, however, the information flow has been discussed during the interviews and considered when designing the final model. However, the ecosystem related sub-goals of the map, created together with ecosystem experts, have the aim of providing the capabilities which imply the collaboration of more parties. The two ecosystem related sub-goals of the capability map have been used when defining the ecosystem core model.

7.2 Model Applicability

In order to review the quality of the conducted research, in this section, the applicability of the artifact is being reviewed. Given the use of Design Science Research Methodology, which implies that one artifact has been developed to solve the defined problem, the applicability is tested based on the Design Thinking approach. The model used to review the applicability of this research is the Three Lenses of Human-Center-Design (HCD) model. This model can be visualised in Figure 7.1.

The Three Lenses model provides a suggestion for defining when an artifact can resolve the predefined problem. "The designer should first seek to generate solutions that are **desirable** to people, in that the solution meets their needs; **viable**, in that solutions are financially and environmentally sustainable, and; for the people who will use it, and lastly, that the solution is socially and culturally appropriate, in the sense that the solution can be produced on a technological level, that the technology is appropriate for the people who will use it, and lastly, that the solution is socially and culturally appropriate" [87].

Desirability

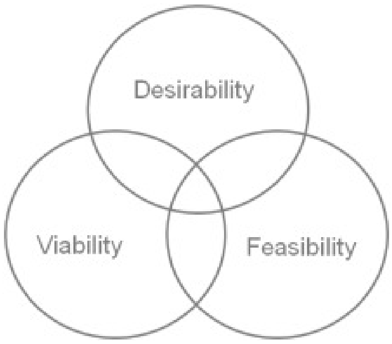

FIGURE 7.1: The 'Three Lenses of HCD' [13]

The desirability of the solution refers to whether or not the solution is wanted by the parties that are expected to apply it[13]. In the context of this research, the reference ecosystem model needs to be desired by the main ecosystem parties (the airlines, the airports, air traffic control, the aircraft manufacturers and the fuel suppliers).

During the expert interview sessions, experts from each of the fields previously mentioned have been consulted. All experts agreed that for reaching the current decarbonisation targets, all measures are inter-depended and cannot be solved singularly by one organization or even one industry. Moreover, all experts interviewed showed interest in implementing the final model as they believe in its functionality and are prone to adopting the artifact.

Additionally, during the validation sessions, testing the desirability of the models was a principal focus. The validation session aimed to review the models with industry experts and define whether or not there is a desirability to adopt the models in the real business context. Based on the responses received from both validation sessions, all experts were willing to apply the models in their work. Lastly, it can be concluded that all desirability related reviews conducted with industry experts show successful results and so the artifact can be considered desirable.

Viability

The viability lens aims to test whether the solutions are considered sustainable from both the financial and environmental perspectives [13]. In the context of this research, the implementation and maintenance of the ecosystem platform need to be financially viable for all parties involved as well as environmentally sustainable.

When looking at the environmental sustainability of the approach, as the aim main goal of the ecosystem platform is to reduce carbon emissions from the passenger travel industry, it can be defined that the artifact comprises sustainability by design. Additionally, all experts agreed that for reaching the decarbonisation targets proposed by the Pairs Agreement, most measures are inter-depended and cannot be solved singularly by one organization. This interview result confirms the applicability of the ecosystem approach in the aviation decarbonisation context. Moreover, all experts consulted found the artifact viable for providing a sustainable solution. Nevertheless, it is important to mention that the research focuses on sustainability in terms of CO_2 emissions and considers other gases or pollution sources out of scope.

Determining the financial viability perspective was not in the scope of this research. However, a few concussions can be drawn from the interviews and validation sessions.
Firstly, there is an overall lack of systematic communication and data management in aviation, so having an ecosystem platform will help make the industry more efficient. An example is that now most communication is done on a one-to-one meeting base, so a lot of extra labour will be reduced by this platform.
Second, most experts agreed that having a sustainable future process is needed to survive in the industry, so investing in decarbonisation already will put the enterprise in a higher market position.
Third, from the research, it became clear that an ecosystem platform is more likely to have financial benefits. However, initial investments are required to fully design the ecosystem and implement it in the current way of working.

Lastly, the viability of this research was focused on reaching environmental sustainability, which aligns with the research goal. It can be concluded that the artifact is viable from the sustainability perspective as reaching sustainability was the main focus of its design process.

Feasibility

The feasibility of the solution tests whether the solution can be produced on a technological level and if the people operating with the solution can adapt to the new technology [13]. In the context of this research, this section defines if the current technology state of each industry is enough to implement the ecosystem approach. As well as if the people working in each industry are ready to collaborate as an ecosystem.

When defining the feasibility of the ecosystem platform from a technological perspective, it is important to see if such ecosystems already exist. When looking for an example of ecosystem platforms, no examples were found in the aviation industry, however, a very similar example was found in the Dutch public transportation system. This example refers to the Trans Link Systems which orchestrates the ecosystem of Dutch public transport and supports the Contactless Smart Card System (OV-chipkaart) [88],[89]. The existence of similar ecosystems which imply a similar infrastructure assures that there is technology available in the market to support the creation and maintenance of an ecosystem platform for aviation.

Additionally, based on the interviews, all industries suggested taking part in the ecosystem already make use of technology daily and have a stable infrastructure of both software and hardware. However since the technology layer of the model has not yet been designed, the technological feasibility of the research cannot be fully determined.

Based on the results of the validation, it was shown that most parts of the industry are already encouraging the implementation of new technologies. Moreover, the experts interviewed perceived the technological implication of an ecosystem platform as an improvement toward working more efficiently.
The process changes described by the models did not appear major for the parties interviewed as the experts confirmed that there are already a lot of tasks involving technology in all industries. The experts considered that the implementation of working with a digital ecosystem will imply minor changes in the day-to-day activities and they appeared ready and motivated to undertake the changes, as the goal is decarbonisation. Moreover, most experts considered that a digital ecosystem will make their work easier by removing administrative activities and allowing them to focus more on other tasks.

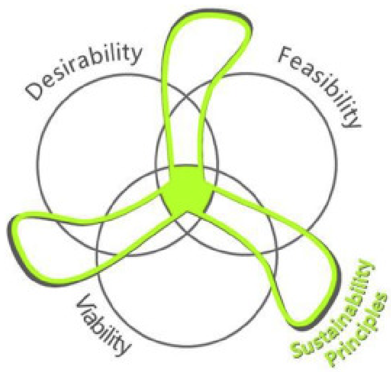

FIGURE 7.2: The propelling HCD model [14]

Sustainability

Figure 7.2 displays the Propelling HCD model. This model was designed to incorporate Sustainable Thinking into Design Thinking. This model was selected for this research as the artifact presented in this research was designed to increase sustainability. "The 'Three Lenses of HCD' were combined with a 'propeller-shaped' illustration aiming to represent the Sustainability Principles (SPs) as part of reaching a successful outcome" [14].

In the visual, the propeller is a symbol of the ongoing progress of defining possible solutions towards a sustainable future [14]. This model supports the approach of Thompson et al. who describes sustainability as an opportunity, a driver for innovation [90].

The propelling HCD model was presented as it provides an inline approach to this research and encourages constant sustainable progress.

While the applicability of the construct has been confirmed in this discussion session, current applicability checks need to be conducted during the implementation stages to assure the ongoing applicability of the artifact.

7.3 Future Research

This research has resulted in a new way of perceiving Aviation as more than an industry, as a digital business ecosystem.

Firstly, due to the limited time and novelty of the topic, a lot of qualitative research was needed before creating the models. For this reason, the artifact proposed by this research is a business level reference model. Future research should look into finalising the models, by designing the application and technology layers based on the TOGAF outlines. A recommended approach toward extending the models, together with an example, can be found in Section 6.4.

Secondly, due to the novelty of the topic, qualitative research was found suitable to the context and has managed to bring more light to the current knowledge on the topic. However, this implied a limited amount of resources available to start with, which directly lead to limitations in terms of validation quality. For this reason, aside from future qualitative research, future quantitative research is recommended.

One approach towards implementing quantitative methods based on this research makes use of the complete ecosystem reface model, including all TOGAF layers. A complete reference model can be used to measure emissions for both current and desired situations. However, based on the findings, no standardised measuring process is presented now in the industry. For this reason, using Science-Based Targets Implementation would be the suggested way to approach future quantitative research.

Thirdly, future work can focus on better defining the players and sub-players inside the industry. As this research had an academic focus and the practical interviews focused on the main industry stakeholders, it would be interesting to consider the smaller players in further research. Examples of such stakeholders are the airport handlers, the fuel transport suppliers, the booking agencies and the customers.

Fourthly, looking into the applicability of the artifact in a real-world context is recommended for future research. As the methodology of this research was based on Wirignas DSM, applicability was not in the scope [86]. However, during the interviews, a lot of information was gathered regarding the applicability of the research in a non-formal way and was presented in the discussion chapter. Based on views on DSM of Peffers et. al "the development of artefacts that can be applied to the solution of real-world problems or to enhance organisational efficacy" [91]. For future research, it would be interesting to purposely conduct a series of interviews focusing on the applicability of the artefact.

Lastly, during the technological feasibility of this research, similar ecosystem examples have been investigated. During this part, the Dutch public transport system was offered as an example. Looking into more transport ecosystems and researching how other parties such as railway transport, land transport and maritime transport can be integrated into the ecosystem, is a suggested next step. Although this research defines the aviation ecosystem, in the future, it can be seen as a sub-part of a bigger public mobility ecosystem.

7.4 Future Work

Although this research had an academic purpose, a lot of stakeholders from the business aviation ecosystem have been involved. For this reason, this section defined the recommended future work from a business implementation perspective.

First of all, despite the relevance of all information presented in this paper, academic research formats are not always preferred in a business context. For this reason, it would be recommended that the information collected in this research be translated into a more business-oriented presentation. Moreover, most models have already been summarised for the purpose of the interviews, where a clear method of model simplification is presented. Additionally, a suggested next step would be to develop Value Networks and clear a Road-Map based on this research.

Second, to implement the ecosystem platforms and get stakeholders involved, contacting aviation organisations is a suggested next step. Based on the interviews it was suggested that the Ecosystem Board should consist of independent unbiased third parties, rather than the stakeholders. Organisations such as the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) should be contacted.

Lastly, during the expert conversations, the certification feature was broth up. This feature implies that all members of the ecosystem will be provided with a certification which confirms their participation in the ecosystem. Such certification can work as a patent which reassures the customers of the sustainability standards held by the enterprise. Looking further into how this certification can be developed, and what benefits it can have on kick-starting the ecosystem and supporting its existence is also a recommended next step.

7.5 Recommendations for Practitioners

When defining the recommendations for practitioners, the goal is to transpose the conclusions drawn based on this research into useful feedback for the aviation industry.

Firstly, the lack of current legislation and clear targets for aviation should not be a reason for being reticent to work as an ecosystem. Based on expert interviews, it was shown that aside from the emission-related benefits, the use of an ecosystem platform can help the current process become more efficient. Additionally, in the opinion of most experts, the legislation will follow soon, as there is knowledge in the industry regarding the ongoing development of targets and regulatory measures. Based on the both previously mentioned arguments, the recommendation for practitioners is to consider implementing the ecosystem approach and maintain decarbonisation high on the priority list.

Secondly, based on this research, all parties consulted show interest in the ecosystem approach and in using the reference model proposed. However, to make sure the industry is ready to implement this approach, further interviews with more stakeholders need to be conducted. Furthermore, as mentioned in the Future Work section 7.4, having contact with the current organisations orchestrating the aviation context (ICAO, IATA, etc.) can help kick-start the ecosystem by providing potential candidates for orchestrating the ecosystem. Having a big aviation organisation supporting the ecosystem approach will increase the interest of stakeholders and will help set the standard for the ecosystem.

Lastly, as mentioned in the Future Work section 7.4, a more business-oriented visualisation of this model is needed. The recommendation is that for business, this research needs to be transposed into a presentation, the simplified version of the models must be used, as well as Value Networks and Technology Roadmaps. During the process of this research, it was understood that the majority of enterprises and organisations have a separate sustainability department, which most of the time is not necessarily technology focus, so most stakeholders do not have experience with architectural models.

7.6 Recommendations for Deloitte

Given that this research was conducted with the help of Deloitte, the following recommendations aim to provide helpful advice for further consultancy opportunities.

The aviation industry is a large market which supports the economy worldwide. The importance of this market is recognised internally and a lot of investments are made to assure the success of this market. At the moment, all enterprises and organisations interviewed are focusing on technological improvements. However, some experts admit that technological development is not the strength of their industry and that outsider assistance might be considered. For this reason, the recommendation for Deloitte is to reach out to the aviation industry as collaboration could be beneficial for all parties.

Additionally, when it comes to decarbonisation, there is a lot of interest from all stakeholders interviewed for this research. Based on the reactions to this research, most experts are willing and interested to have open discussions about sustainable improvements and are open to implementing new strategies. As Deloitte also operates in the field of sustainability, collaboration is also recommended for decarbonisation projects.

Lastly, integrating technology and sustainability is a point of interest for the aviation industry. Using the ecosystem approach to enable better collaboration in the industry can have benefits for both industrial development and decarbonisation. Based on most experts' opinions, there is a clear connection between reaching sustainability and improving technology, which is an interest that can be further explored by Deloitte.

7.7 Limitations

Naturally, this research has certain limitations that need to be addressed. In this section, the limitations of this research will be discussed.

The first limitation originates from the qualitative method chosen for this study. Both the structure of the literature review process and the capability gathering based on the interviews can be considered subjective. This is caused by the limitation that the literature review and the interviews were conducted by only one researcher, as well as the fact that some interviews could not be recorded due to privacy reasons. The choice of experts was made based on relevance to the subject and availability, so the privacy requests of the experts have been respected. These limitations could have been reduced by including more researchers in the process, however, that was not possible due to the nature of the graduation research. Nevertheless, measures such as: using structured literature review methods, defining structured interview protocols and using digital visualisation platforms for the interview (Miro Boards) have been taken to prevent the bias. Additionally, to assure the validity of this research, two iterations of validation interviews have been conducted with new experts, excluded from any other research phase.

The second limitation is that the aviation industry is very competitive. This limitation implies that, as some of the experts interviewed worked in competing enterprises, the quality of the information shared by the experts might be subject to bias. However, in most cases, the subjects interviewed came from complimentary business and this information was shared during the interviews. Additionally, all interviews were anonymised, and all subjects were informed about the privacy approach. While this limitation could have been avoided by interviewing subjects from the academic field, that would not align with the applicability goals of this research.

The third limitation is that the aircraft design and manufacturing industry could not be reached. Although there were attempts, the researchers did not manage to get in touch with any parties from aircraft design and manufacturing. However, from the academic perspective, a few of the experts interviewed had an educational background in aircraft engineering and could provide helpful information regarding capabilities and processes. On the other hand, aircraft design and manufacturing as the topic most sources found during the literature review addressed.

A fourth limitation is that the models do not contain all TOGAF layers and focus on the business approach. This limitation was caused due to the limited time of 6 months allocated to this research. However, during validation, a clear approach to extending the models has been presented and during the future research, the completion of the models has been suggested.

The final limitation was caused by the current situation of the COVID-19 pandemic. This situation caused two different experts interviewed to be fully cancelled and a few postponed. Moreover, during the validation one expert could not join as well due to a medically related context. Lastly, this situation did not allow the interviews to take place in person, so the use of Miro Boards was included as a replacement for the physical brainstorming and modelling activities.

Chapter 8

Conclusion

In this chapter, the findings based on the research question, are presented. Additionally, the contributions of this research are discussed.

8.1 Conclusion

The goal of this research is to answer the main research question:

How can ecosystem architecture improve the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?

To answer the main research question, a series of sub-questions have been formulated. This section presents a summary of the results for each sub-question.

8.1.1 Ecosystem architectures including CO_2 emissions for the aviation industry

"How are the current Scope 3 targets of CO_2 emission represented in the passenger travel in the aviation industry?"

The answer to this question has been defined based on the state of the art academic literature. According to the literature review, despite the variety of aviation industry models analysed, only six academic sources were considered, which shows the novelty of the topic. These 6 papers were selected since they were the only ones to provide visual models of the CO_2 emissions in the aviation industry.

However, since this research is focused on finding ecosystem-level solutions, only two of the papers identified provided multi-focus models and so they were the ones presented in the results. This initial finding clearly emphasized the novelty of the topic by showing the lack of state of the art academic literature, from both the perspective of aviation ecosystem modelling and aviation decarbonisation modelling. Most academic sources reviewed, focused on one unique process, or included only one singular strategy of CO_2 emission reduction.

The only inclusive ecosystem models currently available in the literature, based on the literature review, are made from the perspective of system dynamics and have been visualised and discussed in Section 2.3.2. System dynamics was used to address the nonlinear behaviour of complex aviation systems [9] which is similar reasoning to the use of a digital ecosystem. As most papers found focused on a linear Value Chain model, the papers including the system dynamics perspective were considered the closest to the ecosystem approach.

Based on the research conducted to answer the first research question, it can be concluded that the topic is relatively novel and no exact ecosystem models of the aviation industry reflect the decarbonisation targets. Additionally, it became clear, based on the literature review, that the topic of decarbonisation in aviation has steeply grown in the last few years.

Moreover, the research has concluded that there are no clear targets set for the aviation industry in the Netherlands, or worldwide. The lack of clear emission measuring standards has also been confirmed during the research.

Lastly, the two papers discussed in Section 2.3.2, together with the models presented provide an interesting approach to reducing CO_2 emissions. However, these studies do not refer to clear targets or measurements standards; and they do not provide a clear ecosystem model of the aviation industry.

8.1.2 Decarbonisation Capabilities and Capability Mapping

"What are the ecosystem capabilities which affect the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry"

To provide an answer to the question mentioned above, an initial set of 22 unique capabilities has been collected based on the academic literature review. Since the purpose of this research consisted also of business applicability, these capabilities have been validated through expert interviews. Based on the results obtained during the first round of interviews, all 22 initial capabilities have been considered relevant, and 59 capabilities have been added by the experts. Moreover, 10 more capabilities were added contingent on the literature sources mentioned by the experts during the interviews. After a final review, a list of 87 unique capabilities has been defined.

To better visualise and understand the role of all 87 capabilities, a goal-based capability map was modelled. This capability map contains all 87 capabilities and structures them based on the goals they aim to help to achieve. During the literature review stage, two main goals have been defined which aim to help classify the capabilities: "Reducing the number of flights" and "Making flights more sustainable". During the structuring of the map, The Open Group Commercial Aviation Reference Architecture has also been considered [12].

Lastly, the capability map was validated with the experts during the second round of interviews, where a few new capabilities were added based on The Open Group model, while others have been removed. During the second interview round, all experts were able to visualise all capabilities inside the Capability Map, including the capabilities proposed by other experts in the previous interview round. The second round of interviews was structured based on the speciality of each expert, which resulted in 6 distinct sessions. Aside from validating the Capability Map, each session had a different focus (Ground Operations, Flight Operations, Aircraft Design, Fuel Management, Ecosystem Management for Flights Improvement and Ecosystem Management for Flights Reduction). The experts managed, during the sessions, to refine the capability map for each specific area of expertise.

In conclusion, after an academic literature review and two rounds of expert interviews, this research has defined a final list of 119 decarbonisation capabilities for the aviation ecosystem which can be visualised in the final capability map in Figure 5.3.

8.1.3 A Reference Model for decarbonising the aviation industry

"How can designing a reference ecosystem architecture based on the defined capabilities can facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?"

The answer to this question has been defined based on the information collected for the previous research questions, as well as the insights gathered during Interview Round II. According to the opinion of the experts interviewed, a centralized ecosystem collaborative approach is needed to assure the efficiency of all parties when it comes to decarbonisation. Additionally, a list of ecosystem core capabilities has been defined and aims to support and enforce the ecosystem functionality. The main core capability is Ecosystem Governance, which consists of Integrated Data Management, Integrated Decision Management, Integrated Process Management and Integrated Communication Management. The model of the Ecosystem Core can be visualised in Figure 5.5.

The concept of working together as a digital ecosystem was classified as novel to the industry by the experts, so the business layer was decided as the focus of this research. Despite the novelty of the ecosystem approach, all parties interviewed appeared to have an increased interest in the benefits of this approach. When discussing the reference architecture with the experts, it becomes clear that the initial focus needs to be placed on the Business Layer, as clear visualization of capabilities and processes is needed before looking in-depth at the Application and Technology layers.

Initially when looking at the aviation industry, the first player to come to mind is the airline, but in this research, the dimensions of the Airline, the Airport, Air Traffic Control, Aircraft Design, and Fuel Management where considered. During the literature review and the interviews, it became clear that all these parties are currently seen as independent value chains. Designing elaborate architectural models, together with experts, of each value chain was the technique used to understand which parties need to be integrated into the ecosystem. The process of defining each model and integrating the models into one ecosystem model can be found in Chapters 4 and 5. Moreover, this approach emphasizes the communication points and allowed the integration of multiple value chains into one ecosystem. The integrated ecosystem reference model can be found in Figure 5.10.

Moreover, during the interviews and other non-formal expert sessions, a very important conclusion was drawn regarding the effectiveness of this research in a business context. All experts with a business-oriented background have underlined the need for clear and simplified models, as in most cases, the decision-makers do not have an architecture background. For this reason, both the Ecosystem Core Model and The Reference Model of the Aviation Ecosystem are designed in a simplified way.

In conclusion, after an academic literature review and two rounds of expert interviews, this research has defined a final Capability Map and independent industry value chain architectures which served as the sources for the reference model of the aviation ecosystem. The Reference Model of the Aviation Ecosystem can be found in Figure 5.10.

8.1.4 Model Validity

"How can an ecosystem architecture be validated to facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?"

To provide an answer to the question mentioned above, two distinct validation sessions were conducted during this research. The first validation session aimed to validate the research based on a business case. According to the feedback received from the first validation session, extensions to the model were made. The extended model created subsequently to the first validation session was also validated in a real business context, with a specialised expert, during the second iteration of validation.

The first validation session focused on the business case of a major Oil and Gas company which is expected to have drastic emission reduction, including Scope 3 emissions, by 2030. In the particular business case, the aviation industry is one of the main customers and subsequently, represented a major part of the Scope 3 emissions produced. One expert working in the specific business case together with an architecture expert was consulted during the validation session.

The key takeaways of the first validation iteration were that the ecosystem approach was found extremely relevant by the experts and there is interest in implementing the models defined by this research. Additionally, the particular value chain models of each industry were found relevant, as they are a step which needs to be considered before defining the ecosystem model to assure the effective integration of all parties. Lastly, the experts have considered this research very relevant for the business case. However, the need for a more in-depth architecture was underlined. The expert in enterprise architecture has emphasized the need for a complete architecture containing all TOGAF layers for all sub-models. Additionally, based on all complete models subsequently, the full architecture of the ecosystem needs to be modelled before implementing it in the real business context.

Based on the first validation session, the next step was taken towards applying the feedback received to the current models. Although all models can be extended with all layers, in this research only one industry focus model was extended with an additional layer, due to the time constraints. More specifically, the Ground Operations model was extended with the Application layer, as an implementation of the validation feedback. The extensive Ground Operation Model can be found in Figure 6.2, while the simplified version for business purposes can be visualised in Figure 6.3.

The key takeaway of the second validation iteration also emphasized the relevance of the ecosystem approach. Moreover, the expert confirmed that there are communication channels in place between all parties, but currently, there is no infrastructure for communication. Additionally, it was emphasized that because of the lack of infrastructure the communication process and the data management process between parties are very time-consuming.

The expert recognised the effectiveness of the ecosystem approach and considered a digital ecosystem platform a valid solution for the decarbonisation problem. The application layer was examined in-depth by the expert as it emphasized the technological way of solving the current predicaments in decarbonisation. Lastly, the expert found both the research and the artifact valid in the business context.

8.2 Contribution

This research contributes to both the academic and practical fields. The contributions for each field are presented below.

8.2.1 Theoretical Contributions

The findings of this research provide contributions from both the perspective of decarbonisation as well as aviation.

Firstly, the research provides a summary of the terminology for CO_2 emissions, as well as the main agreements providing decarbonisation targets. Moreover, the research background looks into the main decarbonisation targets for the Netherlands and a summarised overview of all targets has been created. The summary of dutch targets can be found in Figure 1.3.

Secondly, the state of the art decarbonisation architectures for the aviation industry has been reviewed. The results for the first research question present the main models found during the literature review and discuss their implications for this research. Both the models and the observations can be found in Section 2.3.2.

Thirdly, through this qualitative research, a capability map containing the main capabilities for decarbonising aviation has been designed. The final capability map contains 119 capabilities and sub-capabilities collected from both literature review and expert interview sessions. The Capability Map can be visualised in Figure 5.3.

Fourthly, this research provides novel theoretical contributions by integrating an ecosystem approach in an industry currently structured based on value chains. The information collected during the interviews recognises the existence of collaboration and alliances inside the industry, however, no existing ecosystems were found. The presence of collaborations, together with the interdependence of processes, shows the potential for an ecosystem approach. However, the ecosystem approach is quite novel for the aviation industry, so it is a theoretical contribution to the development of the industry. Lastly, the combination of TOGAF based ecosystem architecture and industry decarbonisation is a novel approach to using a structured architectural perspective to reach sustainability targets.

Aside from the contributions of this research, the ampler value presented by this study leads toward implementing this novel perspective in future research opportunities.

8.2.2 Practical Contributions

This research provides contributions to practitioners both regarding decarbonisation and aviation.

Although the focus of this research was defining the business benefits of the ecosystem approach for reducing CO_2 emissions, two indirect contributions to practice have been defined. The first contribution relates to the benefits of the ecosystem approach for the aviation industry overall and not just for decarbonisation. The second contribution is about the benefits of an ecosystem when aiming to reach decarbonisation targets.

Firstly, based on the findings of this research, especially the interview results, it becomes clear that the industry has some gaps in efficiency and effectiveness. An example is that most communication is taking place in person and most data processes are not automated in-between parties. When discussing the benefits of ecosystems, aside from decarbonisation, most experts were mentioning that the ecosystem will have positive effects on the industry, by making it more efficient, managing the high competitiveness and easing day to day tasks. For this reason, this research brought clear contributions to the aviation industry by recommending a more efficient way of working which aims to benefit all parties.

Secondly, although the research was focused on decarbonisation for the aviation industry, the ecosystem approach presented in the research provides a list of benefits which can apply to other fields as well. The ecosystem core model, created based on the findings of the interviews, can be applied partially to more industries. During the interviews, it become clear that having external ecosystem governance, a clear data structure, transparent decision-making and defined communication channels; is what the ecosystem needs to assure all participants that the competitiveness of the market will not interfere with decarbonisation strategies. These findings were discussed during the validation session and a conclusion that was reached was that these concerns are occurring in multiple industries (such as water and land transport, agriculture, banking, etc.). The method proposed in this research of having external ecosystem orchestrators can be considered a contribution to the field of decarbonisation, which can apply to multiple industries.

Lastly, as mentioned also during the theoretical contributions, the ecosystem approach for decarbonising the aviation industry is the main contribution to the practice of this research. The models provided in this research, especially the summarised versions, can be further developed and used in practice. The models themselves as well as the methodology of creating these models, together with the interview results, provide clear contributions to both the practices of aviation and decarbonisation. Additionally, the methodological and modelling approaches used in this paper provide contributions to the field of ecosystem architecture as well as enterprise architecture.

Appendix A

Literature Review Protocol

This Appendix provides more detailed information regarding the SLR conducted as part of this research.

A.1 Systematic Literature Review Methodology

A.1.1 Research Method

The fundamental research type used to support the analysis of the selected topic and to answer the Main Research Question is an SLR. The SLR method was considered, given that the scope of this research is more structured than in a classical Literature Review (LR) and the aim is to answer the clearly defined research questions [15].

Moreover, an SLR is also recommended in situations when only limited literature is already available. Using the SLR method helps ensure that all relevant and available research is identified [15]. Given the novelty of the topic presented in this research, assuring that all information available is considered, was a principal reason for using an SLR.

The principal outcomes of conducting an SLR in the given situation are the following:

- Delimiting the research problem: In this situation, the Main Research Question of the Research Topics has already been defined.
- Gaining methodological insights: This is the principal focus of the SLR in this particular situation, given that though answering the research questions, we aim to define the terminology and the current architectural modelling of the sustainability factor inside an ecosystem.

These two goals are based on the Educational Research advice for literature review structuring. They are to narrow down the purpose of an SLR and have been redesigned to match the purpose of this research [38].

Additionally to the above reasons, a few other motives were defined based on the Literature Review guide of C. Hart [39], including:

- Discovering important variables relevant to the topic, by formulating the research questions and defining the search terms.
- Establishing the context by defining the research problem and explaining the need of integrating the CO_2 emission factor at an ecosystem architecture level.
- Enhancing and acquiring the subject vocabulary, while aiming to provide a clear taxonomy
- Understanding the structure of both the energy production and distribution ecosystems and the CO_2 emission targets and defining the extent of interconnection between the two.
- Relating the identified theoretical knowledge to clear modelling applications.
- Distinguishing if and how CO_2 emission-related artifacts (reduction strategies, measuring models, decarbonisation prototypes) have been integrated into the energy production and distribution ecosystem from the optimal representation of the CO_2 emission in an architecture.
- Synthesizing the findings and gaining a new perspective regarding the representation of CO_2 emission in an ecosystem.

To better accomplish the goals set for the Research Topics, the SLR model procedure has been adapted to this particular research. This model in Figure A.1 has been extracted from the "Methodology for SRL applied to Engineering and Education" by Torres-Carrión et al [15]. The method proposed in the study provides a step by step approach to arriving at "The current state of the problem", from "My current state of the problem" [15]. This approach aims to offer a multi-angular and unbiased review of the existing literature concerning the Main Research Question.

In summary, the SLR approach was used due to its structural approach which emphasizes the ability to give a clear purpose to an LR, to assure the answering of the previously defined research questions [15].

A.1.2 Research Problem

There are current global efforts aiming to reduce the ongoing growth of CO_2 emission resulting from energy-related industries, in particular, caused by fossil fuel combustion

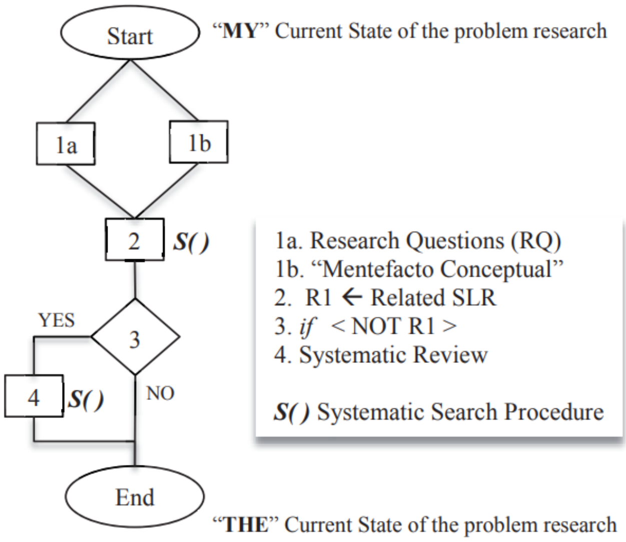

FIGURE A.1: Macro procedure of the Methodology [15]

[18]. Although there exist worldwide initiatives aiming to motivate and reinforce the CO_2 emission reductions, many parties fail to consider the CO_2 emission implication in their sector. The lack of wordwide awareness related to CO_2 emission effects on the Climate Change appears to be a contemporary major problem.

Initiatives such as the Paris Climate Agreement, aim to raise awareness, as well as provide strategies and targets for reduction [24]. Many countries have decided to set clear Net Zero targets and have built and implemented strategies in order to assure the targets are reached [92]. Despite both national and international efforts, the effects of CO_2 emission on Climate Change are continuously growing.

At a national level, the Netherlands has also taken measures and has set targets in order to reduce its CO_2 footprint [92]. However, there is still a long way to go in order to become a carbon-free nation.

The need for reducing the CO_2 emission in the energy industry is a problem that has further implications. Looking at this problem from the perspective of an individual person, an enterprise or even a singular country provides a limited perspective.

Although enterprises play an important role in the energy industry, there are many distinct stakeholders (the government, the customers, the suppliers, the society) and processes taking place [21].

For this reason, an ecosystem perspective might be a more appropriate way to investigate and attempt to solve such a large scale problem.

A.1.3 Research Questions

In order to provide a possible solution for the research problem, the following research questions were formulated. These questions aim to describe the sustainability quota in CO_2 emission when looking at the energy-related industry. Additionally, when formulating the questions, a primary focus was placed on finding a link between sustainability quotas in CO_2 emission and ecosystem architecture.

Main Research Question
To what extent do energy production and distribution ecosystems contribute to reaching current Dutch CO_2 emission targets, and how is this reflected in their architectures?

Sub-Questions

1. What are the current Dutch targets defining sustainability quotas in CO_2 emission?
2. How are the current Dutch national targets of CO_2 emission represented in the energy production, distribution and retail ecosystems architecture?
3. According to the literature, how can the current capabilities of energy production and distribution ecosystems be improved to better reinforce the Dutch targets in CO_2 emission?

A.1.4 Search Strategy

The goal of the Literature Research Strategy is to assure that all existing significant research was taken into consideration and critically reviewed in order to extract the needed information for this research. For defining the Literature Research strategy, the following model adapted from the work of Torres-Carrión et al [15] of systematic search has been implemented in the methodology.

The goal of the SLR is to collect specific information which is needed to answer the research questions. The reasoning for using an SLR, aside from answering predefined research questions, was to access a large number of Primary Sources relating to the research question through an unbiased search process.

A.1.4.1 Search Term Definitions

In order to guide the search for proper literature, search terms were developed based on keywords derived from the research questions. The following list presents the search terms that have been used in the SLR.

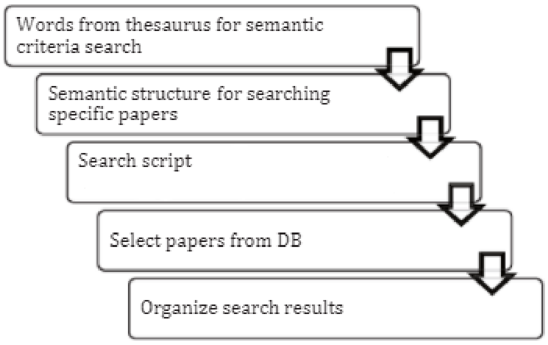

FIGURE A.2: Systematic Search Procedure
(Adapted from [15])

- greenhouse gas protocol Netherlands
- CO_2 emission targets Netherlands
- energy production ecosystem Netherlands
- energy distribution ecosystem Netherlands
- energy ecosystem architecture
- energy ecosystem artifacts
- CO_2 and Enterprise Architecture
- CO_2 and Digital Ecosystem Platforms
- Energy value chain and emission scopes

The search terms were used in a set of databases that are defined in the Search scripts subsection. To define the specifically relevant papers, the "AND" operator was used. The "AND" operator was used to assure that in the searches there is a combination between the sustainability factor and the architectural perspective. Additionally, the "OR" operator was used in order to increase the variety of the search results.

A.1.4.2 Semantic structure for searching specific papers

Although information containing the search words can be widely found, in order to assure the quality of this research, only scientifically reliable sources were taken into consideration.

Moreover, in order to assure the actuality of the sources, the information considered as Primary Source should be published after 2010. As for restricting the document type, the following document types have been reviewed: "Review and Research article", "Book chapters", "Conference Paper", "UN Agreements", "Legal Acts" and "Legal Agreements".

Additionally, to the sources found through the SLR model, the references of each study selected have been thoroughly analysed. This technique is called Snowball sampling and helps the researcher obtain a larger collection of relevant sources. This technique implies analyzing the bibliographies of Primary Sources in order to find potentially appropriate Secondary Sources [93]. This approach was used due to the limited amount of appropriate primary sources found.

A.1.4.3 Search Scripts

To obtain the list of Primary Sources, the above-explained methods have been applied to the following list of databases:

- Scopus
- Web of Science
- IEEE Xplore
- Research gate
- United Nations - Digital Library
- EUR-Lex

A.1.5 Inclusion and Exclusion criteria

For this SLR, the following inclusion and exclusion criteria were defined. The following specifications have been defined based on an adaptation of the General/ Specific Model to the current topic:

A.1.5.1 General Criteria:

- Studies containing at least one of the search terms
- Studies written in or officially translated to English
- Studies published after 2009
- Only the following document types: "Review and Research article", "Book chapters" "Conference Paper", "UN Agreements", "Legal Acts" and "Legal Agreements"

A.1.5.2 Specific Criteria:

The studies selected must comply with at least one of the below-stated specifications in order to assure the applicability with the current SLR:

- Studies that present clear information regarding the Dutch targets of CO_2 emission
- Studies that present architectures of the energy production and distribution ecosystem
- Studies that present correlations between CO_2 emission and energy production and distribution ecosystems

A.1.6 Selection of Journals

Using the above mention search terms on the databases selected, 119 unique primary sources were identified.

The 119 identified primary studies were refined based on the inclusion and exclusion criteria. After consulting the criteria, 70 sources were initially excluded mostly because was an insufficient focus on EA and ecosystems. The refinement of the studies was done by reading the title, the abstract, and in some cases the introduction and conclusion.

After this process step was executed, the 49 remaining sources were retrieved and fully analysed. The sources which apply to the topic were divided based on their ability to answer research questions. The division technique is presented in the Data extraction and monitoring strategy A.5.1.

A.1.7 Identification of Research

In order to develop a search strategy for the SLR, the following two methods have been used:

- Trial searches using various combinations of search terms derived from the research question [17].
- Consultations with experts in the field [17].

Aside from the classical educational databases, specific software engines were used for retrieving national and international targets of CO_2 emission. The legal databases used were: the United Nations - Digital Library and EUR-Lex.

Lastly, for the Scope 3 part of the Discussion, an additional Literature Research was conducted in order to assure the variability and applicability of the findings to the research.

A.1.8 Selection of primary studies

The 49 Primary Sources mentioned above have been read and taken into consideration. However, for many situations, it became clear that the most interesting information for this research presented in the source was fully originating from a reference, and not newly presented by the authors themselves. For this reason, the snow-bowl sampling method was used in order to assure the quality of the information.

After reading the 49 Primary Sources their references were checked by reading the title, the abstract, and in some cases the introduction, the conclusion and the reference list. Based on the Primary Sources and the references mentioned within those sources, the Primary and Secondary references mentioned in Table B.1 have been used.

A.2 Integrative Literature Review

A.2.1 Research Method

The research method used for this paper is Design Science Methodology (DSM) as presented by Wieringa [7]. Based on this methodology, in order to conduct research following the DMS technique, the main component needed is an artifact. This artifact operates in the context defined by the research target and has the goal to solve the given problem defined by the research.

According to this methodology, the process starts by formulating a design problem. The design problem includes a problem context, based on which we design an artifact. This artifact needs to satisfy some requirements and ultimately achieve the goals set. For this, the following template introduced by Wieringa [7], will be used.

Improve	*a problem context*
by	*(re)designing an artifact*
that	*satisfies some requirements*
in order to	*help stakeholders achieve some goals*

In order to define the design problem for the particular context of this research, the above template was:

In order to solve the above defined design problem, we will follow the Design Cycle methodology by Wieringa [7]. The Design Cycle is part of the Engineering Cycle and consists of 4 stags: the Implementation evaluation /Problem investigation, Treatment design, Treatment validation and Treatment implementation. However, for the purpose

Reduce	*Scope 3 CO_2 emissions for oil and gas resulting from passenger travel in the aviation industry*
by	*designing a reference ecosystem architecture incorporating emission reduction capabilities*
that	*enhances the current ecosystem architecture by incorporating the key capabilities needed to reduce CO_2 emissions*
in order to	*become more sustainable by lowering environmental footprint*

of this research, the Treatment implementation and Implementation evaluation stages will e considered out of scope. The adapted model can fond in Figure A.3

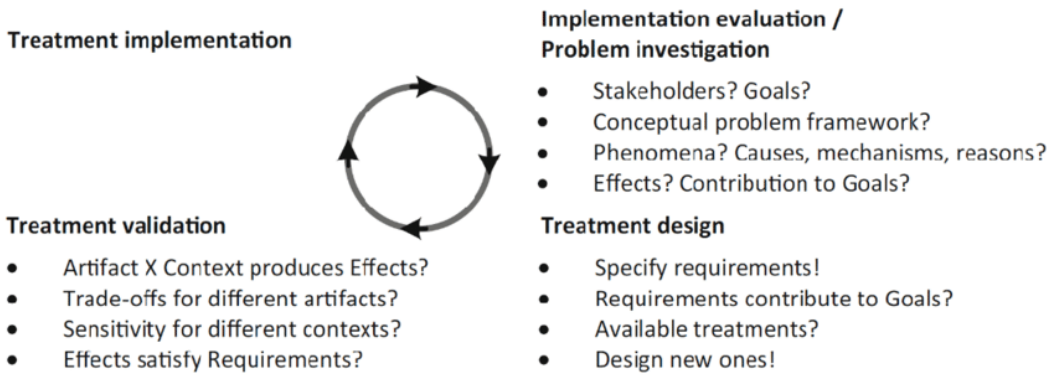

FIGURE A.3: The Engineering Cycle (Adapted after[7])

A.2.2 Research Objective

There are current global efforts aiming to reduce the ongoing growth of CO_2 emission resulting from energy-related industries, in particular, caused by fossil fuel combustion [18]. Although there exist worldwide initiatives aiming to motivate and reinforce the CO_2 emission reductions, many parties fail to consider the CO_2 emission implication in their sector. The lack of word-wide awareness related to CO_2 emission effects on the Climate Change appears to be a contemporary major problem.

In 2007, the aviation industry contributed about 3% to CO_2 emissions and Climate Change, and these numbers have been considerably growing since then [1]. These numbers consist of both passenger travel (81%) and freight travel (19%). Moreover, aviation is considered the most unsustainable mode of transport currently available [1].

The objective of the thesis is to help passenger travel in the aviation industry to become more sustainable by lowering its environmental footprint. The direct aim of this research is to reduce Scope 3 CO_2 emissions for oil and gas resulting from passenger travel in the aviation industry. Ultimately, this research could result in designing a reference ecosystem architecture incorporating emission reduction capabilities.

A.2.3 Research Questions

To provide a possible solution for this particular research, the following research questions were formulated. These questions were designed as a follow up to the Research Topics, informal research completed in preparation for this study.

Through these questions, we aim to describe the sustainability quota in CO_2 emission for oil and gas, when looking at the passenger travel sector of the aviation industry. Additionally, when formulating the questions, a primary focus was placed on designing an artifact which can help solve the research problem, as well as reach the defined objectives [86].

Main Research Question
How can ecosystem architecture improve the Scope 3 CO_2 emission for oil and gas resulting from passenger travel aviation industry ?

Sub-Questions

1. How are the current Scope 3 targets of CO_2 emission represented in the passenger travel in the aviation industry?
    (a) 1.1. How are the current Scope 3 targets of CO_2 emission represented in the energy ecosystems architecture?
2. What are the ecosystem capabilities which affect the Scope 3 CO_2 emission for oil and gas resulting from passenger travel in the aviation industry?
    (a) What are the types of ecosystem capabilities which affect the Scope 3 CO2emission in the aviation industry?
    (b) How can these capabilities be better represented in an ecosystem architecture of the passenger travel in the aviation industry?
3. How can designing a reference ecosystem architecture based on the defined capabilities can facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?
    (a) What architectural requirements should be considered when building a reference ecosystem architecture aiming reduction Scope 3 CO2 emission in the passenger travel aviation industry?

4. How can an ecosystem architecture be validated to facilitate the reduction Scope 3 CO_2 emission in the passenger travel aviation industry?

A.2.4 Search Strategy

The goal of this Literature Research Strategy involves theory development. Based on the Design Science Methodology concept used, the outcome of this research should consist of a novel artifact especially designed for the purpose of this study. The primary objective is to propose a reference ecosystem architecture incorporating emission reduction capabilities in order to reduce Scope 3 CO_2 emissions for oil and gas resulting from passenger travel in the aviation industry [40].

The goal of the Integrative Literature Review (ILR), given the novelty of the topic, is to create preliminary conceptualizations and theoretical models, rather than review existing models [41]. In this particular situation, the goal is to create a preliminary reference architecture of the passenger travel aviation ecosystem which considers Scope 3 emission as a principal design characteristic, based on background research, this specific topic appears to be under-researched.

This ILR method was used since the purpose was not to cover all articles ever published on the topic but rather to combine perspectives and insights from different fields or research types [41]. Unlike the goal set for the Research Topics, this study requires a more creative method of collecting the appropriate data.

For defining the Literature Research strategy, the following list shows an adaptation of the integrated search method proposed by Whittemore et al. [43]. This search method has been reinterpreted to better serve the purpose of this paper and has been implemented in the methodology.

- **Problem identification** In 2007, the aviation industry contributed about 3% to CO_2 emissions worldwide, and these numbers have been considerably growing since then [1]. During the Research Topics, it was suggested that there is a theoretical connection between CO_2 emission and ecosystem architectures.
  The direct aim of this research is to reduce Scope 3 CO_2 emissions for oil and gas resulting from passenger travel in the aviation industry. Ultimately, this research could result in designing a reference ecosystem architecture incorporating emission reduction capabilities.

- **Literature search** Clearly defined literature search strategies are critical for assuring the rigour of the review, since incomplete or biased searches may result in inaccurate results [44].
  Although the previously used approaches managed to gather all information needed for the Research Topics, in this particular study, more than academic literature

needs to be considered. In most cases, studies show that though an SLR of the peer-reviewed documentation available can provide all the information needed to support a Design Science Review [86]. However, in this particular case, due to the novelty of the topic, the area can be considered under-explored. For this reason, aside from the academic search, Grey Literature, as well as, Business Cases will be considered for this paper.

- **Data evaluation** Due to the variability of sources and search method considered, additional measures were used to evaluate the quality of the studies found. Clear information regarding the quality assessment of the data used can be found in Section A.5.

- **Data analysis** Although most sources considered provided qualitative information, the information used has a high level of versatility. The majority of information used has been extracted from descriptive reports, categorisations and architectural models. in-depth information regarding the data analyses can be found in Sub-chapter A.5.1.

- **Presentation** This part entails that the conclusions of the integrative review will be reported in the form of a model [45]. Particularly, in this case, the desired model can be better described as a reference ecosystem architecture. Additionally, the information extracted from primary sources will be used to demonstrate a logical chain of evidence [45].

A.2.4.1 Search Term Definition

In order to guide the search for proper literature, search terms were developed based on keywords derived from the research questions. The following list presents the search terms that have been used as an initial search for the ILR.

- scope 3 emission AND aviation
- CO_2 emission modelling AND aviation
- aviation ecosystem architecture
- passenger travel aviation architecture
- process capabilities of aviation industry
- CO_2 emission capabilities
- requirements for ecosystem architectural reference models

- standards for ecosystem architectural reference models

The search terms were used in a set of databases that are defined in the Search Scripts subsection A.2.4.3

A.2.4.2 Semantic structure for searching specific papers

Although information containing the search words can be widely found, in order to assure the quality of this research, only scientifically reliable sources were taken into consideration for the initial key term based search. Moreover, additional information has been added based on the suggestion of the interviewed experts. Both initial sources and the ones collected through expert recommendation have been the subject of a quality assessment procedure found in Section A.5.

Moreover, in order to assure the actuality of the sources, the information considered as the initial source should be published after 2009. As for restricting the document type, the following document types have been reviewed: "Review and Research article", "Book chapters" and "Conference Paper". For the secondary sources, collected though expert recommendations, "Gray Literature" as well as "Business Cases" have been reviewed.

Additionally, for the sources found through the key term search, the references of each study selected have been thoroughly analysed. This technique is called Snowball sampling and helps the researcher obtain a larger collection of relevant sources. This technique implies analyzing the bibliographies of Primary Sources in order to find potentially appropriate Secondary Sources [93]. This approach was used due to the limited amount of appropriate primary sources found.

A.2.4.3 Search Scripts

In order to obtain the list of initial sources, the above-explained methods have been applied to the following list of databases:

- Scopus
- Web of Science
- IEEE Xplore

A.2.5 Inclusion and Exclusion Criteria

A.2.5.1 General Criteria:

- Studies containing information regarding at least one of the research questions

- Studies written in or officially translated to English
- Studies published after 2009
- Qualitative methodology
- Only documents which fulfill the study quality assessment checklist presented in Table A.1

A.2.5.2 Specific Criteria:

The identified studies must comply with at least one of the below-stated specifications in order to assure the applicability with the current IRL:

- Studies that present clear information regarding the Scope 3 emission targets defined for the aviation industry
- Studies that present architectures of the aviation industry ecosystem
- Studies that present CO_2 emission components and capabilities for the aviation ecosystem
- Studies that present architectural requirements for building a reference ecosystem architecture

A.2.6 Selection of initial sources

Using the above-mentioned search terms on the databases selected, 51 unique primary sources were identified.

The 51 identified primary studies were refined based on the inclusion and exclusion criteria. After consulting the criteria, 16 sources were initially excluded. The refinement of the studies was done by reading the title, the abstract, and in some cases the introduction and conclusion.

After this process step was executed, the 35 remaining sources were fully analysed. This list describes the initial sources for this research and can be found in the following table.

The sources which apply to the topic were divided based on their ability to the answer the research questions. The division technique is presented in the Data extraction and monitoring strategy.

A.2.7 Identification of Research

In order to develop a search strategy for the ILR, the following two methods have been used:

- Trial searches using various combinations of search terms derived from the research question [17].
- Consultations with experts in the field [17].

A.2.8 Selection of primary studies

The 35 initial sources mentioned above have been read and taken into consideration. For the first research question, 6 primary sources were

A.3 Preparing a data extraction form

In order to better structure and inventorise the studies considered for the SLR and ILR, the Zotero bibliography management tool has been used. This tool did not only facilitate the analysis, but also helped organise the study information. Additionally, with the help of this tool, each research has been attributed a data extraction form. The model of one data extraction form, presenting the standardized categories, can be found in Figure A.4.

A.4 Data extraction and monitoring

Data extraction forms were designed for each of the Primary Sources with the help of the Zotero tool. This tool enables the automatic creation of data extraction forms.

In addition to the automated extraction process, the keywords sections of the documents were manually filled in based on the information gathered during reading the document. Moreover, the main keyword of each document was attributing the specific paper to one of the research questions.

Lastly, additional notes were attributed to each paper and the most relevant points have been highlighted in the document.

Methodology for systematic literature review applied to engineering and education

Type	Conference Paper
Author	Pablo Vicente Torres-Carrion
Author	Carina Soledad Gonzalez-Gonzalez
Author	Silvana Aciar
Author	Germania Rodriguez-Morales
Abstract	A systematic review of the scientific literature in a specific area is important for identifying research questions, as well as for justifying future research in said area. This process is complex for beginners in scientific research, especially if you have not developed skills for searching and filtering information, and do not know which high-level databases are relevant in their field of study. The method proposed leads the researcher from "My" to "The" current state of the problem; we propose an adaptation of the method by Kitchenham and Bacca, which divides the process into three sub-parts: planning, conducting and reporting results. From the approach of the research problem in the preliminary phase research questions (recommended between 3 to 5) and "mentefacto conceptual" is drawn; this last one gives originality to the method and facilitates the development of the thesaurus for searches and inclusion and exclusion criteria. Early research requires doing a basic systematic study to identify work done to review the literature in the area and, if any is found, to verify if those results yield an answer to our research questions. As part of planning the search process, general and specific inclusion and exclusion criteria were defined, along with some complementary inclusion and exclusion parameters. The method followed with rigor, returns to the researcher a list of impact journals in the study area, and a detail of articles that are related to each category of the research questions. A study case has been considered as a guide to expose each of the phases of the methodology in a practical way, with results that support the proposal.
Date	4/2018
Language	en
Library Catalog	DOI.org (Crossref)
URL	https://ieeexplore.ieee.org/document/8363388/
Accessed	9/17/2021, 1:45:08 PM
Place	Tenerife
Publisher	IEEE
ISBN	978-1-5386-2957-4
Pages	1364-1373
Proceedings Title	2018 IEEE Global Engineering Education Conference (EDUCON)
Conference Name	2018 IEEE Global Engineering Education Conference (EDUCON)
DOI	10.1109/EDUCON.2018.8363388
Date Added	9/17/2021, 1:45:08 PM
Modified	9/17/2021, 1:45:08 PM

FIGURE A.4: Model of Data Extraction From, created though Zotero

A.5 Study quality assessment

Additionally to applying the already established inclusion and exclusion criteria to every single primary sources retrieved, the quality of used resources was further assessed.

Considering the wide focus of this research, the initial SLR was not restrained to any files of study. However during the inclusion and exclusion criteria check, many sources were dismissed. Given that some of the terms used during the search had multiple meanings depending on the context, some studies found showed a lack of relevancy regarding the topic.

The studies used have been extracted from educationally accredited databases. As a result, the majority of sources have been either peer-reviewed or belong to the official documentation emitted by a national Government, the European Union and the United Nations. Additionally, a quality assessment checklist has been used.

The method used for the study quality assessment is "Study quality assessment checklists for qualitative studies" [17], since it has been mentioned by the SLR model used in this research [15]. The quality assessment checklist can be found in Table A.1.

1	How credible are the findings?
1.1	If credible, are they important?
2	How has knowledge or understanding been extended by the research?
3	How well does the evaluation address its original aims and purpose?
4	How well is the scope for drawing wider inference explained?
5	How clear is the basis of evaluative appraisal?
6	How defensible is the research design?
7	How well defined are the sample design/target selection of cases/documents?
8	How well is the eventual sample composition and coverage described?
9	How well was data collection carried out?
10	How well has the approach to, and formulation of, analysis been conveyed?
11	How well are the contexts and data sources retained and portrayed?
12	How well has diversity of perspective and context been explored?
13	How well have detail, depth, and complexity (i.e. richness) of the data been conveyed?
14	How clear are the links between data, interpretation and conclusions – i.e. how well can the route to any conclusions be seen?
15	How clear and coherent is the reporting?
16	How clear are the assumptions/theoretical perspectives/values that have shaped the form and output of the evaluation?
17	What evidence is there of attention to ethical issues?
18	How adequately has the research process been documented?

Table A.1: Checklist for qualitative studies [17]

A.5.1 Data extraction and monitoring

This part of the research refers to determining whether the sources found provide quantitative or qualitative information. A combination of both data types was used to ensure that the limitations of one type of data are balanced by the strengths of another.

As the Research focuses on Ecosystem Architecture, most sources provide qualitative information. For the purpose of this research, the sources used for questions two and three were organised into two categories: "Sources that contain architectural models" and "Sources which do not contain architectural models".

Additionally, some sources used for question one include quantitative information regarding emissions and energy reduction. However, even those sources have qualitative research as a focus.

Appendix B

Literature Review Sources Overview

B.0.1 SLR Primary and Secondary

	Source Name	**Source Type**
1	”Implications of the implementation of decisions 2/cmp.7 to 5/cmp.7 on the previous decisions on methodological issues related to the Kyoto protocol, including those relating to articles 5, 7 and 8 of the Kyoto protocol.”	Primary
2	”The Kyoto protocol to the United Nations framework convention on Climate Change.”	Secondary
3	”The Kyoto Protocol in the EU: European Community and member states under international and European law.”	Secondary
4	”Paris agreement to the United Nations framework convention on Climate Change.”	Secondary
5	”Nationally determined contributions under the Paris agreement. synthesis report by the secretariat.”	Secondary
6	Current status of treaties - Paris agreement.	Secondary
7	”The death of competition. leadership and strategy in the age of business ecosystems.”	Secondary
8	”Towards a network of digital business ecosystems fostering the local development.”	Secondary
9	”An introduction to enterprise architecture.”	Secondary
10	”A business ecosystem architecture modelling framework.”	Secondary
11	”Exploring indirect scope 3 greenhouse gas emissions for oil and gas.”	Primary

12	"Compendium of greenhouse gas emissions estimation methodologies for the oil and gas industry."	Secondary
13	The value of hydrogen and carbon capture, storage and utilisation in decarbonising energy: Insights from integrated value chain optimisation."	Primary
14	"The greenhouse gas protocol:a corporate accounting and reporting standard."	Secondary
15	"Ghg protocol corporate value chain (scope 3) account and reporting standard."	Secondary
16	"Integrated national energy and climate plan 2021-2030."	Secondary
17	" CO_2 and greenhouse gas emissions."	Secondary

Table B.1: SLR Primary and Secondary

B.0.2 ILR Primary and Secondary

	Source Name	**Source Type**
1	”Sustainable Growth of the Commercial Aviation Industry in Malaysia Using a System Dynamics Approach.”	Primary
2	”Would CORSIA implementation bring carbon neutral growth in aviation? A case of US full service carriers.”	Primary
3	”Reducing aviation’s climate impact.”	Secondary
4	”Aircraft routing with minimal climate impact: The react4c climate cost function modelling approach (v1. 0).”	Primary
5	”An airliner fleet planning and airway allocation algorithm under carbon emission constraint.”	Primary
6	”Assessing the climate impact of formation flights.”	Primary
7	”Climate-optimized trajectories and robust mitigation potential: Flying atm4e.”	Primary
8	”Formation Flight in Civil Air Transport.”	Secondary
9	”Aerodynamics of formation flight.”	Secondary
10	”Co2 neutral fuels.”	Primary
11	”A comparative study on engine performance and emissions of biodiesel and jp-8 aviation fuel in a direct injection diesel engine.”	Primary
12	”Cost impacts of the inclusion of air transport into the European emissions trading scheme in the time period 2012-2020.”	Primary
13	”Performance assessment of a multi-fuel hybrid engine for future aircraft.”	Primary
14	”The contribution of carbon dioxide emissions from the aviation sector to future climate change.”	Primary
15	”The Kyoto protocol to the united nations framework convention on climate change.”	Secondary
16	”Paris agreement to the united nations framework convention on climate change.”	Secondary
17	”An environmental air traffic flow management model.”	Primary
18	”Analysis of different methods to improve the fuel cell dynamics for modern aircraft applications.”	Primary
19	”Campus motor fleet analysis for the FAA technical center to meet executive order 13514.”	Primary
20	Change-oriented aircraft fuel burn and emissions assessment methodologies.”	Primary
21	”Research on the dynamic CDA track optimization based on the optimal trajectory points selection.”	Primary
22	”Conceptual design of PrandtlPlane civil transport aircraft.”	Primary

23	" The PrandtlPlane configuration: overview on possible applications to civil aviation."	Secondary
24	"Digitalization's role in shaping the new energy landscape."	Primary
25	"Distributed electric propulsion for small business aircraft a concept-plane for key-technologies investigations."	Primary
26	" Flying along the supply chain: accounting for emissions from student air travel in the higher education sector."	Primary
27	"Global aerostructural design optimization of more flexible wings for commercial aircraft."	Primary
28	"Holiday travel behaviour and correlated co2 emissions—modelling trend and future scenarios for Austrian tourists."	Primary
29	"Multimodal transportation operational scenario and conceptual data model for integration with UAM."	Primary
30	"Requirements for communication systems in future passenger air transportation."	Primary
31	Why tourism mobility behaviours must change."	Primary
32	"The future of tourism: Can tourism growth and climate policy be reconciled?"	Secondary
33	"Managing airports: An international perspective"	Expert Recommended
34	"The Open Group Commercial Aviation Reference Architecture"	Expert Recommended
35	"Decarbonising Aviation: Clear for Take-of"	Expert Recommended

TABLE B.2: ILR Primary and Secondary

Appendix C

Interview Guide

This section provides an in-depth guide for both Interview Round I and II. In the Background section C.1.1, the background obtained from the literature review will be described. This information will be used as a base for the interview. Secondarily, the goals of each specific Interview round will be defined together with a deception of the type of parties who will be interviewed. The following sections show the structure of the interview and the resources which will be used. The final section presents the results processing method used.

C.1 Interviews Round I

The following section describes in-depth the first round of interviews.

C.1.1 Background

The papers studied during the literature review have emphasized the need for reducing the CO_2 emission from the aviation sector, especially when it comes to passenger travel. However, in order to be able to build a reference architecture for a more sustainable aviation ecosystem, it is important to understand which factors can enable the CO_2 emission reduction.

During the literature review, a set of 23 capabilities has been collected and can be reviewed in Figure 2.7. In order to assure the applicability of these capabilities in the business context, information needs to be considered outside of literature sources and from an actual business context.

Since the aim of this part of the research is to list and categorise the most relevant capabilities for CO_2 emission reductions, expert interviews were used to not only review the capability list found in the literature but to help create an accurate list of capabilities for the current business scenario occurring in the aviation ecosystem.

Additionally, aside from listing the categories, this research aims to classify the categories found by the capability types, based on the Capability Map model of ArchiMate [6]. This aim will also be tackled during the expert interview sessions.

Lastly, it is important to mention that all interviews will take place in an online meeting due to the unfortunate situation of COVID-19 occurring at the time of the research. However, online interviews also reduce the CO_2 emission resulting from travelling to interviews, which perfectly aligners with the goal of the thesis.

C.1.2 Goals

In order to achieve the goal of this research, the following goals have been defined for the first round of interviews:

1. Identify and evaluate CO_2 emission reduction capabilities.
2. Classify and categorise the CO_2 emission reduction capabilities based on the ArchiMate Capability Map model.

C.1.3 Interview Protocol

In this section, the protocol for the Standardized Open-ended Interviews is described. This type of interview can be classified as a semi-structured interview. The protocol serves as primarily guideline during the interviews, to ensure that all necessary questions are appropriately addressed and answered.

Introduction
Introduce the purpose of the interview.

Permission
Before we continue, I would like to ask for your permission to record the interview. The recording will be deleted shortly after the interview, and it will be used to fill the gaps in the interview notes.

Additionally, during the interview, we will be using Miro boards for a more visually interactive experience. The Miro boards will be saved and used in my research.

Background information
The results of this interview will be used only as a source of data for my Master Thesis. The only personal information which will be mentioned in the paper is your job title, as

well as your area of expertise. However, if you consider any of the two to be too private, it can all be anonymised.

If during the interview you consider any information shared sensitive information this information will not be taken into consideration or noted down. This interview will take up around one hour of your time.

Lastly, it is important to know that this research is conducted by the University of Twente as public academic research.

Introducing questions To be clear on the meaning of decarbonisation and the digital business ecosystem, the following definition will be used:

Decarbonisation: *"Decarbonisation is the term used for removal or reduction of carbon dioxide (CO_2) output into the atmosphere. Decarbonisation is about reducing CO_2 emissions resulting from human activity, with an eventual goal of eliminating them."* [22].

Digital Business Ecosystem: *"The developments in information and communication technologies in the digital age have significant and varying effects on organizations. Changes in traditional business ecosystems have created new business environments called digital business ecosystems."*[94].

- Could you please introduce yourself?
- Can you tell me something about your professional background?
- Could you elaborate upon your current experience with working on sustainability, [prime focus decarbonisation]?
- What is/was your role regarding the example you just gave?
- Could you elaborate upon your current experience with working on digital ecosystems?
- What do you think are the areas of improvement when it comes to [decarbonising] in the aviation sector?

Decarbonisation capabilities

During the upcoming questions, the focus will move toward ecosystem capabilities. To be clear on the meaning of capabilities, the following definition will be used: *"Capabilities are defined as the ability to employ resources to achieve some goal. This can be translated to capabilities use resources to achieve a goal"* [95].

- Based on the previously mentioned definition of capabilities, what do you think appropriate decarbonisation capabilities would be for the aviation industry?

Moreover, this will be the first interactive part of the interview and will make use of the Miro program. In order to answer this question, the party being interviewed will make use of Miro Board Capabilities C.2.

The following Miro board contains a list of all decarbonisation capabilities found during the preliminary literature review. Although these capabilities are relevant in literature, through this interactive interview, we aim to test their validity in a business context. If you have any questions about any of the before mentioned capabilities, I can provide an explanation for any you find unclear.

- Which of these capabilities do you find relevant and why? Which do you find redundant and why? Please remove the capabilities you found redundant from the board.
- Aside from these capabilities, which other decarbonisation capabilities do you find relevant for the aviation sector and why? We can add the ones you mentioned before and moreover you can think of more. Can you please add the new capabilities to the board?
- Lastly, is there any literature available from which you can collect capabilities? Any literature type such as Research Paper, Grey Literature and Business Cases are welcomed.

Decarbonisation capability types

During these questions, the focus will move toward classifying the predetermined capabilities based on the ecosystem capability types. The three types of capabilities used for classification are Strategic, Operational and Supporting. These three types of capabilities have been defined based on the ArchiMate Model 1.5 [6]. Since there might be confusion about the meaning of Supporting capabilities, it is important to mention that these capabilities are neither strategic nor operational, but they provide the help needed in order to realise the other capabilities.

Moreover, this part will also have an interactive element based on the Miro program. In order to answer this question, the party being interviewed will make use of Miro Board Capability Types C.3.

The following Miro board consists of three segments. Each segment represents a type of capability. These capability types aim to provide a clear way of categorising the capabilities, which will be later on used to create a capability map.

- In which of these three categories would you place the capabilities established during the previous question and why? Can you please appoint the capabilities from the first board to the relevant type by moving them into the correct segment?

C.1.4 Interview Shortlist

In order to better visualise the process of the first round of interviews, Figure C.1 provides an overview of the interview stages, we well as interview questions.

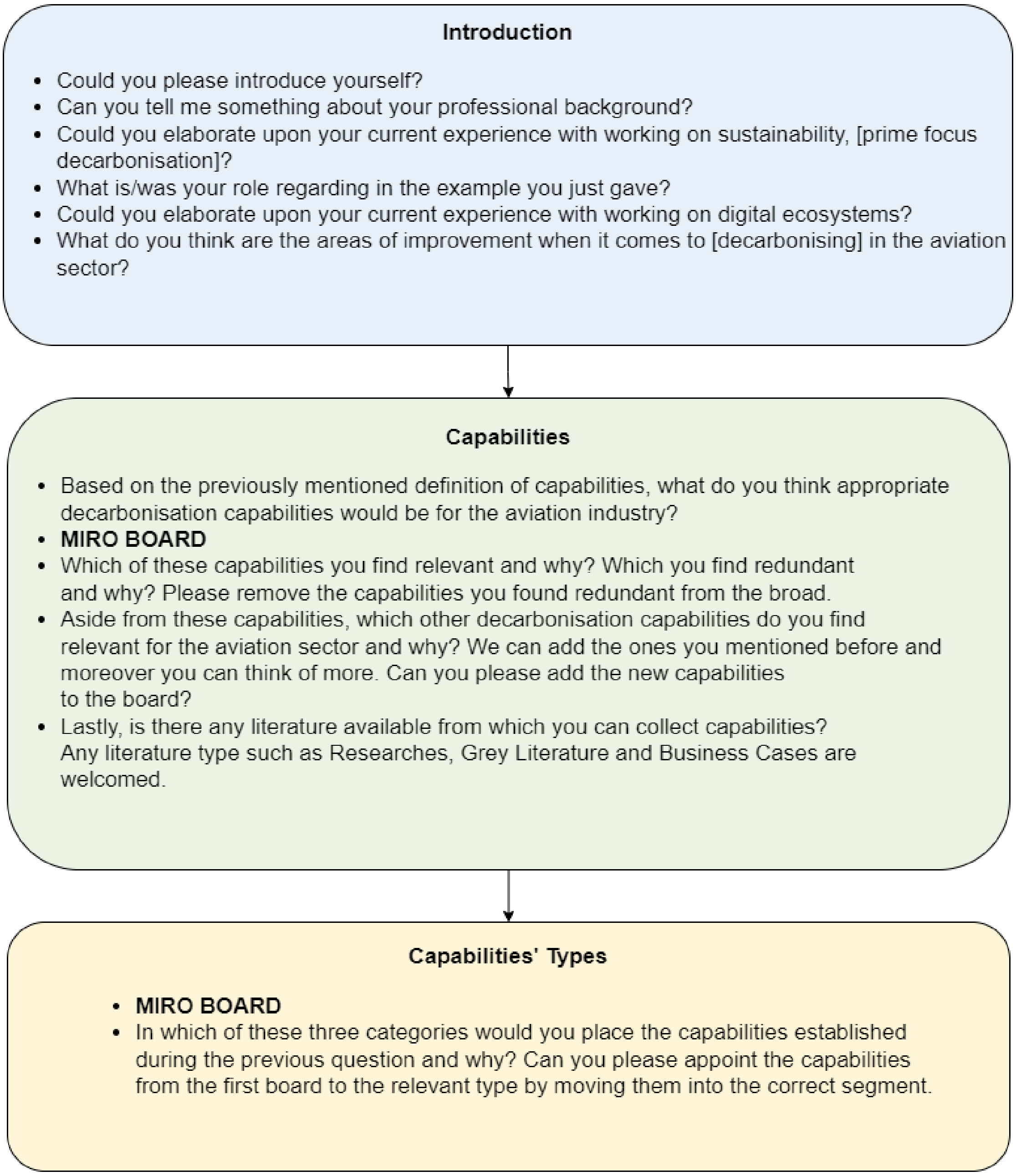

FIGURE C.1: Interview Round I Overview

C.1.5 Interview Resources

Given the semi-structured form of the interviews and the interview questions, a need for an online white-boarding platform supporting the brainstorming activity is required.

For this reason, the Miro platform was used as a resource for the interviews. Although the final modelling will be done in ArchiMate, the Miro platform was used during the interviews due to its user-friendly characteristics for multiple online users.

Two distinct boards have been prepared for each of the first-round interviews. Each board saved a distinct purpose and aimed to answer one of the interview questions. The following sub-chapters describe the background and purpose of each board, as well as provide a visual of the board before the interviews.

C.1.5.1 Miro Board Capabilities

The first Miro board can be found in Figure C.2. The yellow post-its represent the list of capabilities found during the literature research 2.7. The blue post-its have been added and left empty to encourage the party being interviewed to add additional capabilities. The blue colour was used to ease the identification of newly added capabilities. Lastly, the party being interviewed was also encouraged to remove any of the capabilities already mentioned, by chaining the post-it colour to red. This decision aims to facilitate the final comparison between distinct interviews.

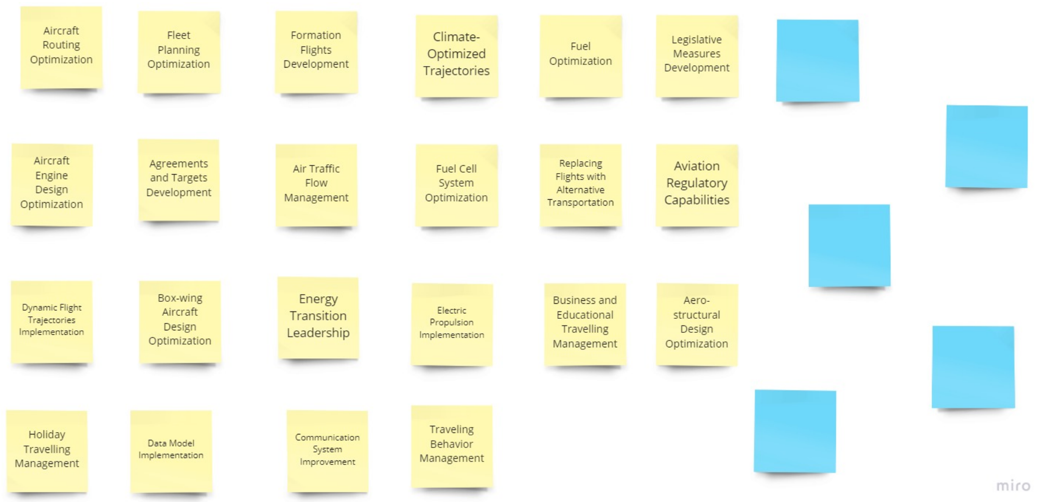

FIGURE C.2: Miro Board Capabilities

C.1.5.2 Miro Board Capability Types

The second Miro board can be found in Figure C.3. This board is initially empty of capabilities but contains three main segments, each representing one type of capabilities defined by the ArchiMate capability map 1.5. The yellow segment represents Strategic capabilities, the green one represents Operational capabilities and the blue one represents Supporting capabilities.

During this part of the interview, the party being interviewed will be asked to transfer the predefined capabilities from the first Miro board to one of the sections. The party being interviewed has the liberty to decide for each capability which section they find the most appropriate.

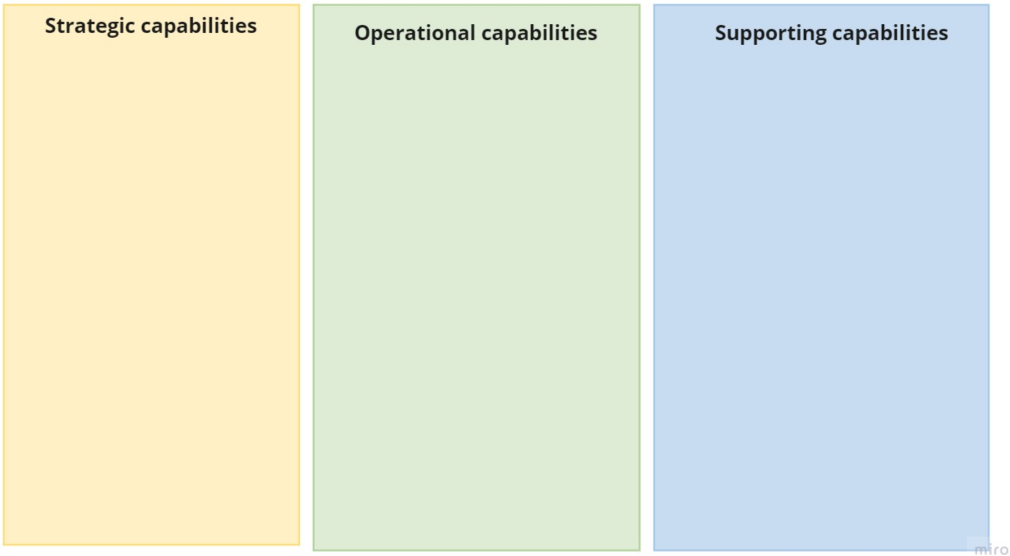

FIGURE C.3: Miro Board Capabilities Types

C.1.6 Results Processing

The processing of the interview results contains several steps. Firstly, the interview participant role will be presented in the appendix together with the Miro board visualisations obtained during the interview. Additionally, the explanation regarding the capabilities removal or addition will be provided, as well as the capability categorising.

Based on the information gathered from the first Miro board, a final list of capabilities will be created. Together with the list, a clear deception of each additional capability will be provided. The final list containing all capabilities from literature and interviews will be modelled in ArchiMate.

During the discussion, the difference between the initial capability list based on the literature and the final one will be analysed.

Lastly, the capability classifications will be transposed in a clear ArchiMate model, which will also be used as the base of the Capability Map construction.

C.2 Interviews Round II

The following section describes in-depth the second round of interviews.

C.2.1 Background

During the first round of interviews, an additional list of capabilities has been added to the capability list. After finalizing all interviews included in the first-round, all capabilities collected have been included in the final capability.

Based on the final capability list and The Open Group model of the aviation ecosystem a clear capability map of the capabilities has been defined based on the domains provided in the Commercial Aviation Reference Architecture and the logical structuring process based on goals. The capability map can be found in Fig 5.2. The classification of the capabilities will be validated by the experts during the second round of interviews.

Additionally, in order to build a reference architecture, the relation between the capabilities needs to be defined. This relation will be discussed during the interview with each expert/expert group, in particular, based on their area of expertise. As multiple experts have a similar background, some interviews will have one interviewee while others will have a group.

There will be 6 unique interviews, each focused on a specific part of the capability map. The interviews will have the following focuses: Ground Operations, Flight Operations, Aircraft Design, Fuel Management, Ecosystem Management for Flights Improvement and Ecosystem Management for Flights Reduction.

Lastly, the main processes affected by the capabilities mentioned will be defined. The reason for focusing on goals, capabilities and processes is to understand the reasoning behind the need for the change and the type of change needed.

During this round of interviews, concepts such as actors have been avoided since during Interview Round I it became quite clear that there is a lack of clarity when it comes to the parties responsible for the emissions. For this reason, the reference architecture will focus on modelling clear capabilities and processes. By discussing each process in the specific context one can determine the actoractors responsible for reaching each goal. Additionally, during the discussion segment, more ways of transposing the reference architecture into a practical example will be defined.

C.2.2 Goals

In order to achieve the goal of this research, the following goals have been defined for the second round of interviews:

1. Validate the final list of capabilities and the capability map.
2. Define the relations between capabilities within each domain and combine the current capability map with the one proposed by The Open Group.

3. Formulate the list of processes each capability will help realise.

C.2.3 Interview Protocol

In this section, the protocol for the second round of interviews is described. This type of interview can be classified as a semi-structured interview. The protocol serves as a primary guideline during the interviews, to ensure that all necessary questions are appropriately addressed and answered.

Introduction
Introduce the purpose of the interview.

Permission
Before we continue, I would like to ask for your permission to record the interview. The recording will be deleted shortly after the interview, and it will be used to fill the gaps in the interview notes.

Additionally, during the interview, we will be using Miro boards for a more visually interactive experience. The Miro boards will be saved and used in my research.

Background information
The results of this interview will be used only as a source of data for my Master Thesis. The only personal information which will be mentioned in the paper is your job title, as well as your area of expertise. However, if you consider any of the two to be too private, it can all be anonymised.

If during the interview you consider any information shared sensitive information this information will not be taken into consideration or noted down. This interview will take up around one hour of your time.

Lastly, it is important to know that this research is conducted by the University of Twente as public academic research.

Research Introduction Since all interviewees have already participated in Interview Round I, the research introduction and personal description will be skipped.

Validating the Capability Map The processed results of the first round of interviews together with the Capability Map 5.2 will be presented.

- Based on the previously mentioned information and your expertise, do you find this capability map relevant for decarbonising the aviation industry?Why?

Capability Mapping

Moreover, this will be the first interactive part of the interview and will make use of the Miro program. In order to answer this question, the party being interviewed will use one of the Miro Boards presented in the resources section C.2.5.

The following Miro board contains a segment of the previously shown capability map, together with a segment of the capability map proposed by The Open Group. However, through the Miro environment, you can connect capabilities with an arrow to show their relations, you can also move one capability inside another if you find any capabilities listed as subcategories.

- Looking more in-depth at these capability maps, what are the relations you notice between the capabilities?
- How would you combine the two maps in one?
- Do you notice any relationships between these capabilities?

Capability Processes

During these questions, the focus will move toward the business processes needed in order to enable the capabilities and achieve the main decarbonisation goals.

To better understand the term business process, the following definition is provided "A business process represents a sequence of business behaviours that achieves a specific result such as a defined set of products or business services. A business process describes the internal behaviour performed by a business role that is required to produce a set of products and services." [96]. Moreover, this part will also have an interactive element based on the Miro program.

- What are the main processes supporting the capabilities previously presented in the capability map?
- How can you integrate the processes suggested by The Open Group in your diagram?

C.2.4 Interview Shortlist

In order to better visualise the process of the first round of interviews, Figure C.4 provides an overview of the interview stages, we well as interview questions.

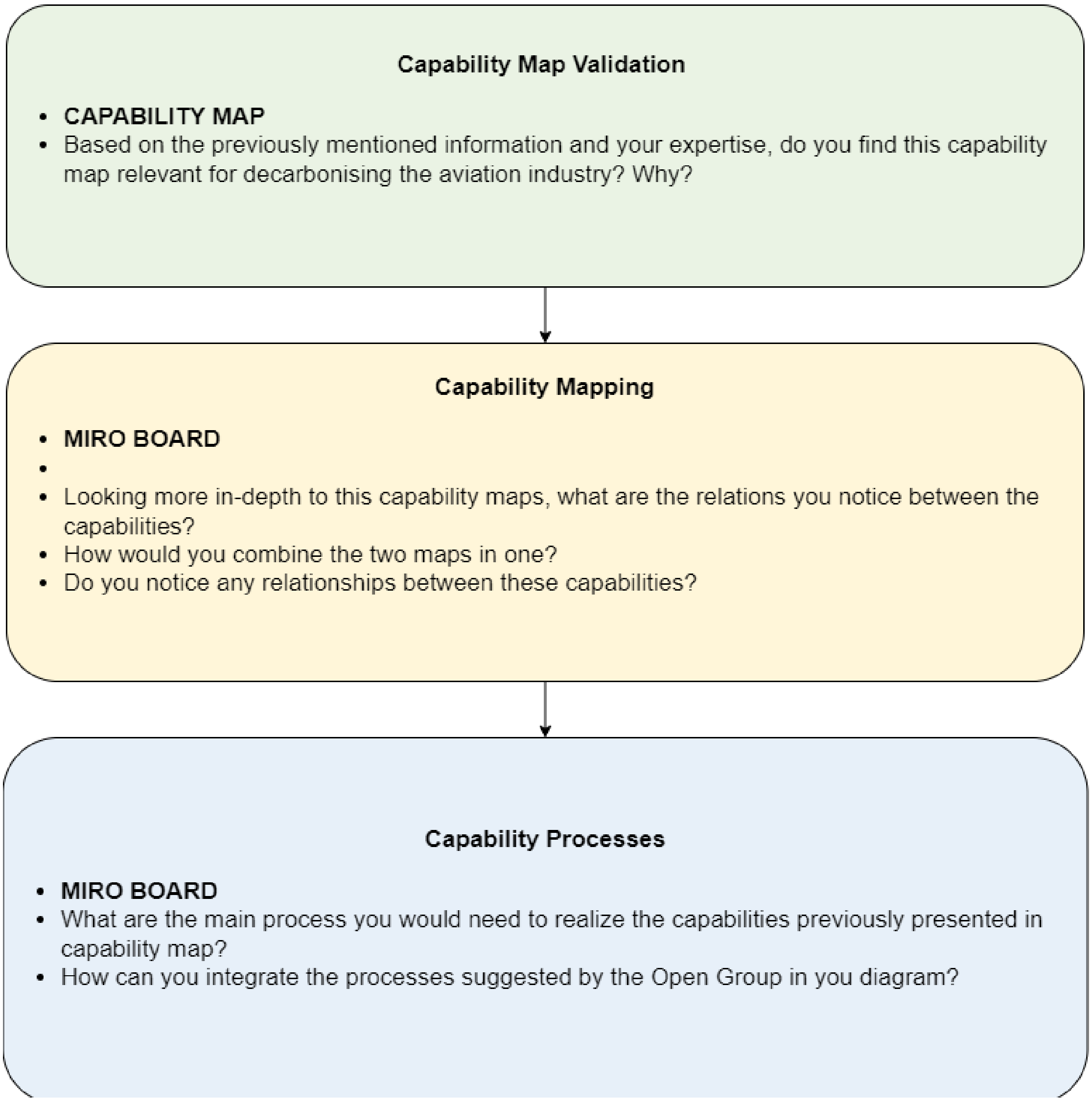

FIGURE C.4: Interview Round II Overview

C.2.5 Resources

Given that the stricture of Interview Round II is rather similar to the one of the first round, an online white-boarding platform supporting the brainstorming activity is also required for this round of interviews. For this reason, the Miro platform was used again as a resource for the interviews. As all interviewees attending the second round had taken part in the first round, using the same tool appeared as an obvious choice. Although the final modelling will be done in ArchiMate, the Miro platform was used during the interviews due to its user-friendly characteristics for multiple online users.

The following Miro Boards contain a particular part of the Capability Map 5.2 together with the most appropriate capability categories provided in The Open Group Commercial Aviation Model [12].

The upper part of the visual focuses on capability relations and includes Goals and Capabilities. Each visual contains in the upper left upper corner the respective part of the capability map being utilized, while in the right upper corner, the capability maps provided by The Open Group have been included. The upper part of the model will be used to answer the questions regarding Capabilities' Relations.

The lower part of the visual focuses on capability processes and includes Capabilities and Processes together with three types of relations Realization, Composition and Triggering. The visuals reflect the capability diagrams provided by The Open Group. The lower part of the model together with the results obtained in the upper part will be used to answer the questions regarding Capabilities' Processes.

C.2.5.1 Interview Round II - Ground Operations

The following model will be used in the interview dedicated to Ground Operation which will take place in Interview Round II. The expert used for this interview is Respondent 3.

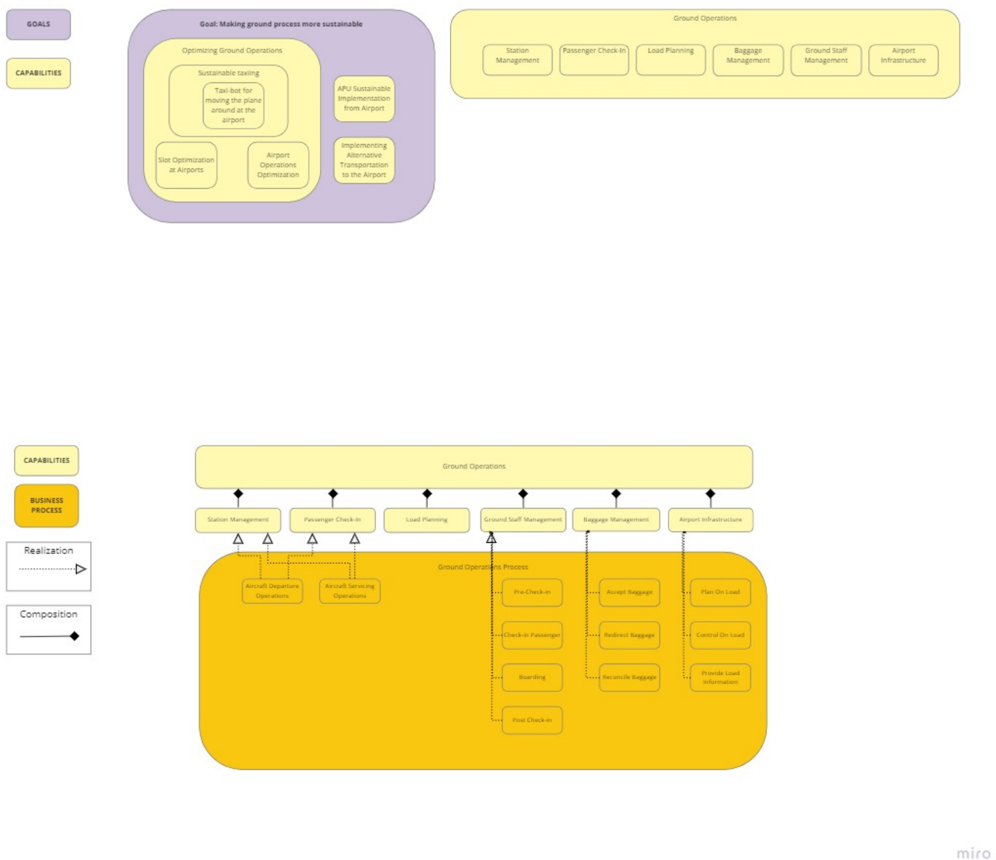

FIGURE C.5: Miro Board Ground Operations

C.2.5.2 Interview Round II - Flight Operations

The following model will be used in the interview dedicated to Flight Operation which will take place in Interview Round II. The expert used for this interview is Respondent 9.

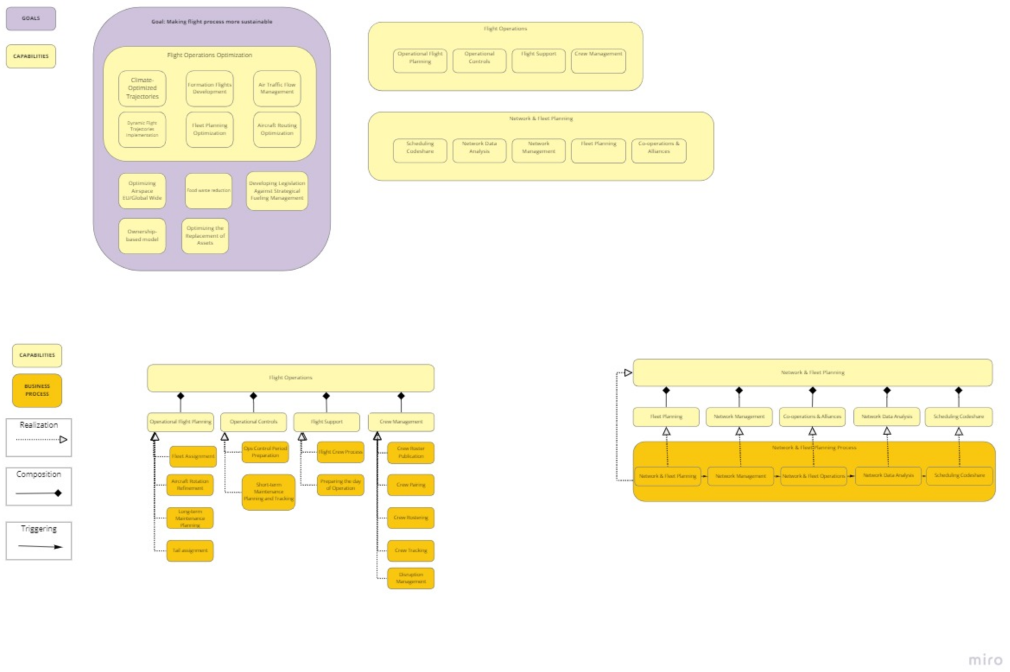

FIGURE C.6: Miro Board Flight Operations

C.2.5.3 Interview Round II - Aircraft Design

The following model will be used in the interview dedicated to Aircraft Design which will take place in Interview Round II. The expert used for this interview is Respondent 1.

C.2.5.4 Interview Round II - Fuel Management

The following model will be used in the interview dedicated to Fuel Management which will take place in Interview Round II. The experts used for this interview are Respondents 5 and 8.

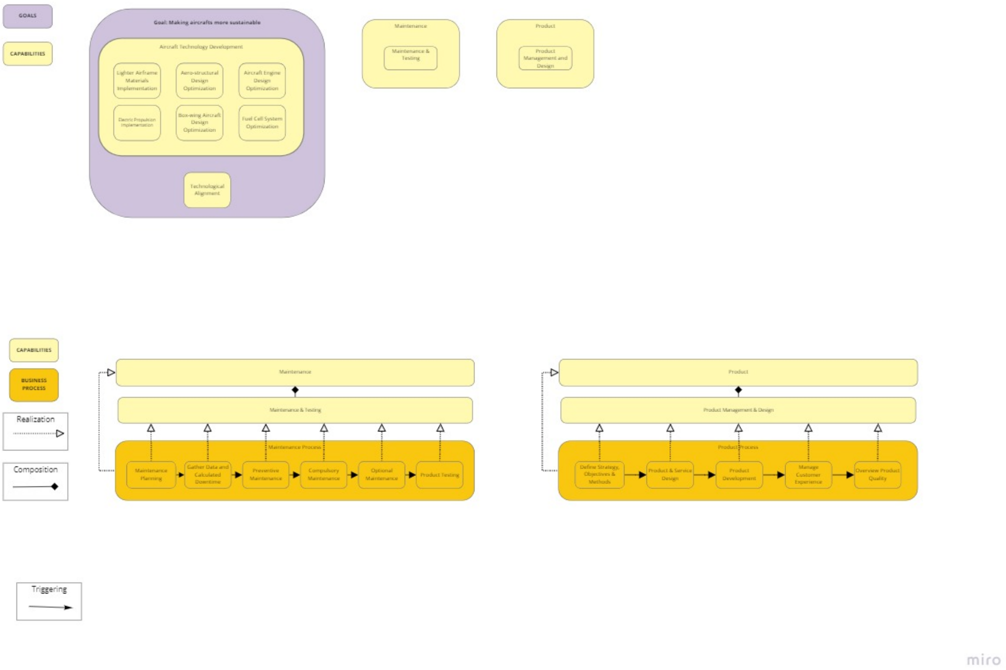

FIGURE C.7: Miro Board Aircraft Design

C.2.5.5 Interview Round II - Ecosystem Management for Flights Improvement

The following model will be used in the interview dedicated to Ecosystem Management for Flights Improvement which will take place in Interview Round II. The experts used for this interview are Respondents 2 and 4.

C.2.5.6 Interview Round II - Ecosystem Management for Flights Reduction

The following model will be used in the interview dedicated to Ecosystem Management for Flights Reduction which will take place in Interview Round II. The experts used for this interview are Respondents 6 and 7.

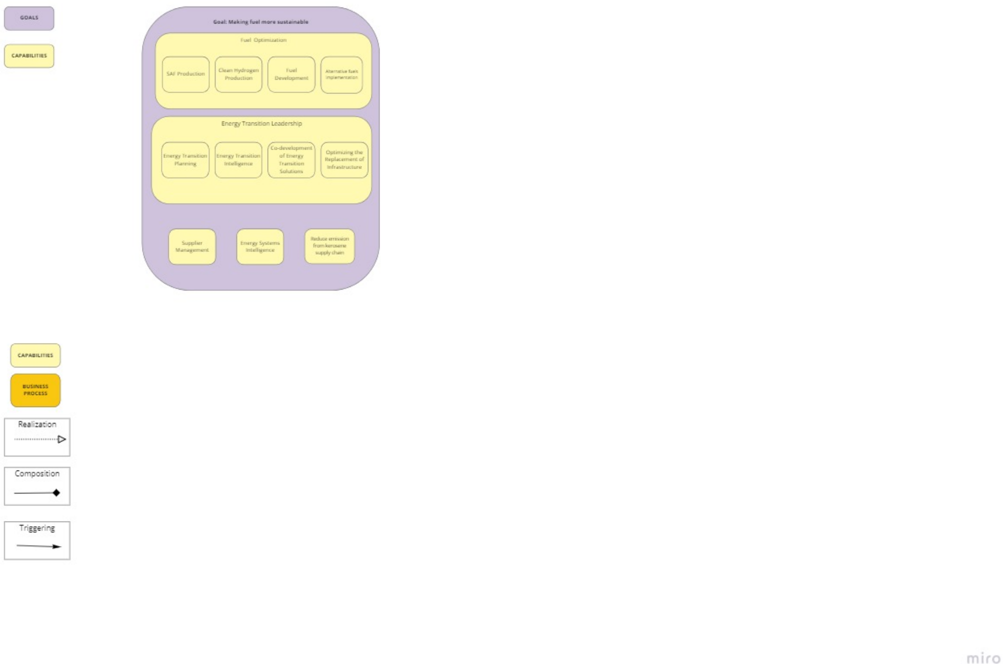

FIGURE C.8: Miro Board Fuel Management

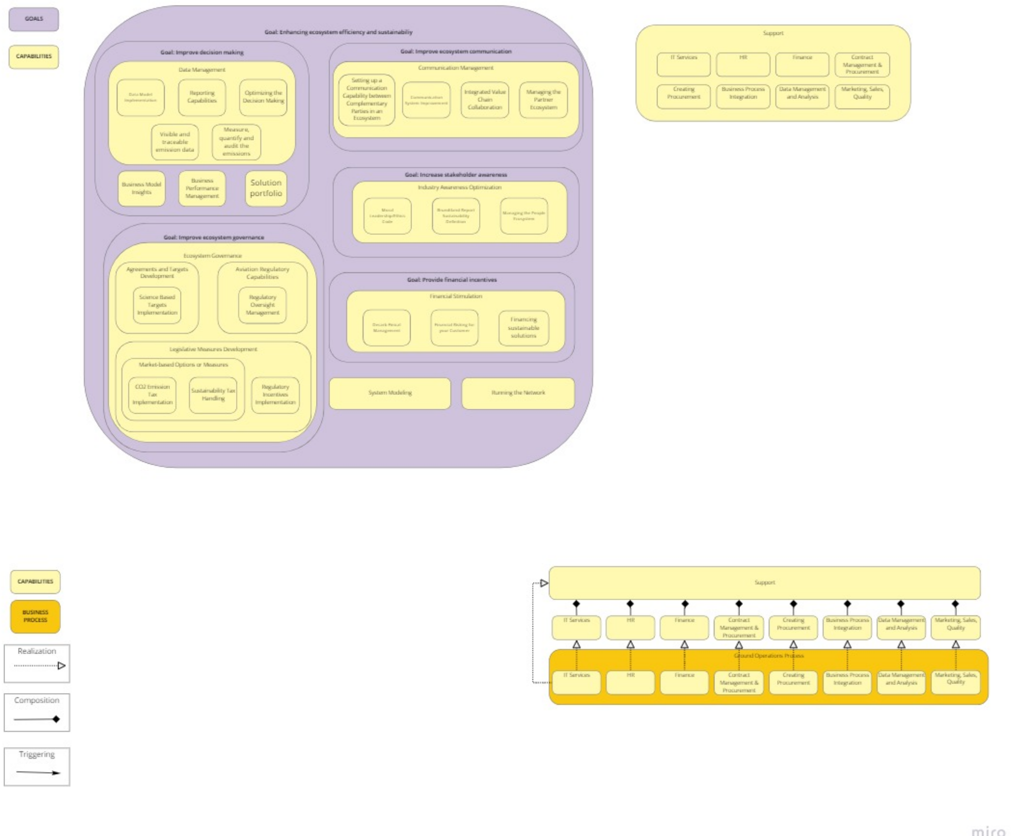

FIGURE C.9: Miro Board Ecosystem Management for Flights Improvement

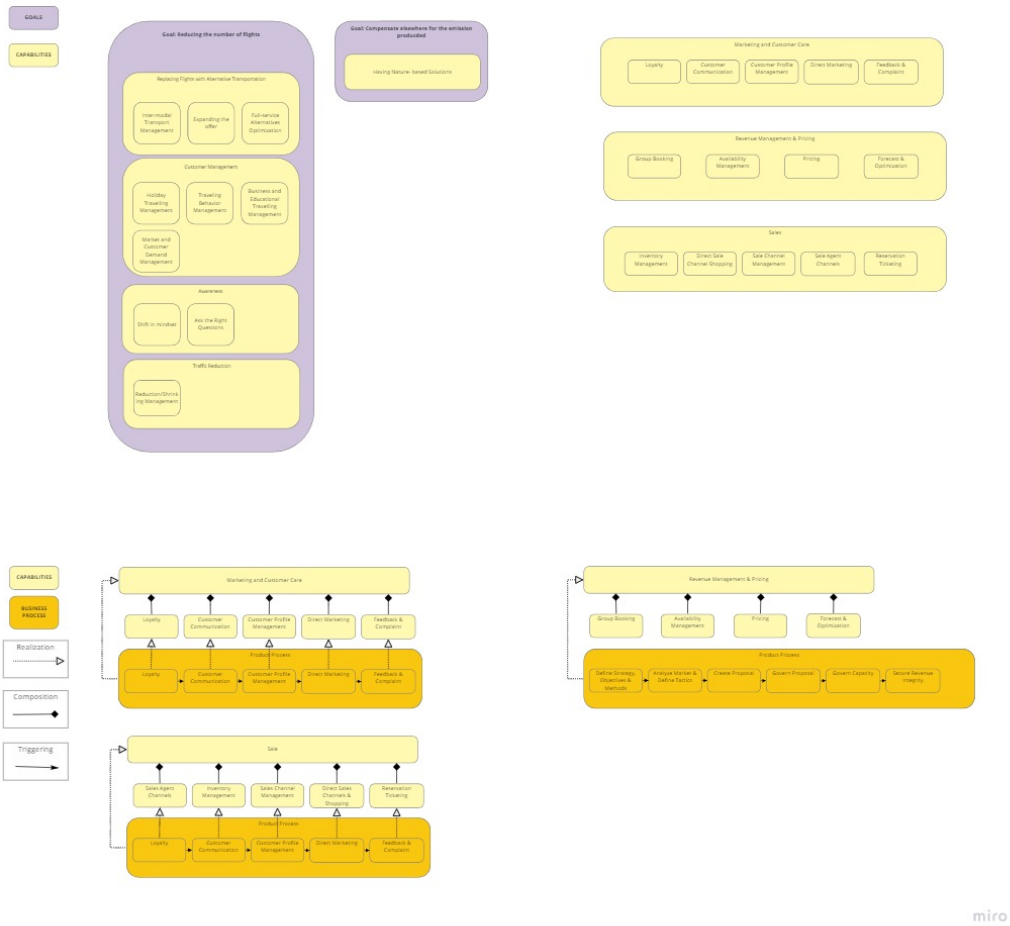

FIGURE C.10: Miro Board Ecosystem Management for Flights Reduction

Appendix D

Interview Results

In this chapter, an in-depth deception of the interview results can be found. This chapter does not only provide a summary of all interview results, but it provides the information directly extracted from the interview notes based on the three topics of focus for each of the interviews from Interview Round I. The three topics of focus together with the summary of interview results can be found in Section 4.2.

Additionally, the boards for each of the focuses presented in Interview Round II have been added to this Appendix. The summarized results together with the focus of Interview Round I can be found in Section 4.3.

D.1 Pilot Interviews Results

For Interview Round I, two distinct pilot interviews were conducted with subjects who already possess background information regarding the content of the research. The pilot interviews were used to provide feedback regarding the interview protocol and interview questions. Moreover, this also helped the interviewer get accustomed to the process.

Pilot I During the first pilot, all parts of the interview were covered and a lot of positive feedback was received. Additionally, one structural change was recommended and adapted to the interview. The pilot subject recommended that the question regarding capabilities be asked also prior to showing the Miro board in order to assure the creative freedom of the person interviewed. Subsequently, the following question was added to the interviews:" Based on the previously mentioned definition of capabilities, what do you think appropriate decarbonisation capabilities would be for the aviation industry?".

Lastly, based on the feedback from the first Pilot, a PowerPoint presentation was created to support the course of the interview and to offer the party being interviewed a visual overview of the interview structure, background and questions.

Pilot II During the second pilot, all parts of the interview were covered as well and a lot of interest from the subject was observed. Moreover, the subject also agreed that the overall structure of the interviews is clear and feasible, as well as appreciated the use of Miro Boards for assuring interaction.

The main observation of the subject was that the capability map model used in this paper is focused on an enterprise perspective rather than an ecosystem. For this reason, the subject suggested that an adaptation of the map should be designed for presenting the results. The interviews also showed his/her concerns regarding how the second Miro Board can be processed in a combined way for all subjects. However, he/she agreed that the Miro Board Capability Types C.3 can be very useful when creating an adapted capability map of all capabilities.

Informal Pilot Session for Round II During the informal pilot session conducted for the second round of interviews, the following feedback has been summarized:

- The initial thesis introduction can be still used to remind the expert about the focus of the thesis, although in most cases it won't be necessary.
- Some of the definition slides should be removed in the context where the expert is familiar with the terminology.
- When having multiple experts in one interview, the interviewer must be aware of the time constraints and manage the time.

D.2 Interview Results

In this section, in-depth decryption of the interview results is provided based on the data collected through interview notes.

D.3 Interview Round I

In this section, Table D.1 shows all capabilities obtained during the interviews, while Table 4.3 provides a list of all capabilities obtained from expert-recommended literature. The classification of the capabilities made by the experts can be also visualized in Table 4.1. Lastly, the interview notes have been included, which contain the description of all capabilities added.

Capability	**Source**
Implementing Fly Tax	Respondent 1

Optimizing Aerospace EU/Global Wide	Respondent 1
Optimizing Ground Operations	Respondent 1
Inter-modal Transport Management	Respondent 1
Regulatory Oversight Management	Respondent 2
Supplier Management	Respondent 2
Decarb Finical Management	Respondent 2
Communication Management	Respondent 2
Customer Management	Respondent 2
Business Model Insights	Respondent 2
Reporting Capabilities	Respondent 2
Energy Transition Strategy Planning	Respondent 2
Data Management	Respondent 2
Slot Optimization at Airports	Respondent 3
Developing Legislation Against Strategical Fueling	Respondent 3
Sustainable taxiing	Respondent 3
Industry Awareness Optimization	Respondent 3
CO2 Emission Tax Implementation	Respondent 3
Financial Stimulation	Respondent 3
APU Sustainable Implementation from Airport	Respondent 3
Energy Transition Planning	Respondent 4
System Modelling	Respondent 4
Co-development of Energy Transition Solutions	Respondent 4
Energy Systems Intelligence	Respondent 4
Ecosystem Governance	Respondent 4
Business Performance Management	Respondent 4
Setting up a Communication Capability between Complementary Parties in an Ecosystem	Respondent 4
Energy Transition Intelligence	Respondent 4
Financial Risking for your Customer	Respondent 4
Having Nature- based Solutions	Respondent 4
Running the Network	Respondent 4
Managing the People Ecosystem	Respondent 4
Managing the Partner Ecosystem	Respondent 4
Integrated Value Chain Collaboration	Respondent 5
SAF Production	Respondent 5
Clean Hydrogen Production	Respondent 5
Moral Leadership/Ethics Code	Respondent 6
Reduction/Shrinking	Respondent 6
Traffic Reduction	Respondent 6
Collaborate	Respondent 6

Ask the Right Questions	Respondent 6
Brundtland Report Sustainability Definition	Respondent 7
Taxi-bot for moving the plane around at the airport	Respondent 7
Food waste reduction	Respondent 7
Ownership-based model	Respondent 7
Expanding the offer	Respondent 7
Shift in mindset	Respondent 7
Visible and traceable emission data	Respondent 8
Measure, quantify and audit the emissions	Respondent 8
Solution portfolio	Respondent 8
Reduce emission from kerosene supply chain	Respondent 8
Financing sustainable solutions	Respondent 8
Alternative fuels implementation	Respondent 8
Aircraft Technology Development	Respondent 9
Flight Operations Optimization	Respondent 9
Fuel Development	Respondent 9
Sustainability Tax Handling	9
Full-service Alternatives Optimisation	Respondent 9
Science-Based Targets Implementation	Respondent 9
Awareness	Respondent 9

TABLE D.1: Capabilities extracted from expert interviews

Capability	**Source**
Airport Operations Optimization	[97]
Lighter Airframe Materials Implementation	[97]
Market-based Options or Measures (MBMs)	[97]
Implementing Alternative Transportation to the Airport	[97]
Market and Customer Demand Management	[98]
Regulatory Incentives Implementation	[98]
Technological Alignment	[98]
Optimizing the Decision Making	[98]
Optimizing the Replacement of Assets	[98]
Optimizing the Replacement of Infrastructure	[98]

TABLE D.2: Capabilities extracted from literature recommended through interviews

D.3.1 Interview Round I - Respondent 1 (I1-R1)

During this interview, the following results can be defined:

Capabilities	Strategic	Operational	Supporting
Aero-structural Design Optimization	3	1	3
Agreements and Targets Development	5	0	2
Air Traffic Flow Management	0	7	0
Aircraft Engine Design Optimization	3	1	3
Aircraft Routing Optimization	2	5	0
Aviation Regulatory Capabilities	4	1	2
Box-wing Aircraft Design Optimization	3	1	3
Business and Educational Travelling Management	1	4	2
Climate-Optimized Trajectories	3	4	1
Communication System Improvement	2	1	4
Data Model Implementation	3	1	3
Dynamic Flight Trajectories Implementation	2	4	1
Electric Propulsion Implementation	3	1	3
Energy Transition Leadership	6		1
Fleet Planning Optimization	2	4	1
Formation Flights Development	2	4	1
Fuel Cell System Optimization		4	3
Fuel Optimization	1	4	2
Holiday Travelling Management	2	3	2
Legislative Measures Development	4		3
Replacing Flights with Alternative Transportation	3	3	1
Travelling Behavior Management	3	3	1

Table D.3: Overview of Capability Classification

D.3.1.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added four new capabilities to the list, two before visualising the literature capability list and two after. The Capability Miro Board after the interview can be found in Figure D.1.

Implementing Fly Tax The expert mentioned that many countries, including the Netherlands, have imposed an environmental tax per passenger. This task aims to discourage the airlines which use cost incentives to motivate people to buy flights in order to keep the aeroplane full. The argumentation around this capability is that in the situations when the aeroplane is not very full, it can be replaced with a smaller size aeroplane instead of using incentives of filling in the empty spots.

Optimizing Aerospace EU/Global Wide Optimizing the aerospace globally, can help reduce emissions by creating more direct trajectories, which will result in reducing the energy consumed as well as the in-flight emissions. Although that might seem like

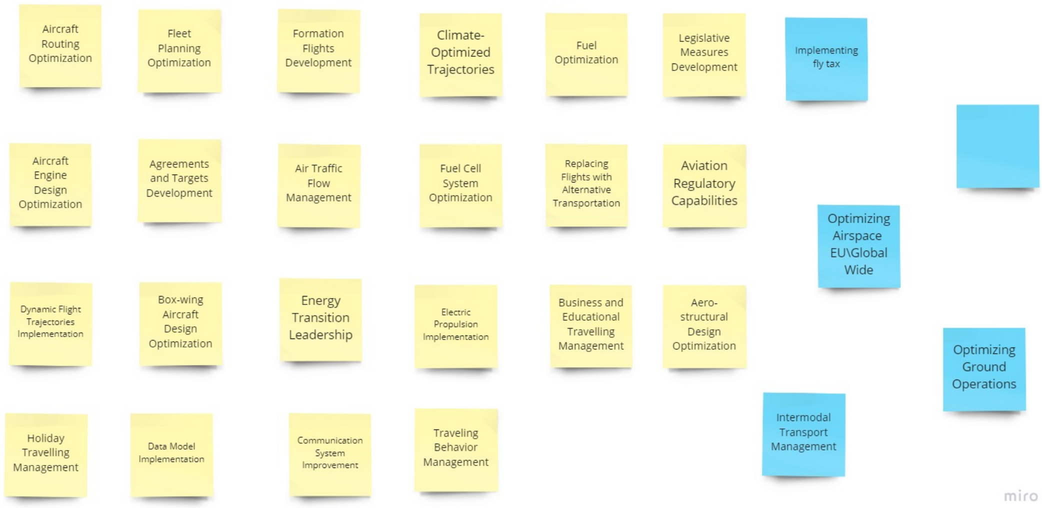

FIGURE D.1: Capability List for Interview Round I Respondent 1

a Utopian scenario, a good starting point can be the European Union. The expert interviewed explained that currently, each country is responsible for its own aerospace which implies that the flight trajectories are not a "straight line" from one location to another, but they consist of multiple mini trajectories decided upon by each country.

Optimizing Ground Operations The expert mentioned that aside from the airline attempting to reduce emissions, emissions can be impacted also by the airport. In explanation to this, the subject refereed also to the book "Managing airports: An international perspective" [97].

Inter-modal Transport Management The expert also mentioned that having a better inter-modal transport system would have major effects on decarbonisation. Additionally, the subject emphasised the need for more efficient railway transportation between countries, as there is a lot of current development and focus on the railway network. Lastly, it was emphasize that the inter-modal system should not only focus on replacing flights but also on making the overall travel more sustainable. Travelling by public transport to the airport was also suggested as a resource for this capability. The need for a transportation system that acts as an entity overarching all transportation systems was also underlined.

D.3.1.2 Literature Recommendation

The expert has recommended the book "Managing airports: An international perspective", Chapter 10 "The environmental impact of airports" [97].

This book chapter focuses on the five main environmental impacts of airports: noise, emissions, water pollution and usage, waste and energy management. "In considering emissions, a distinction is made between global emissions that are responsible for climate change and are a very significant problem for the air transport industry, and local emissions affecting people within the location of the airport." [97].

Aside from the previously considered capabilities, this source provides us with the following capabilities:

Airport Operations Optimization The chapter identifies the main environmental impacts associated with airport operations and describes four main environmental management approaches which can help reduce the emissions. The four levels of accreditation needed to reduce emissions are "mapping (which requires compilation of carbon footprint reports); reduction (which requires achieving emissions reduction targets for emissions under the airport operator's control); optimisation (which requires engaged third parties in carbon reduction); and neutrality (which requires offsetting remaining emissions to achieve carbon-neutral operations)." [97]. This capability has been partially mentioned by the expert interviewed as well, as the Optimizing Ground Operations capability. However, this one considers also the emissions of the airport aside from the activities that have to do with the plan itself.

Lighter Airframe Materials Implementation The usage of lighter airframe materials will subsequently result in a lighter aircraft. Since a lighter aeroplane requires less fuel to operate, it also results in lower emissions [97].

Market-based Options or Measures (MBMs) There are a number of MBMs such as the kerosene tax or the environmental passenger tax which are growing in popularity currently. "Taxing on a per passenger basis is a very blunt instrument for tackling the emissions problem, as each passenger pays the same regardless of the level of emissions from the aircraft and how full it is." [97]. This capability has been also partially mentioned by the expert interview as well, as the Implementing Fly Tax capability defined during the interview overlaps with the environmental passenger tax approach of this capability.

Implementing Alternative Transportation to the Airport This capability focuses on "the role of other transport modes and in particular developments and strategies that have encouraged more public transport use in accessing the airport. This leads to consideration of general environmental management policies that airports are adopting, followed by an examination of how airports can adapt their operations as a consequence of climate change." [97].

D.3.1.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.2.

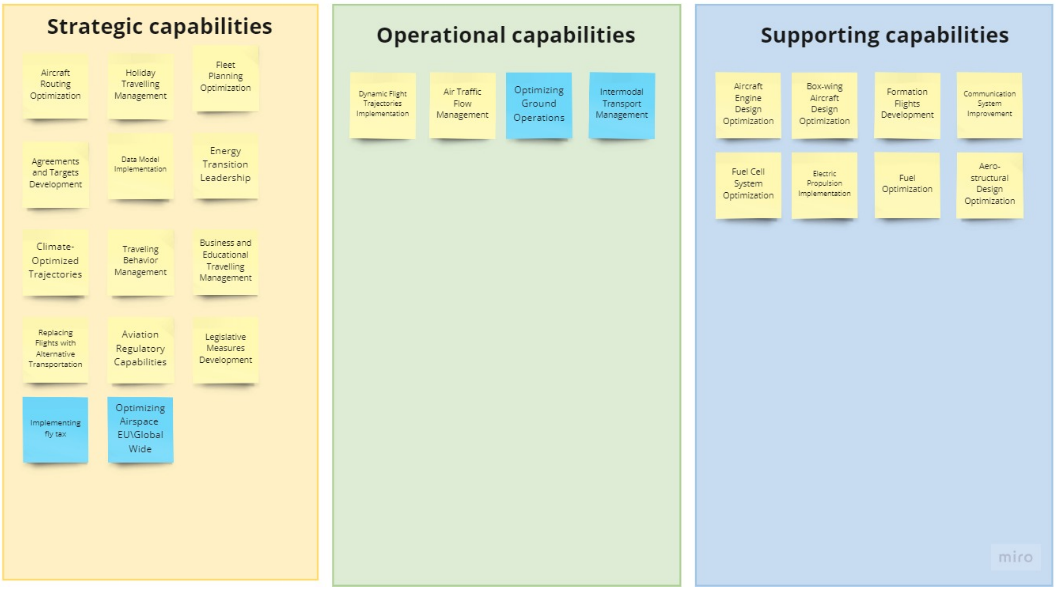

FIGURE D.2: Capability Categorisation for Interview Round I Respondent 1

D.3.2 Interview Round I - Respondent 2 (I1-R2)

During this interview, the following results can be defined:

D.3.2.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added nine new capabilities to the list, three before visualising the literature capability list and six after. The capabilities added by the expert aimed to focus on enabling the digital business ecosystem by assuring data transparency. The Capability Miro Board after the interview can be found in Figure D.3.

Regulatory Oversight Management Based on the expert's opinion, sometimes having regulations in place is not enough for a company. Having clear information oversight of all regulations, together with clear ownership of each regulation is needed in order to assure that the regulations are applied accurately. Lastly, the expert mentioned that the regulatory oversight should also contain the systematic reporting ways or even reporting standers in order to assure that all rules are applied in the same manner by multiple players.

Supplier Management Refers to a systematic ecosystem-wide assessment of suppliers' strengths and weaknesses when it comes to decarbonisation. Additionally, it focuses on creating and maintaining strong relationships with suppliers.

Decarb Finical Management During the interview, one capability discussed was

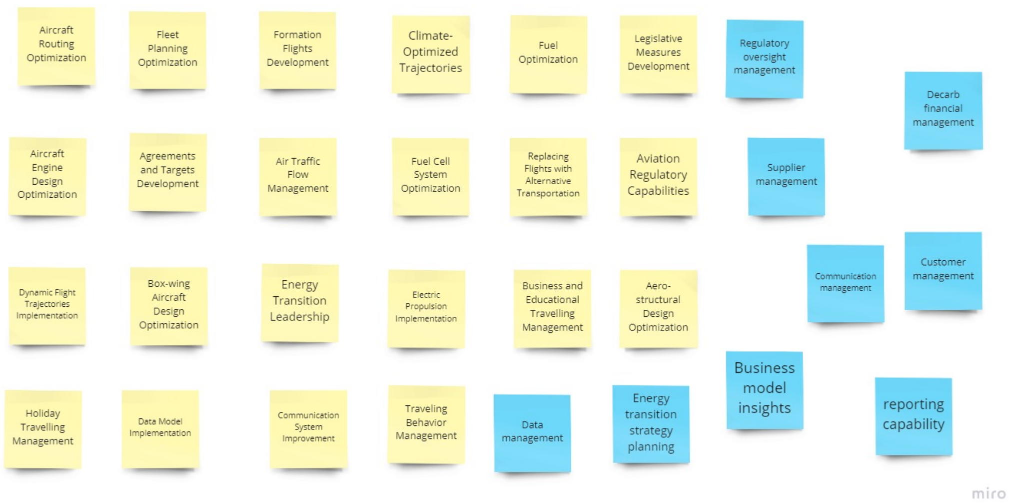

Figure D.3: Capability List for Interview Round I Respondent 2

decarbonisation financial management, which was described as the way of handling a company's finances in a way that encourages decarbonisation and follows all emission-related regulations and targets. Lastly, this should be applied to all companies inside the ecosystem.

Communication Management The expert talks about communication management as the systematic planning and implementation of communication channels, as well as the continuous monitoring and revision of all the channels. These channels should be ecosystem-wide and should allow clear and transparent communication.

Customer Management This capability was used by the interviewee not only to describe the process of managing the relationship between an organisation and its customers, but the relation of the entire aviation ecosystem with the customers.

Business Model Insights During the interview, the interviewee mentioned Change Management as a very important capability of managing the change and coordinating multiple distinct teams to work towards the same goal. As a capability, the expert mentioned it as business model insights as heshe considered that the business models need to combine both data collection and analysis in order to assure and realize a positive change.

Reporting Capabilities The expert mentioned that despite the need for collecting data, there should be a clear and easy way of reporting it so that it can be used and understood by all companies in the ecosystem. Reporting capabilities are usually known as the business intelligence function which assures that all information is clear.

Energy Transition Strategy Planning The expert explains the energy transition strategy as the way of shifting the global energy from fossil-based to zero-carbon. This is a worldwide acknowledged target to be reached by the second half of this century. However, aside from the final goal, during the interview, the need for clear planning was discussed.

Data Management The expert underlined that despite the great amount of data generated daily in the aviation industry, there is no clear data management. Collecting on-flight data, supplier-related data etc. can help gather the information needed. In order to progress in decarbonisation, a good data management system value chain-wide can provide good insights. Additionally, the respondent underlined the need for transparency and how good data management can be used to increase transparency while reducing competitive risks.

D.3.2.2 Literature Recommendation

The expert has recommended the EU government web page as the best way of keeping up with the European measures toward decarbonisation [99]. Additionally, The Open Group Models were mentioned, however, those have already been included for this research [12]. Finally, no sources of new capabilities were collected and as a result, no extra capabilities have been extracted from the literature.

Additionally, the expert-recommended further research on The Open Group sources. Based on this recommendation, the Commercial Aviation Reference Architecture created by The Open Group containing a Capability Map specifically designed for the aviation industry was found [12].

D.3.2.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.4.

D.3.3 Interview Round I - Respondent 3 (I1-R3)

During this interview, the following results can be defined:

D.3.3.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added nine new capabilities to the list, three before visualising the literature capability list and six after. The capabilities added by the expert aimed to focus on enabling the digital business ecosystem by assuring data

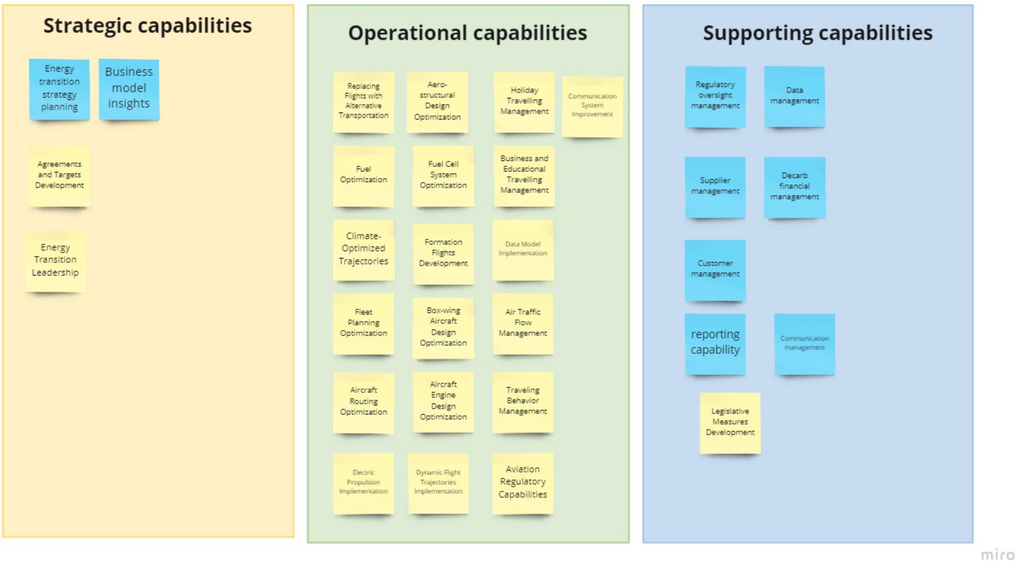

FIGURE D.4: Capability Categorisation for Interview Round I Respondent 2

transparency. The Capability Miro Board after the interview can be found in Figure D.5.

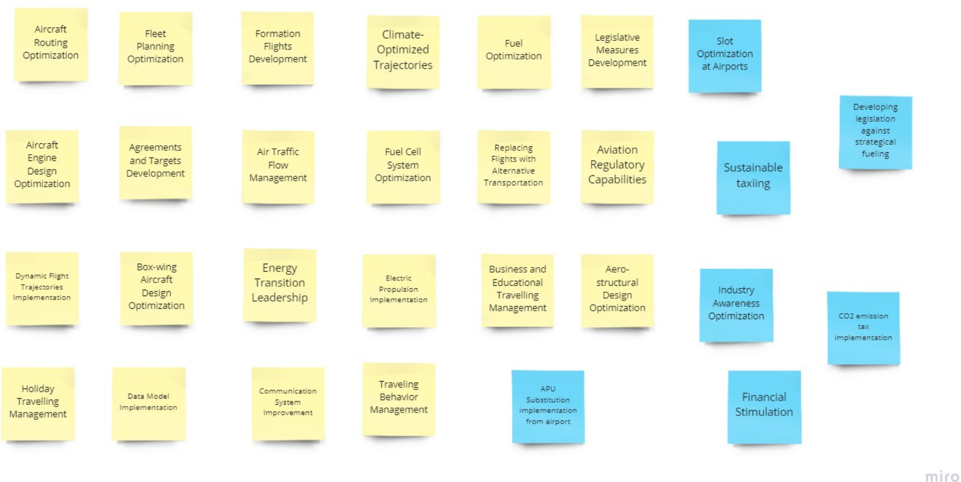

FIGURE D.5: Capability List for Interview Round I Respondent 3

Slot Optimization at Airports Currently landing slots are allocated in accordance with guidelines set down by the International Air Transport Association (IATA) in order to facilitate the landing of more plains. However, the expert mentioned that currently most slots are very short and many times the speed of the flight is increased in order to match the slot. This has a negative effect on the emission due to the increase in flight speed.

Developing Legislation Against Strategical Fueling The expert explained Strategical Fueling as the process of fueling more than necessary when in a country which has a much lower price on fuel. This apparently is a very used tick by airlines who want to reduce the cost of fuel. This is a very bad habit since it implies flying a much heavier aeroplane, which subsequently emits more. The interviewee also mentioned that without clear legislation against this, making the fuel more sustainable in the Netherlands or inside the European Union will not have a very positive overall result.

Sustainable taxiing The expert mentioned that there are a lot of CO_2 emissions generated during the taxi process. The benefits of sustainable taxiing are mainly lower fuel consummation, as well as emission reduction. Additionally, making taxiing more sustainable refers to the improvement of two distinct systems, the onboard system and the ground-based system.

Industry Awareness Optimization The expert mentioned that despite the need for behavioural management of the passengers, the people working inside the aviation ecosystem need to be aware of the sustainability impact. Assuring that all parties involved are aware of the CO_2 emission and have decarbonisation as the main goal in their work is very important.

CO_2 Emission Tax Implementation The expert mentioned that there needs to be a way of keeping airlines accountable for their emissions. The proposed CO_2 emission tax refers to implementing clear cost-based measures from a governmental perspective.

Financial Stimulation In contrast with the CO_2 tax for emissions, positive financial incentives should be used to encourage the airlines to reduce emissions. The expert used as an example the governmental strategies used to encourage people to buy electric cars.

APU Sustainable Implementation from Airport The Auxiliary Power Unit (APU) is the additional motor located inside the aircraft that powers the air conditioning and hydraulics. This system is most of the time while the passengers leave and board the plane, as well as when the playing stops for short times. Providing an airport-based replacement of this system can reduce ground emissions.

D.3.3.2 Literature Recommendation

The expert has recommended his blog ”Prent Aviation” which focuses on explaining what sustainable taxiing is as well as promoting sustainable solutions for ground operations [100].

The capabilities described in the blog have been also mentioned by the expert during the interview. However, the blog was used as a resource, together with the interview notes, to better define each capability. Additionally, one can consult the blog when looking for more in-depth explanations of the above-mentioned capabilities.

D.3.3.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.6.

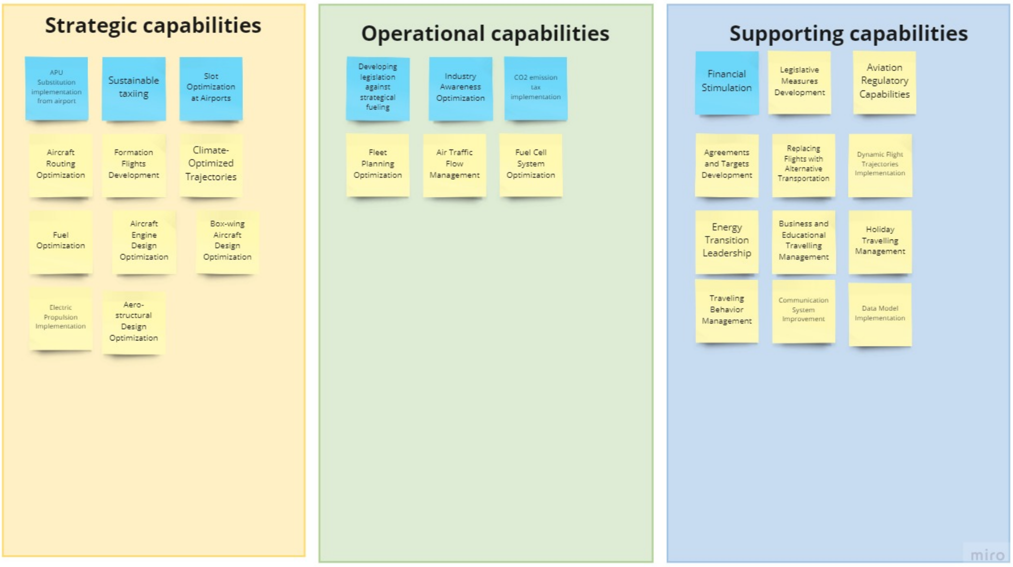

FIGURE D.6: Capability Categorisation for Interview Round I Respondent 3

D.3.4 Interview Round I - Respondent 4 (I1-R4)

During this interview, the following results can be defined:

D.3.4.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added 13 new capabilities to the list. The capabilities added by the expert aimed to focus on making an ecosystem-wide change while providing background from the energy industry. The Capability Miro Board after the interview can be found in Figure D.7.

Energy Transition Planning During the interview the need for clear planning was discussed in terms of the energy transition. The expert has agreed that energy transition is a multi-step process and so there is a clear need for both short term and long term planning.

System Modelling The party interviewed also emphasised the importance of system modelling which refers to the full ecosystem. Having a model of the entire value chain helps make sure that all information which can provide decision support is being tracked.

Co-development of Energy Transition Solutions Since we are talking about an ecosystem and not just one industry or one organization, the interviewee also underlined the need for co-development. Developing solutions based on one singular industry most of the time result in problem shifting instead of problem resolution. Conveying co-development optimizes the energy transition for all the ecosystems including both large and small players.

Energy Systems Intelligence The expert mentioned that collecting the data is not always enough. The need for Energy System Intelligence is emphasised by using the data available, not only the data produced by one company or one industry. Making sure that data is interoperable is key for making informed decisions at an ecosystem level.

Ecosystem Governance The party being interviewed also mentioned that there is a need for ecosystem governance. The best way of managing all players inside the ecosystem and assuring that the ecosystem reaches decarbonisation progress as an entity is by governing the ecosystem as a whole.

Business Performance Management The interviewee also implied that the management strategies should be at a business performance level, so they should include the financial, environmental and industrial perspectives. This is of utmost importance since currently there is a lot of focus on the finical perspective and for clear progress, there needs to be a balance between the three.

Setting up a Communication Capability between Complementary Parties in an Ecosystem The expert mentioned that currently for two distinct complementary companies to work together implies a very long process of creating a collaboration process between the two. For this reason, having preset communication capabilities within the ecosystem can help facilitate the communication time by reducing the receptive collaboration formation.

Energy Transition Intelligence The expert mentioned how energy system intelligence implies also the need for energy transition intelligence since the transition process is very elaborate.

Financial Risking for your Customer The interviewee also explained how chaining the type of fuel is not enough since the customers will still be reticent to adopt new solutions. In order to support the fuel change, the energy companies need to support the customers in the transition by assuming the financial risk for the customer. This not only refers to large customers since the goal is to facilitate the transition for the small customers as well.

Having Nature-based Solutions Unlike all capabilities discussed before, the expert has suggested Nature-based solutions as a parallel way of improving the current natural environment. This solution does not aim to improve the process or reduce the number of flights but to increase sustainability outside the aviation industry. Nature-based solutions are projects which aim to protect, transform or restore the natural environment around. They aim to help nature absorbs more CO_2 emissions. An example of this project is planting trees.

Running the Network Running the network is a terminology originating from internet marketing however, it has been applied to our context by the expert. In the case of the research, running the network should result in lower emissions instead of lower prices.

Managing the People Ecosystem People Ecosystem Management focuses on the people taking part in the ecosystem. In order to assure the sustainability of an ecosystem, one needs to make sure that all people involved understand and share the same sustainability goals.

Managing the Partner Ecosystem Partner Ecosystem Management refers to the collaboration between an enterprise and its partners. When focusing on decarbonisation, one company should assure a transparent process which encourages all partners to focus on decarbonisation as well.

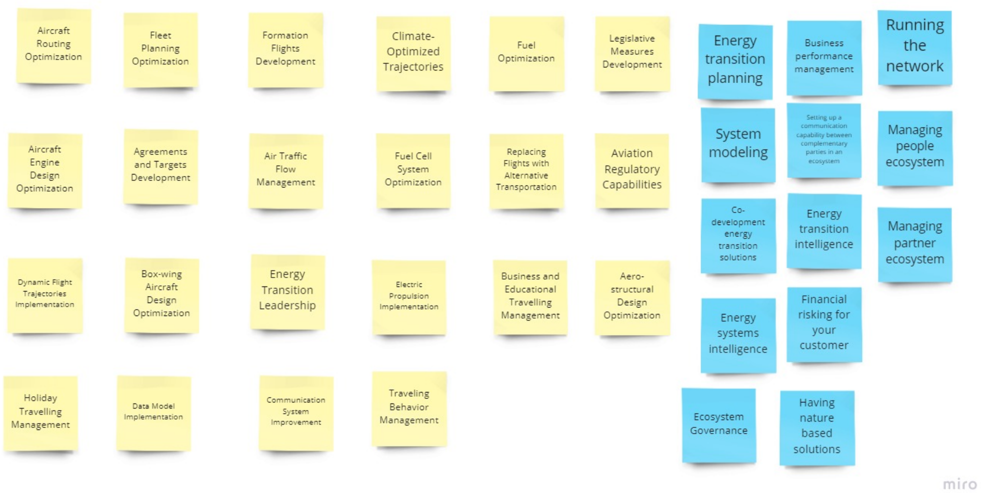

FIGURE D.7: Capability List for Interview Round I Respondent 4

D.3.4.2 Literature Recommendation

The expert has not recommended any literature in particular.

D.3.4.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.8.

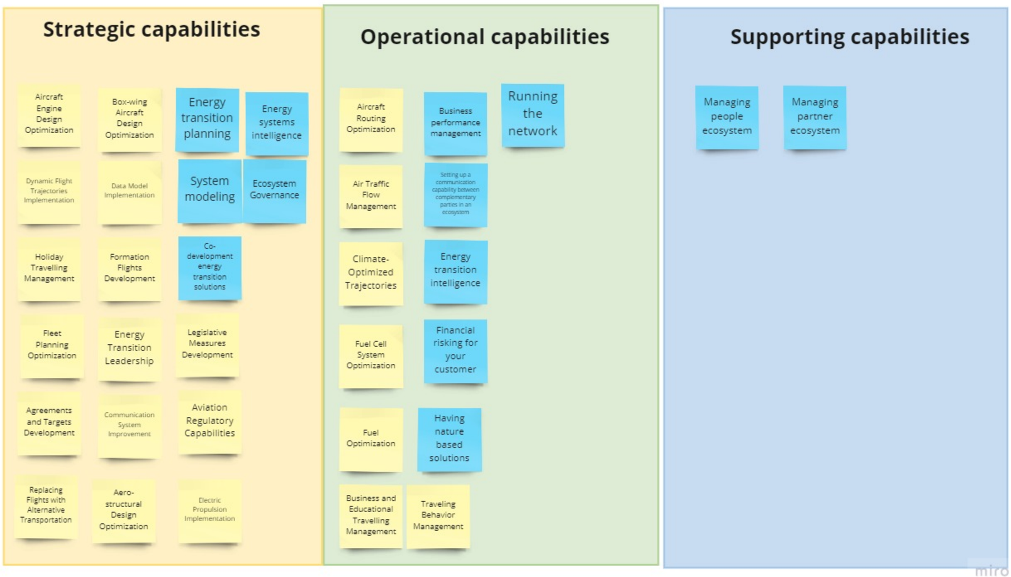

FIGURE D.8: Capability Categorisation for Interview Round I Respondent 4

D.3.5 Interview Round I - Respondent 5 (I1-R5)

During this interview, the following results can be defined:

D.3.5.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added 3 new capabilities to the list. The capabilities added by the expert aimed to focus on sustainable fuel. The Capability Miro Board after the interview can be found in Figure D.9.

Integrated Value Chain Collaboration The expert explains the need for an integrated upstream, from the fuel value chain, in order to align the communication between all parties involved. Decentralized projects of making hydrogen or refinery are not enough to assure the transition to sustainable fuels.

SAF Production SAF are Sustainable Aviation Fuels. The expert explained this as hydrogen derivatives fuels and gave an example of e-kerosene.

Clean Hydrogen Production This is the feedstock needed for producing SAF, which most of the time comes from smaller parties which are hard to supervise. Making sure the entire hydrogen production process is clean is very important to assure the sustainability of hydrogen-based fuels.

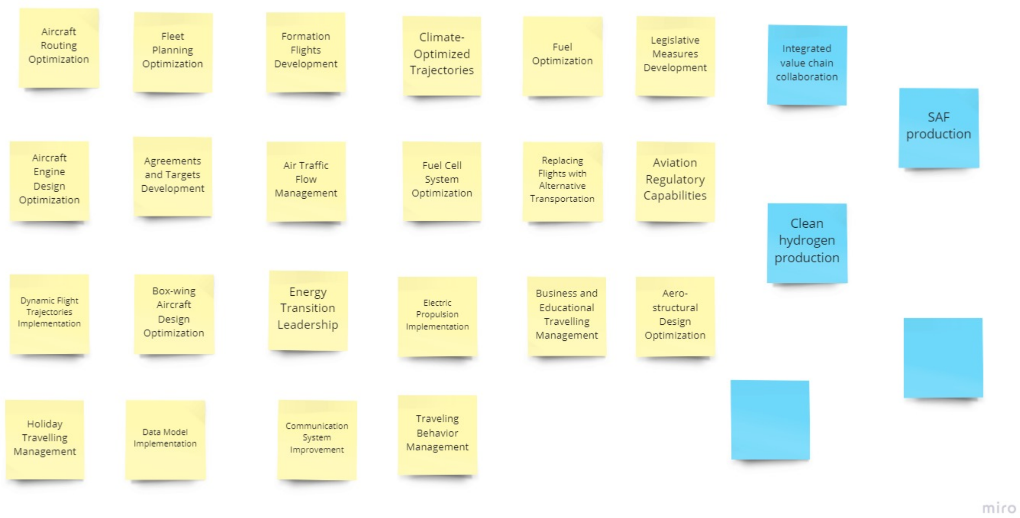

FIGURE D.9: Capability List for Interview Round I Respondent 5

D.3.5.2 Literature Recommendation

The expert has recommended the report "Decarbonising Aviation: Clear for Take-off" report as a source of potential additional decarbonisation capabilities from an ecosystem perspective [98].

The report presents Decarbonisation Readiness Framework which focuses on the main readiness factors:

1. Market and customer demand
2. Regulatory incentives
3. Technology alignment
4. Clarity on roles and decision making
5. Ease of asset replacement
6. Ease of infrastructure replacement

These factors have been considered for the research due to their specific views on the decarbonisation process. Additionally, capabilities have been formulated based on these factors.

Market and Customer Demand Management "Pressure and incentives from society, customers, financiers and investors, which creates motivation for aircraft, engine and propulsion manufacturers, owners and operators to invest in lower-emission technologies." [98].

Regulatory Incentives Implementation "Instruments applied by regional and local authorities. These can include incentives such as grants and tax cuts, and disincentives such as fines, carbon credits and carbon levies." [98].

Technological Alignment "Technical and commercial viability of alternative fuels and other lower-emission technologies, and clarity on development pathways." [98].

Optimizing the Decision Making "The ease in making decisions, clarity on roles and responsibilities, and alignment of priorities for key stakeholder groups in the sector." [98].

Optimizing the Replacement of Assets "What it takes to replace or upgrade the fleet. This depends on cost, complexity and lifespan, the rate at which alternative technologies are developed, and the impact alternative technologies have on fleet operations." [98].

Optimizing the Replacement of Infrastructure "What it takes to set up production of green fuels at scale, deliver them to airports and prepare for charging or fuelling. The more production capacity needed, the more dispersed the infrastructure, the greater the challenge." [98].

Aside from the above-mentioned information, the Decarbonising Aviation report offers a lot of interesting information regarding the current state of the industry as well as potential improvements towards decarbonisation. This report is considered complimentary literature to this research [98].

D.3.5.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.10.

D.3.6 Interview Round I - Respondent 6 (I1-R6)

During this interview, the following results can be defined:

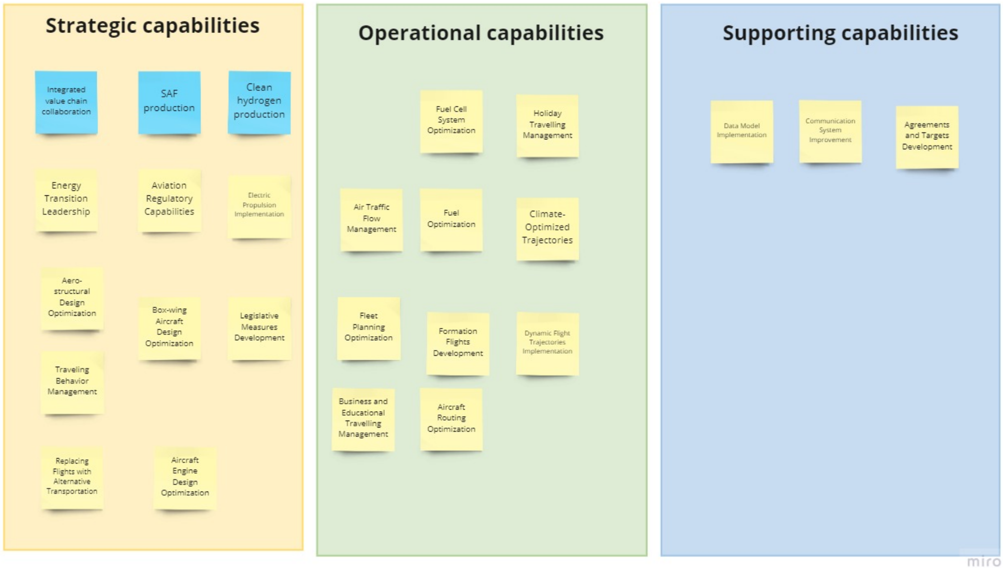

FIGURE D.10: Capability Categorisation for Interview Round I Respondent 5

D.3.6.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added 5 new capabilities to the list. The capabilities added by the expert aimed to focus on a sustainable future. The Capability Miro Board after the interview can be found in Figure D.11.

Moral Leadership/Ethics Code The expert noted that doing the green thing is not always the most profitable approach. For this reason, it is very important to operate in a moral way despite the pressure from the shareholders. Having a code of ethics or a moral action is needed in order to avoid unsustainable decisions. The expert also gave the example of plains flying empty in order to keep the airport slots as a very cost driven immoral action.

ReductionShrinking The interviewee mentioned how in the aviation ecosystem there is a lot of growth management and there is a clear tendency toward growth in all aspects. However, this growth is not in line with the sustainability goals, which require a clear reduction of the current operations. ReductionShrinking management is the capability defined by the expert as the ability to manage and implement reduction inside the ecosystem.

Traffic Reduction Realize how long aircraft are currently being in holding patterns because they are approaching the limits of aerospace. Reducing the traffic by reducing the number of flights being operated daily.

Collaborate The expert also mentioned collaboration as a key capability in the aviation ecosystem. Progress can be easier reached by working together rather than separate. The example was given about aircraft routing optimization together with more airlines.

Ask the Right Questions This capability comes from a more philosophical perspective and refers to human management. Being able to ask yourself "Is this making the world a better place?" for each action you are taking can make one reflect on the impact of your actions. Most people nowadays are not aware of the impact flying has on the ecosystem as this topic is not very popular in the media.

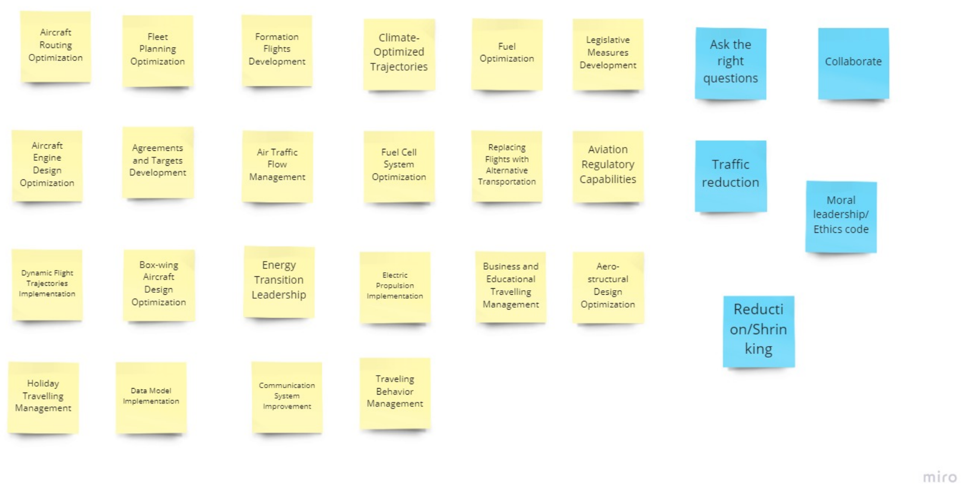

Figure D.11: Capability List for Interview Round I Respondent 6

D.3.6.2 Literature Recommendation

The expert has not recommended any literature in particular.

D.3.6.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.12.

D.3.7 Interview Round I - Respondent 7 (I1-R7)

During this interview, the following results can be defined:

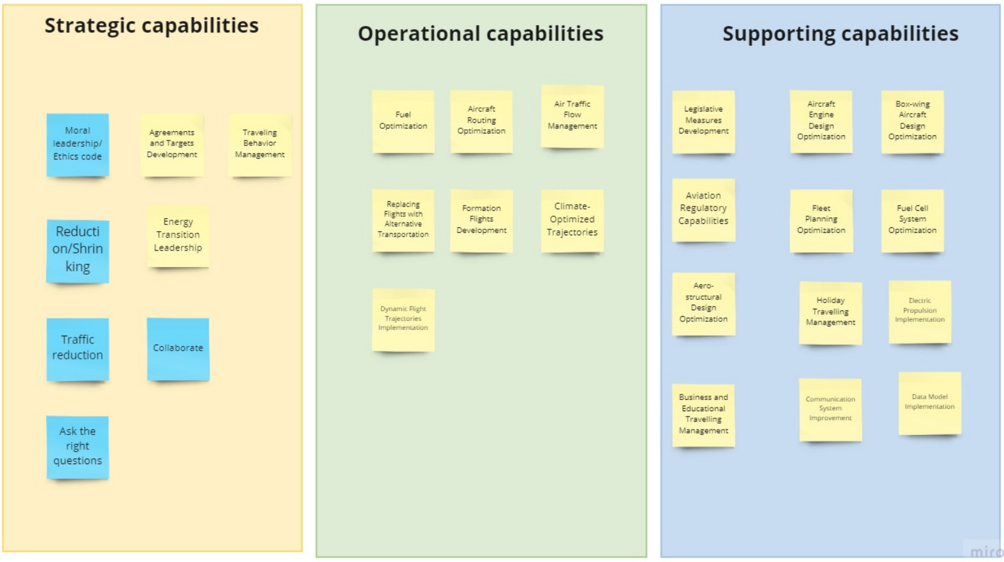

FIGURE D.12: Capability Categorisation for Interview Round I Respondent 6

D.3.7.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added 6 new capabilities to the list. The capabilities added by the expert aimed to focus on a sustainable supply chain. The Capability Miro Board after the interview can be found in Figure D.13.

Brundtland Report Sustainability Definition The expert mentioned that one interesting way of increasing awareness and placing the focus on sustainability is to remember the original definition of sustainable development "Sustainable development is, in essence, a development that meets the needs and aspirations of the present generation without destroying the resources needed for future generations to meet their needs." [101]. The expert hopes that through being aware of the meaning of sustainability, people will be more inclined to act responsibly.

Taxi-bot for moving the plane around at the airport By mentioning this, the expert refers to the newly developed technology of using robotic taxi machines to move and facilitate ground operations. This technology aims to provide sustainable taxiing and drastically decrease the on-ground operations' emissions.

Food waste reduction The expert went one step further and looked at the in-flight cabin sustainability. Heshe also mentioned that there is a lot of food waste, as well as plastic usage for the in-flight services. Although improving those will not have the highest reduction effect right away, it can for sure provide a more sustainable flight and reduce the carbon emission from the supply chain throughout the value chain.

Ownership-based model The expert talked about this model in order to emphasize that leasing is more sustainable than purchasing when it comes to the relationship between an airline and its fleet. The expert used the paper by Bocken et al. to emphasize the application of the ownership-based model [102]. Lastly, it was mentioned how this type of model allows the usage of more modern aircraft which are designed to emit less, rather than using older models until the end of product life.

Expanding the offer This capability refers to the alternative ways of transport providers such as trains or busses, especially for short routes. The expert mentioned that by improving the offer of alternative transport, the number of flights can be reduced. The expert said that the alternative transportation needs to reduce the costs, increase the reliability and increase the service in order to match compete with air-based solutions.

Shift in mindset Creating a shift in the mindset of the population is very important when influencing the travelling behaviour of people. Using tools such as influencers or role models can increase the general focus on aviation sustainability.

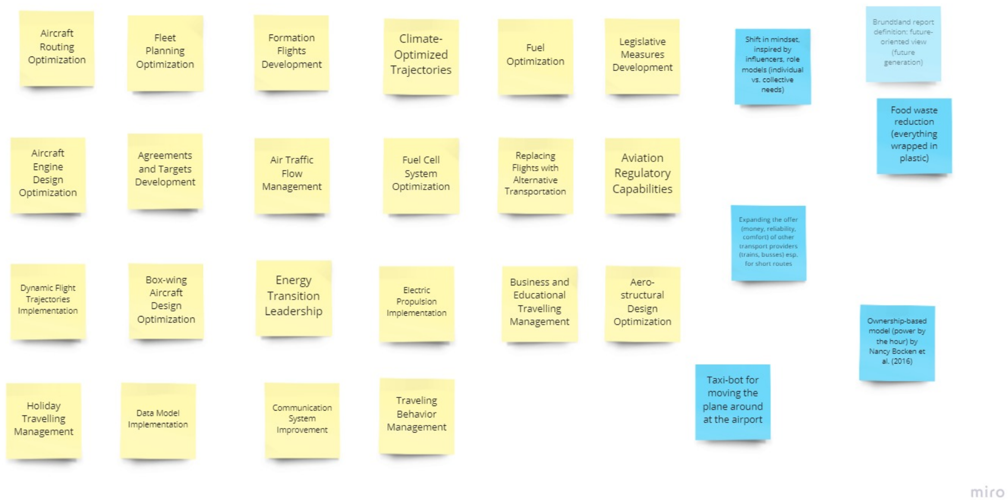

FIGURE D.13: Capability List for Interview Round I Respondent 7

D.3.7.2 Literature Recommendation

The expert has recommended one paper, however,heshe already mentioned the capability that was extracted from that paper. The recommended literature is ”Product design and business model strategies for a circular economy” [102].

D.3.7.3 Capability Classification

During the interview, the subject was also requested to classify the capabilities based on their type with the use of the Miro Board. The visualisation of the capability categorisation can be found in Figure D.14.

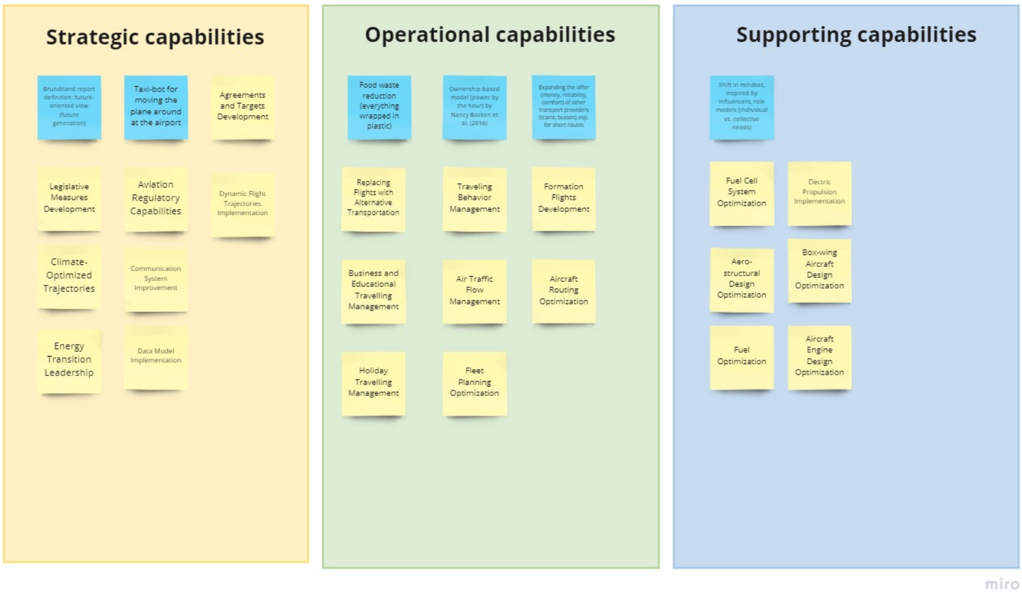

FIGURE D.14: Capability Categorisation for Interview Round I Respondent 7

D.3.8 Interview Round I - Respondent 8 (I1-R8)

Due to the busy schedule of the expert interviewed the interview was divided into two distinct meetings. However, because the interviewee has encountered medical problems, the second part was cancelled. Subsequently, the interview included the full introduction part and capabilities part, while the capability categorisation has been removed. During this interview, the following results can be defined:

D.3.8.1 Capabilities

The party interviewed has considered all capabilities provided by literature valuable. Moreover, the expert interviewed had added 6 new capabilities to the list. The capabilities added by the expert aimed to focus on sustainable ecosystem development. The Capability Miro Board after the interview can be found in Figure D.15.

Visible and traceable emission data The ability to measure the emission through the entire value chain and have this information visible to all players in the ecosystem.

Tracing the exact moments of the emission can be used for decision making at a global level.

Measure, quantify and audit the emissions The ability to measure the emission through the entire value chain and quantify the exact emissions. Being able to measure the emissions in a singular way throughout the ecosystem as well as audit the results at the end. Verifying that the measures worked should be done in an unbiased way by an auditing firm.

Solution portfolio A documentation of all clear solutions that can help reduce emissions at every level of the value chain.

Reduce emission from kerosene supply chain The supply chain of kerosene (collecting the oil, transportation, process and usage) is also a place where there is a need for emission reduction. Given that kerosene will not immediately be replaced.

Financing sustainable solutions Using distinct players inside the ecosystem and even outside to reduce the costs. An example can be encouraging banks to support (give credits) sustainable companies rather than have less CO2 impact. Another example is increasing the price of each flight to make it more sustainable. All these options aim to take the pressure on the airline or the government to sponsor the decarbonisation.

Alternative fuels implementation Using alternative fuels which have a less environmental impact and developing them at a level which allows them to replace kerosene-based fuels.

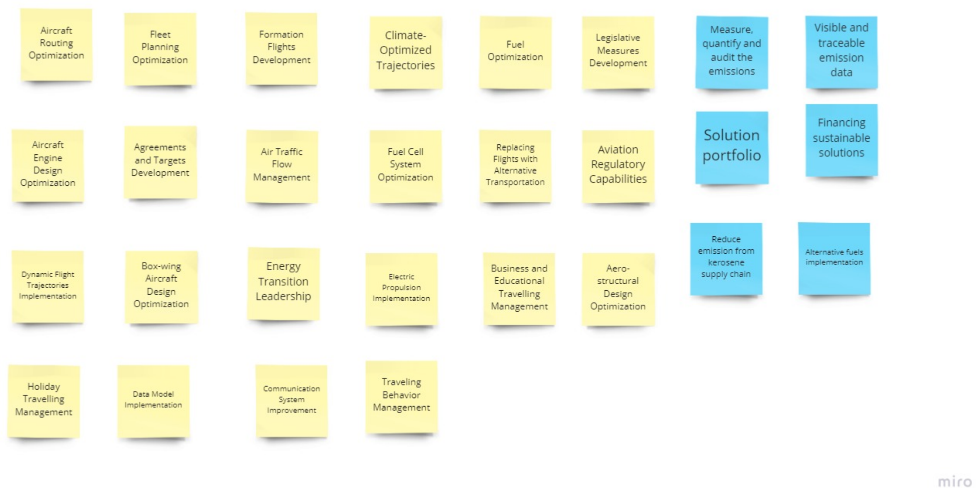

FIGURE D.15: Capability List for Interview Round I Respondent 8

D.3.8.2 Literature Recommendation

The expert has not recommended any literature in particular.

D.3.9 Interview Round I - Respondent 9 (I1-R9)

Due to the virtual nature of this meeting and the preference of the interviewee, this interview has been conducted through a phone call. Because of the lack of visual aids, the structure of the interview was updated by excluding the interactive segments of Miro Boards. Subsequently, the interview included the full introduction part and the first question about capabilities, while the rest has been removed. During this interview, the following results can be defined:

D.3.9.1 Capabilities

The party interviewed has not validated the literature capabilities due to the audio nature of the interview. However, the expert interviewed had mentioned and described 7 capabilities. These capabilities will be listed and described in the following section.

Aircraft Technology Development The expert mentioned that it is very important there are current investments in aircraft technology development. Despite plains becoming more and more sustainable with each new model, the interviewee also empathized that since jet fuel, there have not been any revolutionary changes in the field. Lastly, it was emphasised that the airline has not had a very big impact on the sustainability of the plane and that the best practice for the airline is to consider sustainability when purchasing new aircraft.

Flight Operations Optimization The expert mentioned this as a very important point of emission reduction, however, heshe also admitted that the reduction encountered here is rather minor. Lastly, it was discussed the need for communication between all parties affecting the flight process.

Fuel Development The interviewee mentioned that fuel development is the key capability here and that airlines need to show commitment to producers in order to encourage the development of sustainable fuels.

Sustainability Tax Handling From an airline perspective the sustainability tax is currently not encouraged as it has no clear focus on development. The need for a clear plan of using the money collected from taxation by reinvesting them in the industry to help decarbonise is vital. The expert emphasised that a clear and transparent way of handling sustainability taxation is needed.

Full-service Alternatives Optimisation The interviewee emphasised the need for full-service alternatives, as currently the infrastructure, cost, safety, service and comfort of the train travelling or bus travelling do not reach the airline standards. It was also discussed that the airlines encouraged alternative travel for the short distances provided that the quality is in line with their expectation.

Science-Based Targets Implementation Science-Based targets are goals set by a business to reduce GHG emissions. A target is considered 'Science-Based' when it is in line with the scale of reductions required to keep global warming below 2 degrees Celsius. Implementing such targets will assure that all companies focus on the same goals and follow the same paths.

Awareness The expert mentioned that it is very important to make people aware of the emissions caused by flying. This will encourage the customers to opt for a more sustainable airline and will ultimately result in encouraging all airlines to become more sustainable.

D.4 Interview Round II

In this section, Table D.1 shows all processes obtained during the interviews. The interview notes have been included, which contain the description of all processes added. Moreover, the notes of each interview will contain two Miro Board parts. The first board will include the capability map combined by the experts with The Open Group Model capability map for the specific focus area of each specific interview. In the second interview round, the visual representation of the Miro Boards of the final reference model includes the business process for each specific focus area.

Additionally, the parts of the model taken from The Open Group Model have been underlined. As mentioned before, The Open Group Model was focusing only on the Aviation industry, while the model constructed in this research contains information about the entire ecosystem. For this reason, the expert-based models are more extensive and have a larger focus. Additionally, the parts of The Open Group Model which did not align with the sustainability goals have been removed or redesigned by the experts. In some cases, the experts emphasised the fact that The Open Group Model is very different to a decarbonisation model as it reflects the current status of the industry and the industry that is cost-oriented rather than sustainable.

For this reason, in the following models, the Blue capabilities represent the parts taken directly from The Open Group Model. The Green capabilities represent parts that have been taken from The Open Group Model with slight modifications. All the other capabilities and processes have been added by the experts in order to include the entire ecosystem and meet the sustainability goals. Lastly, since the Fuel Management focus was not included in The Open Group Model, the model for Fuel Management does not contain any parts from The Open Group Model.

D.4.1 Interview Round II - Focus 1 (I2-F1)

The following figure provides both the Capability Map and the Reference Model for Ground Operation built by the expert during thee session.

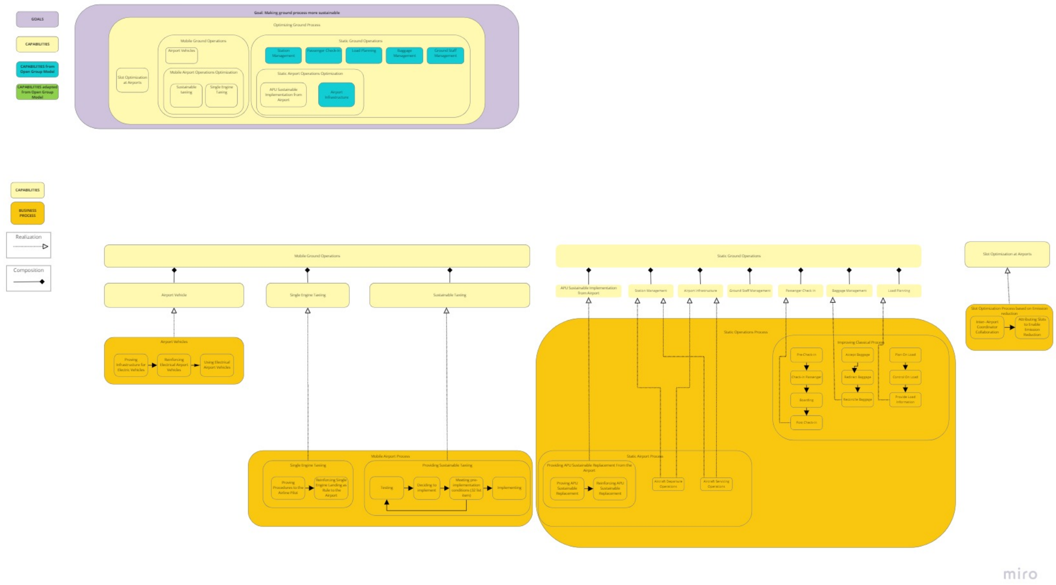

FIGURE D.16: Miro Board for Interview Round II - Focus 1: Ground Operation

D.4.2 Interview Round II - Focus 2 (I2-F2)

The following figure provides both the Capability Map and the Reference Model for Flight Operations built by the expert during thee session.

D.4.3 Interview Round II - Focus 3 (I2-F3)

The following figure provides both the Capability Map and the Reference Model for Aircraft Design built by the expert during thee session.

D.4.4 Interview Round II - Focus 4 (I2-F4)

The following figure provides both the Capability Map and the Reference Model for Fuel Management built by the expert during thee session.

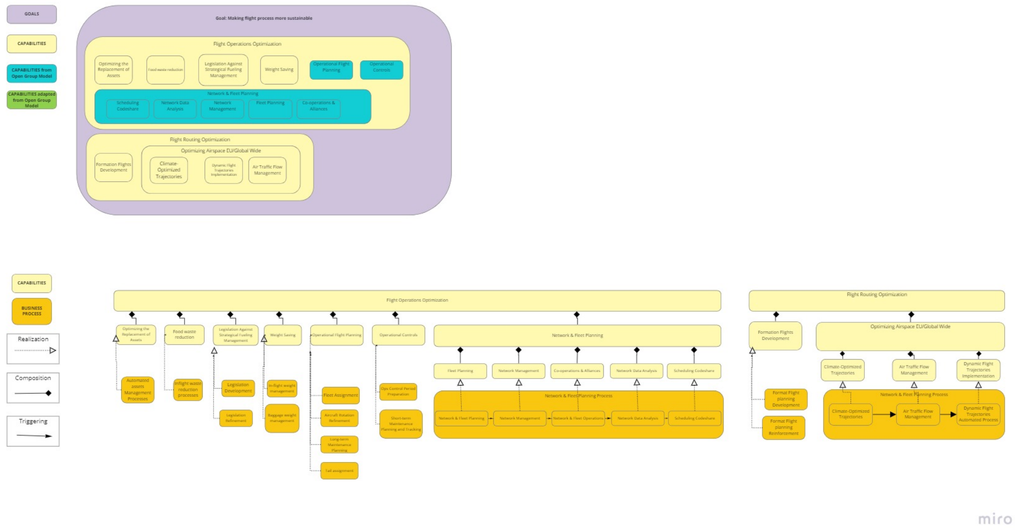

FIGURE D.17: Miro Board for Interview Round II - Focus 2: Flight Operations

D.4.5 Interview Round II - Focus 5 (I2-F5)

The following figure provides both the Capability Map and the Reference Model for Ecosystem Management for Flights Improvement built by the expert during thee session.

D.4.6 Interview Round II - Focus 6 (I2-F6)

The following figure provides both the Capability Map and the Reference Model for Ecosystem Management for Flights Reduction built by the expert during thee session.

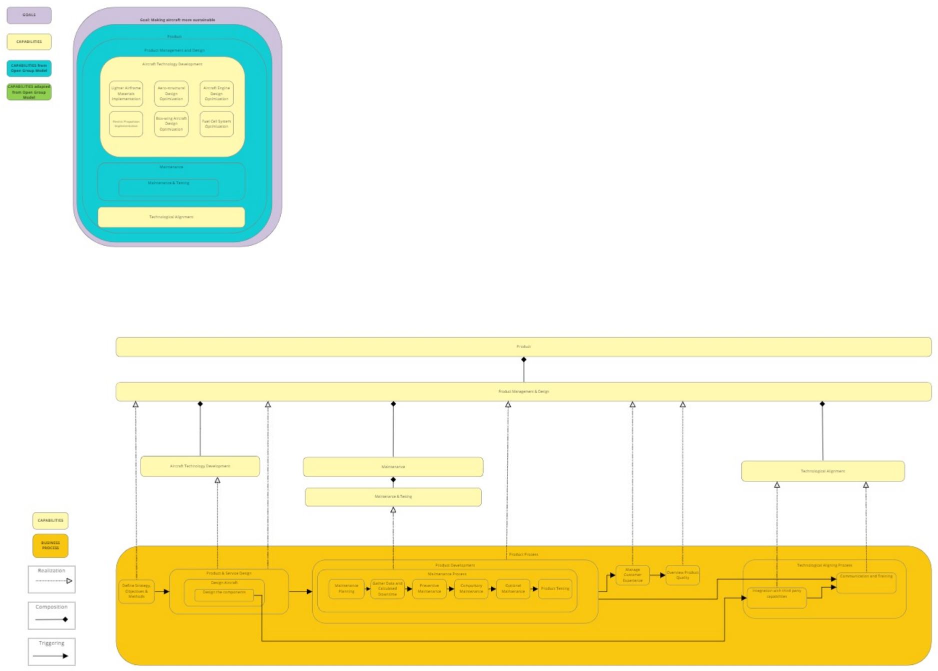

FIGURE D.18: Miro Board for Interview Round II - Focus 3: Aircraft Design

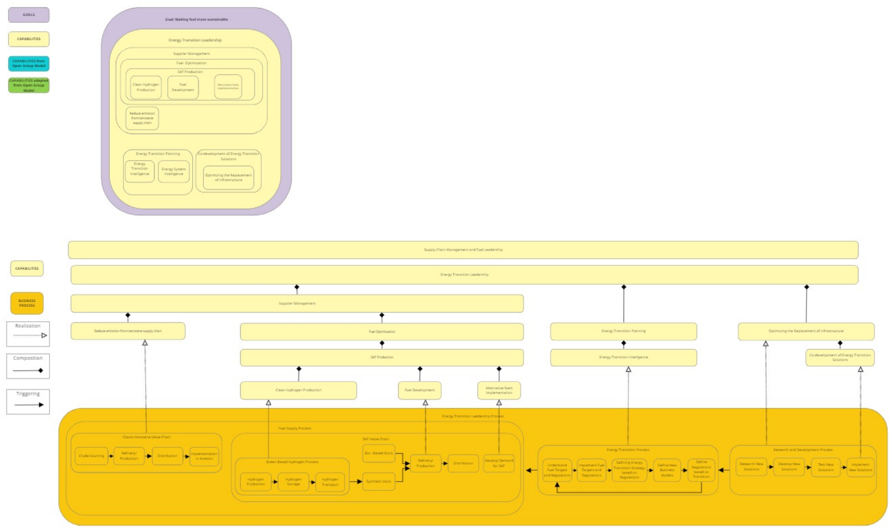

FIGURE D.19: Miro Board for Interview Round II - Focus 4: Fuel Management

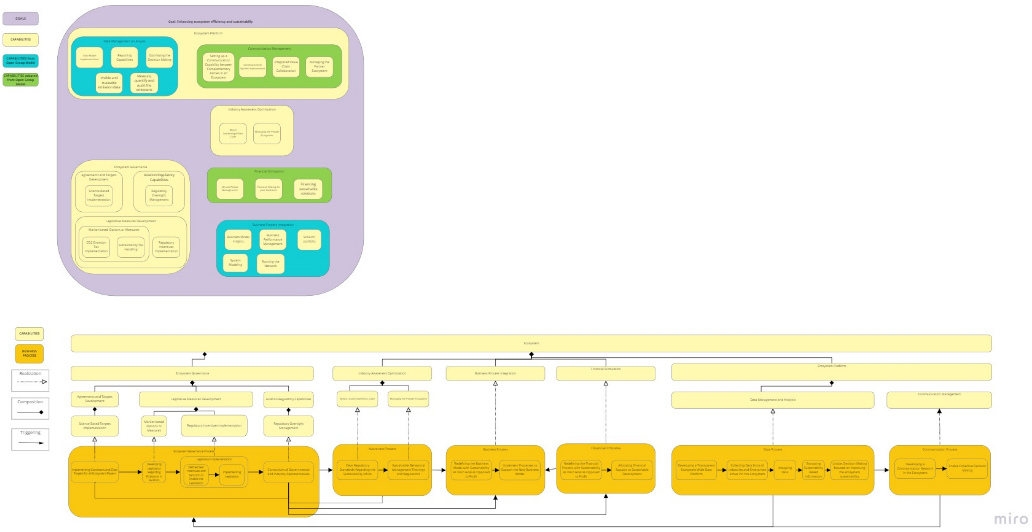

FIGURE D.20: Miro Board for Interview Round II - Focus 5: Ecosystem Management for Flights Improvement

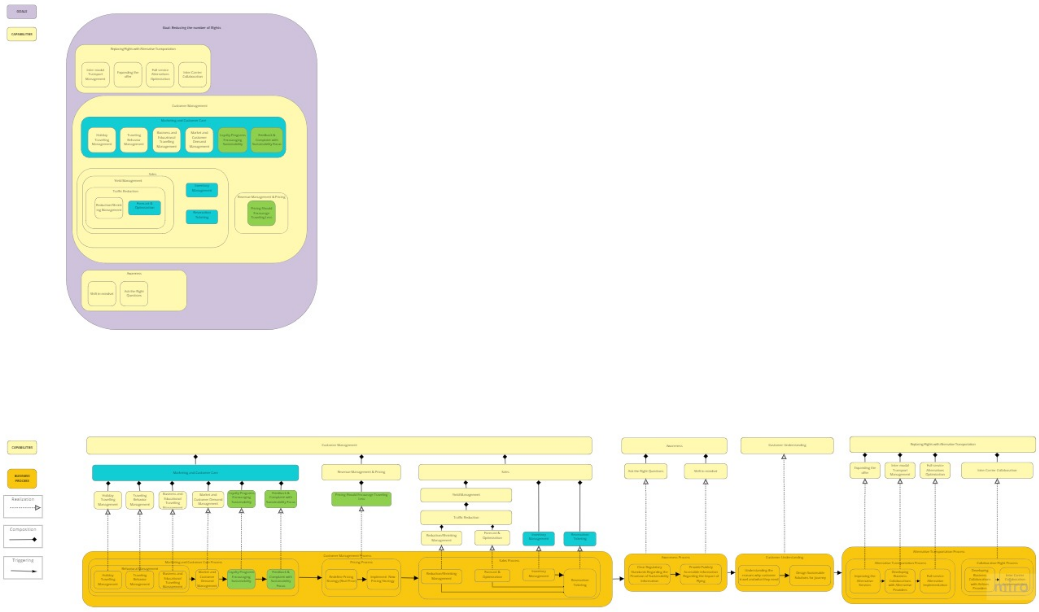

FIGURE D.21: Miro Board for Interview Round II - Focus 6: Ecosystem Management for Flights Reduction

Appendix E

Treatment Design Models

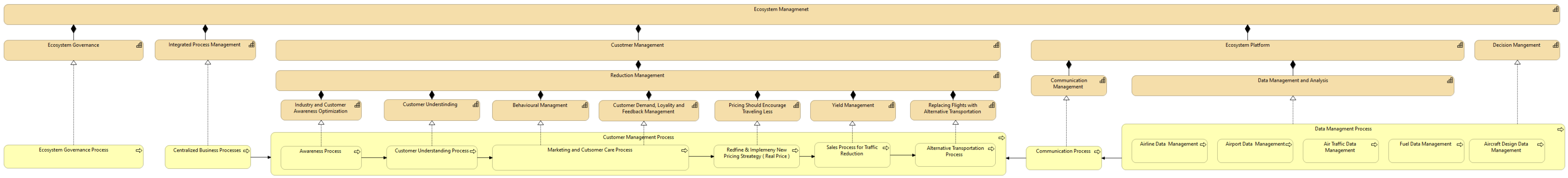

Figure E.1: Integrated Model

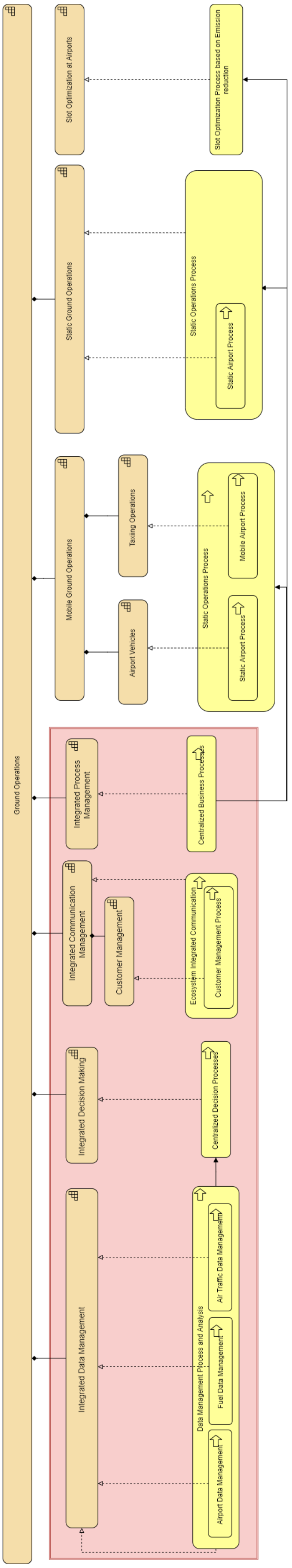

FIGURE E.2: Ecosystem Core integrated in Ground Operations

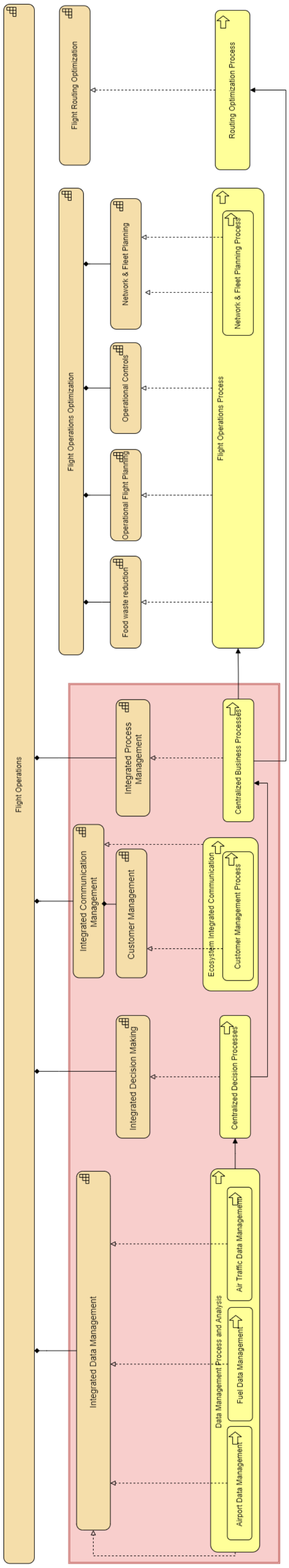

FIGURE E.3: Ecosystem Core integrated in Ground Operations Flight Operation

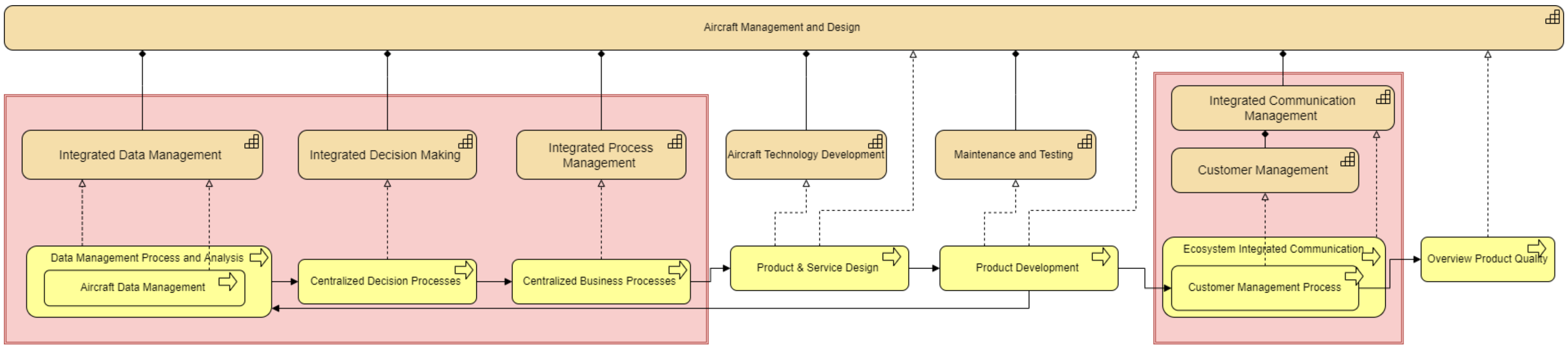

FIGURE E.4: Ecosystem Core integrated in Aircraft Design

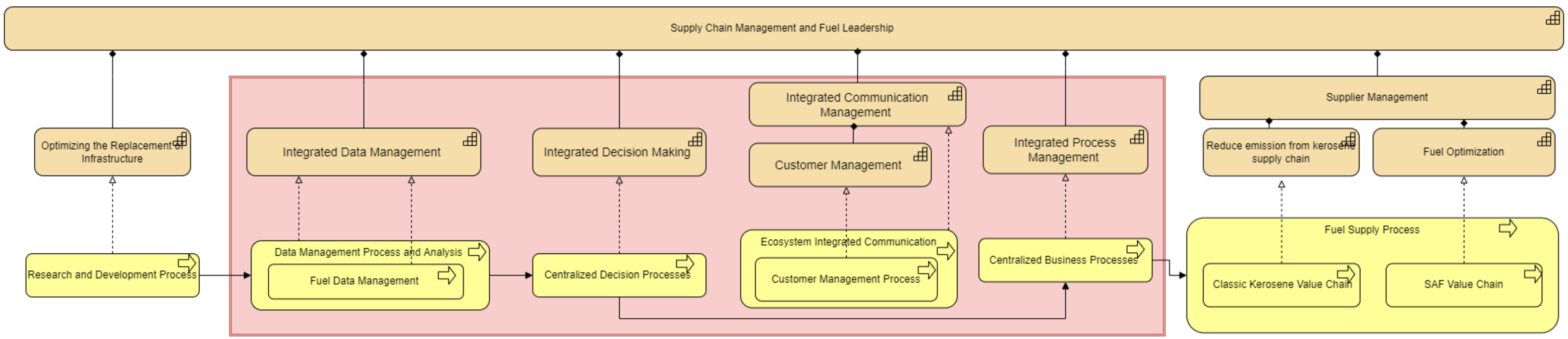

FIGURE E.5: Ecosystem Core integrated in Fuel Management

Appendix F

Validation Guide

This chapter contains a deception of the validation processes, together with an elaborated explanation of the Validation Interview process.

F.1 Business Case Validation Session

The following section describes in-depth the validation interview.

F.1.1 Background

Based on the two rounds of interviews previously conducted, a clear Capability Model 5.10 has been defined. This model is the main artifact of this paper and will be validated based on a business case. Additionally, the particular models developed during the second round of interviews will be validated.

F.1.2 Goals

To achieve the goal of this research, the following goals have been defined for the validation interview:

1. Validate the specific Capability Model for each of the focuses
2. Validate the integrated Capability Model by a business case

F.1.3 Interview Protocol

In this section, the protocol for the Standardized Open-ended Interviews is described. This type of interview can be classified as a semi-structured interview. The protocol serves as the primary guideline during the interviews and ensures that all necessary questions are appropriately addressed and answered.

Introduction

Introduce the purpose of the validation interview

Permission

Before we continue, I would like to ask for your permission to record the interview. The recording will be deleted shortly after the interview, and it will be used to fill the gaps in the interview notes.

Background information

The results of this interview will be used only as a validation method for my Master Thesis. The only personal information which will be mentioned in the paper is your job title, as well as your area of expertise. However, if you consider any of the two to be too private, it can all be anonymised. Also, if you want to keep your personal information private from the other interviewees, you do not have to share your name or any information.

If during the interview you consider any information shared sensitive information this information will not be taken into consideration or noted down. This interview will take up around 2 hours of your time.

Lastly, it is important to know that this research is conducted by the University of Twente as public academic research.

Introducing questions

- Could you please introduce yourself?
- Can you tell me something about your professional background?
- Could you elaborate upon your current experience with working in aviation/ architecture decarbonisation?
- What is/was your role regarding in the example you just gave? What was your role?

Case Study

Based on the visual of the final Integrated Capability Model, Figure 5.5, with a focus on the Ecosystem Core 5.5, the experts will be asked to answer the questions presented in Table F.1.

Has an **Ecosystem** been considered when defining the strategy to reduce emission?	Yes ( )			No ( )	
In your opinion, how relevant is an **Ecosystem** to emission reduction?	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?					
Do you find the **Ecosystem** approach relevant for reaching decarbonisation goals?	Yes ( )			No ( )	
In your opinion, how relevant is the **Ecosystem** approach for reaching decarbonisation goals?	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?					
Do you find **this research** relevant for decarbonising aviation?	Yes ( )			No ( )	
In your opinion, how relevant is **this research** for reaching decarbonising aviation?	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?					

FIGURE F.1: Business Case Validation Questions

Models

Based on the visualisation of the following models: Ground Operations 4.6, Flight Operations 4.7, Aircraft Design 4.8 and Fuel Management C.9, the experts will be asked to answer the questions presented in Table F.2.

Have **Flight Operations** been considered when defining the strategy to reduce emission?	**Yes ( )**			**No ( )**	
In your opinion, how relevant are **Flight Operations** to emission reduction?	**1 ( )**	**2 ( )**	**3 ( )**	**4 ( )**	**5 ( )**
Can you please elaborate on your relevance decisions?					
Have **Ground Operations** been considered when defining the strategy to reduce emission?	**Yes ( )**			**No ( )**	
In your opinion, how relevant are **Ground Operations** to emission reduction?	**1 ( )**	**2 ( )**	**3 ( )**	**4 ( )**	**5 ( )**
Can you please elaborate on your relevance decisions?					
Has **Aircraft Design** been considered when defining the strategy to reduce emission?	**Yes ( )**			**No ( )**	
In your opinion, how relevant is **Aircraft Design** to emission reduction?	**1 ( )**	**2 ( )**	**3 ( )**	**4 ( )**	**5 ( )**
Can you please elaborate on your relevance decisions?					
Has **Fuel** been considered when defining the strategy to reduce emission?	**Yes ( )**			**No ( )**	
In your opinion, how relevant is **Fuel** to emission reduction?	**1 ( )**	**2 ( )**	**3 ( )**	**4 ( )**	**5 ( )**
Can you please elaborate on your relevance decisions?					
Do you find the use of **architecture** relevant in this context?	**Yes ( )**			**No ( )**	
In your opinion, how relevant are these models for visualizing the emission reduction opportunities in each industry?	**1 ( )**	**2 ( )**	**3 ( )**	**4 ( )**	**5 ( )**
Can you please elaborate on your relevance decisions?					

FIGURE F.2: Models Validation Questions

Treatment effects

- **"How does this treatment perform compare to other possible treatments?"[86].**
- What are the differences you see between this treatment and other current treatments? Which one would you choose?
- Do you find the partial models or the integrated treatment more relevant?

- **"Would the treatment still be effective and useful if the problem changes?"[86].**
- What would happen if the problem becomes larger or more focused?
- What would happen if the problem is compounded with other problems (ex. other emissions brought in scope)?

F.1.4 Resources

During the last round of interviews, the visual of 4 capability models presented in the Results, Section 4.3, will be used (Ground Operations 4.6, Flight Operations 4.7, Aircraft Design 4.8 and Fuel Management 4.9). Additionally the visual of the final Integrated Capability Model, Figure 5.5, with focus on the Ecosystem Core 5.5 will be used.

F.2 Future Work Validation Session

The following section describes in-depth the Future Work validation interview.

F.2.1 Background

Based on the two rounds of interviews and the validation interview previously conducted, a suggestion was made for future work and research. To validate the continuity of the research, the model for Ground Operation was extended.

F.2.2 Goals

In order to achieve the goal of this research, the following goals have been defined for the future work validation interview:

1. Validate the Ground Operation model in a real business context
2. Validate the extension with the model with the application layer
3. Validate the need for an ecosystem from the perspective of Ground Operations

F.2.3 Interview Protocol

The interview protocol for the Future Work validation interview is almost identical to the Interview Protocol for the validation interview F.1.3. The only adjustments were made in the questions asked. The questions used for this interview can be found in Figure F.3.

Has a **Ground Operations Architecture** been considered when defining the strategy to reduce emissions?	Yes ( )			No ( )	
Can you please elaborate on your decisions?					
Has an **Ecosystem** been considered when defining the strategy to reduce emission?	Yes ( )			No ( )	
Can you please elaborate on your decisions?					
Do you find the **Ecosystem** approach relevant for reaching decarbonisation goals?	Yes ( )			No ( )	
In your opinion, how relevant is the **Ecosystem** approach for reaching decarbonisation goals?	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?					
Do you find **this research** relevant for decarbonising aviation?	Yes ( )			No ( )	
Can you please elaborate on your decisions?					

FIGURE F.3: Ground Operation Validation Questions

F.2.4 Resources

The resources for this interview can be found in Section 6.4.

Appendix G

Validation Results

G.1 Business Case Validation Results

	Expert 1					Expert 2				
Has an **Ecosystem** been considered when defining the strategy to reduce emission?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant is an **Ecosystem** to emission reduction?	1 ( )	2 ( )	3 ( )	4 ( )	5 (x)	1 ( )	2 ( )	3 ( )	4 ( )	5 (x)
Can you please elaborate on your relevance decisions?	In the current case, the expert makes use of ecosystem as thor current approach focuses of bringing more parts of the value chain together.					The expert's current focus is on ecosystems and considers the need of working together as an ecosystem vital.				
Do you find the **Ecosystem** approach relevant for reaching decarbonisation goals?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant is the **Ecosystem** approach for reaching decarbonisation goals?	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )	1 ( )	2 ( )	3 (x)	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?	If you can create the ecosystem platform and continuously assess the members and have continuous drives, it will help a lot reaching goals.					Setting the ecosystem and maintain its functionality will be quite challenging, but one the ecosystem is in place it will help reach the goals.				
Do you find **this research** relevant for decarbonising aviation?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant is **this research** for reaching decarbonising aviation?	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )
Can you please elaborate on your relevance decisions?	This research provides a lot of new information and is very relevant.					Very relevant research. Future work needs to be done but this can be very relevant.				

FIGURE G.1: Results from Business Case based Validation

	Expert 1					Expert 2				
Have **Flight Operations** been considered when defining the strategy to reduce emission?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant are **Flight Operations** to emission reduction?	1 ( )	2 ( )	3 (x)	4 ( )	5 ( )	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?	Since the reduction that can be reached by managing flight operation is not very big (around 20%).					The expert decided to not answer this question as it is not his area of expertise.				
Have **Ground Operations** been considered when defining the strategy to reduce emission?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant are **Ground Operations** to emission reduction?	1 ( )	2 (x)	3 ( )	4 ( )	5 ( )	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?	All players need to be there, but based on their impact on their own on decarbonisation, they are probably the ones that can influence the least.					The expert decided to not answer this question as it is not his area of expertise.				
Has **Aircraft Design** been considered when defining the strategy to reduce emission?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant is **Aircraft Design** to emission reduction?	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )	1 ( )	2 ( )	3 ( )	4 ( )	5 ( )
Can you please elaborate on your relevance decisions?	They are quite important as they can make very impactful changes in decarbonisation.					The expert decided to not answer this question as it is not his area of expertise.				
Has **Fuel** been considered when defining the strategy to reduce emission?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant is **Fuel** to emission reduction?	1 ( )	2 ( )	3 ( )	4 ( )	5 (x)	1 ( )	2 ( )	3 ( )	4 ( )	5 (x)
Can you please elaborate on your relevance decisions?	Realistically, they are the ones that can influence the most decarbonisation at the moment.					The expert said that based on his current knowledge they seem to be the most relevant ones.				
Do you find the use of **architecture** relevant in this context?	Yes (x)			No ( )		Yes (x)			No ( )	
In your opinion, how relevant are these models for visualizing the emission reduction opportunities in each industry?	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )	1 ( )	2 ( )	3 (x)	4 ( )	5 ()
Can you please elaborate on your relevance decisions?	As a person with not a lot of experience in architecture, the models are very relevant together with the explanation, but without the explanations. But they are definitely a plus.					Architecture is always relevant to getting people on the same page and sharing clear knowledge. But once the models will become more in depth the relevance will become 5.				

FIGURE G.2: Results from Model based Validation

G.2 Ground Operation Model Design

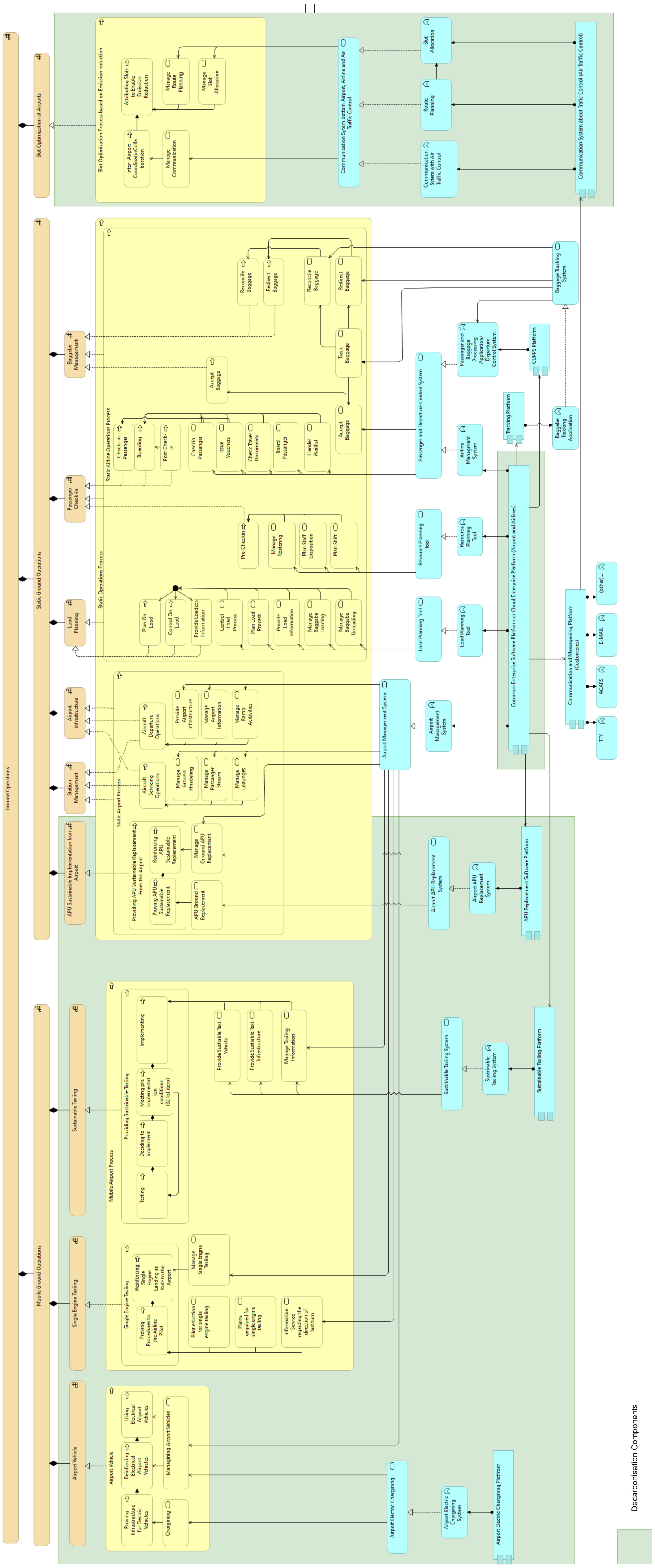

FIGURE G.3: Design Process for Desired Ground Operation Model

G.3 Future Work Validation Results

	Expert 3				
Has a **Ground Operations Architecture** been considered when defining the strategy to reduce emissions?	Yes ( )			No (x)	
Can you please elaborate on your decisions?	The expert has mentioned that they do not have a decarbonisation architecture, however a clear roadmap for decarbonisation has been created by the airport. This roadmap provides a structured overview of the emission reduction points and targets.				
Has an **Ecosystem** been considered when defining the strategy to reduce emission?	Yes ( )			No (x)	
Can you please elaborate on your decisions?	The expert has explained that there is no ecosystem in place from the perspective of a digital ecosystem platform, however, that there is a clear communication structure and ongoing communication channels with all parties involved. Currently this communication is taking place in person.				
Do you find the **Ecosystem** approach relevant for reaching decarbonisation goals?	Yes (x)			No ( )	
In your opinion, how relevant is the **Ecosystem** approach for reaching decarbonisation goals?	1 ( )	2 ( )	3 ( )	4 (x)	5 ( )
Can you please elaborate on your relevance decisions?	The expert has found the use of an ecosystem very interesting as it makes communication much more efficient and easy. It was also stated that an ecosystem wide communication platform can help with making the data more reachable.				
Do you find **this research** relevant for decarbonising aviation?	Yes (x)			No ( )	
Can you please elaborate on your decisions?	The expert found the research very useful and considers this approach very relevant. It was also mentioned that clear practical applicability can be found in the current business context and that this research will be considered by the enterprise represented by the expert.				

FIGURE G.4: Results from Extensive Ground Operation Model based Validation

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