Exploring uncharted skies

A European perspective on the impact of sustainable aviation fuels on business models across the air cargo industry value chain

Master Thesis

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Exploring uncharted skies

A European perspective on the impact of sustainable aviation fuels on business models across the air cargo industry value chain

by

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to obtain the degree of Master of Science in Management of Technology
at the Delft University of Technology,
to be defended publicly on Monday July 8, 2024 at 3:30 PM.

Student number:	5802830	
Project duration:	February 2024 - July 2024	
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Cover: Boeing 737 NG being refuelled

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Preface

Dear reader,

I am proud to share the final product of my academic research. The thesis you are about to read represents the formal ending of my two-year journey at Delft University of Technology, in which I pursued a Master's in Management of Technology. The compilation of this work would not have been possible without the continued support and guidance I received over the last five months.

I would like to express my gratitude to my first supervisor and chairperson, Jan Anne Annema. His guidance in refining the research question and problem definition greatly enhanced the relevance of this research. He motivated me throughout all the months in which I worked on this research, always giving me important suggestions and incentives. A special thanks goes also to my second supervisor, Linda Kamp, for her insightful comments and suggestions that really helped to improve the quality of this thesis. I also want to thank all the experts who took some time out of their day to answer my questions and provided interesting insights into this emerging field.

Carsten Höwelhans
Delft, July 2024

Summary

Aviation is one of the fastest-growing sources of greenhouse gas (GHG) emissions and continues to expand its emission footprint due to the growth of the global middle class and expanding international trade. Air cargo in particular is expected to grow rapidly over the next three decades at 4.1% globally, even outpacing expected growth rates for passenger air traffic. Abating emissions in aviation, however, is extremely challenging, making aviation a so-called hard-to-abate industry. Hard-to-abate industries typically have high energy consumption and limited options for decarbonization without substantial technological advancements or changes in industrial processes. Aviation is a hard-to-abate industry due to its strict operational requirements, limited potential for improvements to incumbent technologies, complex infrastructural requirements, a challenging market environment that leads to economic constraints, and the slow turnover of aircraft. Meanwhile, the importance of air cargo for the global economy is enormous because approximately 20% of international trade by value is transported by air while accounting for less than 1% by volume. Therefore, sensible decarbonisation strategies have to be outlined that preserve air cargo in its function as a catalyst for prosperity around the globe.

To achieve the aviation industry's net-zero emissions goal by 2050 the only feasible option for decarbonisation is the large-scale adoption of Sustainable Aviation Fuels (SAFs). SAF is a type of jet fuel that can be produced from biomass or electricity, reduces carbon emissions by up to 80% and has similar physical properties to conventional jet fuel, enabling its use in existing aircraft without modifications. Yet to date, adoption of SAF is extremely low at under 1% of total fuel consumption globally. The main barriers to large-scale diffusion of SAF are high production costs compared to conventional jet fuel and a lack of investments in new production facilities, leading to low availability of SAF. Nonetheless, policymakers and key industry actors are making tremendous efforts to drive the quick and reliable adoption of SAF. The USA, for instance, massively incentivises the domestic production of SAF through tax breaks as part of the "Inflation Reduction Act". Furthermore, the EU passed the "RefuelEU Aviation Act" in the fall of 2023, mandating the increased use of SAF within the aviation sector. The act sets clear targets for SAF uptake, requiring that airlines use at least 2% SAF by 2025, increasing to 6% by 2030, and reaching 70% by 2050. Similarly, other countries like the UK, Norway, Singapore, Japan, Malaysia, Thailand, Turkey and Brazil have implemented or are expected to implement a SAF quota this decade. Moreover, large private corporations are dedicated to reducing their indirect emissions from their supply chain, referred to as scope 3 emissions. This commitment is driving significant demand for SAF, as businesses seek to lower their carbon footprint from transportation and logistics to meet stringent sustainability targets.

While mandated or voluntary demand for SAF will inevitably increase the adoption of SAF in the near term, for the foreseeable future the price premium of SAF over conventional jet fuel will remain a major concern for all value chain members. Airlines, for example, are oftentimes unable to recoup the additional costs of SAF through the commercialisation of sustainable transportation products. Since cargo airlines are the focal link of the air cargo value chain, connecting the upstream segment, e.g. OEMs and airports, with the downstream segment, e.g. freight distributors, changes to one actor of the air cargo value chain will create follow-up effects on adjacent actors. Consequently, the current business models of all air cargo value chain members, including their respective revenue streams, value propositions and cost structures, are called into question. This leads to the following research question:

How does the use of SAF impact companies' business models across the air cargo industry value chain?

To address the research question a two-pronged research approach was taken. Initially, a conceptual model was developed based on a modified version of the "Business Model Canvas" by Osterwalder and Pigneur (2010) to dissect the rather abstract construct of a business model. This conceptual mode was then used to analyse the current business model of the most relevant air cargo value chain actors, e.g. aircraft manufacturers, airports, cargo airlines and freight distributors, and to hypothesise poten-

tial changes to these caused by the large-scale adoption of SAF. Subsequently, ten semi-structured interviews assessed industry experts' perceptions on this topic to enrich the understanding of SAF's impact on air cargo.

The findings suggest that the impacts on investigated business models can be roughly divided into two groups. On the one hand aircraft manufacturers and airports are not directly affected by the adoption of SAF in air cargo. Therefore these actors function as facilitators and coordinators for the diffusion of SAF. Cargo airlines and freight distributors are expected to experience fundamental changes to their business model caused by SAF. These actors must quickly reevaluate their business model to align with the emerging sustainability standards and regulations.

As mentioned above, aircraft manufacturers and airports are expected to experience negligible or minor impacts on their cost structures and revenue streams due to the adoption of SAF in air cargo. Airports currently do not own or operate fuelling facilities. This responsibility is outsourced to energy companies such as BP and Shell, which acquire multi-year concessions from airports to operate these facilities. Consequently, airports show little interest in investing in SAF production plants due to the associated risks, making additional revenues from SAF unlikely. Similarly, aircraft manufacturers do not anticipate significant revenue gains from producing aircraft with improved SAF blending certifications. This is primarily because OEMs are already operating at maximum production capacity and the industry's focus is on producing as many new aircraft as possible to reduce emissions. Additionally, aircraft manufacturers will not experience changes to their cost structures, as existing technological knowledge can be leveraged without the need for new developments. This allows them to continue their operations without incurring extra costs related to SAF integration.

Nonetheless, aircraft manufacturers' and airports' role as coordinators for the adoption of SAF requires changes to other building blocks of their respective business models such as partner networks and key activities to maintain business model consistency. For aircraft manufacturers, this means adding organizations involved in the production and certification of SAF to their partner network. Additionally, new key activities for aircraft manufacturers include orchestrating the scale-up of SAF production and facilitating and coordinating SAF adoption to avoid technological disruption. For airports, it involves positioning themselves strategically within the new SAF value chain to drive adoption advantageously. Additionally, airports need to rethink their customer relationships with airlines to create and sustain demand for SAF from airlines which will then attract investments in SAF infrastructure and production. Furthermore, SAF offers a unique opportunity for differentiation. Airports can use their well-established relationships with important stakeholders to advocate for SAF production in close proximity to the airport or analogue SAF transportation infrastructure. This step will enhance the airport's value proposition by offering airlines the possibility to fuel large quantities of SAF. Aircraft manufacturers on the other hand can use higher SAF blending certification for their aircraft models to gain an advantage over competitors and improve their value proposition.

Cargo airlines and freight distributors are expected to experience tremendous changes to their cost structure caused by consistently higher prices for SAF in the long term. This circumstance presumes higher revenue streams to maintain their business models' financial viability. The ability to generate higher revenues is contingent upon the value proposition provided by cargo airlines and freight distributors. Therefore, the effective commercialization of sustainable transportation services will become a key activity for these companies. Promising approaches to the commercialisation of SAF include the ability for cargo owners to claim scope 3 emissions reductions based on the use of SAF, and the ability to offer SAF as part of a wider business case where sustainable transport is offered as an added value to the consumer purchasing a specific product. To conduct these measures the industry requires standardised carbon accounting rules to claim emissions reduction, a comprehensive approach to SAF certificate trading to track the flow of SAF and emissions across the value chain, and a reliable legal framework that allows companies to communicate the benefits of SAF to the consumer without the risk of being accused of greenwashing. Achieving this will require cargo airlines and freight distributors to expand their partner network to include new collaborators. For example, organizations that set standards for carbon accounting should be integrated. Additionally, developing a SAF certificate trading system with the necessary partners in the fuel supply chain is essential. Ultimately, these measures will significantly enhance the value proposition. Nonetheless, it has to be noted that not all cargo owners yet demonstrate a sufficient willingness to pay for sustainability. Therefore, close customer relation-

ships and a comprehensive but concise communication of the benefits of SAF will become pivotal for cargo airlines and freight distributors. To identify lead customers for the commercialisation of SAF customer segmentation will be conducted along novel criteria. Examples of these are a cargo owner's emphasis on emissions reduction (in this case a customer's adherence to the SBT initiative is usually a good proxy), a fixation on high-margin industries that are able to pay a premium for SAF (e.g. the luxury goods or pharmaceuticals sector), and a focus on industries that are close to the consumer and are therefore able to communicate sustainability as an added value (e.g. the retail or apparel sector). Lastly, amid the significant uncertainty surrounding the adoption of emerging technologies like SAF, effective risk management will be pivotal. Especially demand, price, policy and technology risks require careful consideration, positioning effective risk management as a second key activity.

Despite these changes, the early and decisive adoption of SAF by cargo airlines and freight distributors presents numerous opportunities. The complexity of SAF certificate trading and carbon accounting, among other aspects, means that the successful commercialization of SAF will be the result of a long learning process. To avoid falling behind, companies must set out today to capitalise on the rapidly growing market for sustainable transportation services. Furthermore, the decarbonisation of aviation through the use of SAF presents a unique opportunity to showcase that the aviation industry is able to address its problems effectively, creating social and political acceptance for future industry growth in the process.

This thesis is the first study to investigate the intersection of SAF, business model transformation, and air cargo. Beyond its contribution to research, the results also have significant practical implications. The anticipated cost increases, coupled with the prevalent inability to recoup these additional expenses through the successful commercialization of sustainable transportation services, pose a substantial risk to the viability of cargo airlines' and freight distributors' business models. Mandated SAF quotas in the EU, which can lead to competitive distortions between airlines and freight distributors from different geographic regions, are a particular concern. The insights from this study can help companies navigate these emerging risks by identifying the areas of their business models most impacted. To address potential risks, companies must first be aware of their existence and pinpoint where they occur. Now that an awareness of the aforementioned potentially negative impacts is created, companies can carry out an as-is analysis of the relevant areas. Additionally, this study advocates for a shift in the conversation around SAF. Instead of viewing SAF as a cost burden, it suggests recognising the early adoption of SAF as an opportunity to gain valuable experience in the commercialization of sustainable transportation solutions, especially in light of growing public pressure for decarbonization. This opportunistic view on SAF can help to create and sustain company internal support for early investments in SAF. Furthermore, the study's results highlight the importance of aircraft manufacturers and airports as facilitators for the adoption of SAF. This is contrary to the prevailing conviction that the actors can not shape the transition. Being aware of this will help aircraft manufacturer and airports to re-evaluate their corporate strategy, potentially strengthening their business models' resilience and flexibility.

In conclusion, the research reveals that the adoption of SAF significantly impacts the business models of companies across the air cargo industry value chain. Aircraft manufacturers and airports, playing coordinative roles, experience minimal direct effects on their cost structures and revenue streams. Instead, their contribution lies in facilitating the diffusion of SAF by coordinating between new and existing partners. In contrast, cargo airlines and freight distributors face substantial changes due to the higher costs associated with SAF. These companies must adapt their business models to effectively commercialise sustainable transportation services, which includes developing robust carbon accounting practices, SAF certificate trading systems and strong customer relationships focused on sustainability. The findings indicate that proactive adjustments to business models, focusing on the commercialization of sustainability to allocate the additional costs of SAF across the value chain, will be essential for cargo airlines and freight distributors to sustain financially viable and globally competitive business models. The study also emphasises the necessity for these actors to view SAF adoption as an opportunity rather than a burden, enabling them to gain valuable experience and lead in the sustainable air cargo market. This shift in perspective, combined with necessary strategic changes in partner networks and key activities, can help mitigate risks and leverage the growing demand for sustainable transportation. By addressing these challenges proactively, companies can position themselves advantageously in an increasingly environmentally conscious air cargo market.

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Nomenclature

Abbreviations

Abbreviation	Definition
ATAG	Air Transport Action Group
AtJ	Alcohol-to-Jet
BM	Business Model
BMC	Business Model Canvas
FT	Fischer-Tropsch
GHG	Greenhouse Gas
HEFA	Hydro-processed Esters and Fatty Acids
PtL	Power-to-Liquid
NGO	Non Governmental Organisation
RPK	Revenue Passenger Kilometre
SAF	Sustainable Aviation Fuel
SBT	Science-based Targets
SBTi	Science-based Targets Initiative

1
Introduction

1.1. Motivation

1.1.1. Climate impact

The aviation industry is one of the fastest-growing sources of greenhouse gas (GHG) emissions due to the rising demand for air travel as well as a surging need for air cargo as a means of transporting high-value or perishable goods quickly and reliably (Kim et al., 2019; Okolie et al., 2023). The impact of these emissions on climate change is significant and cannot be overlooked. As other sectors decarbonize more quickly, the European Commission estimates that aviation's shares of global emissions could rise from 2% - 3% today to over 22% by 2050 (Vigeveno, 2021). Additionally, aircraft engines release other gases, including nitrous oxides (NOx), sulfur dioxide (SO2), water vapour (H2O), and soot, all of which contribute to global warming as well. When considering both CO2 and non-CO2 emissions from aviation, this sector contributes approximately 5% to the total global warming effects caused by human activities (Okolie et al., 2023). Air cargo accounts for 17% of aviation fuel use (Gössling & Humpe, 2020), hence contributing roughly 1% to global warming. Consequently, as the industry continues to expand, it is crucial to reduce these emissions urgently.

1.1.2. Aviation growth

Advancements in aerodynamics, lightweight materials and engine improvements have significantly increase efficiency in the aviation sector. Compared to 1990 CO2 emissions per Revenue Passenger Kilometre (RPK) have fallen by 53% (Airbus, 2023). However, at the same time absolute CO2 emissions from aviation have doubled to more than 1 billion metric tonnes per year (Ritchie, 2020). This highlights the enormous growth trajectory of this sector, which is projected to intensify over the next two decades. While air cargo volume grew by an average of 3.6% between 2001 and 2021, the world's largest manufacturer of cargo aircraft, Boeing, forecasts an annual growth rate of 4.1% over the next 20 years (Boeing, 2023b). The expected growth in air cargo volume is driven by increasing demand from e-commerce platforms and the growing market on routes from East Asia to Europe, North America and other East Asian countries. Thus air cargo will even outpace expected growth rates for global GDP (2.6%) and global industrial production (2.2%) (Boeing, 2023b). Meanwhile, efficiency improvements cannot catch up with this rapid growth and are predicted to reach a rate of only 1.5% per year. This leads to an expected doubling of air cargo CO2 emissions by 2050 unless radical changes are made (Pinheiro Melo et al., 2020).

All industry participants recognise the necessity of carbon reduction programs in air cargo. Airlines that operate in the global air cargo industry are aware of their environmental impact and have developed and implemented a comprehensive array of measures and strategies to decarbonize their operations (Baxter, 2021). However, the significance of this sector for global trade should not be overlooked when proposing GHG reduction measures. For instance, the proportion of air cargo within global trade constitutes merely 0.2% by volume, yet it commands a substantial 18.9% share in terms of nominal value (S&PGlobal, 2021). Enforcing carbon reduction measures on air cargo without delineating clear path-

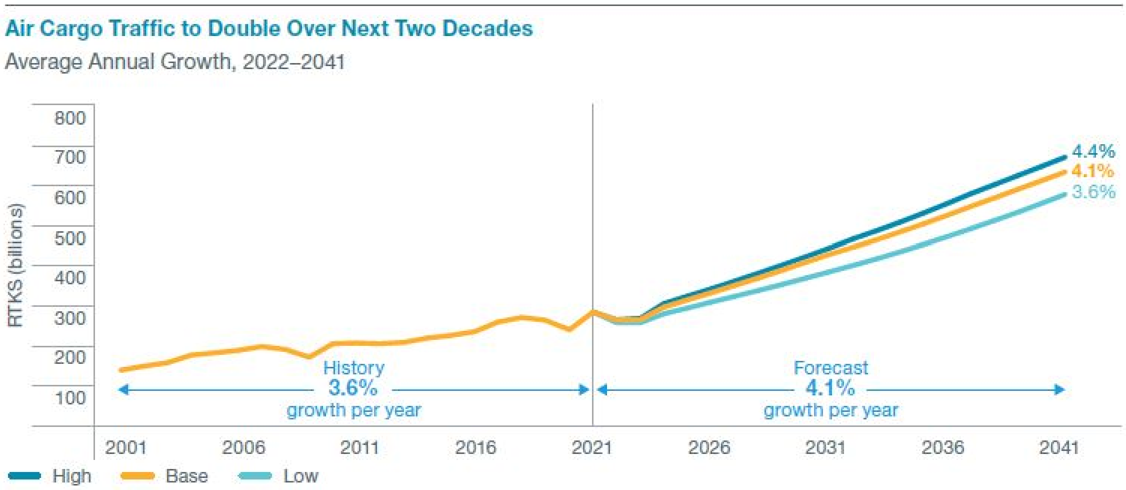

Figure 1.1: Air cargo traffic growth (Boeing, 2023b)

ways and thoroughly examining the ramifications for stakeholders along the value chain hence may lead to significant negative consequences for the global economy. Airbus asserts that decarbonization necessitates a diverse array of solutions, including renewing fleets with the latest generation of aircraft, enhancing operational efficiency and infrastructure, utilising SAF, adopting disruptive technologies such as hydrogen as a fuel and for electric cells, and implementing market-based measures (Airbus, 2023). The Air Transport Action Group (ATAG), an NGO endorsed by all leading aircraft and engine manufacturers, has devised a strategy to achieve net zero despite ongoing growth trends. This comprehensive plan assesses the impact of all aforementioned technologies, with SAF projected to yield the most significant impact on GHG reduction (figure 1.2), accounting for 61% of the total share, (ATAG, 2020). The utilisation of SAF has the potential to reduce carbon emissions by up to 80%, contingent upon the feedstock utilised in its production (Bullerdiek et al., 2021). This is backed by independent research stating that SAF is the most promising pathway for GHG reduction based on impact and feasibility. Furthermore postulating that a fully decarbonised airline structure based on existing SAF production technologies could be a reality by 2050 (Santos & Delina, 2021).

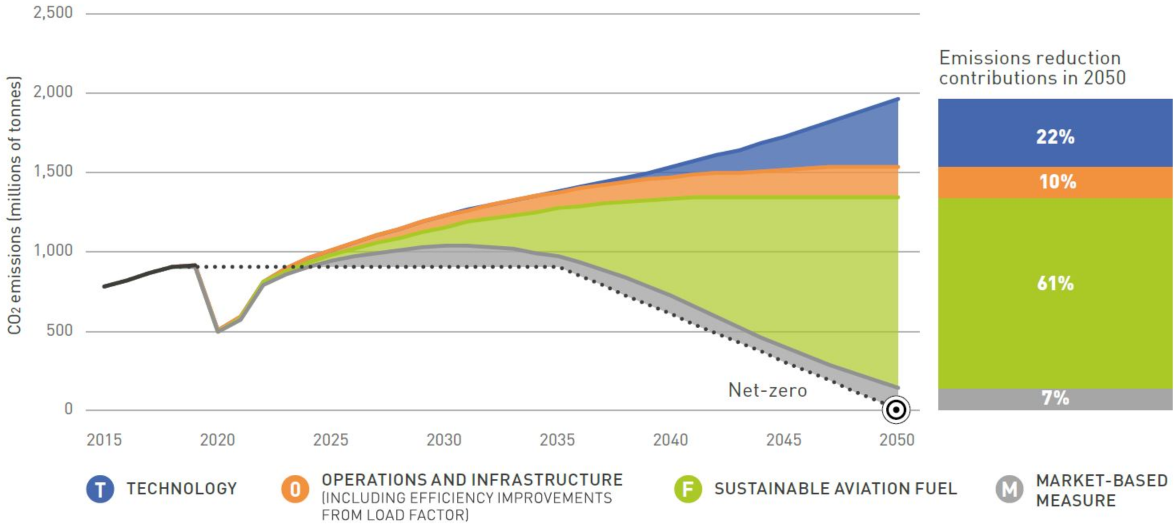

Figure 1.2: Emission Reduction Contributions (ATAG, 2020)

1.2. Problem definition

Assuming a 10% quota on SAF in 2030, as initially proposed by the European Union but later revised to only 6%, aviation fuel prices are expected to increase by 5% to 45% compared to the historical average of €550 per ton between 2013 and 2019 (Bullerdiek et al., 2021). Meanwhile, the sector is still focused on capacity growth with low profitability (Gössling & Humpe, 2023), leading to many airlines struggling to consistently earn their cost of capital and maintaining long-term profitability (Wendel et al., 2024). This calls into question existing business models in the industry, including their respective revenue streams and pricing models, hence necessitating the need for further research to investigate the exact effects on each part of te business model.

1.2.1. Systematic literature review

Looking at the subject area of SAF, a steady increase in research interest can be observed. While in 2010 ”only” 177 research articles or conference papers were published containing the keywords ”SAF” or ”Sustainable Aviation Fuel” this number gradually increased to 527 research articles in 2023, totalling 4536 research articles from 2010 to 2024. In the same period, 511 papers were published in the field of SAF and aviation. Initially, 198 papers were excluded from this set because they did not align with the subject areas of Energy, Business, Economics, or Multidisciplinary. Subsequently, 237 papers were excluded based on their article titles, and an additional 44 were removed after reviewing their abstracts. This process resulted in a final set of 32 papers for further analysis. Notably, no papers were excluded due to language considerations. Furthermore, one paper that falls at the intersection of business models and SAF was included in the set of relevant papers, as well as another paper related to air cargo and SAF (refer to table 1.1).

Keywords	**# of Papers (included)**
”SAF” OR ”Sustainable Aviation Fuel”...	4.536
AND ”Aviation”	511 (32)
AND ”Business Model”	3 (1)
OR ”Biofuel” AND ”Air Cargo” OR ”Air Freight”	1 (1)
AND ”Business Model” AND ”Air Cargo” OR ”Air Freight”	0

Table 1.1: Total number of publications in subject area between 2010 and 2024 according to Scopus database

Several strands in the literature are relevant to the context of this study, see table 1.2. First, the impact of SAF on the civil aviation industry in general from which more specific implications for the air cargo industry can be derived. Low-emission fuels in aviation, primarily biofuels, have been subject to an ample body of research. Smith et al. (2017) investigated drivers and barriers to the adoption of SAF providing valuable insight into the perception of relevant stakeholders. Later Kim et al. (2019) acknowledge that the large-scale adoption of SAF necessitates a socio-technical regime change. They identify increasing fuel costs and international pressure for emission reductions as the key landscape pressure. Yet, the authors conclude that ”progress towards commercialization of aviation biofuels has remained largely stagnant” (Kim et al., 2019). Dodd and Yengin (2021) address this ”deadlock in sustainable aviation fuels”, which is caused by a general uncertainty of key stakeholders on how to move forward, lack of investment and the issue of free-riding across sectors when it comes to carbon reduction. The authors advocate for collective leadership over a handful of companies spearheading the transition (Dodd & Yengin, 2021). Nonetheless, the cost and supply problem for SAF prevails. While the cost of SAF is estimated to fall over the next years, even the cheapest production pathway will incur production costs two times higher than regular kerosene (Bullerdiek et al., 2021). Furthermore, the cheapest production pathways are biofuels that require large amounts of animal fats or vegetable oils as feedstock which have limited production potential (Mayeres et al., 2023). Bergero et al. (2023) remark the interactions with food security and land use as ”enormous” hurdles for the ramp-up of biofuel production.

A second relevant strand of research consists of literature that deals thematically with the air cargo industry. There is a general imbalance between the number of academic papers addressing passenger and cargo aspects of aviation (Bombelli et al., 2020), leading to a limited amount of relevant research in air cargo. The relevant papers of the second strand of literature either examine the implications of SAF for the air cargo industry at large or delve into the transformative processes that can reshape business

Paper	Low-emission Fuels	Business Model Transformation	Air Cargo (Aviation in general)
Mayeres et al. (2023)	x		(x)
Bergero et al. (2023)	x		(x)
Bullerdiek et al. (2021)	x		(x)
Dodd and Yengin (2021)	x		(x)
Kim et al. (2019)	x		(x)
Smith et al. (2017)	x		(x)
Baxter (2021)	x		x
Bartle et al. (2021)	x		x
Wang et al. (2023)		x	x
Malmgren et al. (2023)	x	x	
Colak et al. (2023)		x	(x)
Gössling and Humpe (2023)	x	x	(x)
This study	x	x	x

Table 1.2: Most relevant recent scientific publications categorised based on thematic focus

models within this sector. Baxter (2021) for instance reviewed current and potential decarbonising strategies of the world's air cargo-carrying airlines. He points out that the use of SAF is the key lever for carbon reduction, as it provides the most significant potential for carbon reduction. Bartle et al. (2021) examined the interplay of air cargo and sustainability in light of the global COVID-19 pandemic. The authors acknowledge the urgent need to address emissions from air transport. At the same time, they emphasise the importance of fast and reliable shipments by air for the global economy and advocate for "carefully constructed solutions" (Bartle et al., 2021) to make air cargo more sustainable. Wang et al. (2023) emphasise that the transition to greener air transport is not the exclusive responsibility of air cargo airlines but the result of a collaborative effort, necessitating private investment, knowledge transfer through partnerships and eco-friendly insurance services.

The third strand in the literature concerns the transformation of business models in the transportation sector through external pressure. Colak et al. (2023) investigated how UK airports were changing their business model in response to the global Covid-19 pandemic and the resulting rapid fall in demand. The COVID-19 pandemic represents an external shock that significantly impacted the aviation industry, much like climate change and the resulting regulatory push for SAF adoption (Anser et al., 2020). The study by Colak et al. (2023) found that airports were able to adapt their business models in response to COVID-19 by diversifying revenue streams and introducing more flexibility into their cost structure, leading to improved long-term resilience to "future systemic shocks". Malmgren et al. (2023) looked more specifically into possible business models for the commercialisation of low-emission fuels in maritime transport, a sector that faces obstacles to GHG reduction similar to aviation. They identified several specific business models, such as green corridors, public procurement and cargo owner initiatives, to drive adoption. Notably, maritime shipping companies are confident that investment in low-emission fuels will eventually pay off (Malmgren et al., 2023). Lastly, Gössling and Humpe (2023) investigate how aviation business models must evolve to remain within the 1.5°C global warming target, specifically considering the financial constraints faced by airlines. The study concludes that maintaining continuous capacity growth at low profitability while achieving net-zero emissions by 2050 is highly improbable. Consequently, the researchers advocate for a reassessment of the need for continued capacity expansion in the industry.

According to the literature, a reassessment of current business models is required to meet the industry's own carbon reduction targets. However, this is proving to be a difficult endeavour due to the industry's financial constraints and a number of unresolved issues relating to SAF as emphasised by several studies. Simultaneously, hardly any research investigating the role of sustainability in air cargo exists (see table 1.1). This research gap needs to be addressed.

1.2.2. Academic value added

To date, there has not been any research conducted at the intersection of SAF, business model transformation and air cargo, as presented in the table 1.1. However, understanding the impact of low-carbon fuels on business models is of utmost importance due to the aviation sector's constrained financial situation and the urgency to reduce carbon emissions (Gössling & Humpe, 2023). Therefore, contemporary business models in aviation need to undergo a rapid transformation. If this transformation is not successful and "current business models [in aviation] are continued, it is likely that aviation's contribution to climate change will grow" (Gössling & Humpe, 2023). Meanwhile, transition pathways to net zero by 2050 are characterised by a considerable amount of unexplored complexity, which urgently requires additional research (Gössling & Humpe, 2023). Wang et al. (2023) investigate the impact of green investment on the Chinese air cargo market and recognise a prevailing research gap regarding the shift to low-carbon fuels within the air cargo industry, prompting them to advocate for future investigations into regulatory, financial, and market-based mechanisms for carbon reduction programs (Wang et al., 2023).

Dodd and Yengin (2021) postulate that future research on the adoption of SAF should include potential value chain partners to better understand synergies and conflicts between these. Momentarily however researchers criticise lacking cross-sector collaboration to foster the diffusion of SAF and create aforementioned synergies (Dodd & Yengin, 2021; Martinez-Valencia et al., 2023). Effective collaboration plays a pivotal role in the creation of novel products in the realm of sustainability by mitigating financial risks and facilitating the exchange of "green" knowledge (Martinez-Valencia et al., 2023). Consequently, new business models based on low-carbon fuels are emerging slowly since every business model is embedded in a socio-technical context (Strupeit & Palm, 2016). This study acknowledges this issue by applying the concept of the value chain as outlined by Porter (1985) to analyse the effects of low-carbon fuels on business models. By utilising this model, businesses are examined not in isolation, but as integral components of a system (value chain), enabling a deeper comprehension of the interactions among various members.

Market-based mechanisms, such as SAF certificates and emission trading schemes, offer significant potential for the air cargo industry but will fundamentally alter business models, including cost structures, revenue streams, and value propositions. Understanding these changes is crucial for value chain members to assess their capabilities and for policymakers to develop an adequate regulatory framework. To date, there is no research examining how the large-scale adoption of SAF impacts companies' business models in the air cargo industry.

1.3. Objective & research question

The implementation of SAF in air cargo to foster green logistics services poses numerous challenges. It necessitates substantial capital investments, amidst a landscape of uncertainty regarding the dominance and timeline of emerging technologies (McKinsey & Company, 2024). On the revenue side of SAF adoption, a rising interest in the commercialisation of emerging technologies as a source of innovation can be observed (Haessler et al., 2023). This study aims to identify changes to incumbent business models in air cargo caused by the adoption of SAF to point out nascent risk on the one hand. On the other hand, an improved understanding of the implications of SAF for business models can act as a foundation for successful commercialisation strategies, ultimately functioning as a driver for innovation in the realm of low-emission fuels.

In essence, the environmental impact of aviation, the role of SAF as the most feasible solution to mitigate this impact (chapter 1.1.1), the existing research gap regarding SAF utilisation in air cargo operations (chapter 1.2.2), and the substantial influence of SAF on business models within the air cargo industry culminate in the following research question:

RQ. How does the use of SAF impact companies' business models across the air cargo industry value chain?

Business models are pivotal and can catalyse the diffusion of new technologies by overcoming internal and external barriers. They foster efficiency and reduce uncertainty, complexity, information asymmetry and ultimately cost (Strupeit & Palm, 2016). This study will make use of three key concepts, namely the "Business Model Canvas" by Osterwalder and Pigneur (2010) and the "Industry Architecture" by Jacobides et al. (2006) and Teece (1986) to describe the contemporary composition of the air cargo industry. To analyse the transformational impact of large-scale SAF adoption on value chain members the dynamic business model framework by Kamp et al. (2021) will be applied.

Initially, the air cargo industry value chain will be defined and a common framework will be applied to map the contemporary business model of each member of the value chain. This process will establish a basis for all subsequent analyses:

SQ1. What are the current business models across the air cargo industry value chain?

Subsequently, a conceptual framework must be constructed to theorise the prospective influence of low-carbon fuels on business models throughout the value chain. The integration of SAF will alter the fuel flow dynamics, necessitating the consideration of various adoption strategies to facilitate SAF uptake. Additionally, the existence of multiple technological pathways to the production of SAF impacts the composition of a low-carbon air cargo industry value chain. These aspects must be duly acknowledged in the development of the conceptual model, culminating in the emergence of the second sub-question:

SQ2. How could the use of low-emission fuels conceptually impact companies' business models across the air cargo industry value chain?

Finally, the novelty of SAF as a substitute for fossil kerosene, coupled with the inadequate documentation in research, underscores the necessity for validating and expanding the conceptual model. This is essential to attain a comprehensive understanding of this emerging phenomenon and to differentiate which changes to the business model are the most significant. Hence, the conceptual model will be improved by including the perception of industry participants:

SQ3. What are according to industry participants the implications of low-emission fuels for companies' business models?

1.4. Thesis outline

The following thesis is divided into seven chapters. First, chapter 2 outlines the research approach, which is based on the development of a conceptual mode and subsequent semi-structured expert interviews. Next, chapter 3 provides a basic understanding of SAF as a technology as well as barriers and drivers for its adoption. Important SAF regulations and decarbonisation initiatives will be introduced that are crucial to comprehending the results of the expert interviews. Furthermore, adoption barriers provide an understanding of the prevalent problems associated with SAF diffusion. In chapter 4.1 research sub-questions one and two are addressed. This chapter will develop a conceptual model outlining the current business models of the four key actors (aircraft manufacturer, cargo-focused airport, cargo-carrying airline, freight distributor) within the air cargo value chain, prior to the large-scale adoption of SAF. Moreover, potential changes to these business models caused by adopting SAF are identified and the scope of these changes is theorised. The resulting conceptual models are the focal part of this research and provide the basis for further analysis throughout subsequent expert interviews. The following chapter 5 analyses and presents the results of the ten interviews with industry experts. The chapter's structure follows the six-step approach for reflective thematic analysis proposed by (Braun & Clarke, 2006) to ensure a high level of transparency. Using insights from expert interviews, each business model will be analyzed and a narrative constructed, detailing the anticipated transformations within each model driven by the adoption of SAF. Next, the results of analysis conducted in chapter 4.1 and 5 are presented in chapter 6. Subsequently, chapter 7 discusses the results of the empirical part, puts them into perspective to changes theorised in chapter 4.1 and points out limitations. Finally, conclusions are drawn in chapter 8.

2 Research Approach

This chapter outlines the methodological approach employed in this study, which follows a two-pronged research design approach. The first prong of research that is outlined in this chapter entails the construction of a conceptual model, the application of this model to describe contemporary business models and the identification of areas within these business models that are particularly affected by the adoption of SAF. The second prong of research used in this study aims to further analyse these effects based on primary data. Consulting primary data for further analysis is necessary due to the insufficient documentation of this phenomenon in literature, as pointed out in chapter 1.2.1. Primary data is collected in the form of semi-structured expert interviews. This chapter describes the process of participant recruitment, the conduct of the semi-structured interviews and the data analysis using reflective thematic analysis by Braun and Clarke (2006). Additionally, this chapter addresses considerations of trustworthiness and ethical procedures.

The research adheres to the epistemological approach of critical realism, positing the existence of an external, causally-driven reality that is independent of empirical perceptions. This epistemological theory acknowledges social actors' subjective knowledge as an integral part of research (Bhaskar, 2013).

2.1. Research design

Initially, a conceptual model was developed in the form of an adapted version of the Business Model Canvas (BMC) by Osterwalder and Pigneur (2010). The conceptual model serves two purposes. First, it is used to analyse current business models in air cargo. Second, the nine building blocks of the BMC help to guide in structure the further analysis of changes to these business models. The BMC is commonly used in research to analyse, describe and compare business models and provides a consistent and reliable framework which has been tested extensively (Rodríguez-Molina et al., 2014; Schwidtal et al., 2023). Since the analysis of all air cargo value chain members would exceed the scope of this study a power-interest matrix is constructed to identify those actors mostly relevant to the goal of this research, e.g. aircraft manufacturers, airports, cargo airlines and freight distributors. Once these actors are identified their business models are analysed and key areas affected by the adoption of SAF are highlighted. Subsequently, through a series of expert interviews, this research delves into the viewpoints of industry stakeholders, aiming to construct a more comprehensive understanding which is eventually used to refine the preliminary conceptual model. Differences and non-differences between incumbent and emerging business models, affected by the introduction of SAF, are outlined at the end of the empirical part in chapter 6.1.

A qualitative research design was adopted for the collection of primary data, specifically utilising semi-structured interviews, to explore the rich and complex perspectives of experts on the impact of SAF on the air cargo business model. Qualitative research allows for an in-depth understanding of participants' experiences and viewpoints, making it well-suited to investigate complex contemporary phenomena (Creswell, 2008). Interviews serve as a popular research approach in qualitative research, bridging the

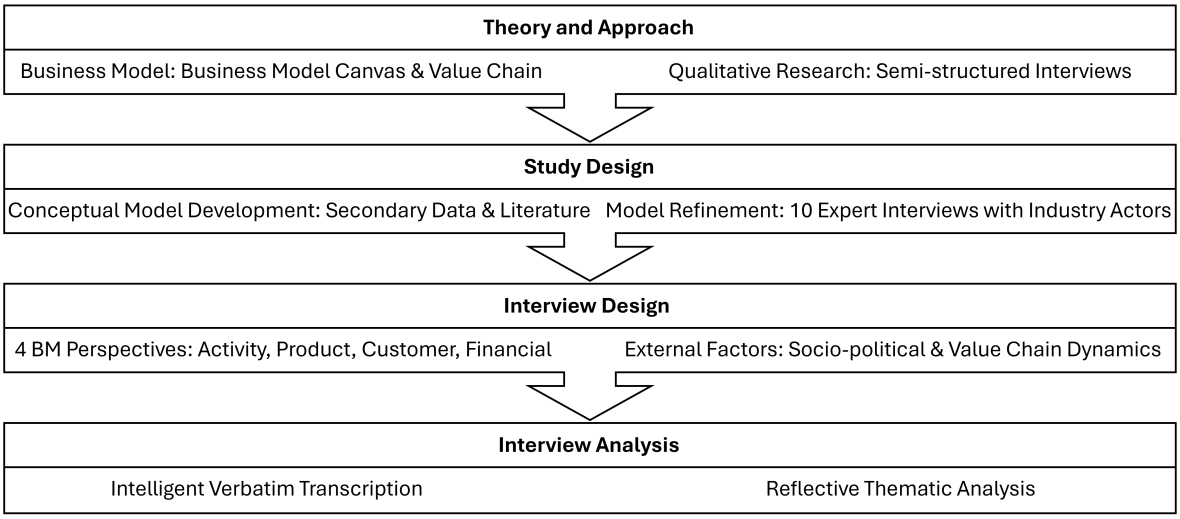

Figure 2.1: Research Methodology (Inspired by Colak et al. (2023))

gap between real-world practices and academic theory. Notably, they have been employed successfully in understanding the impact of external developments on the aviation industry (e.g. Colak et al. (2023)) and the dynamics of the aviation value chain (e.g. Wendel et al. (2024)). Semi-structured interviews were chosen to balance a pre-defined set of open-ended questions with the flexibility to explore emerging themes during conversations (Myers & Newman, 2007).

In total 10 semi-structured interviews with industry experts from Germany, the Netherlands and the USA were conducted. The experts represent eight different organisations. Some, but not all, of these organisations are part of the air cargo value as defined in figure 4.2, with an emphasis on those value chain actors addressed in this study. On top of this, experts from SAF interest groups, aviation consultancies, cargo owners and SAF certification organisations were interviewed as well to draw a more comprehensive picture. Important information about each interview participant is summarized in table 5.1 in chapter 5. Throughout the analysis of the expert interviews a three-letter alias is used to refer to each expert. Therefore the table with the information on the expert and their respective alias is placed in the same chapter as the interview analysis. To guide the analysis and interpretation of the interview material I attended the ”Sustainable Aviation Futures Congress 2024” from 22nd to 23rd of May. Attending this congress helped me to contextualise the primary data and greatly improved the subsequent analysis.

A purposive sampling strategy was employed to recruit participants who possess significant experience and knowledge in the area of air cargo or sustainable transportation. Participants were recruited through professional networks, relevant online forums, and academic publications. Inclusion criteria include years of experience, job roles related to sustainability and the relevance of a company in driving SAF adoption (Chun Tie et al., 2019). This approach ensures that the interview data reflects the perspectives of key stakeholders. A detailed stakeholder analysis identifying these key players is presented in section 4.1. Participants are approached through LinkedIn or Email. Informed consent was obtained from all participants prior to the interview. This included a detailed explanation of the study’s purpose, data collection procedures, confidentiality measures, and the right to withdraw at any point. Interviews were conducted either face-to-face or digitally via Microsoft Teams and automatically transcribed for ease of analysis. Following the interviews, summaries were constructed based on the transcripts and shared with participants for their approval within two weeks.

The semi-structured expert interviews follow a pre-prepared interview guide. Mayer (2013) suggests structuring the interview guide by dividing it into topic areas. In this research, the topic areas are derived from four distinct ”perspectives” on the business model, which correspond to a group of similar building blocks outlined in the BMC. A detailed topic guide outlining the open-ended interview questions is included in Appendix B for reference.

To prevent biased data collection as much as possible, the study implemented strategies to maintain interviewer neutrality. Interviewers avoided suggesting solutions, used only open-ended questions and maintained a neutral stance throughout discussions. This approach aims to prevent interviewer biases from influencing participant responses (Myers & Newman, 2007).

2.2. Data analysis

The study employs qualitative coding to analyse the empirical data, focusing on identifying recurring concepts and constructing overarching categories that explain the phenomenon under study (Chun Tie et al., 2019). ATLAS.ti software and its data analysis tools are used to facilitate this process. This study employed reflective thematic analysis (Braun & Clarke, 2006) to identify, analyse, and interpret patterns within the interview data. Reflective thematic analysis ”emphasises the importance of the researcher’s subjectivity as an analytic resource, and their reflexive engagement with theory, data and interpretation” (Braun & Clarke, 2021). Hence this approach was chosen to acknowledge subjectivity when dealing with qualitative data and to overcome uncertainty in an explorative study by utilising the structured process outlined by Braun and Clarke (2006). This iterative approach involved a six-stage process:

1. Familiarisation: Extensive familiarisation with the transcribed interviews through repeated reading and immersion.
2. Initial Coding: Assigning preliminary codes to data segments that capture significant concepts, experiences, or opinions.
3. Searching for Themes: Identifying recurring codes and grouping them into potential themes.
4. Reviewing Themes: Refining themes, ensuring coherence, and establishing relationships between them.
5. Defining and Naming Themes: Providing clear definitions and descriptive names for each identified theme.
6. Writing Up the Analysis: Discussion of the implications of findings in light of the research question and objectives. Acknowledgement of any limitations of the analysis.

As recommended by Byrne (2022), themes are systematically reviewed and discussed with researchers external to the project (e.g. thesis supervisor). Finally, a model of higher-order themes is generated.

A core challenge in qualitative research is maintaining an open mind and minimizing researcher bias. Given that researchers bring their own background knowledge to the analysis, verification and reflexivity are particularly important, especially during the later coding stages (Boeije, 2002). To address this, the study involves experts from the field of SAF and experienced researchers to review and test the developed concepts and their relationships. However, the generalisability of the resulting theory needs careful consideration. The specific context of the study may not be directly applicable to all situations. Nonetheless, the research aims to enhance generalisability by ensuring a well-documented and reproducible coding approach and rigorous verification processes (Boeije, 2002). To expedite data collection, the study relied on a limited number of experts and managers, potentially introducing an elite bias. This bias arises from an over-representation of articulate, well-informed, and often high-status individuals, as described by Myers and Newman (2007). This research acknowledges this limitation and recognises the need for future research to incorporate a more diverse sample.

3
Background

Throughout this study, several technical terms and SAF-specific regulations are referenced frequently. These are explained in this chapter. The chapter commences in 3.1 by introducing SAF production pathways. As a reader of this study, a fundamental understanding of SAF as a technology is essential for accurately assessing the drivers and barriers to its adoption and grasping how SAF relates to the broader context of efforts to reduce the environmental impact of aviation. Despite SAF's potential as a means of abating emissions in aviation, some barriers prevail, which are explained in subchapter 3.2. These barriers underpin the need for additional research in this area.

Conversely, subchapter 3.3 focuses on regulatory measures as the primary driver for SAF adoption, highlighting their role in shaping the industry's response to climate change. Regulations such as emissions trading schemes and SAF blending quotas are pivotal in promoting the use of SAF by creating economic incentives and setting mandatory usage targets. These regulatory frameworks help reduce GHG emissions and stimulate investments in sustainable technologies. In addition, secondary drivers for the introduction of SAF, in the form of scope 3 emission reductions, are presented. The complexities of scope 3 accounting are frequently mentioned by interview participants in chapter 5. Therefore common accounting frameworks and initiatives are introduced to guide the understanding of the subsequent chapters.

3.1. A brief introduction to Sustainable Aviation Fuel (SAF)

Various technological pathways for the production of SAF exist, and each has varying associated costs and GHG savings potentials (see table 3.1). Yet no dominant technology has emerged.

All types of SAF are so-called ”drop-in” fuels which have similar chemical and physical properties to conventional jet fuel and can hence be used as a direct replacement for it. Current ”ASTM International” standards require that SAF is mixed with at least 50% fossil kerosene to be used to fuel a commercial aircraft (Okolie et al., 2023). Generally, three categories of SAF can be distinguished. First, biomass-based SAF is produced from lipids (e.g. oil crops, oleaginous residues, wastes, byproducts or algae), starch (e.g. corn, wheat, sugar cane/beet), ligno-celluloses material (e. g. agriculture residues or energy crops), or organic waste (Bullerdiek et al., 2021). Second, electricity-based SAF is produced by combining electricity, water and CO2 from the atmosphere. Lastly, hybrid SAF represents a combination of the aforementioned options. Unlike pure biomass-based or electricity-based pathways, the energy content of the final fuel stems from the feedstocks and processes involved in both pathways (Bullerdiek et al., 2021).

Although power-to-liquid (PtL) and hybrid SAF are promising production pathways for SAF in the long term, those are not yet technically feasible on a commercial scale. This leaves biomass-based SAF as the only feasible option. Biomass-based SAF can be derived from four currently approved conversion processes: Fischer-Tropsch synthesis (FT), hydroprocessed esters and fatty acids (HEFA), alcohol to jet fuel (AtJ) and sugar to jet fuel (StJ) (Okolie et al., 2023). SAF is not only superior to traditional jet fuel because of lower CO2 emission, it also produces significantly less soot during combustion. Fur-

Conversion	Feedstsock	GHG emissions savings [%]	Production costs 2021 [€/t]	Production costs 2030 [€/t]
AtJ	Wheat straw	82	1015	815
FT	Willow	67	990	740
FT	Wheat straw	70	1685	1520
FT	Municipal solid waste	94	1555	1336
PtL	CO2	98	2700	2130
HEFA	Jatropha oil	60	2095	2015
HEFA	Used cooking oil	85	1146	966
HEFA	Palm oil	70	980	925
HEFA	Rapeseed oil	55	1755	1530
AtJ: Alcohol-to-Jet; FT: Fischer-Tropsch; HEFA: Hydro-processed Esters and Fatty Acids; PtL: Power-to-Liquid				

Table 3.1: Parameters of sustainable aviation fuel options (Bullerdiek et al., 2021)

thermore, HEFA, a type of SAF, boasts a lower sulfur content as well as a lower aromatic content and leads to better engine performance compared to conventional jet fuel. HEFA stands out as the leading and economically most feasible method for producing SAF owing to its high product yield and currently lowest production cost, as seen in table 3.1. HEFA is an established production process and is already widely used, making it the most advanced technology in the SAF landscape (Okolie et al., 2023). However, HEFA, as well as all other biomass-based production pathways, face the problem of feedstock availability and concerns about the indirect effects of feedstock production on deforestation, biodiversity and land degradation. Consequently, the EU plans to cap or exclude feedstocks like palm, soy and rapeseed oil from the HEFA SAF supply, leaving producers with limited quantities of waste oils. On top of this biomass-based SAF faces limitations due to escalating demands for feedstocks, and increasing market values for sustainably provided biomass (Bullerdiek et al., 2021). Biofuels from third and fourth-generation sources, derived from non-invasive crops and algae, present a promising avenue with reduced environmental and social footprints. These alternatives effectively address certain environmental and social challenges posed by first and second-generation fuels. However, despite their potential, the technology has yet to mature sufficiently to facilitate widespread commercial adoption (Dodd & Yengin, 2021). Therefore achieving large-scale SAF usage necessitates the timely development of non-biogenic SAF alternatives such as Power-to-Liquid (PtL). However, the production of PtL fuels, particularly, has not yet been demonstrated on an industrial scale. In this decade the production of substantial amounts of PtL SAF is unlikely, but it will represent a critical fuel component in the future (Bullerdiek et al., 2021).

3.2. Primary barriers for SAF adoption: Price and scalability

A plethora of barriers impedes the adoption of SAF with the most significant being the high price of SAF and a lack of investments to reduce the former.

3.2.1. High SAF production cost

High production costs stand out as the primary hurdle obstructing the widespread adoption of Sustainable Aviation Fuel (SAF). Pinpointing the precise cost increases proves to be a challenging task, heavily contingent upon various factors such as feedstock costs (refer to table 3.1), production methodologies, infrastructure expenses, and legislative backing. The cost dynamics of each element fluctuate based on the specific technology employed, geographical location, existing infrastructure, and the level of legislative support in place (Gegg et al., 2014). Limited financial capacities of key members of the value chain and an inability to pass on the additional costs of SAF to end customers amplify the negative effect of fuel cost increases (Dodd & Yengin, 2021). Part of the relative cost disadvantage of SAF compared to fossil kerosene stems from subsidies given to fossil fuels. Many countries consider oil and gas a key industry and hence heavily subsidies research and exploitation. Furthermore, jet fuel is completely exempt from taxation. A 2019 report by the European Commission showed that the abolishment of this tax exemption alone could reduce carbon emission from aviation by 11% without any significant impact on GDP (Dodd & Yengin, 2021).

3.2.2. Lack of investment in new production facilities

Low technology readiness for advanced SAF production pathways requires extensive investment in research and development (Okolie et al., 2023). But in a study by (Gegg et al., 2014) 80% of respondents mentioned that biofuel technology receives insufficient investment. The primary obstacles impeding investment levels include uncertainty surrounding technologies and legislative support, coupled with difficulties in accessing credit (Gegg et al., 2014). Respondents in another study conducted by Smith et al. (2017) complain that lack of policy stability and harmony divert investments from aviation biofuels to on-road biofuels which receive better incentives. Additional factors encompass challenges in mitigating investment risks and a deficiency in appropriate government-backed funding initiatives. While plenty of government-backed funding opportunities exist in theory, accessing these can sometimes take up to 18 months making it an unfeasible funding option for cash-strapped, innovative start-ups (Gegg et al., 2014).

3.3. Primary driver for SAF adoption: Regulation

3.3.1. Emissions trading

Emissions trading, or cap-and-trade, sets a limit on total greenhouse gas emissions and allocates permits to companies, allowing them to emit a certain amount. The system is based on the principle that entities responsible for emitting carbon should bear some of the costs associated with their negative impacts, as carbon emissions impose significant costs on society. These societal costs can come in the form of reduced yields in agriculture, negative consequences to public health, property damage from extreme weather events, and other consequences associated with climate change (Rennert et al., 2022). These costs can be quantified. The resulting measure is referred to as the social cost of carbon dioxide (SC-CO2) and indicates the economic value of harm inflicted on society by each additional metric ton of CO2 emissions. SC-CO2 plays a crucial role in shaping climate policy decisions (Rennert et al., 2022). In the past, the costs of emissions were not borne by the emitting companies and therefore constituted a ”major subsidy” (Gössling & Humpe, 2020). However, the social costs of carbon are substantial and continuously increasing. Rennert et al. (2022) estimate the average cost to society from every emitted ton of CO2 to be $185, with a high estimate of up to $413.

To reduce the climate impact of air transport, two key CO2 trading schemes for aviation are currently in place or will be implemented soon. The EU Emissions Trading Scheme (EU ETS) for aviation, launched in 2012, and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), presented by the International Civil Aviation Organization (ICAO) in October 2016, are critical measures (Scheelhaase et al., 2018). These so-called market-based measures provide a twofold economic incentive to companies to reduce emissions. First, companies that reduce their emissions can sell their excess permits to others, creating a financial incentive for overall emission reduction. On the other hand, companies that exceed their emissions allowances have to acquire additional permits. This system ensures that environmental goals are met while promoting cost-effective emission cuts (Oesingmann, 2022). Second, if companies exceed their assigned carbon allowances and need to buy additional carbon credits, emissions trading schemes incentivise investments in sustainable technologies based on the concept of abatement costs. Abatement cost for carbon reduction refers to the expenditure required to decrease GHG emissions by, for instance, one ton (Li et al., 2024). If the cost of reducing emissions by a certain amount is lower than the costs resulting from the need to buy additional emission allowances, it is financially viable for companies to invest in carbon-reducing technologies. Abatement cost serves as a key incentive for carbon reduction by creating a financial motivation for entities to decrease their carbon emissions.

European Union Emissions Trading System (EU ETS)

All EEA airlines are subject to the ”European Union Emissions Trading System” (EU ETS) the world’s largest cap-and-trade GHG emissions market, affecting airlines’ competitiveness as discussed in chapter 7. Within EU ETS airlines are obligated to hold a sufficient amount of allowances to account for the quantity of emissions they produce. A gradually decreasing number of allowances is allocated to all companies every year. If the actual emissions emitted on intra-EEA flights exceed the allowances an airline holds, they are obligated to buy additional allowances from other airlines or industries. Within its system, SAF is assumed to have zero GHG emissions. Consequently, it reduces the number of allowances airlines and freight forwarders need to acquire or increases the number of allowances they can sell and thus represents a direct financial incentive (Oesingmann, 2022). The price of EU ETS allowances has increased more than tenfold over the past decade. A similar global emissions trading programme for the aviation sector, known as CORSIA, is currently in the pilot phase (Baxter, 2021).

3.3.2. SAF blending-quotas

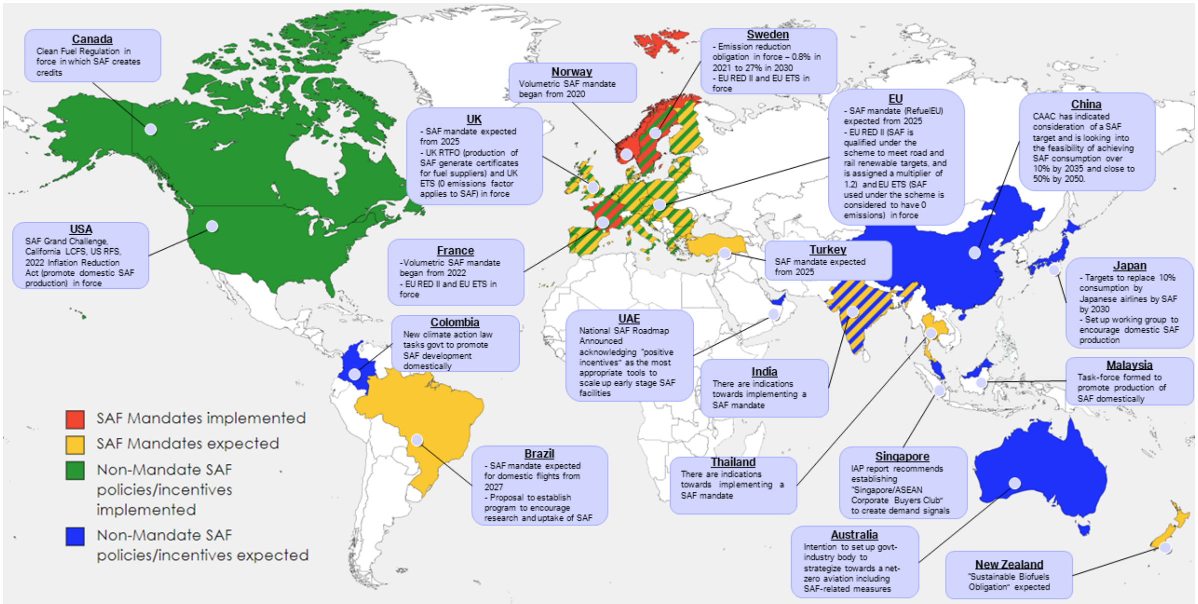

Figure 3.1: Global SAF Policy Landscape (ISCC, 2023)

Figure 3.1 shows that countries accounting for the vast majority of global air traffic are either working on a SAF mandate or planning to implement policies to foster the uptake of SAF. One of the most significant programs to promote the adoption of SAF is the EU's RefuelEU Aviation initiative. This initiative is part of the broader European Green Deal, targeting net-zero greenhouse gas emissions by 2050. The initiative mandates a progressive increase in the blending of SAF with conventional jet fuels. Airlines operating within or from the EU must use a specified percentage of SAF, with blending mandates set to increase over time, starting with modest targets and becoming more ambitious as production capacities and technologies improve. Specifically, the quota starts at 2% in 2025 increasing to 6% by 2030, by 2035 the target is 20%, by 2040 it rises to 32%, by 2045 the quota is 38% and finally by 2050 the quota reaches 70% (International Trade Administration, 2024). Incentives and penalties are in place, with airlines and fuel suppliers receiving incentives for early adoption and exceeding blending targets. Non-compliance with the mandated quotas can result in penalties, ensuring adherence to the regulations. The initiative also encourages investment in SAF production technologies and infrastructure, supporting research and development in advanced SAF production methods to make these fuels more cost-competitive and scalable (European Parliament, 2023).

3.4. Secondary driver for SAF adoption: Carbon accounting

The primary advantage of SAF is the reduction of GHG emissions. In the context of a company's own GHG emissions, these are subdivided into three scopes and calculated based on standardised protocols, the most widely known being the "Greenhouse Gas Protocol". Several themes presented in chapter 5 suggest that reducing a company's emissions by purchasing SAF and subsequently claiming these scope 3 emissions reductions is a promising starting point to recoup the additional costs of SAF.

3.4.1. Scope 3 emissions

Companies can track their GHG emissions through a system called scope emissions, which categorises emissions based on their source in relation to the company's activities. From the perspective of an airline scope 1 covers direct emissions from company-owned sources like the burning of jet fuel. Scope 2 focuses on indirect emissions from the consumption of purchased electricity (e.g. purchased electricity for airport ground services) (World Resources Institute, 2004). Finally, scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. They encompass all other indirect emissions across the entire value chain, for example, the production and distribution of jet fuel (World Resources Institute, 2004). This comprehensive approach helps companies understand their total environmental footprint. For airlines and large integrated freight forwarders (e.g. DHL, UPS, FedEx) alike kerosene, a scope 1 emission, represents the largest source of GHG emissions and is therefore the area which offers the biggest emission savings potential (DHL Group, 2024b).

3.4.2. Greenhouse Gas Protocol

There has been a recent increase in voluntary corporate GHG accounting and reporting instruments, one of them being the Greenhouse Gas (GHG) Protocol. This form of business self-regulation has gained prominence and is now the most common voluntary business action addressing climate change. Companies voluntarily measure and manage their GHG emissions because they expect the introduction of future mandatory GHG controls (Hickmann, 2017). The GHG Protocol is a comprehensive global standard framework for measuring and managing greenhouse gas emissions from public and private sector operations, value chains, and mitigation actions. Developed through a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), it provides a detailed methodology for businesses, governments, and organizations to quantify and report their GHG emissions. WRI and WBCSD represent important emerging partners for freight distributors as discussed in chapter 7.3. The GHG Protocol provides specific methodologies for calculating emissions, often tailored to particular sectors or types of emissions. This calculation process generally involves collecting data on activities that produce GHGs, such as fuel consumption, electricity use, and production output. Appropriate emission factors, which are coefficients quantifying the emissions associated with a particular activity are then applied. The total emissions are estimated by multiplying the activity data by these emission factors (Hickmann, 2017).

3.4.3. Science-Based Targets Initiative

Attempts to develop science-based targets (SBTs) to help the private sector contribute to global environmental sustainability goals have intensified in recent years. The term SBT typically refers to corporate climate targets aligned with the goals of the Paris Agreement, according to the criteria established by the Science Based Targets Initiative (SBTi). The SBTi aims to drive climate action, particularly among large transnational corporations in the highest-emitting sectors. Since its inception in 2015, the number of companies setting and committing to climate SBTs has grown annually (Quahe et al., 2023). Chapter 7 discusses that a cargo owner's adherence to the SBTi can be a valuable tool to freight distributors for customer segmentation The SBTi provides clear criteria and detailed guidance for companies to develop and submit their targets. The process typically involves an initial commitment, where companies commit to setting SBTs by signing a commitment letter, indicating their intent to develop science-based targets within 24 months. This is followed by the development phase, where companies develop their targets following the SBTi criteria and methodologies, involving rigorous data collection and analysis to ensure targets are scientifically robust. The developed targets are then submitted to the SBTi for official validation, where a team of experts reviews the targets against their criteria to ensure alignment with climate science and the goals of the Paris Agreement. Once validated, companies implement their targets and integrate them into their business strategies, also being encouraged to annually report their progress to ensure transparency and accountability (Quahe et al., 2023). The SBTi plays a critical role in mobilising the private sector for climate action.

3.5. Preliminary conclusion

This study examines SAF's, a potential solution for reducing aviation emissions, impact of business models in air cargo. SAF production pathways (explained in section 3.1) face challenges like high cost and limited investment (section 3.2). Regulations (section 3.3) and scope 3 emission accounting (section 3.4) act as drivers for SAF adoption. Biomass-based SAF is currently the dominant production pathway but faces its limitations. Non-biogenic alternatives like Power-to-Liquid (PtL) hold promise for the future. Overall, overcoming cost barriers and attracting investment are crucial for widespread SAF adoption. However, addressing these issues will require an unprecedented level of coordination between different actors.

4
Conceptual Model & Application

To address the research gap identified in chapter 1.2.1, this chapter will develop a conceptual model outlining key aspects for business models in air cargo and relationships between these aspects. Once developed, the conceptual model will be applied to describe the contemporary business models of air cargo's most relevant value chain actors. This chapter concludes by hypothesising potential effects on these business models caused by SAF based on literature and secondary data. The analysis of these impacts will be guided by drivers and barriers for SAF adoption as described in chapter 3.2 and 3.3.

The adoption of new technologies requires innovations in the underlying technology but more importantly organisational innovation in the form of business model transformation (Strupeit & Palm, 2016). Business models play a vital part in the adoption of new and emerging technologies. Case studies from other "green" technologies have shown that dedicated business models can catapult the diffusion of sustainable technologies and help overcome the adoption barriers outlined in chapter 3.2. Conversely, the absence of robust business models can impede adoption, irrespective of the technology's maturity. Strupeit and Palm (2016) for example concluded that dedicated business models functioned as a catalyst for the adoption of PV in Japan, Germany and the US. However, they note that "green" business models are significantly influenced by the unique contextual conditions within each country and advise business managers "to analyse the contextual environment in order to identify well-suited business models" (Strupeit & Palm, 2016). This leads to the conclusion that business models can not be assessed in isolation but as an integral part of a system. To address this fact, the study utilises the two concepts of value chain and Business Model Canvas.

Other scholars acknowledged the lasting impact of SAF on business models across the aviation industry. Gössling and Humpe (2023) assessed the potential impact of SAF on passenger air traffic. Their analysis suggests that adopting low-emission fuels could trigger new business models, ultimately leading to a new equilibrium in global travel patterns. This highlights the potential for SAF to permanently reshape business models across the air cargo value chain as well. To capitalise on this, an in-depth analysis is necessary to ensure business model transformation acts as a driver for SAF adoption, underscoring the relevance of this study.

4.1. From theory to conceptual model: The business model

Despite growing scientific interest in the concept of business models, there is no generally accepted definition (Rodríguez-Molina et al., 2014). Many different conceptualisations have been suggested (Zott et al., 2011). For the sake of this study the definition by Zott et al. (2011) is adapted who states that a business model is a "unit of analysis, offering a systemic perspective on how to "do business," encompassing boundary-spanning activities (performed by a focal firm or others), and focusing on value creation as well as on value capture". The most widely known framework to conceptualise business models is the Business Model Canvas (BMC). According to this framework, a business model consists of nine building blocks: Customer Segments, Value Propositions, Channels, Customer Relationships, Key Resources, Key Activities, Key Partnerships, Cost Structure and Revenue Streams (Osterwalder &

Pigneur, 2010). The result is a visual representation of a company's business model as shown in figure 4.1. The BMC is commonly used in research to analyse, describe and compare business models and provides a consistent and reliable framework which has been tested extensively (Rodríguez-Molina et al., 2014; Schwidtal et al., 2023). It provides a basis to understand changes and how they affect industries as well as organisations (Colak et al., 2023). Scholars applied the BMC before to analyse the impact of strong external pressure (e.g. legislative pressure through SAF quotas) on the business model of companies across the aviation value chain (Colak et al., 2023; Heiets et al., 2019). Colak et al. (2023) for instance explored how an external shock, in the form of the Covid-19 pandemic, affected the business model of airports in the UK. They employed the BMC to group the analysis of BMs into three aspects. Firstly they assessed the business models of UK airports before the shock. Secondly, they identified the most important BMC building blocks to adapt to this shock. Thirdly, they described the building blocks after businesses had adapted to the shock and were positioning themselves to increase their resilience for the future.

Following this example, this study analyses contemporary business models across the air cargo value chain, focusing on the most significant stakeholders. The analysis begins by developing a base scenario Business Model Canvas (BMC) for these actors. Subsequently, key building blocks most impacted by the adoption of SAF are identified. This allows the study to hypothesise a future BMC reflecting the potential transformation caused by SAF.

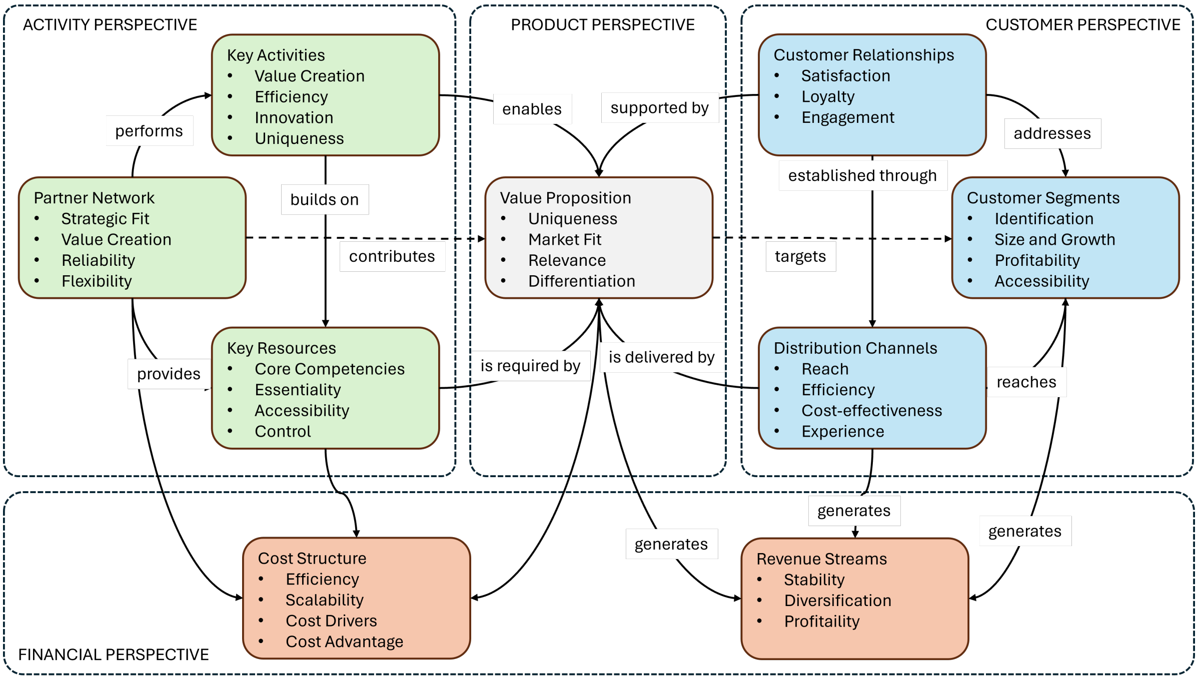

Figure 4.1: Conceptual model for air cargo business model: BMC grouped into perspectives and extended with criteria and relationships (Adapted from Fritscher and Pigneur (2011) and Osterwalder and Pigneur (2010))

To take a more comprehensive approach to analysing business models with the BMC, the BMC's building blocks are further grouped into four perspectives: activity perspective, product/service, customer perspective and financial perspective (see figure 4.1). This will help to structure the subsequent base-case analysis and the flow of the semi-structured expert interviews. The four perspectives revolve around the focal aspects of value creation and value capture (Zott et al., 2011). The product/service perspective focuses on understanding the core problems faced by target customers and how an offering uniquely addresses them. This requires a clear value proposition that demonstrates why a product or service is more valuable than similar offerings from competitors. The activity perspective helps businesses to understand the operational requirements and resource allocations necessary to execute their business model successfully. It also enables companies to assess the efficiency and effectiveness of their current operations and identify areas for improvement or optimisation. The customer perspective of the BMC emphasises understanding the needs, preferences, and behaviours of the target customers.

It revolves around creating value propositions and channels that resonate with customers, ultimately driving customer acquisition, satisfaction, and retention. Lastly, the financial perspective of the BMC focuses on the revenue streams, cost structure, and overall financial viability of the business model. It provides a framework for understanding how the business generates revenue, manages costs, and achieves profitability (Bengo & Arena, 2013; Fritscher & Pigneur, 2011). Changes stemming from one perspective (activity, product/service, customer or financial perspective) are likely to impact the other perspective as well. The reason for this is the need for business model consistency among BMC building blocks. For example, the addition of a new product (value proposition) requires new suppliers and sales channels (key partners) and so forth (Kamp et al., 2021). For this reason, relationships between the different building blocks of the BMC were added in the form of ”action” words (see figure 4.1). These will help to understand how changes in one building block impact related building blocks, supporting business model consistency.

In summary, the BMC will form the basis for the subsequent analysis of business models in air cargo. This study aims to analyse each perspective of the BMC by describing the underlying building blocks. Building blocks most relevant to the transition to SAF will be identified. Thereafter, potential changes to these building blocks will be hypothesised based on secondary data and validated by conducting semi-structured exporter interviews. The resulting conceptual model will be extended with two external dimensions to aid in the explanation of causes for certain changes.

4.2. Unit of analysis: The air cargo industry value chain

This chapter begins by establishing a comprehensive understanding of the air cargo industry's value chain. This will provide an overview which is crucial for subsequent analysis. Following that, all identified actors will be mapped based on their interest in a well-managed adoption of SAF and their potential to influence key decisions. The resulting power/interest matrix will highlight the most significant players in relation to SAF adoption that will then be subject to further investigation in this thesis.

4.2.1. Value chain composition

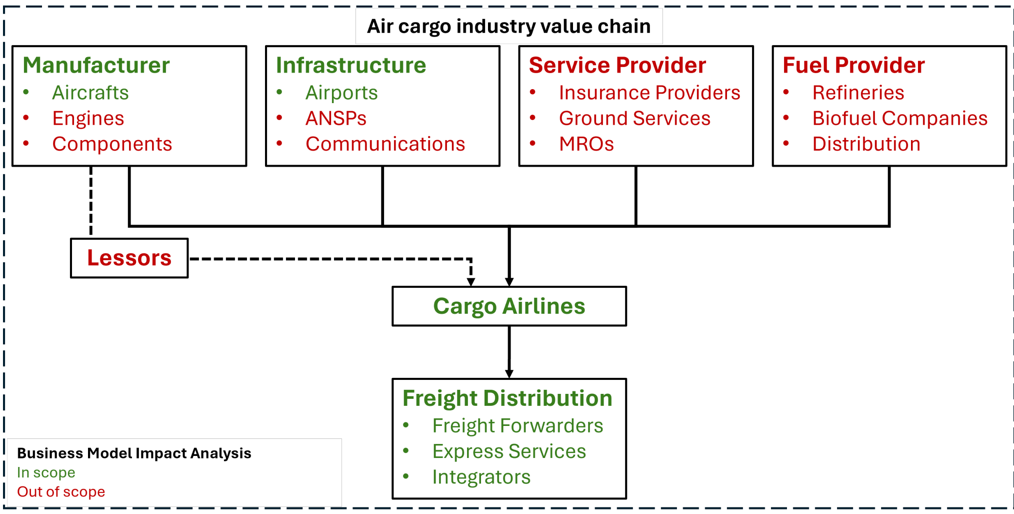

Figure 4.2: Unit of analysis: The air cargo industry value chain (Adapted from Tretheway and Markhvida (2014) and Colak et al. (2023))

For the subsequent analysis of air cargo industry actors, with a focus on those that are within the scope of this study, the value chain concept by Porter (1985) will be applied. According to Porter (1985), the value chain concept depucts the interconnected activities a company (or industry) performs to deliver a valuable product or service to its customers. In order to analyse the value chain within an industry, it's crucial to establish the elements comprising it first. Typically, the production of goods or services across an industry can be segmented differently, influenced by regional variations or the methodology employed in delineating the production process (Jacobides et al., 2006). Consequently, defining an industry, such as air cargo, may vary depending on geographical locations and organisational viewpoints, necessitating the establishment of a baseline definition before delving into any detailed analysis. For this study the commercial aviation value chain definition by Tretheway and Markhvida (2014) (see figure 4.2) serves as a starting point for the definition of the industry architecture since it provides a simple but comprehensive overview of relevant actors that are affected by the transition to SAF. Generally, the aviation industry can be divided into an upstream segment, a central node, and a downstream segment.

4.2.2. Power-interest matrix

Analysing all members of the value chain proposed by Tretheway and Markhvida (2014) would exceed the scope of this study. Hence a power-interest matrix was developed (see figure 4.3) to assess which industry actors have the highest interest in a well-managed transition to SAF in air cargo while also being able to influence key decisions. The analysis sheds light on key stakeholders – organizations whose involvement is essential for effective system modifications (Johannesson & Perjons, 2014). The actors' interdependence mandates a thorough comprehension of their objectives, interests and relationships (Enserink et al., 2022). Figure 4.3 builds on the stakeholder analysis from Figure 4.2 by utilising a power-interest matrix, also known as a power-interest grid (Bryson, 2004). This grid visually organises stakeholders based on their level of influence (power) and their level of concern (interest) regarding the well-managed introduction of SAF into the air cargo industry. Specifically, the matrix considers power as the stakeholder's ability to influence key decisions related to SAF adoption and interest as the stakeholder's level of concern regarding a smooth transition that doesn't overburden individual actors within the industry.

Five focal actors were identified, based on high power and high interest, of which four will be the subject of this study: Aircraft manufacturers, (cargo) airports, (cargo) airlines and freight distributors. The stakeholders are either engaged in developing the required infrastructure and technological prerequisites (indicating high power) or involved in developing dedicated business models that take into account SAF-specific hurdles (indicating high interest), or both. Airports, alongside fuel companies, are considered the actors with the highest power since they provide the technological prerequisites for the adoption of SAF in the form of (1) aircraft that are certified to fly with SAF and (2) certified and scalable production pathways for SAF. Conversely, they could also hinder SAF adoption by developing aircraft that use other technologies (e.g. electric or hydrogen aircraft) or not providing sufficient amounts of SAF at competitive prices. Airlines and freight distributors score also relatively high in interest since they have to develop new revenue streams to deal with the cost increase. Moreover, they can assert a significant amount of power due to the fact that they are ultimately the ones who make purchasing decisions for or against SAF. Airports will have to build dedicated SAF blending fuelling infrastructure, which makes them another significant actor in SAF adoption.

Fuel companies will not be part of this analysis since (1) the complexity of fuel supply chains could only be insufficiently analysed within the scope of this study, (2) a dominant technology for the production of SAF has not yet evolved (Bullerdiek et al., 2021) and other scholars analysed the business model of fuel companies prior (e.g. Martinez-Valencia et al. (2021)). Other actors, such as Communications, Ground Service Providers, ANSP, MRO and Insurance Providers, are also not considered for this study since the transition to SAF will have little immediate impact on their operations and business models (third and fourth quadrant). They are part of auxiliary industries which are necessary for carrying out flight operations, however, their operating model is largely independent of the technology used within the aircraft. Furthermore, some actors are directly impacted in their business model through the use of SAF or other alternative propulsion technologies but are not powerful enough to decisively drive the adoption of SAF (second quadrant). Lessors have a financial interest in controlling the adoption of new propulsion technologies because these could reduce the value of other aircraft in their portfolio. For instance, if governments around the globe mandate SAF quotas demand for aircraft that have the appropriate certification will rise while demand for aircraft without this certification will fall. Component and Engine manufacturers have a high interest in SAF adoption since they develop and produce the technologies that enable the use of alternative fuels. Nevertheless, their ability to exert influence is limited by the dominance of the Airbus/Boeing duopoly, as important decisions on technological trajectories are largely in the hands of these two companies.

In the following subchapter, a general overview of the remaining four actors, their interconnections and position in the value chain as well as some key aspects of their business models will be provided.

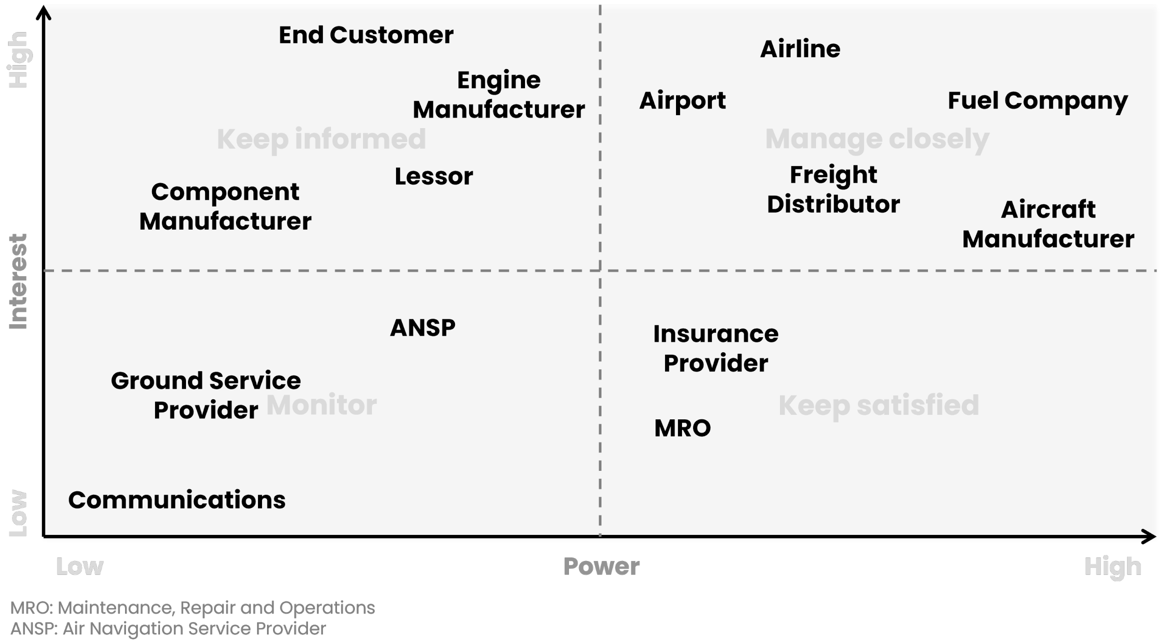

Figure 4.3: Power-Interest Matrix for SAF Transition in Air Cargo

4.3. Application: Current business models across value chain

Amidst constant technological change companies must reorganise their business mode in a way that aligns with their value chain (Awan et al., 2022). To analyse a business model for a particular value chain member, so-called business model criteria can be used which are assigned to a BMC building block (Scholtysik et al., 2023).

Looking at the first perspective of the business model canvas, the *activity perspective*, business mode criteria for the three BMC building blocks of partner network, key resources and key activities were developed. Partner networks undergo scrutiny based on their strategic fit, reliability, flexibility and contribution to value creation. Key activities are evaluated through lenses of value generation, operational efficiency, innovation, and distinctiveness. Meanwhile, key resources are analyzed for their core competencies, essentiality, accessibility and management control. Transitioning to the *product perspective*, the value proposition is scrutinised against business model criteria such as uniqueness, market fit, relevance and differentiation. Shifting to the *customer perspective*, customer segments undergo evaluation on parameters like identification, size/growth potential, profitability, and accessibility. Customer relationships are analyzed in terms of satisfaction levels, loyalty, and engagement metrics. Similarly, distribution channels are assessed for their reach, operational efficiency, cost-effectiveness, and overall customer experience. Finally, moving to the *financial perspective*, revenue streams come under scrutiny for their stability, diversification, and profitability. Meanwhile, the cost structure is evaluated against key business model criteria, including efficiency, scalability, cost drivers, and overall cost advantage (Osterwalder & Pigneur, 2010).

Once the BMC archetype for each of the four value chain actors is developed the impact of SAF on the nine building blocks will be assessed. The focus in this regard will be on the building blocks which are most affected by a transition to SAF. The fact that a BMC building block is significantly affected is assessed based on four criteria: Significance, Relevance, Consistency and Permanence. These criteria are based on the OECD (2021) assessment framework. In this context, the criteria significance assesses if there are any direct effects of the introduction of SAF on a particular BMC building block. Relevance securities if the introduction of SAF leads to a misalignment between the current definition of the building block and the necessary state after the introduction. The consistency criteria assess if changes in other building blocks of the BMC impact a particular building block through prevalent interconnections. Finally, permanence evaluates if the changes in a BMC building block will be constant over time or are only short-dated. If at least three out of four of these criteria are met, the impact of SAF on this building block is considered high. Consequently, the building block will be the primary focus for further analysis and subsequent expert interviews.

The subsequent analysis is sorted by the degree of impact on the business model of an actor starting with the least affected, namely aircraft manufacturer, and ending with the most affected, freight distributor.

4.3.1. Aircraft Manufacturers

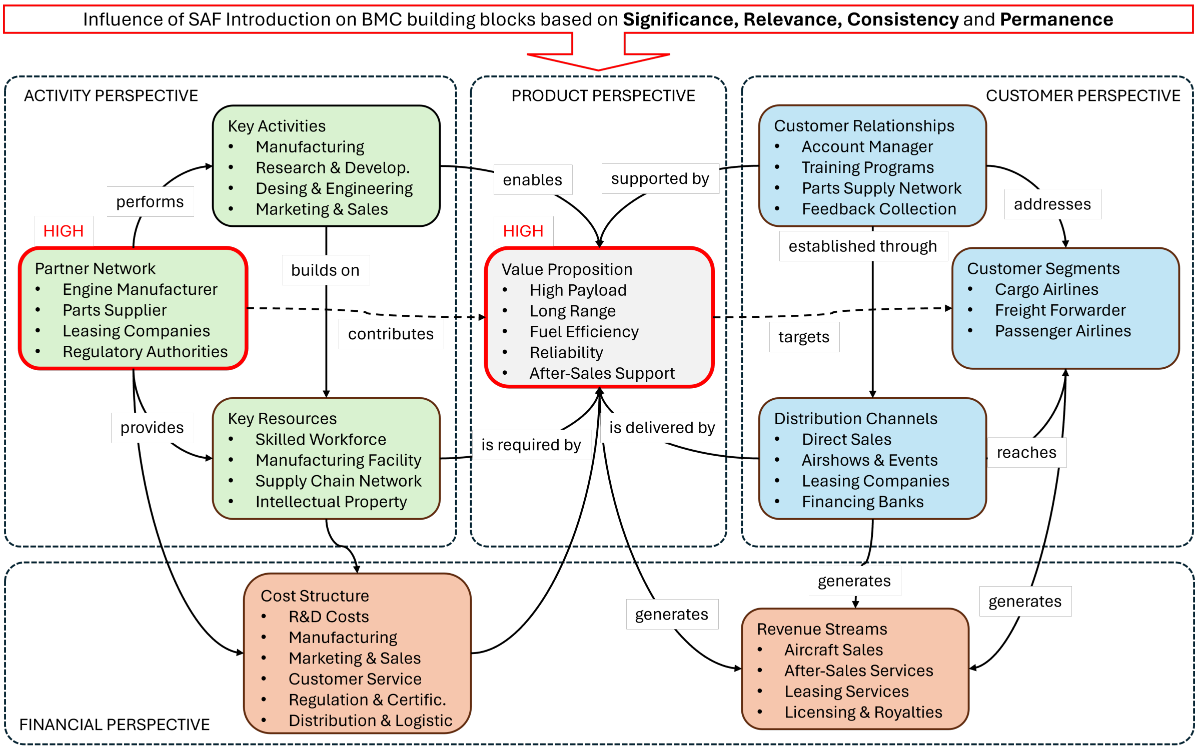

Figure 4.4: Archetypal example of business model canvas for aircraft manufacturer

The fundamental idea behind the use of SAF is the direct replacement of conventional jet fuel without the necessity of any technical modifications to current-generation aircraft. All types of SAF are so-called ”drop-in” fuels which have similar chemical and physical properties to conventional jet fuel and can hence act as a direct replacement (Okolie et al., 2023). Consequently, the impact of SAF on aircraft manufacturers can be considered minimal because no modifications to their current product portfolio are required. However, current ”ASTM International” standards require that SAF is mixed with at least 50% fossil kerosene to be used to fuel a commercial aircraft (Okolie et al., 2023). Since this standard was established in 2011 no commercial aircraft has been developed and certified that exceeds this number. Nevertheless, one recent test flight conducted by British airline Virgin Atlantic in cooperation with research institutes, fuel companies, aircraft and engine manufacturers demonstrated that long-distance flights powered by 100% SAF are technically feasible (Brogan, 2023).

Due to this American aircraft manufacturer Boeing set a goal in 2021 to deliver commercial airplanes certified to run on 100% SAF by 2030 (Boeing, 2023a). This step comes at a time when legislators are pushing for the adoption of SAF in aviation by implementing mandatory quotas that go beyond the currently certified 50% SAF. In 2023 the European parliament passed a law that mandates airlines to use at least 2% by 2025, rising to 6% in 2030, 20% in 2035 and gradually to 70% in 2050, representing a significant step towards large-scale utilisation of SAF (Reuters, 2023). As a consequence of this development, the *value proposition* of an aircraft manufacturer is impacted by the certification status of their aircraft with respect to SAF requirements in a given region. Aircraft manufacturers must increase their certification for the maximum permitted admixture of SAF accordingly to keep and extend the provided *value proposition*. Otherwise, airline customers who operate non-certified aircraft will face significant disadvantages. They may be unable to operate flights in specific regions because their aircraft do not match the local SAF quota requirements. Alternatively, these airlines may need to purchase SAF certificates from other carriers that have exceeded the minimum SAF requirements, potentially incurring additional costs. For these required certifications aircraft manufacturers need to add new stakeholders to their *partner network*. In addition to the existing certification authorities for new aircraft, such as the Federal Aviation Administration (FAA) in the US and the European Union Aviation Safety Agency (EASA) in the EU, other standardisation bodies should be included in the *partner network*. Specifically, ASTM International and the European Committee for Standardisation (CEN) should be actively involved in the partner network for the certification of SAF production pathways. Moreover, the environmental organisation ISCC (International Sustainability and Carbon Certification) plays a crucial role in ensuring the sustainability of SAF feedstock and should therefore also be added to the *partner network* to cover certifications for the entire production process of SAF. It is important for aircraft manufaturer to participate actively in the certification process for SAF to ensure low-emission fuels satisfy technical requirements for their complex products.

4.3.2. Airports

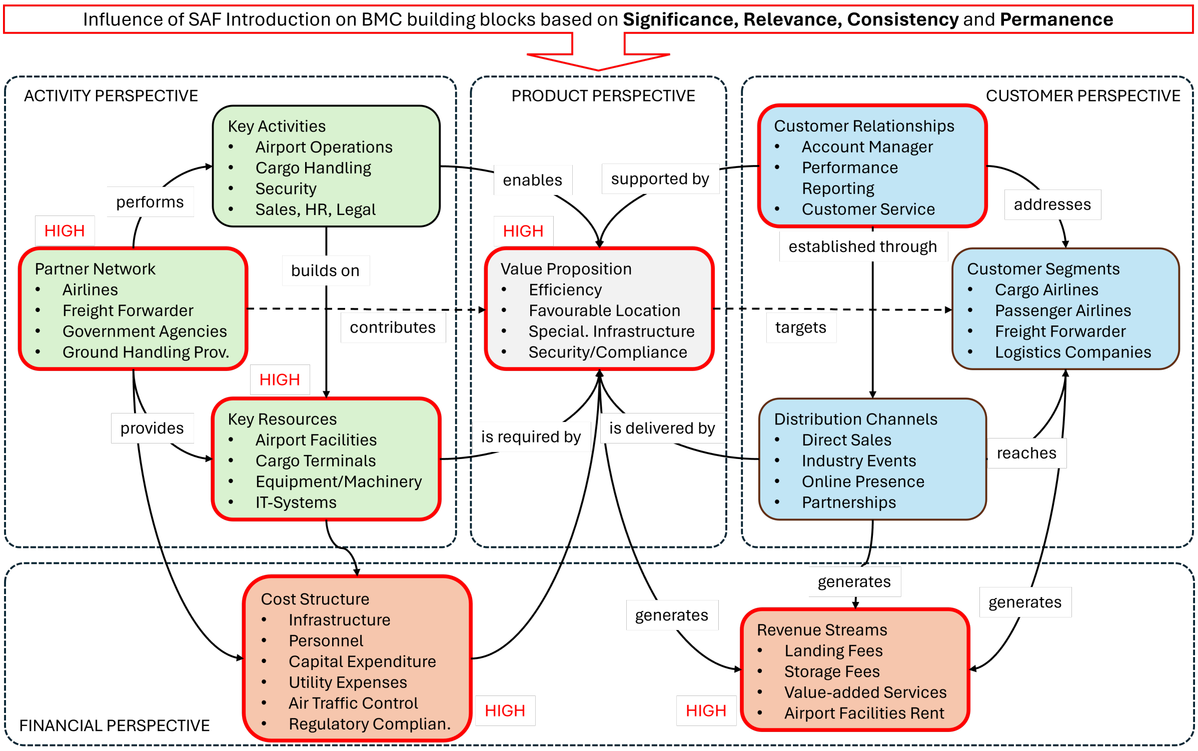

Figure 4.5: Archetypal example of business model canvas for cargo airports

Cargo airports derive *revenue streams* from two primary sources: (i) aeronautical activities and (ii) commercial activities. Revenues from aeronautical activities are proportional to flight frequency and cargo volume. On the other hand, revenue from commercial activities depends solely on cargo volume. The steep growth in air traffic has resulted in a twofold rise in airport business, as revenue has surged from both these channels (Graham, 2022). Yet, airports struggle to break even due to a *cost structure* characterised by high fixed costs and intense market competition (Colak et al., 2023; Dixit et al., 2023). Between 2012 and 2019, for example, airports reported approximately $5 billion in economic profit, yielding a Return on Invested Capital (ROIC) of roughly 6%. However, despite this positive ROIC, it is notable that the median profit margin of the 68 largest airport groups globally has remained in the negative territory, hovering around -6% over the past two decades (IATA & McKinsey & Company, 2022). Many airports can only sustain themselves because they are owned by local governments and are funded affordably through tax-efficient local government bonds. Their operations prioritise broader economic benefits over accounting profits (IATA, 2013). This underscores the challenging business landscape within which airports operate, often relying heavily on government subsidies to sustain their operations (Fu et al., 2011). Consequently, airports frequently find themselves unable to generate adequate cash flows independently, hindering their ability to undertake inherently risky investments, such as those in SAF infrastructure. Despite this, mandates by policymakers have forced airports to increase investments in carbon-reducing technologies, further burdening their *cost structure* (Dixit et al., 2023).

Deepening existing relationships within the airport's *partner network* through vertical integration between airports and airlines can help mitigate financial risk for both parties. This type of collaboration has been subject to an ample body of research, e.g. D'alfonso and Nastasi (2014), Fu et al. (2011), and Yang et al. (2015). The strategies employed for vertical integration include airline ownership of airport facilities, long-term use contracts, the issuance of revenue bonds to airlines by airports and revenue sharing between airlines and airports. Airports profit from collaboration through financial support and necessary business volume (passenger or cargo). Meanwhile, airlines secure access to key airport facilities, allowing for long-term planning (Fu et al., 2011). Vertical integration agreements are generally beneficial leading to higher profits for profit-maximising airports and higher welfare for welfare-maximising airports (Xiao et al., 2016). The success of these arrangements has sparked interest in employing collaborative efforts to drive the transition to sustainable aviation. Airport bonds could be used to finance *key resources* such as fuel farms for the mixing of SAF with fossil kerosene. In project financing arrangements of this nature, airports maintain ownership of the asset while transferring the exclusive right to their use to the project sponsor (e.g. cargo airline, freight forwarder) through a long-term lease agreement, minimising the associated risk (Fu et al., 2011). Dixit et al. (2023) demonstrate that collaborations between airports and airlines for sustainability initiatives outperform carbon taxes in mitigating GHG emissions within the aviation industry.

Leipzig-Halle Airport in eastern Germany, the fourth largest cargo airport in the EU, exemplifies a collaborative approach to advancing the adoption of SAF. In partnership with customers such as DHL and Condor Airlines, technical partners like Airbus, Sasol, and HH2E, and with political support, the airport has initiated a project to produce SAF on an industrial scale near the airport (Leipzig-Halle Airport, 2023). This initiative highlights the necessity for airports to engage new technical partners in their *partner networks*. Moreover, it demonstrates how cargo airports can differentiate themselves and offer an enhanced *value proposition* to their customers by ensuring reliable access to SAF.

4.3.3. Freight Distributors

From an integrated freight forwarder's perspective green transporting offerings can help to position and differentiate their brand, and to anticipate future demand increase for sustainable transportation options (McKinsey & Company, 2024). DHL, for example, has been delivering all parcels from private customers in the German domestic market in a CO2-neutral way since 2011 without additional cost for their clients. In 2022, they extended this offering to international shipments from Germany by private customers. The following year DHL launched the first service to reduce carbon emissions from individual shipments for commercial customers, called GoGreen Plus (DHL Group, 2023). Focusing on sustainability as a premium service can attract eco-conscious customers and extend the provided *value proposition*. A valuable initial insight for further analysis of the business model, yet, cost remains a major obstacle.

The most cost-effective technology for the production of SAF is the HEFA production pathway based on palm oil as feedstock. Yet the derived SAF is still approximately 80% more expensive than conventional kerosene (Bullerdiek et al., 2021). This leads to the situation that SAF is, despite improvements in production efficiency, not yet cost-competitive with petroleum-derived jet fuel, leading to additional costs for airlines, freight distributors and ultimately end customers (Martinez-Valencia et al., 2021). Based on the high price of SAF, an air cargo industry that relies on SAF will inevitably incur higher transportation fees. This alters the *cost structure* as well as *revenue streams* and consequently negatively impacts the *value proposition* provided by freight forwarders, which is partly based on the fact that air cargo is a cost-effective mode of transportation. This issue has to be addressed by freight forwarders through the addition of other aspects to the *value proposition*.

Charging higher prices does not seem to be a problem in itself, since air cargo has historically always been pricier than transportation by container ship, typically costing 10 to 15 times more per unit weight (Boeing, 2023b). But this price premium comes with a significant advantage: speed and reliability. Air cargo offers much faster transit times, making it ideal for valuable, time-sensitive, or perishable goods

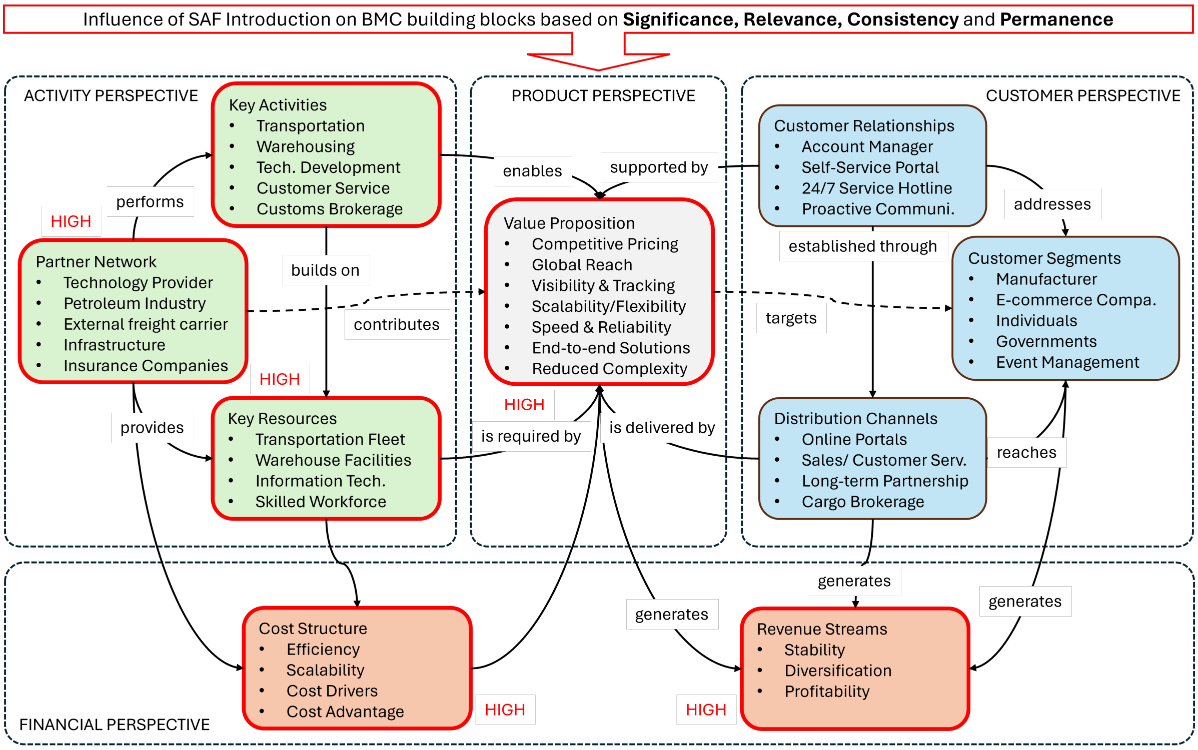

Figure 4.6: Archetypal example of business model canvas for freight distributor

(Boeing, 2023b). In total 18.9% of global trade in terms of nominal value is transported by air while only accounting for 0.2% of volume, underlining the high monetary value of transported goods (S&PGlobal, 2021).

Logistics companies should therefore focus on one aspect to broaden SAF's *value proposition* to the customer: Scope 3 emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. They encompass all indirect emissions (excluding electricity) across the entire value chain, for example, the production and distribution of goods manufactured in production plants not directly owned by the respective company (World Resources Institute, 2004). Various reasons exist as to why cargo owner would want to reduce their scope 3 emissions. Certain industries, such as retail, are close to the end consumer and seek to enhance their brand image by establishing themselves as leaders in sustainability. Some large corporations in sectors like pharmaceuticals or automotive, with high-priced products and healthy profit margins, can more readily adopt green transport due to their financial resources. Other companies that have publicly committed to sustainability in capital markets, or those headquartered in regions with stricter environmental regulations and a strong public focus on sustainability (like Scandinavia), are driven by regulatory concerns or stakeholder desires (McKinsey & Company, 2024). Driven by this desire to reduce scope 3 emissions, the market for green logistics solutions is rapidly growing. McKinsey & Company (2024) estimate that total spend for green logistics will amount to $50 billion in 2025, representing 2% of overall logistics spend. This number will increase seven-fold by 2030 with a total spend of $350 billion representing a 15% market share in the logistics sector. The buying decision of cargo owners for green transportation services will predominantly hinge on the logistics companies' ability to aid them in achieving their emission reduction goals. Prerequisites for this are the auditablity of emission reductions (McKinsey & Company, 2024). In this context, however, it has to be considered that not every type of carbon reduction effort qualifies as Scope 3 emission reduction. Scope 3 emission reductions have to adhere to carbon accounting standards such as the "Greenhouse Gas Protocol", "GLEC Framework" and "EN 16258" (DHL, 2022).

In the past, sustainability services in the logistics sector were based on the principle of emissions compensation, commonly referred to as offsetting. Carbon offsetting is the practice of compensating for carbon dioxide emissions by investing in projects that reduce or capture an equivalent amount of carbon elsewhere (DHL, 2022). Offsetting does not qualify as carbon reduction under the aforementioned accounting standards (Scoping Interview, 2023). Instead, so-called insetting measures have to be taken to reduce carbon emissions. Insetting tackles emissions head-on by investing in carbon reduction projects directly within the company's supply chain. SAF is considered an insetting measure and offers a powerful tool for cargo owners to significantly reduce their Scope 3 emissions directly at the source. Since carbon accounting standards assume SAF to be carbon neutral, creating a strong lever for emissions reduction. (DHL, 2022). This is exacerbated by the fact that kerosene is the largest source of carbon for integrated freight forwarders such as DHL (DHL Group, 2024b). First practical evidence suggests that airfreight customers are willing to pay a premium for SAF, suggesting that a demand-sided approach should drive the initial adoption of SAF (World Economic Forum, 2022).

Therefore, it becomes apparent that cargo owners want to reduce carbon emissions and that SAF offers the largest lever to do so. Yet on an operational level, most logistics companies are not able to commercialise green logistics successfully McKinsey & Company (2024). McKinsey & Company (2024) recently conducted a study based on 41 expert interviews and concluded that logistics companies have to collaborate with cargo owners to develop green transportation services that provide tangible value to the end customer. This strategy involves finding a niche group of customers who value green transportation enough to pay a slight extra. Logistics companies would partner with cargo owners to identify these environmentally-conscious consumers and develop specialised green shipping options. This creates a new *value proposition*, demonstrating that green transport does not have to be cost-prohibitive when approached this way. For instance, green logistics might only add a small percentage (approx. 2%) to the cost of a pair of jeans. Many logistics companies with strong customer relationships believe consumers would be willing to pay a small premium for clear and understandable reductions in emissions. The success of this strategy hinges on two key factors: a deep understanding of specific customer segments and effective communication of the *value proposition* for green logistics. However, if executed well, these early adopters can become powerful advocates, accelerating broader diffusion and market acceptance of SAF (McKinsey & Company, 2024).

4.3.4. Cargo Airlines

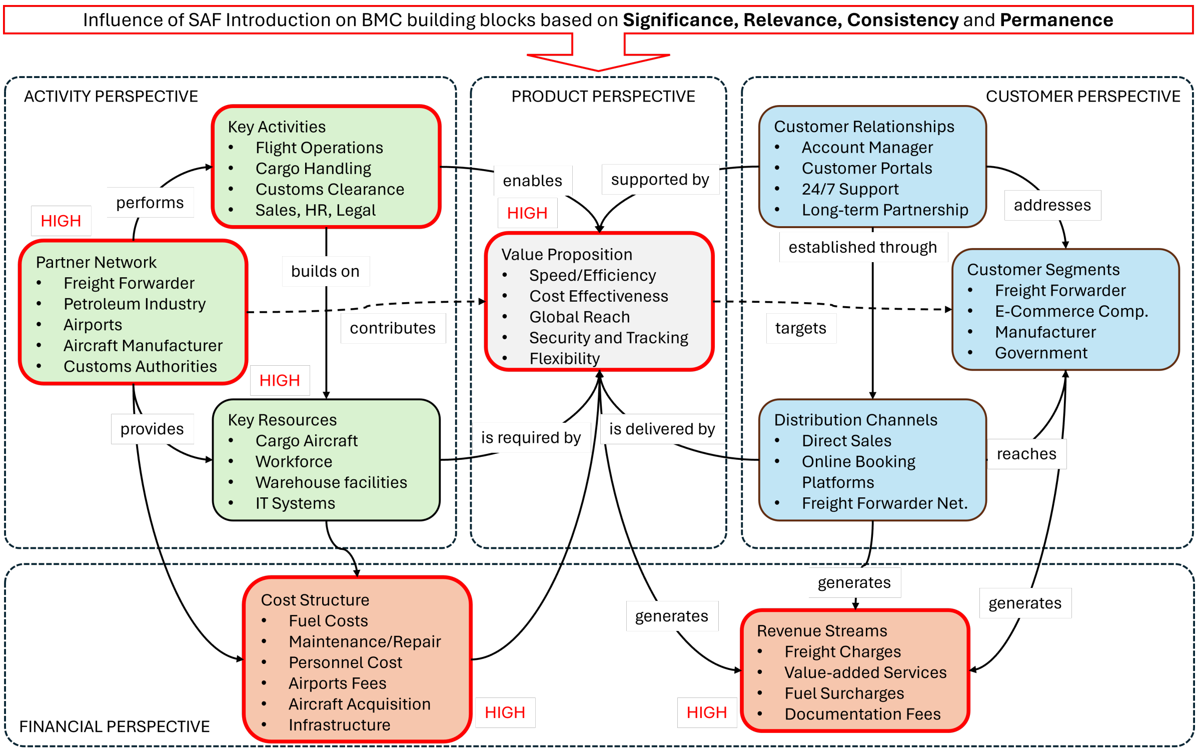

Figure 4.7: Archetypal example of business model canvas for cargo airlines

Integrated freight forwarders, including major carriers like DHL, FedEx, and UPS, manage their dedicated fleet of cargo aircraft. Consequently, any previous discussions regarding the influence of SAF on freight forwarders inherently extend to cargo airlines as well. Notably, the increased costs associated with SAF will significantly impact the financial structure of cargo airlines and freight forwarders alike, making it a critical consideration for their *cost structure*. However, an essential advantage enjoyed by integrated freight forwarders lies in their substantial reliance on express services, which are highly profitable. DHL Group for instance generates only 30% of their revenues from express deliveries, meanwhile, these services account for more than 50% of profits (DHL Group, 2024a). Express services encompass the entire logistics chain, from the shipper to the consignee, covering export and import customs procedures, as well as air transport. In contrast, airlines that exclusively transport cargo via dedicated cargo aircraft or within the holds of passenger planes typically do not provide these comprehensive services. Instead, they operate within the so-called general freight market, focusing solely on air cargo transportation (Boeing, 2023b). The focus on one aspect of the transportation chain makes it harder for cargo airlines to differentiate themselves. Additionally, ”operating freighter aircraft has historically been a business with tight margins” (van Leeuwen, 2024). This situation significantly challenges cargo airlines in formulating a compelling *value proposition* that can offset the additional costs associated with SAF for cargo owners.

Simultaneously, European cargo airlines face substantial disadvantages due to the EU Emissions Trading System (EU ETS) for various reasons. As discussed in chapter 3.2 all EU airlines are subject to the EU ETS emission market and thus have to hold a sufficient amount of allowances to account for their emissions (Oesingmann, 2022). The EU ETS has faced criticism for its perceived failure to effectively incentivize emission reduction. This criticism stems from undesirable distributional effects and competition distortions arising from divergent rules across sectors and regions Efthymiou and Papatheodorou (2019). For instance, the European Union has opted to allocate emissions from aviation based on the country of departure or arrival (Preston et al., 2012). Consequently, airlines departing from or landing within EU borders are required to purchase emissions allowances. However, this rule can be easily circumvented (Preston et al., 2012). Considering a scenario where a cargo owner intends to ship goods from the Netherlands to China. They have two choices: (1) Direct Flight: Booking cargo space on a direct flight between the Netherlands and China, operated by either a European or Chinese carrier. In this case, both carriers would be subject to EU legislation and emissions quotas for the entire journey. (2) Third-Party Carrier: Opt for a carrier from a third-party country, such as the UAE. The flight from the Netherlands to the UAE would indeed adhere to EU regulations and the associated costs. However, during the second leg of the journey from the UAE to China, these regulations no longer apply. This strategic manoeuvre places carriers from third-party countries in an economically advantageous position, while local companies bear the brunt, and the overall climate impact remains unaddressed. Inevitably, the issue of GHG emissions from aviation transcends national borders, affecting the policies of countries beyond the European Union, and giving rise to questions of sovereignty (Preston et al., 2012). The vast majority of cargo airlines are not able to cover the additional cost from SAF (McKinsey & Company, 2024), suggesting that the industry was not yet able to overcome this issue by formulating a compelling *value composition*. Collaboration with other actors such as airports, freight distributors and road transportation companies appears to be crucial to developing green transportation services that cover all steps in the transportation of goods to the end customer (Dixit et al., 2023; McKinsey & Company, 2024).

From an activity perspective, two key BMC building blocks come into focus: *Partner Network* and *Key Activities*. The relationship with airports, in particular, will undergo a significant shift. They will no longer just supply conventional kerosene, but also the infrastructure and sufficient quantities of SAF. Additionally, the supplied SAF must be appropriately certified to enable airlines to claim the resulting reductions in Scope 3 emissions for their customers. While challenging this also presents a significant opportunity for intense collaboration between airports and cargo airlines. Dixit et al. (2023) found that collaborations between airports and airlines for sustainability initiatives are more effective in mitigating GHG emissions within the aviation industry compared to carbon taxes. Collaboration offers a promising path forward and will increase the relevance of airports within the *partner network* of airlines.

With the implementation of SAF overseeing production processes and ensuring adherence to sustainability criteria will emerge as a *key activity* for airlines Airlines should therefore collaborate with independent organisations for the certification of SAF. It is sensible to add these organisations to the *partner* *network*, as the use of current first and second-generation biofuels, while leading to a reduction in GHG emissions, also has unintended indirect effects such as deforestation, reduced biodiversity and land degradation (Bullerdiek et al., 2021; Okolie et al., 2023). ISCC is one such organisation that provides a globally applicable sustainability certification system for SAF feedstock. It sets standards and criteria for sustainable production practices, ensuring that SAF is produced deforestation-free and climate-friendly (ISCC System, 2024). At the same time, all companies in the biofuel supply chain are also part of the airlines' indirect partner network. However, these relationships are primarily managed by the airports which provide SAF.

4.4. Preliminary conclusion

The above analysis of SAF's impact on selected business models was conducted based on literature and secondary data. The result highlights some impacts of SAF on contemporary business models of important value chain actors, e.g. aircraft manufacturers, airports, cargo airlines, and freight distributors. However, the results obtained from desk research paint a fragmented picture of these effects, necessitating further investigation in the proceeding chapter. The following findings have been obtained so far:

Firstly, SAF blending quotas and the need for greater flexibility from airlines regarding the timing and quantity of SAF usage necessitate that aircraft manufacturers increase their SAF blending certification beyond the current 50%. However, it remains unclear how and if this will impact *cost structure, revenue streams* and *key partnerships*.

Secondly, airports find themselves in a challenging competitive landscape, characterised by high fixed costs and oftentimes negative profit margins, which necessitates innovative approaches to realise necessary investments in sustainability, such as vertical integration. A key question that prevails is how airports can attract investment in SAF and if airports even have a strategic interest in engaging in this kind of project.

Thirdly, the increasing demand for sustainable transportation options offers a unique opportunity for freight distributors to differentiate their brands and cater to eco-conscious customers. However, the use of SAF incurs higher costs. Collaboration with cargo owners to target specific customer segments willing to pay a premium for eco-conscious shipping offers a promising solution to recouping these costs. Yet, evidence from practice shows that freight distributors are currently not able to commercialise SAF successfully.

Lastly, cargo airlines are in a much more challenging position compared to freight distributors when it comes to the definition of a compelling value proposition. A primary reason for this is that cargo airlines are only one link in a longer transportation. This makes it hard for them to differentiate themselves leading to generally low margins for cargo airlines. New regulations such as the EU emissions market and SAF quotas within the EU further compromise EU airlines' competitive position due to the resulting competitive distortion. How airlines can solve these problems through effective commercialization of SAF remains questionable.

5
Empirical Results

The previous chapter identified some areas in relevant business models that will likely experience significant changes due to the adoption of SAF in air cargo. However, as pointed out in the literature review in chapter 1.2.1, existing literature and secondary data draw an incomplete picture of these changes. This creates a need for additional primary data collection in the form of semi-structured expert interviews. This chapter outlines the process through which these interviews were conducted and analyses. Furthemore, themes that emerged for each business model as a result of this primary research will be explained and interpreted in the wider context of the air cargo industry. In the subsequent chapter 7, this chapter's resulting themes will then be discussed in concatenation with the previous chapter's (see chapter 4.1 findings to provide actionable results for practitioners and industry participants.

5.1. Expert Interviews

Based on the interview approach outlined in chapter 2.1 and the stakeholder analysis conducted in chapter 4.2, ten semi-structured interviews were carried out with experts across eight organisations representing different angels on the air cargo value chain. Four of these organisations were representing the stakeholder groups identified as the highest in power and interest in chapter 4.2, namely aircraft manufacturers, cargo airports, cargo airlines and freight forwarding & distribution companies. Additionally, an expert from an SAF interest group and an expert from an SAF certification organisation were interviewed to gain a better understanding of the important regulatory aspect of SAF adoption. The aviation consultancy expert provided a holistic view of the interactions between the different members of the value chain. Finally, the representative of a cargo owner working for a major apparel company gave insights into how cargo airlines and freight forwarders can create a compelling value proposition for customers by using SAF.

In addition, I attended the "Sustainable Aviation Futures Congress 2024" in Amsterdam from the 22nd to the 23rd of May, which significantly enhanced my understanding of the topic and improved my analysis of the qualitative data. The congress provided valuable insights into current trends, challenges, and innovations in sustainable aviation, enabling me to contextualise and interpret the qualitative data more effectively.

The participants were chosen based on their roles within organizations involved in sustainable aviation, with a preference for senior positions to ensure a comprehensive understanding of the business model under evaluation. The interviews followed a set of predefined open-ended questions while allowing for additional follow-up questions to arise. Throughout the interview process, ethical guidelines were rigorously followed, including obtaining informed consent and ensuring data anonymity.

In qualitative empirical research, additional interviews should be conducted until data saturation is achieved, which means no additional insights are identified and further data collection is redundant. A systematic review by Hennink and Kaiser (2022) of empirical studies' sample size shows that data saturation can already be achieved within a low range of 9 to 17 interviews. However, the feasibility of data saturation is largely contingent upon a narrow research objective (Hennink & Kaiser, 2022). It

Alias	Organisation	Position	Relevant Experience	Country
AM1	Aircraft Manufacturer	Technology Strategist	16-20 Years	Netherlands
AP1	Cargo-focused Airport	Head of Communications	2-5 Years	Germany
AP2	Airport Consultancy	Head of Sustainable Aviation	11-15 Years	Netherlands
AG1	Airline Group	Director of Operations	6-10 Years	Germany
FD1	Freight Distribution	Sustainability Expert	11-15 Years	Germany
FD2	Freight Distribution	SAF Expert	11-15 Years	Germany
FD3	Freight Distribution	Sustainable Aviation Expert	6-10 Years	Germany
CO1	Cargo Owner	Director of Climate & Energy	20+ Years	USA
EX1	SAF Interest Group	Fuel Policy Expert	2-5 Years	Germany
EX2	SAF Certification Orga.	Manager for Sustainable Fuels	6-10 Years	Germany

Table 5.1: Profiles of Interview Participants

is important to consider the following empirical results in light of the complexity of the air cargo value chain, which covers the entire globe, hundreds of airports and dozens of airlines, and is often linked to other modes of transportation. Hence the claim of data saturation is not made for this study. Instead, this study focuses on gaining insights into the topic from a broad range of perspectives by interviewing a diverse group of industry stakeholders. This approach is sensible considering the non-existence of research at the intersection of SAF, business model transformation and air cargo, as pointed out in chapter 1.2.1.

To gain insight from the raw data the interview transcripts were analyzed through reflexive thematic analysis. Reflexive thematic analysis involves identifying codes from the raw data, translating these codes into concepts as well as themes and creating a model of higher-order themes. The resulting model is then checked for trustworthiness (Cruzes & Dybå, 2011). Throughout the coding stage of the qualitative data analysis, an inductive open coding approach was pursued. This way entirely new concepts can be derived from the data to build a novel explanation for the research question at hand.

The succeeding sections present the results. The following interview analysis follows the worked example for thematic analysis done Byrne (2022) which is based on the six steps for reflexive thematic analysis outlined by Braun and Clarke (2006). The interviews are analyzed according to the four business models for which a conceptual model was previously developed. The codes in tables 5.3, 5.2, 5.4 and 5.5 are organised in groups which form the basis for themes. The codes are grouped to provide a high level of transparency. Following Braun and Clarke (2006) six-step process the codes are developed and it is explained how these emerged from the interview in steps 2 and 3. In step 4, a thematic map, as proposed by Byrne (2022), is constructed. This visual representation includes both themes and sub-themes. Eventually, themes are defined and a narrative is developed that captures the essence of the data and seeks to answer the research question.

5.2. Aircraft manufacturer

The insights for the analysis of aircraft manufacturers' business models were drawn from the expert interview with AM1, who is working as an innovation manager for a commercial aircraft manufacturer. In addition, findings from a panel discussion at the "Sustainable Aviation Futures Congress 2024" with Brian Moran, Chief Sustainability Officer at Boeing, were included in the analysis. In table 5.2 the alias "Boeing" is used to refer to this panel discussion. The summary of all resulting codes can be found in table 5.2.

5.2.1. Stage 1: Familiarisation with the data

The initial stage necessitates a deep dive into the data pertaining to aircraft manufacturer business models. This in-depth exploration requires thorough and repeated readings of the collected information. This intensive engagement allows for the identification of initial patterns, emerging themes, and potential meanings embedded within the data. Additionally, to enrich the initial insights, the analysis will consider relevant external sources such as conference proceedings. Insights gleaned from these sources will guide the subsequent stages of detailed coding and thematic development.

5.2.2. Stage 2 & 3: Generating and iterating codes

As hypothesised in chapter 4.1 the large-scale adoption of SAF has little immediate impact on the business model of aircraft manufacturers. Nevertheless, some important aspects emerged that show how aircraft manufacturers can shape the adoption of SAF in a way that protects their current revenue streams and offers the possibility to gain a slight competitive advantage. Overall, the introduction of new technologies is an inherent part of the business of aircraft manufacturers such as Boeing and Airbus, making SAF just one of many innovations in recent decades.

The first group of codes revolve around the technological aspect of SAF. AM1 emphasises that SAF is a key technology for the quick decarbonization of aviation. He mentions the long lifetime of aircraft which can be up to 30 years. Furthermore, AM1 adds that the development of new aircraft might take several years. Combining this with existing orders for current-generation aircraft with delivery dates going well into the 2030s, SAF is the only feasible option to reduce carbon emissions in aviation significantly. The expert goes on by listing other technical improvements of modern aircraft that lead to an overall CO2 emissions reduction of 20% to 30% and noise emission reductions of up to 50% compared to previous generation aircraft. He explains that these improvements combined with the up to 80% lower emissions of SAF provide a huge potential for emissions reduction without the need for entirely new aircraft. AM1 is critical of the potential of alternative drive technologies, e.g. battery electric or hydrogen, as these are far from technologically mature. The estimated time to market maturity is 20 years and the greatest short-term potential for these technologies is in the domain of regional aircraft. There are no alternative technologies to address decarbonization in the medium and long-haul market for the foreseeable future.

The second group of codes addresses aircraft manufacturers' role in driving the scale-up of SAF production. AM1 emphasises that aircraft manufacturers have no interest in being directly involved in the production of SAF. Instead, they try to mediate between airlines and SAF producers to assess the exact amount of SAF needed, when it is required and in which geographic location. The type of feedstock also plays an important role in this context since not every region allows for the use of all feedstocks. Palm oil as feedstock for instance is not permitted in the EU. Boeing sees its role as a mediator between policy, financing and airlines. This is important since regulators have to provide a level playing field preventing any airline from a particular region from being disadvantaged. Additionally, SAF producers struggle to secure financing since airlines are unable or unwilling to make long-term fuel purchase commitments. Aircraft manufacturers can mediate between these as a neutral third party. Furthermore, Boeing is seeking to support the proliferation of SAF by making its own commitments to purchase low-emission fuels. The aircraft manufacturer uses SAF for a portion of its fuel requirements on test flights, ferry flights and business travel. Additionally, Boeing is a member of the board at ASTM International, an organisation that certifies production pathways for SAF. This involvement ensures that a diverse range of production methods is certified, helping to meet the growing demand for SAF and enhancing supply security by utilising locally available feedstocks.

The final group of codes looks at the possibility of improving and diversifying revenue streams by gaining an advantageous position through investments in SAF. AM1 mentions that stricter regulations for the use of SAF provide certainty to invest in this technology. This also helped aircraft manufacturers now working on certification to increase the blending rate of SAF to 100%. Currently, a maximum of 50% SAF can be blended into fossil kerosene. This might give aircraft manufacturers a new selling point if competing aircraft models do not allow for this higher blending rate, by giving airlines more flexibility in their operations. In this context, Boeing's involvement in the ASTM International committee, as mentioned by Boeing's Chief Sustainability Officer, is invaluable. This organisation not only certifies production pathways but also determines the allowable percentage of SAF for specific aircraft models.

Group	Groundedness	Participants	Finale Codes (in some cases Sub-Themes)	Themes
	6	AM1	Ability to use current generation aircraft acts as a driver for decarbonization	Utilisation of existing knowledge about technological domains for the decarbonisation to avoid business model distribution caused by technology replacement
1	2	AM1	Technical improvements to reduce Emissions	
	2	AM1	Alternative propulsion technologies	
	2	AM1	Importance of SAF for emissions reduction	
	5	AM1, Boeing	Uncertainty about amount of SAF needed	Orchestrating production scale-up by facilitating communication between relevant stakeholders
2	4	AM1	Lacking investments in SAF production hinder scale-up	
	3	Boeing	AM support scale-up by bringing together Policy-makers, Financing and Airlines	
	2	AM1	Ability to generate additional revenue from green investments	Gaining competitive advantage by delivering aircraft capable and certified to fly on 100% SAF
3	2	AM1, Boeing	AM partners with certification authorities	
	1	Boeing	Boeing's role as part of the ASTM certification committee	
	1	AM1	Risks associated with SAF adoption	

Table 5.2: Codes and resulting themes from aircraft manufacturer expert interviews

5.2.3. Stage 4 & 5: Generating and defining themes

The process of generating themes from the previously discussed codes involves two levels of review (Byrne, 2022). The first level examines the relationships among the data items and codes that inform each theme and sub-theme. If the items and codes form a coherent pattern, it can be assumed that the candidate theme or sub-theme presents a logical argument and may contribute to the overall narrative of the data (Byrne, 2022). The second level involves reviewing the candidate themes in relation to the entire data set. Here, themes are evaluated based on how well they provide the most suitable interpretation of the data concerning the research question (Byrne, 2022). Themes are defined based on internal homogeneity and external heterogeneity. Following the example of Byrne (2022) a thematic map of themes (e.g. figure 5.1) is constructed which will later be used to develop a narrative. This process is identical for all four business models analysed in this chapter.

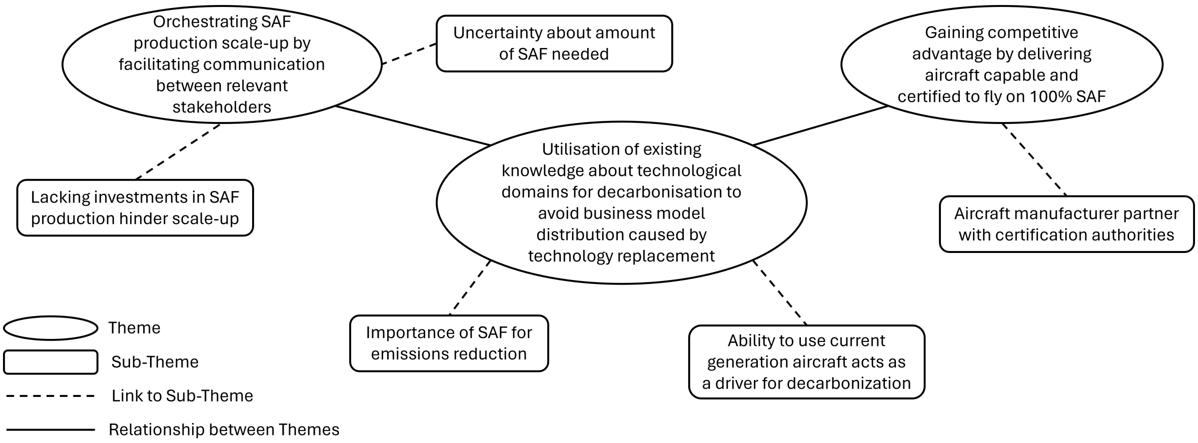

Figure 5.1: Finalised thematic map demonstrating four themes for Aircraft Manufacturer business models (Inspired by Byrne (2022))

In this section, the themes that emerged for the business model of aircraft manufacturers are defined and interpreted. The codes in table 5.2 are already grouped in a way that each group of codes results in one theme. These themes stand in relationship to each other as presented in figure 5.1. Codes that are considered important for the understanding of these themes are added as sub-themes to figure 5.1. Now, in the first step of analysis, each theme is defined. Important quotes might be added to the definition, similar to Byrne (2022), to gain a better understanding of industry participants' perceptions regarding the implications of SAF. The resulting definition is used to construct a narrative that will answer research question SQ3 about the implications of SAF on air cargo business models according to industry participants.

Utilisation of existing knowledge about technological domains for decarbonisation to avoid business model distribution caused by technology replacement

> "That means we have to think about it now because our customers in particular have to decarbonize - there's no way around it. And SAF is simply a way to push and promote decarbonization. [AM1]"

> "Well, in the hydrogen sector, if we see that within the next 20 years I would be surprised. In the electric sector, I think there are still one or two leaps to be made. The battery technology still has to make two leaps. There are now, I think, 80-seater aircraft that are currently the target in the electric sector. [AM1]"

As explained earlier SAF has little imitated impact on the business model of aircraft manufacturers since these are used to incorporating innovative technologies in their products. Nonetheless, aircraft manufacturers have a vested interest in the successful adoption of SAF because the industry is facing increasing pressure to decarbonize. Moreover, they can capitalise on their existing knowledge of jet engine technology when adopting SAF, minimizing the impact of potential disruptions caused by technological regime changes. This is also reflected in the expert's rather pessimistic stance towards hydrogen and electric aircraft, where he acknowledges that small-scale start-ups currently drive their development. Airbus eZero project (Airbus, n.d.) might show that large OEMs participate in the development of hydrogen aircraft but these aircraft are not expected to be launched until 2035 and focus on the regional aircraft market, which currently only makes up a small percentage of the global aircraft market. In essence, this means that incumbent aircraft manufacturers like Boeing, Airbus and Embraer promote the uptake of SAF as a means of protecting their current business and revenue streams. This way they can acknowledge decarbonisation as essential while avoiding the risk that comes with the development of new aircraft.

Orchestrating SAF production scale-up by facilitating communication between relevant stakeholders

> ”So, we have to work with our partners to make sure that we get them all on the same track and help them to be able to make predictions so that they know how big their SAF production plant needs to be and what quantities they can produce each year. [AM1]”

> ”Previously, this was simply not considered important enough that it would have been possible to invest heavily in SAF. People always wanted many things, but these were never politically formulated in such a way that there was an obligation. [AM1]”

Next, aircraft manufacturers will have to orchestrate the scale-up of SAF since there is a lack of investments in production capacity to meet the anticipated demand. Orchestrating the scale-up of SAF goes hand in hand with aircraft manufacturers’ interest in the use of SAF for the decarbonisation of aviation, indicated by the link between these themes in figure 5.1. In this context, OEMs can help SAF producers to overcome the issue of demand uncertainty by communicating with their airline customers and promoting the use of SAF. On the other hand aircraft manufacturers are usually closely involved with political decision makers and tend to have a high level of political influence in their respective countries. They can use this power to advocate for policies that provide investment security to SAF producers. This aspect changes the partner network building block of OEMs’ business model by adding SAF producers to this network.

Gaining competitive advantage by delivering aircraft capable and certified to fly on 100% SAF

> ”But you definitely have the possibility of, let’s say, a higher price, although, at the end of the day, I think everyone is very keen, in terms of Co 2 reduction and Co 2 certificate trading as well as in terms of emission reduction, to have aeroplanes in the sky that significantly reduce their emissions footprint. [AM1]”

Lastly, SAF will add a new dimension to the value proposition of aircraft manufacturers, possibly resulting in additional revenues. Airlines in the EU have to adhere to the EU’s SAF quota, which will rise to 70% by 2050. Since aircraft are used for up to 30 years, purchases of new aircraft scheduled for the next few years already have to consider this quota. Butt current certifications cap the use of SAF at 50%. Higher SAF blending certifications will therefore certainly play a role in the buying decision of airlines. However, due to the fact that only two major manufacturers of aircraft exist globally, the impact of higher SAF certifications on revenues will likely be low. The industry has a common interest in reducing their emissions and aims to produce as many current-generation aircraft as possible, AM1 points out.

5.2.4. Stage 6: Constructing a narrative

Aircraft manufacturers can use their advantageous position in the adoption of SAF to shape the adoption. All manufacturers maintain good relationships with relevant stakeholders such as policymakers, fuel companies and airlines which they can use to identify challenges and opportunities in the adoption of SAF. Together with the relevant stakeholders aircraft manufacturers can then develop the required solutions. In the case that OEMs succeed in decarbonising the industry through SAF, existing technological knowledge and production facilities can be used for many more decades, leading to a promising business outlook. However, if OEMs stay inactive and the adoption of SAF remains low due to a prevailing deadlock, aircraft manufacturers run the risk of further political intervention. Policymakers could push for decarbonisation through the use of hydrogen and electric aircraft, a technological domain in which the incumbent OEMs have little experience. This results in the risk of technological disruption by start-ups or government-funded conglomerates.

5.3. Airport

The codes and themes were generated from three interviews, namely those with expert AP1, AP2 and EX1. AP1 is working directly for a large German airport with significant exposure in the air cargo space. AP2 has several years of experience within the air cargo realm with an emphasise airport consultancy projects. EX1 is representing a SAF interest groups with dozens of members across the aviation fuel sector, including companies operating aircraft fuelling facilities. A summary of all resulting codes is presented in table 5.3.

5.3.1. Stage 1: Familiarisation with the data

Intense familiarisation with data through reading and re-reading was conducted. This process resulted in an initial set of ideas, which were then extended with notes taken during the expert interviews and insights gained from conversations with fuelling infrastructure operators and airport representatives at the ”Sustainable Aviation Futures Congress 2024”. This familiarisation step will ultimately improve the subsequent coding by outlining key aspects of the qualitative data.

5.3.2. Stage 2 & 3: Generating and iterating codes

Initially, it is important to understand that airports are usually not the owners or operators of fuelling infrastructure including pipes and storage facilities. There are exceptions to this such as French ”Aéroports de Paris (ADP)” and Spanish ”Aeropuertos Españoles y Navegación Aérea (AENA)” but these remain a rarity among airports in Europe. The vast majority of aviation infrastructure is operated by aircraft fuel service companies such as ”Air BP” or ”Shell Aviation” which acquire a concession from the airport that allows them to fuel aircraft (IATA, n.d.). At major airports, e.g. Amsterdam Schiphol, there might even be several fuelling companies from which airlines can choose. By not having any ”skin in the game” (AP2) as AP2 expressed very vividly, airports are limited in their power to influence the cause of SAF adoption. EX1 notes the influence of airports and OEMs in driving the adoption of SAF is often overestimated.

In total 19 codes ”resided” (Byrne, 2022) in the data collected from the three interviews. The lack of direct involvement in the SAF supply chain is the root cause for the relatively high number of frequently mentioned codes of group 1 presented in table 5.3. These codes revolve around the topic of facilitation and coordination, shaping the changing value proposition of cargo airports. Even if they are not directly affected, airports have a vested interest in shaping the introduction of SAF in a way that is favourable to them AP1 notes, ultimately extending their value proposition. As a result, the most common code is mentioned 14 times and deals with the airports changing value proposition, as shown in the table 5.3. Both airport experts (AP1, AP2) emphasise the changing value proposition airports can provide by coordinating between different stakeholders. AP1 elaborates on an ongoing project for the production of eSAF close to the airport and says that this will not be a significant part of their business instead this project outscores the airport’s ability to innovate and gain political support. The following four codes of group 1 revolve around similar topics such as collaboration and partnership. Based on the overall number of times codes from this group were mentioned, redefining their value proposition as a facilitator for SAF adoption seems to be the most important aspect for airports.

Moving on to the second group of codes the focus shifts to external forces shaping the business model either driven by regulatory and societal pressure or incentives through regulatory support. Yet, AP1 annotates that there is significant political and societal pressure to decarbonize all sectors, which makes it challenging to gather political support in the form of subsidies since the added value of supporting aviation must be weighed up against the possibility of supporting other industries. AP2 claims that aviation is under particular scrutiny due to aviation’s indirect costs borne by society, such as noise and non-CO2 emissions (e.g. fine dust), and the bad image of the industry as a very visible polluter compared to other less visible polluters, for instance, the cement industry or waste management (both accounting for more or equal amounts of emissions). The topic of EU quotas was subject to ample elaboration across all three interviews and was mentioned a total of 10 times. While being important for airports to be aware of this regulation, AP1 mentions that airports are not directly affected by the

EU quota or the EU emissions trading market. Still, most airports set their own voluntary sustainability goals, as noted by A1, to signal to customers that they are doing their part to foster ”green” aviation. Ultimately EU mandates are stringent for fuel suppliers and airlines and ”then there’s literally no quota for airports” (AP2).

Codes of group 3 focus on the physical infrastructure necessary to allow for the use of SAF. All interview participants mentioned that there is almost no need for new infrastructure at the airport. AP1 mentioned that the airport would like to have a blending facility in close proximity to avoid SAF being blended and fueled at other airports. This improves the airport’s position within the network of airlines by providing these with the flexibility to fuel SAF if needed to fulfil the quotas. Another important aspect discussed by AP1 and EX1 ist the lack of investments in SAF production facilities amplified by a difficulty in securing sufficient financing for these projects. In the end, these prevailing constraints in supply lead to constantly high prices for SAF. All experts point out that the price of SAF is three to four times higher than that of conventional paraffin, which limits demand and creates uncertainty for necessary SAF projects in the vicinity of airports. AP1 brought up that airports try to step in by leveraging their good connections to political decision-makers to lobby for launch funding.

The last group of codes deals with the demand side for SAF. AP1 explains that various airports make huge efforts to support the development of an SAF industry close to the airport in anticipation of upcoming quotas. AP2 brings up that the availability of SAF close to their destinations is important to airlines, However, a prerequisite for SAF projects to take off is long-term commitments from airlines as mentioned by both AP1 and AP2. AP1 notes that many airlines and integrators have set out bold targets for their sustainability goals, but uncertainties in terms of the persistence of legislation and possible new technological development make it hard for airlines and airports to commit to SAF projects.

Group	Groundedness	Participants	Final Codes (in some cases Sub-Themes)	Themes
1	14	AP1, AP2	Airports need to redefine their value proposition	Airports acts as facilitators and enable transition through coordination
	10	AP1, AP2, EX1	Sustainability as a collaborative effort	
	7	AP1, AP2, EX1	Partner Network Extension	
	5	AP1, EX1	Vertical integration / partnerships	
	4	AP1, AP2	Airports as facilitators for change	
2	10	AP1, AP2, EX1	Importance of EU Quota for quick transition	Airports are hardly affected by regulatory requirements, but must capitalise on incentives to gain an advantageous position within the SAF supply chain
	7	AP1, AP2	Political pressure drives SAF adoption	
	7	AP1, AP2	Societal Pressure drives SAF adoption	
	5	AP1, EX1	Limited impact of SAF regulations on airport BM	
	3	AP1, EX1	Need for Political / Regulatory support	
3	10	AP1, AP2, EX1	Few new infrastructure requirements	Fostering SAF uptake by leveraging political and industry relationships in combination with key resources
	5	AP1, EX1	Lacking investments in SAF production	
	5	AP1, AP2, EX1	Prevailing high SAF price / cost	
	4	AP1, EX1	Problems to acquire project financing	
4	5	AP1, AP2	Customer demand prerequisite for scale-up	Need for intense communication with airline costumers to create and sustain SAF demand
	4	AP1, AP2, EX1	Air cargo leads SAF adoption	
	4	AP1, EX1	High level of uncertainty regarding SAF demand	
	4	AP1	Airline customers have ambitious sustainability goals	
	3	AP1	Importance of customer commitment	

Table 5.3: Codes and resulting themes from airport expert interviews

5.3.3. Stage 4 & 5: Generating and defining themes

The themes that emerged from the interviews investigating the impact of SAF on cargo airports' business models are defined and interpreted in this section. Table 5.3 already provides a glimpse into the uncovered themes and their relationships to the codes. A total of four themes were identified. Their relationships to each other as well as respective sub-themes are visualised as a thematic map in figure 5.2. Next, each theme is defined and important quotations from the interviews are provided to support the definition. As a last point, a narrative will be developed to explain the themes' impact on the business model.

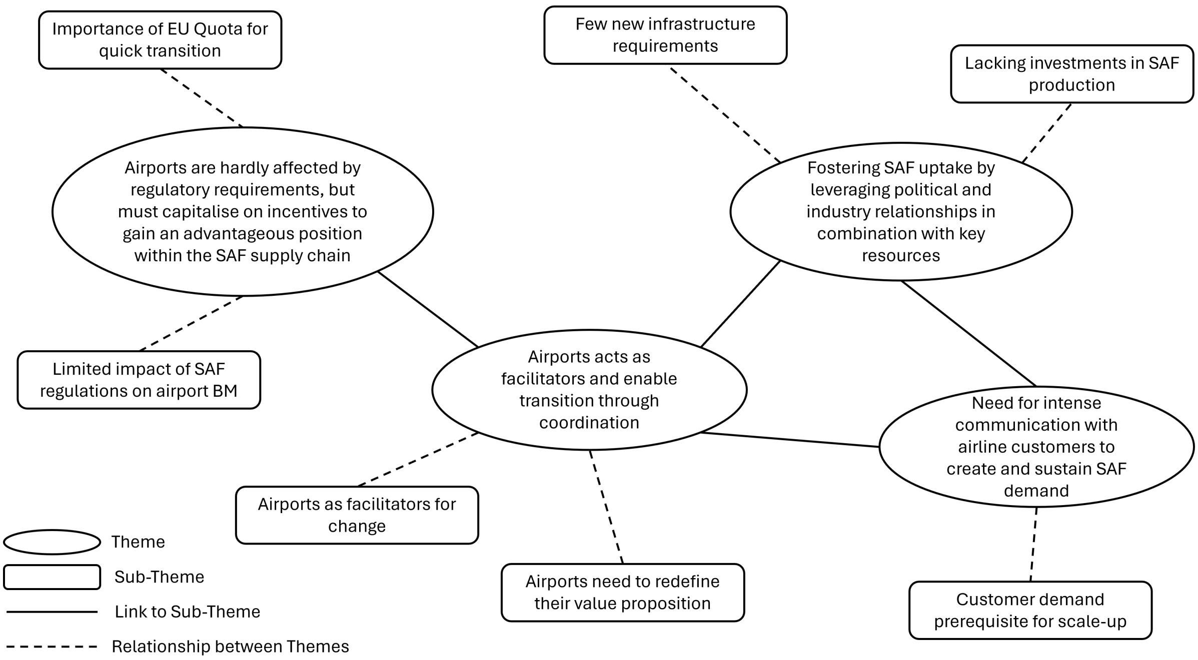

Figure 5.2: Finalised thematic map demonstrating four themes for Airports business models (Inspired by Byrne (2022))

Airports act as facilitators and enable transition through coordination

> ”They [EU] only say that the airports need to facilitate. But then there's no clear indication of what level of facilitation they're expecting from airports to drive this [SAF adoption]. [AP2]”
>
> ”So and then all the pricing and the contracts, it's all only between the airlines and the fuel producers. So nothing to do with the airports in between. So from that standpoint, they don't have skin in the game. So then they cannot really bend anything, so they can only facilitate. [AP2]”

Airports find themselves in a position similar to aircraft manufacturers where they do have an interest in a well-managed and swift uptake of SAF but are unable to SAF uptake directly. As indicated by the second quote, airports are pure infrastructure providers which oftentimes do not even own any of the infrastructure needed for the fueling of aircraft. Nevertheless, airports are in a position to coordinate different stakeholders. Most airports are at least partly owned by the government, providing them with the opportunity to advocate for regional SAF projects. On the client side, an interdependence between airlines/freight distributors and airports exists. Large freight distributors depend on specific airports since they have made additional investments in on-side sorting facilities. Airports can now make further investments by these companies contingent upon their decarbonisation efforts. On the supplier side, fuel companies need to acquire a concession a operate at a specific airport. These concessions have to be renewed every few years. Here as well airports could set sustainable criteria as a requirement for the renewal of a concession, providing airports with some leverage.

Airports are hardly affected by regulatory requirements, but must capitalise on incentives to gain an advantageous position within the SAF supply chain

> ”So as far as the infrastructure is concerned, as far as the supplies to the airport are concerned, these structures are relatively monopolised, these are structures that some fuel producers have been sitting on for a very long time and these are not necessarily the ones who are now, for example, starting to build these smaller SAF plants and invest in the technology. So there is a relatively big difficulty for these new producers, who really specialise purely in renewable fuels, to get in somehow. [EX1]”

> ”So there are three main players for this, right? So one is airlines, fuel producers and airports to drive this, but if you look at even the mandates, it’s stringent for fuel suppliers and airlines. And then there’s is literally no quota for airports. [AP2]”

> ”But in the end, the topic [on-side SAF production] also has added value for us [a cargo airport] later on, also in order to offer added value to politicians, who perhaps also sometimes say why do we need [...] airports or where is the added value? Who still wants to fly? So in this whole debate about aviation, where we as an industry are somehow not presenting ourselves well, we simply show the economic power and the economic engine with which such an airport can function. [AP1]”

Access to fuelling infrastructure is one of the primary hurdles for SAF start-ups that want to supply an airport. What makes this even more complicated is that SAF needs to be blended with conventional kerosene to meet ASTM certification standards. The first quote points out, however, that at many airports only one fuel supplier with long-standing contracts exists. Building redundant fuelling infrastructure would not be financially feasible. Consequently, some cooperation between SAF producers and fuel companies is required. Airports could stay inactive in this regard since they are not affected by EU regulations such as the SAF quota. These quotas have to be met by fuel suppliers and airlines, as pointed out in the second quote. However, airports have to keep in mind that this quota does not have to be met at every individual airport. Fuel suppliers might decide to fuel more SAF at certain airports to exceed the quota and offset the SAF not fueled at other airports. This puts airports that do have not the necessary infrastructure to blend conventional kerosene and SAF in a weaker competitive position, compromising the value proposition they can offer to airline customers. Additionally, airports as well as other parts of the industry are under public scrutiny, as highlighted in the third quote. Showing and communicating the efforts airports take to decarbonize the industry will eventually improve the public image and help justify their existence and expansion.

Fostering SAF uptake by leveraging political and industry relationships in combination with key resources

> ”But SAF kerosene has a price that is four to five times the price of kerosene, which means that you won’t find an airline that simply spends four or five times the price on fuel. [AP1]”

> ”We would have SAF facilities built near the airport, and we would have them built where the infrastructure is already there, i.e. where kerosene takes its route anyway. In other words, nothing new would be built now. For the time being, no major infrastructural changes are needed. [AP1]”

This and the following theme go hand in hand are are practically two sides of the same coin, as indicated by their link in figure 5.2. The first theme for the business model of airports established that airports act as facilitators for the adoption of SAF. This theme addresses the facilitation of SAF production scale-up, while the next theme deals with the facilitation of sufficient demand. The scale-up of production is a prerequisite for the wide-scale adoption of SAF since it will eventually drive down prices. Airports are in possession of many of the key resources for the production of SAF such as fuel pipers and land. Leveraging these resources to foster the establishment of SAF production close to the airport can offer a unique opportunity to gain control over one of the most important input factors.

Need for intense communication with airline customers to create and sustain SAF demand

> ”You don’t get any bank commitments, no investments if you can’t prove that you have somehow secured your production through purchase agreements and can get it to the customer. And we’re talking about a period of time that is completely alien to airlines. [EX1]”

> ”On the other hand, however, I have noticed from conversations that there is also the possibility of effectively selling on the green property for air freight. This is significantly greater than the willingness in the passenger sector. [EX1]”

Lastly, airports need to engage with their airline customers to ensure long-term commitment to the adoption of SAF. Many SAF production projects struggle to secure financing since airlines are not willing to engage in long-term off-take agreements. Airports might be able to help in this regard by lobbying for necessary policy changes. Once the necessary infrastructure and production investments have been made sufficient demand needs to be sustained. Air cargo might act as a driver for SAF adoption since cargo flows are concentrated at a few large airports.

5.3.4. Stage 6: Constructing a narrative

Airports have very little immediate influence on the rate at which SAF is adopted. Nevertheless, providing access to sufficient quantities of SAF to airline customers can act as a strategic advantage in the future, considering ever-stricter EU blending quotas for SAF. By offering airline customers substantial access to SAF, cargo airlines can choose to exceed the SAF quota at a particular airport. This allows them to offset missing SAF at other airports within their network, making this specific airport an anchor point in their operations. The problem that needs to be overcome is that large projects like SAF production facilities and pipeline infrastructure close to the airport usually require political support and incentives for incumbent fuel suppliers to participate in these endeavours. Airports have to facilitate between these stakeholders to gain an edge over other cargo-focused airports and attract further investments from cargo airlines and freight distributors in the future.

5.4. Cargo Airline

Five interviews relevant to the development of cargo airline business models in the context of SAF adoption were conducted. These experts are AG1, AP2, CO1, EX1 and EX2. AG1 has an elevated role in this analysis since he is the only expert working directly for an airline group operating cargo aircraft and offering belly cargo space. As a Director of Operations, this expert provides good insight into the effect of SAF on the daily business. The codes mentioned by AG1 are indicated in brackets in table 5.4 to underline their importance. AP2, EX1 and EX2 are all experts involved in a wide array of projects including airlines and provide a comprehensive perspective on relevant business model changes. The interview with CO1 was particularly interesting since she could provide a glimpse into the perspective of cargo owner who ultimately buys logistics services and how these make their buying decision under consideration of sustainability criteria. The resulting codes are compiled and summarized in table 5.4.

5.4.1. Stage 1: Familiarisation with the data

In the first stage of reflective thematic analysis, familiarisation with the data, the researcher immerses themselves in the collected information through thorough and repeated reading. This deep engagement helps identify initial patterns, themes, and meanings within the data. By noting early impressions and areas of interest, a solid foundation for further analysis. These early observations were combined with insight from the ”Sustainable Aviation Futures Congress 2024” and guided the detailed coding and thematic development in subsequent stages.

5.4.2. Stage 2 & 3: Generating and iterating codes

Business models for the commercialisation of SAF in air cargo are still developing, which makes analysing these a difficult undertaking. Various companies pursue different strategies in this regard and regionally varying policies add another level of complexity to this analysis. The focus will therefore be on the EU air cargo market.

Looking at the first group of codes the nascent nature of SAF business model becomes quickly apparent. All but one expert mentioned the commercialisation of SAF in some shape or form. A key challenge in this regard is the so-called ”Attitude-behaviour gap” as pointe out by AG1. This concept refers to the issue that many cargo owners desire sustainable shipping options but are unwilling to purchase these when they come at a ”green” price premium. But cargo owners also face increasing pressure to decarbonize caused by consumers’ growing green consciousness and societal pressure as outlined by CO1 and AP2. AG1, AP2 and CO1 state that the industry fails to communicate the advantages of SAF concisely to the end customer. AP1 underlines that airlines are an inherently slim-margin business making them unable to carry the extra costs stemming from SAF. Hence all experts call for a collaborative effort to drive the adoption of SAF. AG1 emphasises that airlines might be emitting the CO2 but the carbon footprint belongs to the entire supply chain for a specific product. CO1 points out that they use an internal catalogue to assess their logistics services providers against sustainability criteria. If some logistics companies fail to meet the minimum requirements the cargo owner tries to work with these companies to improve their sustainability KPIs jointly. AP2 also comments on the importance of large cargo owners to drive the transformation. On the side of SAF suppliers, EX2 highlight the importance of interest groups to coordinate the scale-up of SAF production and to lobby for necessary policy changes.

Proceeding to the second group of codes the focus shifts to the sourcing and purchasing aspect of cargo airlines' business model. Four experts note that the persistently high price hinders the development of a voluntary market for SAF. AG1 estimates that the use of 100% SAF would lead to a threefold increase in freight rates. AG1, EX2 and CO1 highlight the relationship between price and availability, stating that a certain threshold of demand needs to be achieved resulting in sufficient economies of scale and decreasing prices significantly. But even airlines that are willing to pay the current price premium struggle to source sufficient quantities. A hundredfold increase in SAF production capacity is necessary to achieve the industry's net zero goals by 2050 according to AG1. EX1 mentions that SAF investors require long-term purchase agreements with airlines to build new production facilities and minimise their risks, but these contracts extend over a period of time that is completely alien to the airlines.

Continuing with group 3 of codes a code that emerged late in the interview process but quickly became an important subject of discussion stands out: AP2 and CO1 lament the lack of a standardised accounting frame for carbon emissions. These accounting frameworks are used to estimate a company's scope 3 emissions. AP2 and CO2 remark that scope 3 emission reductions are one of the primary incentives for airlines to purchase SAF. The lack of a comprehensive accounting framework for SAF and scope 3 emissions has twofold negative consequences. Firstly, cargo owners are unwilling, or at least hesitant, to pay a premium for emission reductions if different accounting frameworks lead to different total scope 3 emissions from the outset. AP2 points out that a simple switch to another accounting framework could have the same negative effect on cargo owners' emissions without making any costly changes to their operations. Secondly, CO1 call attention to the fact that cargo owner is unable to communicate their carbon reduction efforts publicly when there is no generally accepted carbon accounting framework. CO1 states that big corporations like hers are often targeted by greenwashing allegations and a framework would help them to back up their carbon reduction claims. According to CO1 backing up these claims is further complicated by the fact that air cargo is part of a transport chain, often including several modes of transportation, making it hard to estimate the exact carbon emissions of a delivery from source to destination.

Advancing to code group 4 the cost aspect is moving to the centre of the discussion. First of all, a direct comparison between the cost of fossil jet fuel and SAF is insufficient. AP2 points out that EU emissions quotas have to be bought for every ton of CO2 emitted through fossil kerosene. These obligations are being omitted through the utilisation of SAF leading to some cost savings. Furthermore, a Lufthansa representative at the "Sustainable Aviation Futures Congress" noted that the non-adaptation of the SAF is also associated with costs because not making necessary commitments and gaining crucial knowledge now will incur higher costs for airlines in the future. EX2 observes that prices for SAF are decreasing but not sharply. This means that airlines have to deal with a price premium for SAF for the foreseeable future, raising the question how what a fair spread of the additional cost across the value chain could look like. The issue EU cargo airlines face in this regard is that there is no regulatory level playing field among EU and non-EU airlines, as explained in the next paragraph. AP2, CO1 and EX1 have different ideas about who could bear these additional costs. AP2 is of the opinion that freight distribution companies could absorb some of the "green premium" since these companies usually have healthy margins. EX1, on the other hand, believes that policymakers have a responsibility to issue free emissions certificates to companies that use SAF or to redirect revenues from emissions trading to reduce the cost burden for airlines. CO1 believes that cargo owners must bear the additional costs of SAF and can ultimately pass these on to the consumer. Even though there is no doubt that additional costs are incurred, some experts believe that its scope is exaggerated in the short term. Dick Benschop, former CEO at Schiphol Group, highlighted in a panel discussion at ”SAF Congress 2024” that the cost impact of the proposed 6% SAF quota by 2030 in the EU is negligible compared to other cost drivers such as inflation or general price fluctuation for air freight.

Lastly, the fifth group of codes touches upon the impact of new regulations to promote the uptake of SAF adoption on cargo airline business models. AG1, AP2, CO1 and EX1 emphasise the importance of the EU-wide SAF quota for a prompt scale-up of SAF production capacity. AG1 explains that a SAF quota is good for the industry since it provides planning security and points the industry in the right direction. However, AG1 also remark that the quota must go hand in hand with political incentivisation to build and expand the corresponding infrastructure. Furthermore, the EU SAF quota is one of the EU regulations with the longest time horizon going up to 2050, as emphasised by EX1. EX1 goes on by explaining that the EU quota sets a cap on the price premium for SAF, preventing sudden price spikes for SAF. Yet, the EU quota put EU airlines at a competitive disadvantage compared to non-EU airlines, AG1 complains. AG1 gives the example of a flight from Frankfurt to Shanghai with a layover in Dubai. The first leg of the flight is covered by the EU quota, whereas the second leg from Dubai to Shanghai is not. A European or Chinese airline flying directly between these two cities would have to buy expensive SAF for the entire length of the flight. Nevertheless, AG1 underscores that the European aviation industry is aware of the fact that emissions have to be reduced drastically. But he questions if a quota which is set up in the current way will achieve this goal if this can be circumvented so easily.

Group	Groundedness (mentioned by AG1)	Participants	Finale Codes (in some cases Sub-Themes)	Themes
1	18 (9)	AG1, AP2, CO1, EX1	Commercialisation of SAF	Challenging demand-side market dynamics since customers call for sustainability, but the business case for SAF is not yet profitable due to insufficient willingness to pay
	10 (2)	AG1, AP2, CO1, EX1, EX2	Sustainability as a collaborative effort	
	9 (3)	AG1, CO1, EX2	Communicating Decarbonisation to Consumers	
	7 (3)	AG1, CO1	Importance of customer commitment	
	7 (1)	AG1, CO1, EX1, EX2	Need for vertical integration and partnerships	
	5 (3)	AG1, CO1	Consumers growing green consciousness	
	5 (3)	AG1, AP2	Customer demands sustainable shipping options	
	5 (0)	CO1	Cargo owner manage their partner network composition based on sustainability criteria	
	4 (0)	CO1	Cargo owner have decarbonization strategy	
	3 (0)	AP2	Growing societal pressure to decarbonize aviation	
2	13 (3)	AG1, CO1, EX1, EX2	High price of SAF hinders voluntary adoption	Airlines need to balance necessary long-term fuel purchase commitments for SAF production off-take with their own highly cyclical business environment
	8 (6)	AG1, EX2	Difficulties to scale SAF production	
	7 (4)	AG1, AP2, EX2	Low immediate availability of SAF	
	4 (2)	AG1, EX1	Lacking investments in SAF production due to associated risks	
3	12 (0)	AP2, CO1	Lack of standardised carbon accounting rules	Difficulty for airlines to develop and communicate a compelling value proposition as the relevant regulations are not yet sufficiently mature
	10 (0)	CO1, EX1	Business Case for green premium	
	9 (3)	AG1, CO1, EX2	Communicating decarbonisation efforts to consumers risky due to possible greenwashing allegations	
	9 (3)	AG1, AP2, CO1	Changing value proposition of airlines	

	5 (0)	CO1	Value of SAF from a cargo owner perspective	
3	4 (0)	AP2, CO1	Scope 3 emissions reduction as new value dimension	
	3 (0)	AP2, EX1, EX2	Air cargo leads SAF adoption	
	2 (0)	CO1	Air cargo as part of transport chain	
	12 (0)	AP2, CO1, EX1	Fair spread of ”green premium” across value chain	
4	6 (0)	AP2, CO1, EX1	Customer requirements for the purchase of SAF	SAF introduces new elements of demand, price and technology risk to airline business model
	4 (2)	AG1, AP2, EX2	Changing cost structure for airlines	
	3 (0)	EX2	Advantages & Limitations of 2nd generation SAF	
	1 (0)	EX1	Long ivestment horizon as a risk associated with SAF adoption	
	12 (0)	AP2, CO1, EX1	Regionally fragmented SAF regulations impede fair competition	
	11 (3)	AG1, AP2, CO1, EX1	EU Quota imperative for quick scale-up and investment security	Regulatory intervention by EU for SAF off-take provides planning security but distorts global competition
5	10 (1)	AG1, CO1, EX1, EX2	Need for Political / Regulatory support	
	7 (3)	AG1, EX1, EX2	Positive sentiment for some regulatory intervention	
	6 (4)	AG1, EX1	Emissions trading as driver for SAF adoption	
	2 (0)	AP2	Political pressure as driver for SAF adoption	

Table 5.4: Codes and resulting themes from cargo airline interviews

5.4.3. Stage 4 & 5: Generating and defining themes

This section analyses the key themes identified in interviews exploring the impact of SAF on cargo airlines' business models. Table 5.4 offers a preliminary overview of these themes and their connection to the research codes. Five distinct themes emerged, visualised in figure 5.3 as a thematic map that highlights their interrelationships and associated sub-themes. The analysis will now delve deeper into each theme, providing clear definitions and incorporating significant interview quotes to substantiate them. Finally, a comprehensive narrative will be constructed to elucidate the combined impact of these themes on cargo airport business models.

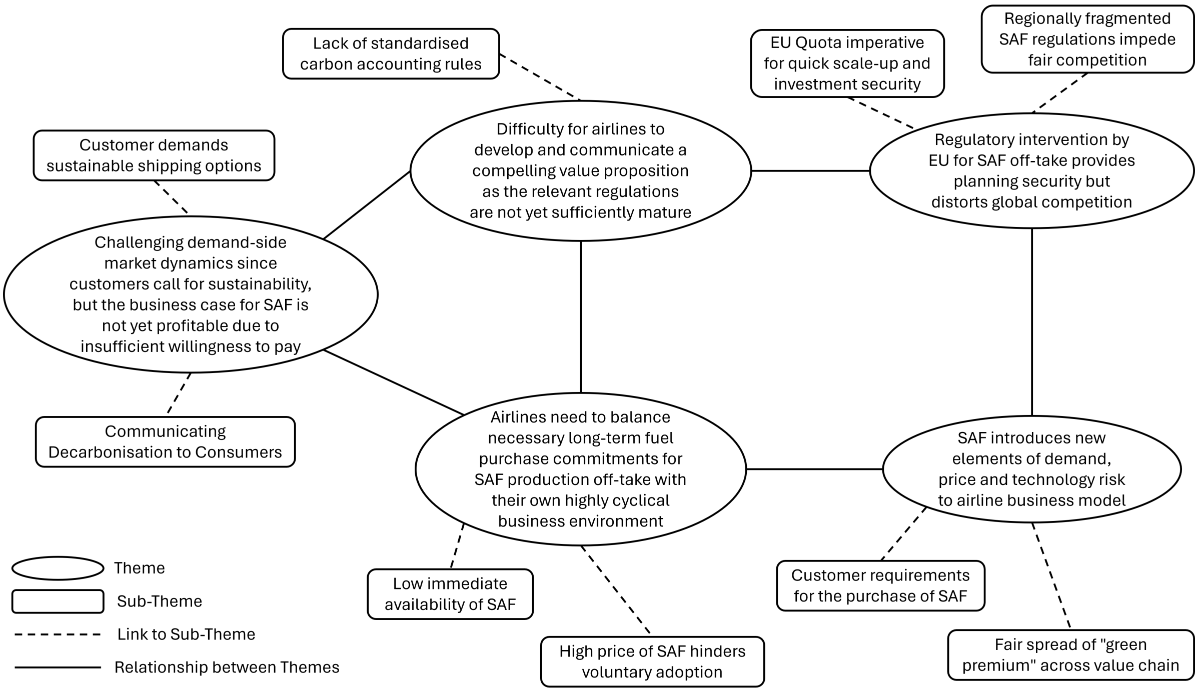

Figure 5.3: Finalised thematic map demonstrating five themes for Cargo Airlines business models (Inspired by Byrne (2022))

Difficulty for airlines to develop and communicate a compelling value proposition as the relevant regulations are not yet sufficiently mature

> ”SAF is always going to be more expensive. There's no payoff for that. Especially since right now the greenhouse gas protocol won't even allow us [a cargo owner] to claim that emission reduction, which is a significant barrier that I'm sure you're aware of. [CO1]”

> ”We at [airline name] will never have a communication where you say: flying with us is green, sustainable et cetera. But we try to give our travellers transparency about their footprint. We are committed to reducing emissions, but they will still be there. [AG1]”

A compelling value proposition stands at the centre of every business model. However, airlines struggle to formulate such since cargo owners can not communicate the benefits of SAF due to the fact that the respective regulatory framework is immature. The primary benefit of SAF for cargo owners would be the reduction of scope 3 emissions for cargo owners. Yet, CO1 points out in the first quote that reporting frameworks such as the greenhouse gas protocol, introduced in chapter 3.4, do not allow cargo owners to claim these emissions reductions if they are not physically linked to the flight the cargo was on. This is impossible in practice since SAF has to be blended with fossil kerosene at some point along the supply chain making it impossible to establish a physical connection between a specific flight and SAF blended in at some point earlier. This results in a current situation where some cargo owners pay a voluntary premium for SAF without receiving any benefit from this additional expense. The second quote underlines that all industry stakeholders are very cautious when it comes to communicating the use of SAF. Most airlines and cargo owners opt to not communicate at all to avoid any possible greenwashing allegations. The result is a market where SAF is a pure cost driver without any reputational value, caused by immature regulations.

Challenging demand-side market dynamics since customers call for sustainability, but the business case for SAF is not yet profitable due to insufficient willingness to pay

> ”When it comes to the purchasing decision, you realise that the customers who previously said “I think it’s great and I would definitely buy it” don’t actually buy it. [...] Yes, there are challenges and I still believe that acceptance on the market is not yet at the level we need it to be. [AG1]”

> ”That’s a very difficult question. That’s the $1,000,000 question. Everybody’s trying to figure out how to make it [SAF] more attractive for the customer. [...] So the question is how can the SAF premium be seen as an investment rather than an expense? [AP2]”

> ”I think in the end it’s an industry problem - it’s not an airline problem. Of course, we [an airline] are the ones who fuel and burn the kerosene, but we are often just part of a common product. [AG1]”

As a result of the previous theme, airlines struggle to make a business case for SAF. Nevertheless, a demand for sustainable shipping options exists, but in most cases, the prevalent willingness to pay does not cover the additional cost of SAF, as observed in the first quote. Industry experts refer to this phenomenon as the ”Attitude-Behaviour-Gap”, referring to a market in which end customers and cargo owners express a desire for ”green” shipping options but don’t reflect this in their buying decision. Currently, the market for SAF is driven by voluntary commitments of cargo owners. Some cargo owners perceive decarbonisation as their own obligation to stay in line with the Paris Agreement to limit global warming to 1.5 degrees. But to further scale the adoption a viable business case has to be constructed. The emphasis has to be put on the value aspect of SAF instead of the pure costs aspect. Furthermore, other value chain members have to realise that decarbonisation is not solely the responsibility of airlines, as highlighted in the third quote. Some cargo owners have realised their responsibility in reducing emissions from air cargo and included sustainability criteria in the assessment of their logistics service providers, however, they will also have to bear the additional cost to ensure successful adoption.

Airlines need to balance necessary long-term fuel purchase commitments for SAF production off-take with their own highly cyclical business environment

> ”I will say price and availability are of course interconnected to each other. The more we have physically available, the lower the SAF price should be. [EX2]”

> ”In my view, the biggest bottleneck is the quantity. It’s too little. And the price today is too expensive. And as an industry, we need to work together to develop a partnership that can produce more cheaply and greener. [AG1]”

> ”We are talking here about at least 10 years that have to be covered [by off-take agreements] and the time horizon that an airline covers [for fuel purchase] is around 6 - 12 months and these are also the previous margins in which the contracts were made. [EX1]”

Every expert acknowledges that SAF production capacity needs to increase to reduce prices. The core issue the industry is facing right now is that even if sufficient demand provided by the EU quota exists, SAF producers cannot secure financing because banks require long-term off-take agreements with airlines. This means that banks want airlines to commit to decade-long SAF purchasing contracts. Airlines, however, usually purchase fuel for a maximum of 12 ahead. If there airlines now have to engage in multi-year purchase agreements this will affect the risks they have to take, as discussed in the next theme. Nevertheless, airlines view partnerships as an integral part of scaling up SAF production, as indicated by the second quote. The issue that remains and that keeps airlines from signing long-term SAF purchase agreements is their own highly cyclical business environment. The demand for air cargo is disproportional affected by the ups and downs in the global economy. Resulting in growth rates exceeding those of the global economy in good years and vice versa if the economy contracts. During economic downturns, even minimal profits become unattainable for airlines.

SAF introduces new elements of demand, price and technology risk to airline business model

> ”We are talking here about at least 10 years that have to be covered [by purchase agreements] and the time horizon that an airline covers is around 6 - 12 months and these are also the previous periods in which the fuel purchase contracts were made. [EX1]”

> ”And without the corresponding regulations, there is no certainty for investors that the product that comes out at the end of the process is really capable of fulfilling all these requirements and then, logically, the entire supply chain will not follow suit. [EX1]”

The link between the previous theme and the current one, as illustrated in figure 5.3, is the sensible management of the additional risks introduced to the business model by SAF. There are several layers of risk caused by the adoption of SAF. First, as stated in the first quote, long-term fuel purchase agreements are new to airlines. If airlines sign long-term fuel purchase agreements, they risk being trapped in unfavourable contracts if the demand for air freight collapses or if other production pathways become significantly cheaper. The commercial production of SAF is still in its early stages, which adds technological risk. Production plants and the associated purchase contracts might become obsolete within a few years if other technologies make significant advancements. Additionally, regulatory risks exist, as stated in the second quote. EU regulations could possibly change with every election and the investment horizon of an SAF production plant exceeds that of election periods.

Regulatory intervention by EU for SAF off-take provides planning security but distorts global competition

> ”Every airline company is aware that we have to do something [to reduce emissions] and is also working on creating the appropriate conditions. Only external control mechanisms and interventions in the market need to be designed in such a way that they are effective without discriminating against individual market participants. [AG1]”

Following up on the previous theme another issue with EU regulation exists: Distortion of competition. Industry experts agree that no significant changes to the current EU quota should be made since these quotas provide planning security and changes would be detrimental to the industry’s trust in the EU as a regulatory body. Nevertheless, the current SAF quota as well as the EU emissions trading market are far from perfect and lead to a distortion in competition between EU and non-EU airlines. Ideas to offset this competitive disadvantage exist, for example by redirecting revenues from the EU emissions market to domestic airlines. However, no mechanism to offset this disadvantage has been implemented yet. This places EU airlines in a precarious position within an already highly competitive global market. All resulting codes a summarized in table 5.5.

5.4.4. Stage 6: Constructing a narrative

Cargo-carrying airlines find themselves at the centre of several opposing trends. First, EU mandates for increased SAF utilisation introduce additional expenses to their cost structure which are also mostly fixed costs because the low availability of SAF requires airlines to engage in long-term of-take agreements with SAF producers. Conversely, airlines are traditionally low-margin businesses which have to deal with high levels of debt accumulated during the COVID-19 pandemic and recently falling freight rates due to a downturn of the global economy. Second, mounting public as well as political pressure forces them to take rapid steps towards decarbonising their operations. However, airlines cannot communicate their decarbonisation efforts because of an immature regulatory framework, i.e. obsolete guidelines set by the GHG protocol. Consequently, airlines quickly have to find ways to enhance their value proposition and get cargo owners on board who are willing to pay a premium for sustainable transportation options. If they fail to do so, they run the risk of falling behind cargo airlines from countries with lax environmental regulations outside the EU. On the other hand, in case European cargo airlines are successful in commercialising SAF they could lead the way in decarbonising aviation in anticipation of growing environmental awareness in other regions of the world.

5.5. Freight Distributor

To investigate the impact of SAF on the business model of freight distribution companies a total of four expert interviews were conducted. These experts are CO2, FD1, FD2, and FD3. CO1 is an expert who works in the sustainability department of one of the largest importers to the USA. FD1, FD2 and FD3 all represent large logistics companies with a global reach and act as company internal specialists for sustainability topics with an emphasis on the decarbonisation of air cargo operations.

5.5.1. Stage 1: Familiarisation with the data

The initial stage involves an in-depth immersion into the data related to freight distributor business models. This deep dive requires thorough and repeated readings of the collected information, such as business descriptions, market reports, and industry publications. This intensive engagement allows for the identification of initial patterns, emerging themes, and potential meanings embedded within the data. Early impressions and areas of particular interest will be noted throughout this process. These observations will form the foundation for further analysis. To enrich the initial insights, the analysis will consider relevant external sources like the ”Sustainable Aviation Futures Congress 2024.” Insights gleaned from this source will guide the subsequent stages of detailed coding and thematic development.

5.5.2. Stage 2 & 3: Generating and iterating codes

Before delving into the codes that emerged for freight distribution companies, it has to be noted that a high level of overlap between changes to the business model of cargo airlines and freight distribution companies exists. However, there are two key differences. First freight integrators cover the whole delivery chain from shipper to consignee and can therefore overlook and control all steps of the delivery process. Cargo airlines on the other hand are mostly just one piece of a fragmented delivery process, CO1 points out, limiting their influence over the decarbonisation of other modes of transportation. Second, the express segment of the international freight distribution market is highly concentrated with only three companies (DHL, FedEx & UPS) controlling 91% of the market. This results in a high-margin freight integrator industry compared to the low-margin business of cargo airlines, providing freight distributors with an advantageous starting position.

Starting with the first group of codes presented in table 5.5 the focus is on communicating SAF correctly to the end customer. All experts admit that communicating precisely but short is one of the major challenges for a broader adoption of SAF. FD1 points out that SAF as a means of decarbonisation is not very visible to the consumer compared to other technologies. He gives the example of an electric delivery van which the end customer can easily differentiate from a diesel van when the parcel is delivered. SAF on the other hand is fueled at the airport far away from the end customer. FD3 adds that most consumers do not understand what SAF is and how it can reduce carbon emissions, creating the need to educate them. The challenge with communicating the advantages in terms of carbon reduction is that no standardised carbon accounting framework exists, as pointed out by all experts. CO1, a representative of a cargo owner, states that their company follows the ”Greenhouse gas protocol”, one of many frameworks (see chapter 3.4), but tries to stay on the conservative side of carbon reduction estimates to avoid accusations of greenwashing. Furthermore, CO1’s company does not communicate their SAF purchase in any advertisement because they consider this too risky due to the immature regulatory framework. Yet, all experts mention that customer commitment is imperative for the scale-up of SAF. Meanwhile, it remains challenging to convince cargo owners to purchase SAF if they can not safely communicate these expensive efforts, FD2 indicates. FD2, FD3 and CO1 detail that freight distributors and cargo owners are very cautious regarding the type of SAF they purchase, setting high company internal standards and avoiding feedstock like palm oil. FD2 explains these high standards for biofuel SAF purchases with concerns over accusations by environmental organisations like Greenpeace.

Transitioning to the second group of codes different commercialisation strategies of SAF’s ”green premium” are discussed. FD3 explains that his company spent a nine-figure amount on the SAF price premium, the price difference between fossil kerosene and SAF, last year alone, while only using a small percentage of SAF in their operations. He goes on by outlining that his company is not yet able to reimburse the extra cost of SAF through green transportation products. FD1 and FD3 explain that the planned further increase of SAF utilisation without successful commercialisation will be fatal for freight distributors’ business model. Consequently, FD1, FD2 and CO1 call for freight forwarders and freight integrators to redefine their value proposition. FD2 emphasises that many large cargo owners are committed to reducing their emissions as part of the ”Science-based targets initiative (SBTi)” (detailed explanation of SBTi in chapter 3.4). The use of SAF can help these cargo owners to achieve these targets by reducing their scope 3 emissions. All experts mentioned scope 3 emissions reductions as an important value proposition of SAF. However, FD1 remarks that the tracking of emissions across the supply chain can be a challenging endeavour. Therefore, FD1 and FD2 demand the establishment of an SAF certificate registry, referring to a system that can track the flow of SAF across the supply chain. However, FD1 complains that SBTi, as one of the most powerful organisations in this realm, has reservations regarding this type of registry. FD1 notes that there will be no further SAF adoption in air cargo if SBTi keeps blocking the establishment of this kind of registry.

Continuing with group 3 of codes several strategies to generate higher cargo rates from using SAF are outlined. As mentioned previously, FD3 noted that his company struggles to recoup the additional cost stemming from SAF. All experts collectively agree that the just allocation of additional costs is an important issue that has to be resolved quickly. FD1 holds the opinion that ultimately the consumer will have to pay higher prices since freight distribution companies are in intense competition with one another, making them unable to carry any additional cost. In this context, an expert at ”Sustainable Aviation Futures Congress 2024” explained that higher prices will lead to a demand contraction, with the lowest price buckets for freight rates disappearing. CO1 is convinced that especially large and high-margin cargo owner can absorb some of the additional cost in the transition cost, stemming from an intrinsic motivation that decarbonization is their obligation. The experts collectively noted that the decarbonisation of logistics is a collaborative effort, in which air cargo is often times just one piece in a long transport chain. Therefore, FD2 sees OEMs and energy companies as being responsible for developing cheaper production pathways for SAF and scaling up their production, leading to lower prices for the entire industry.

Proceeding to the fourth set of codes the supply side of SAF is addressed. High prices and limited availability are well-known adoption barriers for SAF (refer to chapter 3.2) and have hence been brought up by all experts. Concurrently, freight distribution companies have to invest in ”green” product offerings in anticipation of the ever-increasing EU SAF quota accompanying additional costs. FD2 describes his company’s green product offering that can be booked online for individual shipments. He observes a high interest of customers in this service. But in order to be able to offer this product reliably in the long term freight distributors have to make large fuel purchase agreements. FD3 highlights that it is oftentimes challenging to source sufficient amounts of SAF at reasonable prices, requiring companies to engage early with producers. FD3 explains that companies which fail to make the necessary investment now will likely have to pay high prices in the future to catch up with their competition in the realm of sustainable logistics. FD2 goes on by elaborating that his company needs to weigh the need to secure sufficient amounts of SAF so that they can offer their ”green” transportation services against the risks surrounding this technology domain. Changes to the current policy or new technological innovations could potentially disrupt the market for SAF.

The final group of codes deals with the perspective of SAF as an opportunity for the aviation industry. All freight distribution experts emphasise that air cargo is already leading the adoption of SAF compared to passenger air traffic. FD2 explains that it is easier to convince large corporations to pay a premium for SAF compared to individual passengers. FD3 adds that high-priced goods that tend to have a lower price elasticity make up the majority of air cargo volume. However, he also remarks that the market is still developing and logistics companies need patience until investment in sustainable product offerings pays off. FD1 further mentions that cargo owners would prefer an end-to-end ”green” delivery process, however, this is not yet possible due to operational limitations such as the use of electric cars in cold environments or remote areas. He adds that his company still needs a few years before it can offer end-to-end ”green” delivery, but control over the entire transportation process provides the basis for being able to do so at some point. The sentiment for regulatory intervention such as the EU SAF quota is positively assessed by FD1, as these regulations help companies that are taking steps to decarbonize their operations to avoid greenwashing accusations and generally benefit companies that have adopted SAF early. FD2 explained that his company plans to exceed the prescribed EU quota to further drive adoption. It is also considering introducing a higher in-house SAF quota on all of FD2 company’s flights if voluntary demand from cargo owners is not in line with the company’s own SAF utilisation strategy. Lastly, FD1 touches on investor pressure primarily stemming from European shareholders. Meanwhile, he also points out that decarbonization and EBIT maximisation are two opposing goals, which limit investor interest in SAF.

Group	Groundedness	Participants	Finale Codes (in some cases Sub-Themes)	Themes
1	20	FD1, FD2, FD3, CO1	Challenging to communicating decarbonisation in a concise yet precise manner to consumers	SAF needs to be explained and communicated in a comprehensive but concise manner, while avoiding greenwashing allegations in an ambiguous regulatory environment
	17	FD1, FD2, FD3, CO1	Lack of standardised carbon accounting rules	
	15	FD1, FD2, FD3, CO1	Customer commitment imperative for SAF scale-up	
	6	FD1, FD2, FD3	Voluntary customer demand drives current SAF market	
	6	FD2, FD3, CO1	Requirements set by airlines or cargo owners for the purchase of SAF	
2	19	FD1, FD2, FD3, CO1	Strategies for the commercialisation of SAF	Focusing on enhanced value proposition instead of cost by offering SAF as part of a wider business case to create sufficient willingness to pay with cargo owners
	17	FD1, FD2, FD3, CO1	Absence of standardised carbon accounting rules obstruct successful commercialisation	
	15	FD1, FD2, FD3, CO1	Economically reasonable business case for ”green premium”	
	13	FD1, FD2, CO1	Freight integrators redefine their value proposition	
	9	FD1, FD2, FD3, CO1	Value of scope 3 emissions reduction through SAF utilisation for cargo owner	
	7	FD1	Compelling business case for investments in sustainability	
	7	FD2, CO1	Freight forwarders redefine their value proposition	
	4	FD1, FD2	Risks and opportunities of large-scale SAF certificate market	
3	19	FD1, FD2, FD3, CO1	Challenges of spreading extra costs fairly and maintaining a fair competitive landscape	Various scenarios have been developed yet freight distributors struggle to develop strategy for just allocation of SAF across value chain, failing to generate higher revenues
	7	FD1, FD2, FD3	Updated partner network of freight distributors	
	6	FD2, CO1	Sustainability as a collaborative effort	
	5	CO1	Updated partner network of cargo owners	
	5	FD1, FD2	Sustainability goals set by cargo owners	
	5	CO1	Value proposition requested by cargo owners to pay ”green premium”	

3	4	FD1, CO1	Air cargo as part of a larger transport chain	
	4	CO1	Cargo owners own decarbonization strategies	
4	14	FD1, FD2, FD3, CO1	High SAF price act as an adoption barrier	Once green transportation products are developed freight distributors need to make long term SAF purchase agreements to be able to follow through with these, leading to a risk concentration in their cost structure
	9	FD2	Boundaries to large scale biofuel production	
	6	FD2, FD3	Limited immediate availability of SAF	
	6	FD1, FD3	Changing cost structure aviation domain of freight distributors operations	
	5	FD2, FD3	Risks associated with SAF adoption	
5	9	FD1, FD2, FD3	Air cargo leads SAF adoption in aviation	Shifting the conversation from SAF as a cost burden to decarbonization as an opportunity to maintain ”social license” for further aviation growth
	8	FD1, FD2, CO1	Importance of EU quota for the adoption of SAF	
	4	FD2, FD3	Additional revenue from green investments	
	4	FD1	Importance of SAF for aviation industry’s emission reduction goals	
	4	FD1	Investor pressure & ESG reporting as driver for SAF adoption	
	4	FD1	Sentiment for Regulatory Intervention	

Table 5.5: Codes and resulting themes from freight distribution interviews

5.5.3. Stage 4 & 5: Generating and defining themes

This section analyses the key themes identified through interviews exploring how SAF impacts freight distributors' business models. Table 5.5 provides a first look at these themes and their links to the research codes. Figure 5.4 presents a thematic map visualising five distinct themes, their interrelationships, and associated sub-themes. A deeper dive into each theme will be conducted, offering clear definitions and incorporating impactful interview quotes to support them. Finally, a comprehensive narrative will be built to explain the combined effect of these themes on freight distributors' business models.

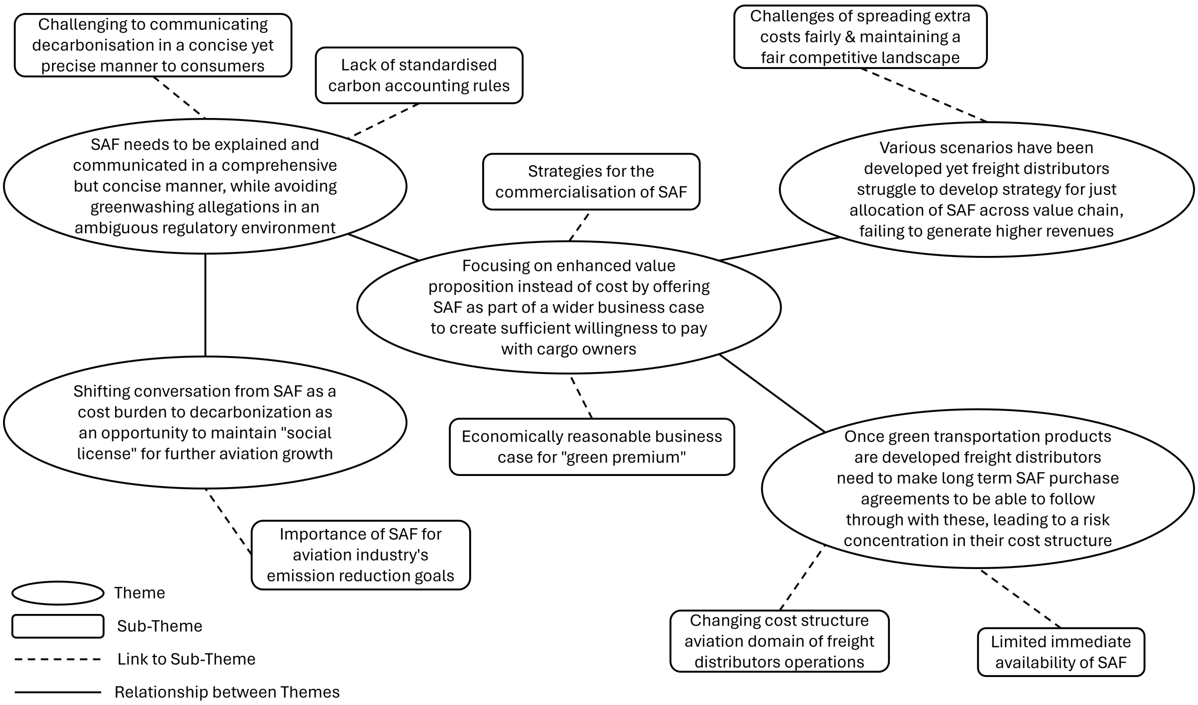

Figure 5.4: Finalised thematic map demonstrating five themes for Freight Distributors business models (Inspired by Byrne (2022))

Focusing on enhanced value proposition instead of cost by offering SAF as part of a wider business case to create sufficient willingness to pay with cargo owners

> "It's like we [a cargo owner] feel we're doing the right thing by buying SAF because we're helping to ensure that there is less emission pollution in the world, right? But it's not something we can take credit for [due to a lack of an appropriate accounting framework], so it's hard to make the business case. [CO1]"

> "And if you don't get it commercialised as an airline [as part of freight distributor in this case], then you won't be able to keep it up for long. So you can't just buy SAF like that without passing it on somehow. They alone have such low margins. If they somehow turn up their costs by 20%, they'll be bankrupt after six months. And then what? [FD3]"

By looking at the visualisation in 5.4 it becomes apparent that a changing value proposition is the central theme shaping freight distributors' business model. The changes to the value proposition are driven by the pure necessity to recoup the additional cost of SAF. Several experts emphasised that if current pricing models persist and the EU mandates an increased percentage of SAF in operations, their business will no longer be profitable. Consequently, freight distributors have to find ways to enhance their value proposition. This presents a challenge since cargo has traditionally been seen as a cost centre for cargo owners. Nonetheless, air cargo can create value through Scope 3 emissions reduction. However, this is a challenging proposition due to the immature carbon accounting framework, as discussed in the cargo airlines' business model and highlighted in the first quote. In the meantime, freight distributors should target another group of clients until the necessary changes to the carbon accounting frameworks are made. Some of the most important customers for freight forwarders, for instance, are in the pharmaceutical and luxury goods industries. In these sectors, transportation costs are negligible, and profit margins are typically so high that a 50% increase in transportation costs would have little impact on their overall profits. This is just one example of specific customers that can be targeted by freight distributors. Another predictor for an increased willingness to pay by cargo owners is their adherence to the "Science-based targets initiative" (see chapter 3.4) or similar initiatives. In summary, freight distributors need to analyse their existing customer base and determine if specific industries of customers have to necessary resources and incentives to pay a "green premium".

SAF needs to be explained and communicated in a comprehensive but concise manner while avoiding greenwashing allegations in an ambiguous regulatory environment

> "We have to basically send out simple messages that are generally understandable and not some kind of completely detached expert-speak. Yes, but simple messages are always a bit simplistic. [FD3]"

> "The basic logic is of course simply to be transparent. What am I doing and what am I not doing? And environmentally friendly is, of course, the wrong term. Of course, flying is not environmentally friendly, at best it is no longer environmentally harmful or less environmentally harmful. [...] But of course, you have to move away a bit from colloquial language, I think, to more accurate language. I don't know if that's always a good thing, but that's simply the reality if you want to be on the safe side. [FD2]"

In passenger air traffic very few customers are willing to pay a voluntary price premium for the use of SAF. One reason for this is a lack of trust by consumers for sustainability promises made by corporations caused by an abundance of greenwashing incidents across all industries in the past. Building back trust in the aviation industry's sustainability efforts will therefore be a lengthy process. The low visibility and high complexity of this technology make it particularly difficult to communicate the benefits of SAF convincingly. Moreover, the EU does not clearly outline if SAF can be described as "green", "zero-emission", "good conscience" or "sustainable", even though the EU itself uses the abbreviation SAF which literally contains the word "sustainable". Accordingly, freight distributor have to strike a balance in their communication between being precise in describing the potential of SAF, while avoiding overly exaggerated promises.

Shifting conversation from SAF as a cost burden to decarbonization as an opportunity to maintain "social license" for further aviation growth

> "What we actually want to achieve is that our customers have to justify to their investors and their customers that they don't use [company name] as their logistics provider, i.e. that they don't use the most sustainable one that comes along. Then we will have won the battle and then all these investments that we are making will have paid off. [FD1]"

> "The problem is that if 70% of the emissions of your entire business are caused by aviation, then we can't avoid SAF. This means that for strategic reasons we have to invest in SAF as well as decarbonizing other areas. [FD1]"

The positive sentiment for SAF within the European aviation industry can to some degree be explained by mounting public pressure to decarbonise. Meanwhile, the Global as well as European passenger air traffic and air cargo industry is pursuing ambitious growth plans, likely resulting in overall higher emissions. Experts at the "Sustainable Aviation Futures Congress" emphasised that there is no self-evidence for further growth if the so-called "social license" is revoked. The "social license" refers to the industry's need for societal acceptance due to the emissions it produces, such as noise and fine dust, which are not covered by the industry and must be endured by society. Countries like the Netherlands are already limiting air traffic and major airports and oppose further expansion plans. If the industry does not prove that it can successfully tackle problems like rising carbon emissions other countries could soon follow suit and impose stricter regulations. In the end, this scenario would hurt all industry stakeholders. Swift SAF adoption therefore has to be seen as an opportunity to maintain the "social license".

Various scenarios have been developed yet freight distributors struggle to develop a strategy for just allocation of SAF across the value chain, failing to generate higher revenues

> ”Because we will now think again about commercialization and I have just mentioned that it is so incredibly difficult because hardly anyone is willing to pay for it, to put it a little exaggeratedly. But too few companies are prepared to pay an adequate share for it and we won’t achieve our decarbonization targets as a result. [FD1]”

> ”If you let it trickle down the value chain in this way, then in the end it is no longer so expensive at product level. And for high-value goods in particular, the customer, i.e. the end customer who buys their cell phone or something like that, hardly notices. They hardly notice it at all. [FD3]”

Now shifting the focus to the right side of figure 5.4, various strategies for the commercialisation of SAF emerged. The industry needs to find ways to split the additional cost caused by SAF adequately among value chain actors since consumers are unlikely to absorb the extra cost in the transition phase. Generally, experts disagree on how significant the extra cost for freight distributors is. While some say that the additional cost of 6% SAF by 2030 will only have a marginal impact on the overall cost base others rightfully point to the sharp increase of this quota, rising to 20% by 2035. Combining this sharp increase with limited biofuel feedstock availability the extra costs can quickly overburden even freight distributors with generally healthy margins. One strategy proposed by English-Spanish airline group IAG is to offer SAF at no additional cost to the cargo owner in exchange for a higher share of their business. IAG reasons that logistics companies only incur slightly higher costs due to SAF, which will be offset by the additional profits generated from the higher cargo volume. On the other side, the cargo owner can profit from reduced scope 3 emission reductions without paying higher cargo rates. A different scenario also counts on freight forwarders to absorb the extra cost of SAF. However, as a consequence, freight forwarders would have to reduce their efforts in other cost centres such as R&D. A third scenario anticipates that the adoption of SAF will lead to a demand contraction. The reasoning behind this is that airlines and freight distributors use different price buckets, whereas the lowest price bucket is offered slightly above marginal cost. If marginal costs increase due to SAF the lowest price bucket will disappear and customers in this bucket will switch to cheaper modes of transportation such as maritime, resulting in overall lower volumes in air cargo.

Once green transportation products are developed freight distributors need to make long-term SAF purchase agreements to be able to follow through with these, leading to a risk concentration in their cost structure

> “We bought SAF in the past and are now selling it. What you can say is that it is selling quite well for the time being and also better than originally expected. However, the product has only been on the market for two years, so it’s impossible to say exactly whether we will recoup the additional costs caused by SAF in the first two years. [FD2]”

> ”We spent a three-digit million amount last year to pay for the SAF Premium, so not for the total costs, but only for the additional costs compared to fossil jet fuel, and that directly affects our EBIT. [FD3]”

Finally, the effects on the cost structure and the concentration of risk within the cost structure caused by SAF were mentioned as a relevant theme for freight distributors. The successful commercialisation of SAF is the result of a lengthy learning process. As part of this process relationships with SAF suppliers and cargo owners have been established. Naturally, freight distributors want to be reliable business partners and need to commit to the promises made to suppliers, customers and the broader public in regard to their decarbonisation efforts. Additionally, the low immediate availability of SAF constitutes a barrier to adoption (see chapter 3.2), creating the need to engage in long-term fuel purchase commitments. Meanwhile, the impact on the cost structure must not be overlooked. Fuel purchase agreements add a high amount of fixed costs to the cost structure of freight distributors, reducing their ability to adapt air cargo capacities to market demand. Freight distributor have to re-evaluate their scale-up strategy for SAF on an ongoing basis to avoid unmanageable fixed cost increases that can not be recouped through ”green” product offerings.

5.5.4. Stage 6: Constructing a narrative

Freight distributors, e.g. freight forwarders and integrators/consolidators, have a decisive advantage over pure cargo airlines by being able to offer the whole transportation chain from consignor to consignee. This makes it easier for them to craft a compelling value proposition. Freight distributors are working on strategies to hand on the additional cost of SAF to cargo owners and ultimately the consumer. Strategies for the commercialisation of SAF include the issuance of SAF certificates that reduce cargo owners' scope 3 emissions and the possibility for clients to add a low-emissions surcharge to individual shipments. Nonetheless, freight distributors struggle with an insufficient willingness to pay by cargo owners for "green" transportation options and an ambiguous regulatory framework in terms of the communication of sustainability efforts and scope 3 emissions accounting. Effectively communicating SAF requires a balance between clarity and brevity, ensuring that the information is both comprehensive and accessible. At the same time, it is crucial to navigate the complexities of an unclear regulatory landscape to prevent any perception of greenwashing. Furthermore, reframing the industry's discussion around SAF from being a cost burden to viewing decarbonization as an opportunity is essential for sustaining the "social license" necessary for continued aviation growth. This shift in perspective can help the industry align with broader environmental goals and foster public support for its future expansion. Lastly, necessary off-take agreements for the production scale-up of SAF may result in a concentration of risk within freight distributors' cost structure, necessitating careful financial planning and cautious risk management strategies.

6
Results

The analysis of the effects of SAF on the air cargo business model commenced with the development of a conceptual model at the beginning of the previous chapter 4.1. The conceptual model is based on the ”Business Model Canvas” by Osterwalder and Pigneur (2010) and is composed of business model building blocks and relationships between these. Now, in the last step of this research, the developed themes will be assigned to these building blocks. Based on the aforementioned relationships between building blocks, the issue of business model consistency will also be addressed. To recap chapter 4.1, changes to a company's business model initially impact one aspect of the BMC, but because business models require a consistent integration of multiple aspects, these changes inevitably influence other aspects as well. Therefore, business model consistency requires follow-up changes in one or more of the other BMC building blocks (Kamp et al., 2021).

6.1. Overview: Key changes to business models resulting from SAF

Throughout the analysis of the four business models, it became apparent that these can be roughly divided into two distinct groups based on the extent to which they are affected in their ability to influence the SAF adoption trajectory. On the one hand spectrum, aircraft manufacturers and cargo-focused airports act as mere facilitators for the scale-up of SAF without being directly affected by SAF regulations and associated cost increases. On the other hand of the spectrum, cargo airlines and freight distributors find themselves in a position where nearly all aspects of their business model have to be adopted to stay competitive. In the following, changes to each business model building block will be explained briefly and resulting changes to associated building blocks, necessary to maintain business model consistency, will be discussed.

6.1.1. Facilitators for change: Aircraft manufacturer & airports

Aircraft manufacturers are expected to take an important role as a facilitator for the scale-up of SAF, constituting a new key activity for these companies (see figure 6.1). Facilitation will take place between existing stakeholders in air manufacturers' partner network, such as policymakers, banks, energy companies and airlines. Additionally, emerging start-ups in the realm of SAF production and distribution, SAF feedstock producers, and SAF certifications as well as emissions accounting organisations represent evolving actors in the air cargo space. These emerging actors require coordination with existing actors. Perspectively, aircraft manufacturer can enhance their value proposition by delivering improved aircraft that support airlines in fulfilling the SAF quotas set by the EU and other regulatory bodies.

Notably, no changes to the cost structure or key resources, and only negligible changes to revenue streams are to be expected. The reason for this is that SAF leverages existing technological knowledge, requiring no technical modifications to aircraft models currently in production. Furthermore, major aircraft manufacturers already struggle to keep up with global demand for their products, making even higher prices for aircraft that provide increased SAF quotas unlikely.

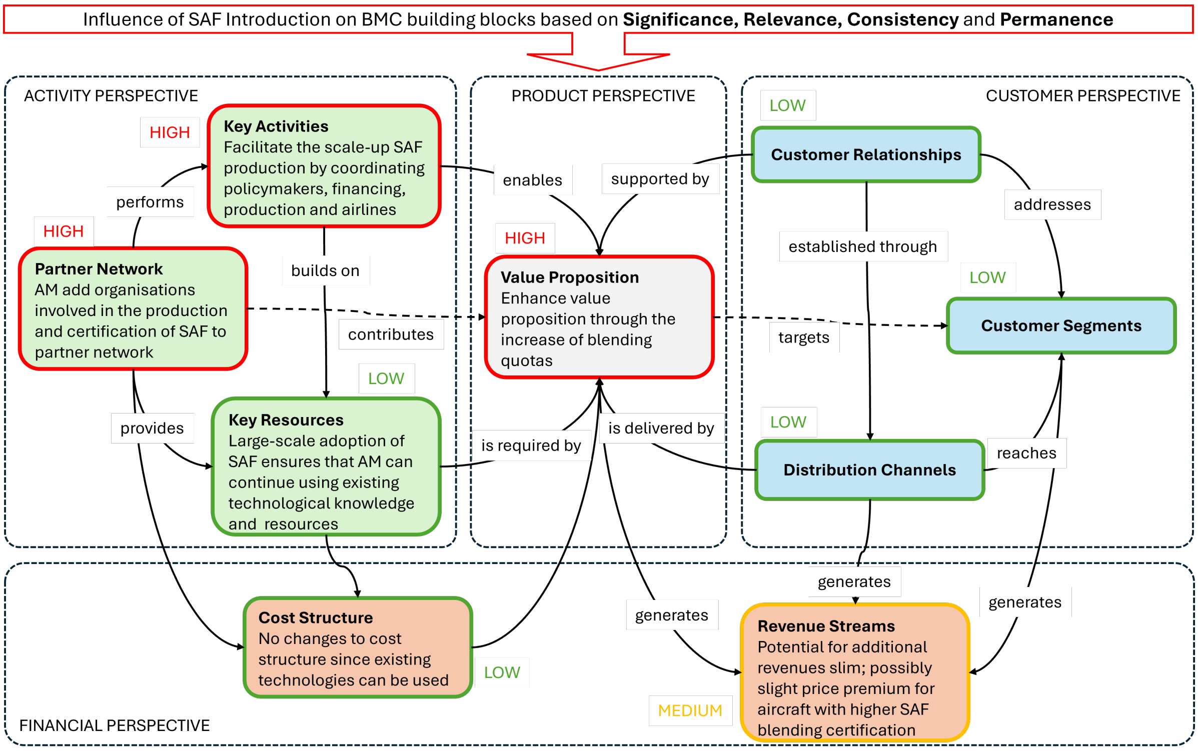

Figure 6.1: Final BMC for aircraft manufacturer depicting impacts on business model building blocks caused by the SAF

Similarly, airports will likely not experience significant changes to their cost structure or revenue streams, refer to figure 6.2. Even though, higher prices for jet fuel could lead to a demand contraction for air cargo and consequently overall lower revenues, as pointed out in the fourth theme of chapter 5.5.3. Airports typically outsource fuel services to specialised energy companies due to the complexity and cost associated with operating fuelling facilities, limiting the impact of SAF adoption on their business models. Their current financial constraints further constrain airports' ability to invest in this area in the future. Nonetheless, reliable access to SAF constitutes a key resource for airports to future-prove their business model.

Conversely, SAF will have a high impact on key activities and airports' partner networks, ultimately leading to changes in the value proposition. Similarly to aircraft manufacturers, as described above, airports act as facilitators for the adoption by orchestrating the interest of different stakeholder groups with which airports maintain long-lasting relationships. Importantly airports need to foster good customer relationships with airlines to maintain demand for SAF over the long term and attract further investments in the future.

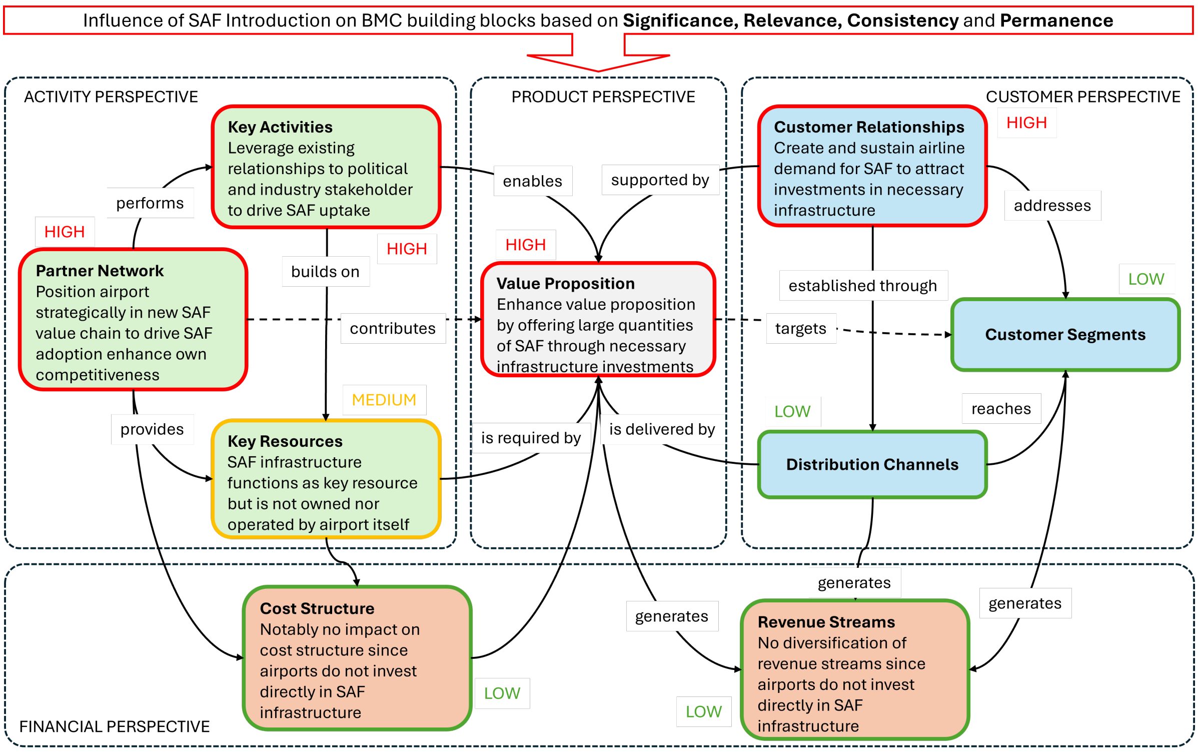

Figure 6.2: Final BMC for cargo-focused airports depicting impacts on business model building blocks caused by the SAF

6.1.2. At the forefront of change: Cargo airlines & freight distributors

The results for cargo airlines and freight distributors paint a completely different picture, as the adoption of SAF affects almost all aspects of these business models. The reason for this is the aforementioned need for business model consistency. Drivers and barriers for the adoption of SAF, refer to chapter 3.2 and 3.3, might initially only impact one BMC building block which, however, later requires changes to adjunct BMC building blocks to sustain consistency. Importantly, a clear distinction between the effects of SAF on cargo airlines' and freight distributors' business models is challenging due to their extensive interconnection.

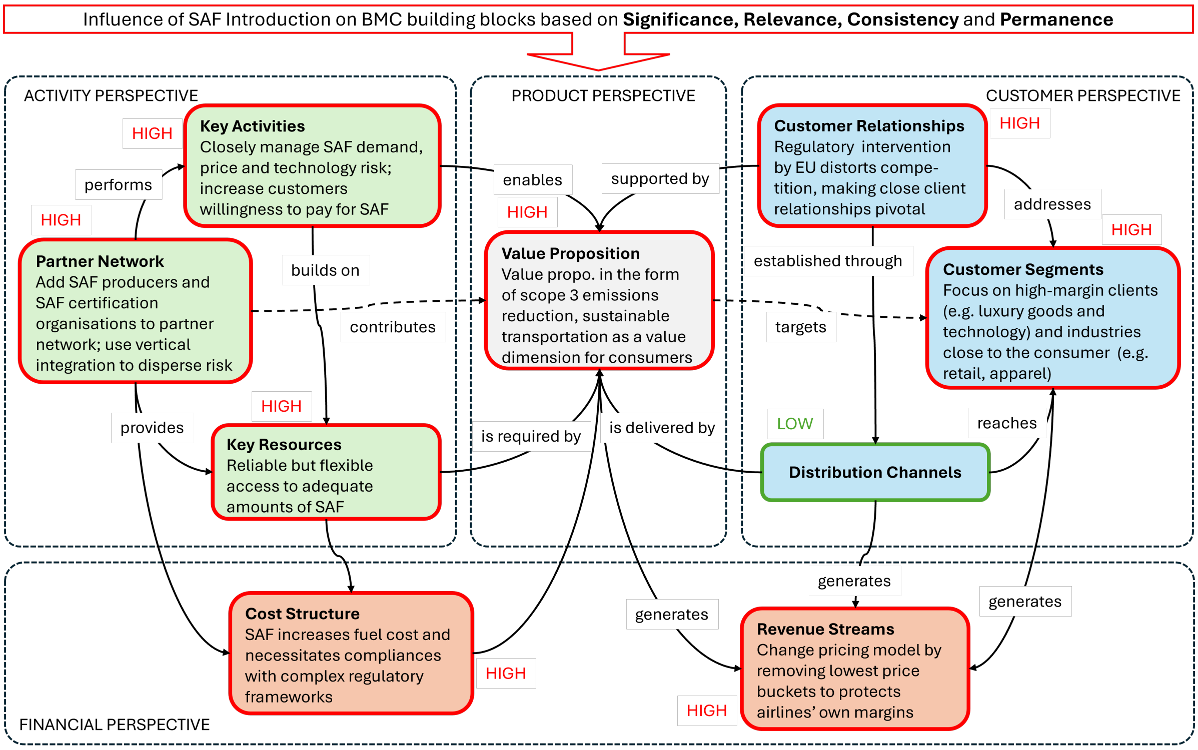

Figure 6.3: Final BMC for cargo airlines depicting impacts on business model building blocks caused by the SAF

Figure 6.3 depicts the impact of SAF on cargo airlines' business models, displaying fundamental changes. The higher cost of SAF compared to conventional jet fuel, leading to significant changes in the cost structure, needs to be recouped through additional revenue to sustain the financial viability of cargo airlines' business model. However, increased willingness to pay for sustainable transportation is contingent upon cargo airlines' enhanced value proposition. How this improved value proposition can be provided remains up for debate and is discussed in further detail in the next paragraph, which looks at the impact of SAF on freight distributors' business models. Currently, cargo airlines are exploring ways to disperse the additional cost of SAF across the value chain by focusing on cargo owners with healthy profit margins or by targeting industries that are close to the consumer, e.g. retail. Resilient customer relationships and clear customer segmentation are pivotal for airlines to identify cargo owners with an increased willingness to pay for sustainability. On the opposite side of the BMC, cargo airlines focus on broadening their partner network by incorporating organisations that can deliver sufficient quantities of SAF at reasonable prices and by engaging with organisations that can support the commercialisation of sustainable transportation, e.g. carbon accounting organisations. Managing the associated demand, price and technology risks that come with the adoption of SAF will become one of the key activities for airlines. Once an improved value proposition is defined, cargo airlines can generate higher revenue streams by charging a premium for SAF from dedicated customer segments which can absorb higher transportation costs.

Looking at the effects of SAF on freight distributors' business models, visualised in figure 6.4, the successful commercialisation of SAF to recoup higher jet fuel costs becomes even more important. Despite the significant hurdles in commercialising SAF for the entire aviation industry, air cargo offers a unique

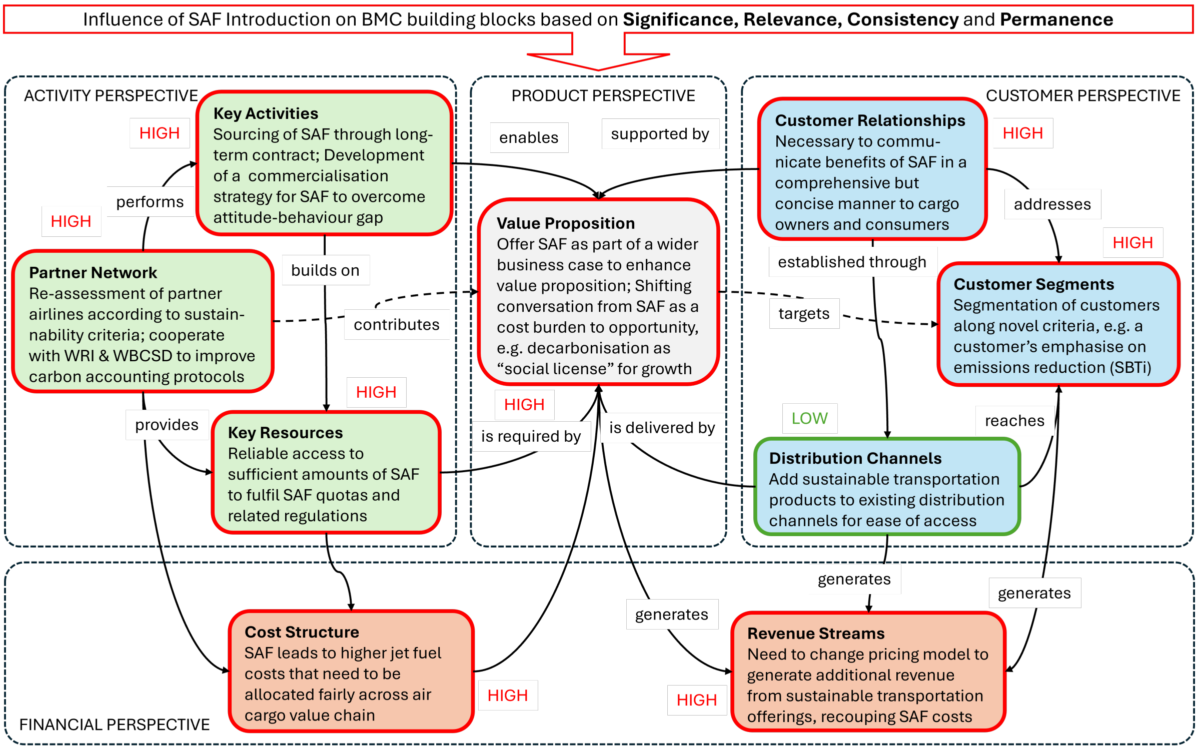

Figure 6.4: Final BMC for freight distributors depicting impacts on business model building blocks caused by the SAF

advantage compared to passenger travel. Air cargo differs from passenger air travel in its customer base. While passenger airlines cater to a large number of individual travellers, air cargo customers are primarily large corporations facing increasing pressure to decarbonize their supply chains. This presents a unique opportunity for freight distributors to craft a compelling value proposition for SAF. They can achieve this by highlighting their contribution to reducing a company's scope 3 emissions. By positioning SAF as a decarbonization tool that cargo owners can communicate to their customers, freight distributors can create a win-win scenario. Building trust and avoiding greenwashing requires careful management of customer relationships with cargo owners and consumers. This ensures realistic expectations around SAF's capabilities. As one of the few aspects of the business model, SAF's impact on distribution channels is considered low, depicted on the right-hand side of figure 6.4, since the use of existing channels simplifies access to "green" transportation options. Moving on to the left-hand side of the BMC, effects on all aspects of the business model can be observed. Besides the sourcing of SAF the commercialisation of SAF will become a key activity for freight distributors. Freight distributors and cargo airlines currently lack a strong value proposition that clearly communicates the value of SAF. One key reason is the immaturity of accounting frameworks for Scope 3 emissions reductions. To address this challenge, freight distributors and cargo airlines have to include organizations like the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), which are developing these accounting standards, in their partner network.

6.1.3. Concluding remarks

Over the cause of this research, it became that the successful adoption and commercialisation of SAF in air cargo is the result of a long and intricate learning process that requires the coordination of a network of stakeholders, each pursuing their own interest. The lengthiness of these processes requires stakeholders to act now to have sufficient time to go through the necessary learning processes before stricter SAF quotas overwhelm the financial and operational capabilities of these actors. Notably, the sentiment within the industry for higher SAF utilisation is very positive, despite prevailing hurdles and a high level of uncertainty. Industry actors acknowledge the need for rapid decarbonisation in aviation and see SAF as an opportunity to do so. They recognise that the effects on their respective business model caused by SAF are minuscule compared to the detrimental consequence of climate change.

7 Discussion

The systematic literature review, refer to chapter 1.2.1, uncovered a lack of research focusing on air cargo compared to a large amount of research investigating passenger air traffic. Additionally, no research inquires into the impact of SAF on air cargo business models, even though the implications of SAF introduction on revenue streams, cost structure and customer relationships are tremendous. This study addresses the research gap by developing a conceptual model (see chapter 4.1) for aviation business models, centred around an extended variation of the Business Model Canvas by Osterwalder and Pigneur (2010). The conceptual model is applied to describe the contemporary business model of focal value chain actors - aircraft manufacturers, airports, cargo airlines and freight distributors - chapter 4.3. Literature and secondary data were inquired to theorise potential changes to these business models caused by SAF. Ultimately, ten expert interviews were conducted, refer to chapter 5, to gather industry experts' perceptions of the impact of SAF on the aforementioned companies. The following chapter will discuss the strengths and weaknesses (see chapter 7.2.2) of this approach and how future research could potentially address these (see chapter 7.2.3). Furthermore, key themes emerging from the expert interviews (Chapter 5) will be analyzed in light of the hypothesised implications derived from secondary data and literature (Chapter 4.1). Lastly, the practical implications of this study will be discussed and connections to the ”Management of Technology” program will be made.

7.1. General discussion

The results of this study showcase two interesting observations that present significant differences between the results obtained from the literature (chapter 4.1 and those generated through expert interviews 5.

First, existing literature underestimates the importance of communication in the adoption of new technologies. In chapter 4.1 no effects on the customer perspective (e.g. Customer relationships, customer segment and distribution channels) were hypothesised. Meanwhile, the effective communication of SAF's benefits was one of the most frequently mentioned aspects for cargo airlines and freight distributors. In chapter 4.1 it was assumed that freight distributors would just continue the same service to an existing customer base, however, this is not the case The reason for the importance of communication is that many consumers have an underlying distrust for sustainability claims made by companies due to false advertisements in the past. To regain this trust companies have to communicate the advantages of SAF in a sensible manner, which is made more difficult by the lack of adequate regulation. It is critical that companies convince cargo owners and consumers of the benefits of SAF since good customer relationships are a prerequisite for an enhanced value proposition. An enhanced value proposition in turn is necessary to generate higher revenues to recoup the additional costs of SAF, as indicated in the conceptual model in figure 4.1.

The second interesting observation touches on the necessary higher revenues. While the literature consulted in chapter 4.1 indicated some kind of commercialisation is necessary to recoup the additional cost of SAF the complexity of SAF commercialisation was not apparent. The subsequent interviews revealed that commercialisation requires changes to legal frameworks, long-term sourcing of SAF, effective risk management, close customer relationships and correct customer segmentation. To this date, cargo airlines and freight distributors struggle to manage all these aspects and make a profit from SAF. Successful commercialisation of SAF in air cargo is the result of a lengthy learning process that urgently requires further research. However, some industry participants seem to think that the complexity of commercialisation can be an advantage for them. Once a commercialisation strategy is defined it will be hard for competitors to copy this.

7.2. Theoretical evaluation

This section elaborates on the theoretical implications of the research findings and emphasises the contribution of this study to existing literature in the academic field. Next, this section discusses the strength of this research approach and presents inherent limitations. Finally, the section proposes avenues for future research, thereby contributing to the academic literature on air cargo and business model transformation.

7.2.1. Theoretical implications

This study contributes to the ever-growing body of research investigating the implications of emerging technologies on different aspects of business models. Moreover, these findings contribute to a scientific perspective on air cargo, an industry that receives comparatively little attention from academia. Other studies researched the effect of disruptions like the COVID-19 pandemic on business models in aviation (e.g. Colak et al. (2023)), investigated strategies for the decarbonisation of air cargo (e.g. Baxter (2021)) or looked into the willingness to pay for SAF in passenger air traffic (e.g. Berger et al. (2022)). Meanwhile, there is very little research that takes a comprehensive approach and investigates how externally driven changes in the form of technological disruption combined with pressure from policymakers affect an entire value chain. Further, this study adds to existing research that applies the BMC to different industries. The results help to identify potentially reoccurring patterns in the diffusion of SAF in the aviation industry. This process has not yet been mapped properly due to the novelty of this technology and requires further research in the future.

7.2.2. Strength & limitations

Haessler et al. (2023) conducted a meta-analysis of studies addressing commercialisation strategies for emerging technologies, such as SAF. The authors note that few studies move beyond anecdotal evidence of isolated success cases and successfully identify and describe reoccurring patterns. A risk that this study faces as well. Consequently, solely conducting a handful of interviews with experts from each stakeholder group will inevitably have to face the claim of being anecdotal in nature. Triangulation is a valuable technique to address this issue. Data source triangulation refers to the collection of data from different types of people, including individuals, groups, and communities, to gain multiple perspectives which can ensure that findings are not based on single, isolated pieces of evidence (Carter et al., 2014). This research employs data source triangulation by integrating information obtained through desk research based on literature and secondary data with expert interviews, as well as insights from panel discussions and presentations attended at the ”Sustainable Aviation Futures Congress 2024” in Amsterdam.

Therefore the variety of data sources and their respective richness can be considered a major strength of this study. Conducting extensive desk research prior to the expert interviews helped to identify key areas that require further investigation, resulting in a well-structured interview guide that still kept room for new emerging themes. Additionally, the knowledge acquired at the SAF Congress supported the contextualisation of the interview data by highlighting which topics, that were discussed in the interviews, are of high relevance to the industry and which are mostly anecdotal and unique to the company interviewed but not necessarily a topic relevant to the industry as a whole. When topics emerged as relevant during the congress but were not addressed in the interviews, insights from experts at the congress were included to provide a comprehensive list of themes. To underpin the data analysis this research aimed for the highest possible level of transparency by (1) providing a comprehensive summary of all interviews (refer to appendix C), (2) listing individual experts that mentioned each of the codes in the respective table, (3) directly linking each theme to a group of codes and by (4) providing literal quotes from the interviews to substantiate the definition of each theme. This approach ensures a high degree of replicability.

Additionally, the superb professional expertise as well as the occupational diversity of interview participants can be considered a second strength of this study. With an average of over 12 years of relevant experience, experts were able to draw from their extensive knowledge to accurately identify and elaborate on emerging long-term trends regarding the impact of SAF on air cargo business models. Furthermore, individuals from a brought range of organisations in terms of company size, position within the value chain, geographical location and SAF technology adoption level were interviewed. This diverse representation ensured that the study captured a wide array of perspectives and insights, contributing to a rich understanding of the subject matter. The inclusion of participants from different operational scales and geographical regions helped to get a grasp of perception across various market conditions. Moreover, the variety in SAF technology adoption levels provided a nuanced view of the challenges and opportunities faced by organizations at different stages of implementation. This methodological approach not only enhances the validity of the findings but also increases their applicability across different segments of the industry, making the conclusions drawn from this study more robust and generalizable.

This study, while providing valuable insights into the impact of SAF on the air cargo industry, is subject to several limitations arising from the research design, data collection methods, and the inherent challenges of studying a complex and evolving field. Three primary aspects of these limitations are the scope and generalizability of the findings, the methodological constraints, and the temporal relevance of the data. These limitations should be addressed by future research.

First, the scope and generalizability of the research are limited by its focus on a selected number of companies within the air cargo value chain. This selective approach, dictated by the study's scope, means that other potentially relevant stakeholders were not included. Consequently, the findings may not be entirely generalizable across the entire air cargo industry. Additionally, the study's geographical focus on experts from Germany, the Netherlands, and the USA may limit the applicability of the results to other regions with different regulatory environments and market dynamics. This effect is worsened by the study's focus on stakeholder perception, which can potentially greatly shift between countries based on factors such as the socio-political environment. While the purposive sampling strategy targeted individuals with significant experience and knowledge, the limited number of participants may introduce a selection bias, as the views of these experts may not fully represent the broader industry. Future research should aim to incorporate a more diverse sample to address this limitation.

Second, methodological constraints present another significant limitation. The study's reliance on semi-structured interviews, while valuable for gaining in-depth insights, introduces subjectivity in data collection and analysis. Despite efforts to maintain interviewer neutrality and use open-ended questions, the possibility of interviewer bias affecting responses cannot be entirely eliminated. The use of reflective thematic analysis, although rigorous and well-suited to qualitative data, involves the researcher's interpretation and reflexivity, which can introduce another layer of subjectivity. The iterative nature of this approach necessitates careful verification and external review, which may still leave room for interpretative bias. Furthermore, given the complexity and global scale of the air cargo value chain, the claim of achieving data saturation within this study is not made. The study aimed to gather a broad range of perspectives rather than exhaustively cover all potential insights. The complexity and interconnectedness of the air cargo industry mean that further interviews and research could yield additional findings. Furthermore, short interviews provide a rather superficial insight into a company's business models and cannot provide an understanding of the underlying intricate processes at work.

Third, the rapidly evolving nature of SAF technologies and regulatory frameworks poses a challenge to the temporal relevance of the study's findings. Changes in technology, policy, and market conditions occurring after the data collection period may affect the applicability of the results. Ongoing developments in SAF production, certification, and adoption could necessitate updates to the study's conclusions. The study's findings are contextualised within the specific regulatory and market conditions prevailing at the time of the research and focuses on the European Union. Variations in these conditions across different regions and over time could impact the generalizability of the conclusions.

In conclusion, despite these limitations, the study offers valuable contributions to understanding the impact of SAF on the air cargo industry. The identified themes and insights provide a foundation for future research and practical implications for industry stakeholders. Addressing the outlined limitations ongoing updates to reflect industry changes (e.g. longitudinal studies), and incorporating additional from an in-depth investigation of business models (e.g. case study) will enhance the robustness of future research in this field.

7.2.3. Future research

Given the limitations identified in this study, future research should focus on utilising longitudinal data and case studies to deepen the understanding of the impact of SAF on the air cargo industry. These approaches will provide more robust and comprehensive insights into the dynamics of SAF adoption and its effects on business models over time.

To address the rapidly evolving nature of SAF, future research should employ longitudinal studies to track changes in the air cargo industry related to SAF adoption over an extended period. Longitudinal data can capture the temporal evolution of SAF implementation, allowing researchers to observe trends, identify long-term impacts, and understand the factors that influence the success or failure of SAF initiatives. This approach will also enable the assessment of how business models adapt to the introduction of SAF, providing insights into the sustainability and scalability of such transformations. Longitudinal studies could involve repeated surveys and interviews with key stakeholders across the air cargo value chain, including airlines, airports, fuel suppliers, and regulatory bodies. By collecting data at multiple points in time, researchers can analyse how perceptions, practices, and performance metrics change, offering a dynamic view of the industry's progression towards sustainable aviation.

Improving the generalizability of results can be done by conducting in-depth case studies of organizations that have successfully integrated SAF into their operations. This type of research provides valuable practical insights and best practices. These case studies should focus on diverse stakeholders, including both large and small companies, to capture a wide range of experiences and strategies. By examining companies at different stages of SAF adoption, researchers can uncover the contextual factors that drive success. Case studies can also highlight challenges and barriers faced by different organizations, offering lessons on how to overcome these obstacles. Detailed case analyses will contribute to a richer understanding of the complexities involved in transitioning to SAF and provide actionable recommendations for industry practitioners.

Combining longitudinal data with case study research will offer a comprehensive approach to studying SAF adoption. While longitudinal data provides a broad overview of industry trends and changes over time, case studies offer in-depth, context-specific insights. This combination will allow researchers to generalise findings from individual cases to broader industry and technology diffusion patterns.

7.3. Practical implications

This thesis is the first study to investigate the intersection of SAF, business model transformation, and air cargo. Beyond its contribution to research, the results also have significant practical implications.

Risks to all aspects of the business model are a constant to companies in the aviation value. For instance, COVID-19 led to a sudden disappearance of demand in passenger air traffic. Similarly, the sudden increases in oil prices have led to turmoil in the industry in the past. The emergence of SAF as a disruptive technology combined with regulatory pressure to adopt this technology as a means of decarbonisation has the potential to have similarly disruptive effects on the industry. Therefore effective risk management is crucial to navigate these risks. If risks are managed effectively companies can gain a competitive advantage and strengthen their market position. However, to be able to manage risk effectively companies have to know which aspects of their complex business models are affected. That is where this study comes into play. It clearly outlines which aspects of each of the business models are affected, what the extent of expected changes is how these changes might look. Therefore this study provides a basis for industry participants to analysis their current business model and to identify gaps in these that need to be addressed. These effects on the business model can be grouped according to the different categories of stakeholders: facilitators of change (aircraft manufacturers and cargo-focused airports) and those at the forefront of change (cargo airlines and freight distributors).

Aircraft manufacturers are positioned to expand their roles beyond producing aircraft to becoming key facilitators in the SAF adoption process. This involves active coordination with stakeholders such as policymakers, banks, energy companies, and airlines. This thesis outlined that early investment in necessary SAF certifications for aircraft models can strengthen their value proposition, by supporting airlines in meeting regulatory SAF quotas. This reinforces aircraft manufacturers' market position without significant changes to their cost structure or revenue streams, as existing technological knowledge and production capabilities are leveraged. Ultimately, the results of this thesis show that aircraft manufacturers should proactively drive the adoption of SAF so that they can use existing technological knowledge and minimal risk of disruption.

Similarly, cargo-focused airports must incentivise investment in SAF infrastructure to ensure the reliable availability of SAF, which is crucial for maintaining their position within airlines' route networks, amidst regulatory pressures and cargo owners' demand for decarbonisation. This may involve enhanced coordination with fuel suppliers to foster increased investments in SAF infrastructure. Maintaining and nurturing strong relationships with airlines and other stakeholders will be essential. Nonetheless, airports' ability to influence the adoption of SAF is low and restricted to the role of a mediator, ensuring that the interests of various parties are aligned to facilitate the seamless adoption of SAF.

The higher cost of SAF will lead to significant changes in the cost structure of cargo airlines. The thesis emphasised the importance of effective commercialisation to recoup these costs and gave a few examples from practice on how this can be done. Developing resilient customer relationships and clear segmentation strategies will be critical. Airlines need to identify and target customers with a higher willingness to pay for sustainable options. Cargo airlines should broaden their partner networks to include organizations capable of delivering SAF at reasonable prices and supporting the commercialization of sustainable transportation.

Freight distributors have a unique opportunity to craft compelling value propositions by emphasising the role of SAF in reducing scope 3 emissions for their corporate customers. This can enhance their competitive edge and justify higher transportation costs. This study shows that the successful commercialization of SAF will require freight distributors to closely collaborate with organizations developing emissions accounting standards. This ensures transparency and builds trust, avoiding the pitfalls of greenwashing. As commercialising SAF becomes a key activity, freight distributors must integrate with entities like the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) to stay ahead in developing and adhering to new carbon accounting standards.

Proactive stakeholder engagement is essential. All industry actors must engage proactively with policymakers, industry bodies, and each other to navigate the complexities of SAF adoption. This includes participating in discussions and collaborations aimed at refining regulations and standards for SAF use. Due to extremely long lead times for new SAF production plants, continuous and early investment in infrastructure and technology is crucial.

Moreover, this study underlined that the decarbonisation of aviation is not the sole responsibility of airlines, but rather the result of an industry effort. The findings point out that expected changes to the cost structure will likely overburden the financial capabilities of cargo airlines. This insight lays the foundation for a constructive discussion within the industry on how the additional cost of SAF can be allocated along the value chain. A long-term perspective beyond the immediate cost is vital and cargo owners have to acknowledge their responsibility in carrying some of the cost of SAF. All industry stakeholders should incorporate SAF adoption into their strategic planning processes, considering future regulatory scenarios and market trends to remain resilient and competitive.

Furthermore, this study advocates for a change in perspective. Industry participants should not regard SAF as a pure cost burden but rather as an opportunity. On the one hand, social and political acceptance for further aviation growth, especially in Europe, is low due to the associated unresolved problems in terms of emissions and noise. The successful decarbonisation of aviation could show that the aviation industry is able to address its own problems. This will create acceptance for further industry growth in the future. Furthermore, this study emphasised that the market for sustainable transportation options is growing rapidly but the necessary changes to the business model take a lot of time. Therefore, companies most act now to capitalise on this growing market. These insights might influence the corporate strategy of some industry actors towards a more sustainable future.

7.4. Link to Management of Technology

This master thesis explores how the adoption of SAF affects the aviation industry, with a specific focus on the air cargo segment. This scientific study integrates technology management, corporate strategy, and innovation management. The methodology is grounded in the principles taught in the MoT curriculum, including the analysis of business models, the diffusion of emerging technologies, and qualitative data analysis. For example, the concept of the business mode canvas is taught in the course ”Technology, Strategy and Entrepreneurship”, and the analysis of technological development patterns was extensively discussed in the ”Emerging and Breakthrough Technologies” class. Additionally, the ”Research Methods” course laid the groundwork for scientific research by introducing proper data collection and analysis methodologies. These elements were combined in this thesis to facilitate a comprehensive view of industries and business models in light of constant technological change, reflecting the holistic, technology-savvy approach taught in the MoT program.

Regarding my personal feedback on the MoT program, the courses I took were instrumental in various aspects of this thesis. Nearly all courses required writing scientific papers, which helped me adapt to academic writing styles and standards. The emphasis on a transdisciplinary approach taught me to consider stakeholders’ diverse interests and to examine problems from multiple perspectives. The program’s focus on responsible innovation and sustainability was also highly valuable for this thesis. These themes are crucial in today’s world, and I appreciate that the MoT courses emphasised this approach. I believe that including more courses that involve direct collaboration with companies, like the ”Integration Moments” course, would be a great addition to the MoT program. Working with professionals provides students with practical experience in organisational environments. Overall, the courses and the professors’ approach were excellent. I always felt heard, and my questions and contributions were valued.

8 Conclusion

This study set out to investigate the impacts of SAF on business models in the air cargo industry value chain. To address the research question a two-pronged research approach was taken. Initially, a conceptual model was developed based on a modified version of the ”Business Model Canvas” by Osterwalder and Pigneur (2010) to describe current business models in air cargo prior to the adoption of SAF. Subsequently, results from desk research and ten semi-structured expert interviews were combined to describe the same business models a second time, in this instance after the large-scale adoption of SAF.

The research reveals that the adoption of SAF significantly impacts the business models of companies across the air cargo industry value chain. Aircraft manufacturers and airports, playing coordinative roles, experience minimal direct effects on their cost structures and revenue streams. Instead, their contribution lies in facilitating the diffusion of SAF by coordinating between new and existing partners. Meanwhile changes to their cost structure and revenue streams are not to be expected since these actors do not own any of the SAF infrastructure in the case of airports or can continue to use existing technological knowledge in the case of aircraft manufacturers. Nonetheless, the companies should use their abilities as facilitators between existing and emerging partners to steer the adoption of SAF in a manner that brings advantages to their strategic position. Aircraft manufacturers can advocate for the continued use of jet engine aircraft, a domain in which they have extensive knowledge, by supporting the rapid scale-up of SAF production. Similarly, airports have to attract investments in the necessary SAF infrastructure to remain reliable partners for airlines which are facing SAF usage quotas and therefore require access to large quantities of SAF

In contrast, cargo airlines and freight distributors face substantial changes due to the higher costs associated with SAF. These companies must adapt their business models to effectively commercialise sustainable transportation services, which includes developing robust carbon accounting practices, SAF certificate trading systems and strong customer relationships focused on sustainability. The findings indicate that proactive adjustments to business models, focusing on the commercialization of sustainability to allocate the additional costs of SAF across the value chain, will be essential for cargo airlines and freight distributors to sustain financially viable and globally competitive business models. The study also emphasises the necessity for these actors to view SAF adoption as an opportunity rather than a burden, enabling them to gain valuable experience and lead in the sustainable air cargo market. This shift in perspective, combined with necessary strategic changes in partner networks and key activities, can help mitigate demand, policy and technology risks associated with SAF, and leverage the growing demand for sustainable transportation. By addressing these challenges proactively, companies can position themselves advantageously in an increasingly environmentally conscious air cargo market.

Due to the absence of existing research in this area, the study at hand can only be considered an initial overview of the potential effects of SAF on air cargo. Future research should conduct in-depth case studies and longitudinal research to acquire a detailed understanding of ”cause-and-effect” relationships, and changes to business models over time.

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A

Business Model Criteria Questions

Key Partnerships:

- Strategic Fit: Do the partnerships align with the overall business model and strategy?
- Value creation: Do the partnerships contribute to creating value for either the business or its customers?
- Reliability: How dependable are the partners in delivering on their commitments?
- Flexibility: Can partnerships adapt to changing business needs and circumstances?

Key Activities:

- Value Creation: What activities are crucial for delivering the value proposition to customers?
- Efficiency: How efficiently are these activities carried out, and are there opportunities for optimization?
- Innovation: Are there ongoing efforts to improve and innovate key business processes?
- Uniqueness: Are there any key activities that give the business a competitive advantage?

Key Resources: Physical, Intellectual, Human

- Core Competencies: What are the unique strengths and capabilities that give the company a competitive advantage?
- Essentiality: Are the resources critical for delivering the value proposition and operating the business model?
- Accessibility: Can the business acquire and maintain access to these key resources at a reasonable cost?
- Control: Does the business have sufficient control over the key resources to ensure smooth operations?

Value Propositions

- Uniqueness: How distinct is the value proposition compared to competitors?
- Market Fit: How well does it align with the needs and preferences of the target market?
- Relevance: Do the value propositions address the specific needs and problems of the targeted customer segments?
- Differentiation: What makes the value proposition unique and compelling compared to competitors?

Customer Segments:

- Identification: Are the target customer segments clearly defined and understood?

- Size and Growth: How large is the market, and is it growing or shrinking?
- Profitability: Are the segments financially viable and able to generate sufficient revenue?
- Accessibility: Can the business effectively reach and acquire customers within these segments?

Customer Relationships:

- Satisfaction: Are customers satisfied with the level of service and support provided?
- Loyalty: Are the chosen methods for customer relationships effective in driving loyalty and repeat business?
- Engagement: What type of relationship does the business want to establish with each customer segment?

Distribution Channels:

- Reach: How effectively do the chosen channels reach the target customer segments?
- Efficiency: How well do the channels facilitate customer acquisition, retention, and satisfaction?
- Cost-effectiveness: Are the channels chosen efficient and cost-effective for delivering the value proposition?
- Experience: Do the channels provide a positive and seamless experience for the customer?

Cost Structure:

- Efficiency: Are costs optimised to ensure maximum value for resources expended?
- Scalability: How do costs change as the business scales up or down?
- Cost drivers: What are the key factors that drive costs in the business model?
- Cost advantage: Does the cost structure provide a competitive advantage over rivals?

Revenue Streams:

- Stability: How predictable and stable are the revenue streams?
- Diversification: Does the business have multiple revenue streams to mitigate risk and capture more customer value?
- Profitability: Are the revenue streams sufficient to cover all the costs associated with the business model?

B

Detailed Business Model Canvas

B.1. Business Model Canvas - Cargo Airline

Customer Segments:

- Freight Forwarders: Businesses that act as intermediaries between shippers and airlines, handling logistics and documentation.
- E-commerce Companies: Businesses that require fast and reliable cargo transportation for online orders.
- Manufacturers: Companies that need to transport finished goods or components internationally.
- High-Value Goods Shippers: Businesses shipping valuable cargo requiring specialised handling (e.g., pharmaceuticals, electronics).
- Logistics Companies: Outsourcing their cargo transportation needs.
- Government Agencies: Transporting relief supplies, military equipment, etc.

Value Propositions:

- Speed and Efficiency: Fast and reliable delivery of cargo compared to other transportation methods.
- Global Reach: Access to a vast network of destinations for international shipping needs.
- Security and Tracking: Secure handling of cargo with real-time tracking capabilities.
- Specialized Services: Temperature-controlled facilities, secure transportation for high-value goods, and time-definite deliveries.
- Industry Expertise: Knowledge of customs regulations and efficient handling of complex cargo needs.
- Flexibility: Accommodating various types of cargo, including perishable goods, hazardous materials, and oversized items.
- Cost Efficiency: Competitive pricing and efficient operations.

Channels:

- Direct Sales: Dedicated sales teams working with freight forwarders, large manufacturers, and logistics companies.
- Online Booking Platforms: Web-based platforms for booking cargo space and managing shipments.
- Freight Forwarder Networks: Partnerships with freight forwarders for wider market reach.
- Travel Agencies (For Belly Cargo): Collaboration with passenger airlines to utilize belly cargo space on passenger flights.

- Marketing and Advertising: Promoting services through trade shows, industry publications, and digital marketing.

Customer Relationships:

- Dedicated Account Managers: Providing personalized service and support to key clients.
- Customer Portals: Online platforms for shipment tracking, documentation management, and communication.
- 24/7 Customer Support: Offering assistance and resolving issues related to cargo shipments.
- Feedback Mechanisms: Gathering input to improve services and address customer concerns.
- Long-term Partnerships: Building relationships with key clients for repeat business.

Revenue Streams:

- Freight Charges: Transportation fees based on weight, size, and destination of the cargo.
- Value-Added Services: Surcharges for special services like temperature control, security measures, and express delivery.
- Fuel Surcharges: Variable charges based on current fuel prices.
- Documentation Fees: Costs associated with processing customs documentation and other paperwork.
- Charter Services: Offering specialized cargo flights for urgent or oversized shipments.
- Ancillary Services: Generating revenue from services such as express delivery, insurance, and charter services.

Key Activities:

- Flight Operations: Maintaining and operating cargo aircraft to ensure on-time deliveries.
- Cargo Handling: Efficient loading, unloading, and ground handling of cargo at airports.
- Customs Clearance: Facilitating the smooth movement of cargo through customs procedures.
- Sales and Marketing: Acquiring new customers and promoting cargo services.
- Network Management: Building and maintaining relationships with airports, freight forwarders, and other stakeholders.
- Fleet Management: Ensuring the fleet of cargo planes is operational and optimized.
- Route Planning and Optimization: Determining the most cost-effective and efficient flight routes.
- Regulatory Compliance: Adhering to aviation regulations and safety standards.

Key Resources:

- Cargo Aircraft Fleet: A fleet of dedicated cargo airplanes or belly cargo space on passenger aircraft.
- Airport Infrastructure: Ground handling facilities, warehouses, and security systems at airports.
- Information Technology: Systems for booking, tracking, and managing cargo shipments.
- Skilled Workforce: Trained pilots, ground staff, and logistics personnel.
- Trained Pilots and Crew: Skilled personnel to operate and manage flights.
- Ground Handling Equipment: Forklifts, conveyor belts, and other equipment for cargo handling.
- IT Systems: Booking, tracking, and management systems for cargo operations.
- Infrastructure: Facilities for maintenance, storage, and administrative purposes.

Key Partnerships:

- Freight Forwarders: Collaborations to offer comprehensive logistics solutions to shippers.
- Ground Handling Agents: Partnerships for efficient cargo handling at airports.
- Airlines (For Belly Cargo): Agreements with passenger airlines to utilize belly cargo space.

- Customs Authorities: Collaboration to ensure smooth and efficient customs clearance processes.
- Aircraft Manufacturers: For acquiring cargo planes.
- Ground Handling Services: For efficient loading and unloading of cargo.
- Maintenance and Repair Organizations (MROs): For aircraft maintenance services.
- Airports and Air Traffic Control: For landing rights and operational coordination.

Cost Structure:

- Fuel Costs: A significant expense for operating cargo aircraft.
- Aircraft Maintenance: Maintaining a fleet of cargo airplanes in airworthy condition.
- Airport Fees: Landing charges, parking fees, and other airport-related costs.
- Personnel Costs: Salaries and benefits for pilots, ground staff, and administrative personnel.
- Marketing and Sales Expenses: Costs associated with acquiring new customers and promoting services.
- Aircraft Acquisition and Maintenance: Including purchase or lease costs and ongoing maintenance expenses.
- Infrastructure Costs: Facilities, equipment, and IT systems.
- Regulatory Compliance: Costs associated with meeting safety and security standards.

Key Metrics:

- Revenue per Ton Mile: Measure of revenue generated per unit of cargo transported over one mile.
- Load Factor: Percentage of cargo capacity utilized on each flight.
- On-Time Performance: Measure of punctuality in delivering cargo as scheduled.
- Customer Satisfaction: Feedback and ratings from customers.
- Cost per Available Ton Mile: Measure of operational efficiency in terms of cost per unit of cargo capacity available.

B.2. Business Model Canvas - Cargo Airport

Customer Segments:

- Cargo Airlines: Passenger airlines with cargo operations, dedicated cargo airlines.
- Freight Forwarders: Companies that manage logistics and transportation of goods for businesses.
- Express Delivery Companies: Providers of expedited shipping services.
- Manufacturers and E-commerce Companies: Businesses needing to transport goods domestically and internationally.

Value Propositions:

- Efficient Cargo Handling: Fast turnaround times, advanced sorting and processing facilities, 24/7 operations.
- Favorable Location: Proximity to major trade routes, access to intermodal transportation networks (e.g., railways, highways).
- Specialized Infrastructure: Dedicated cargo terminals, extended runways for large freighters, cold storage facilities (for perishables).
- Security and Regulatory Compliance: Secure handling areas, efficient customs clearance processes.
- Value-Added Services: On-site freight forwarding, repackaging, labeling, cargo insurance.

Channels:

- Direct Sales: Sales team dedicated to attracting airlines and freight forwarders.

- Industry Events: Participation in trade shows and conferences to promote services.
- Online Presence: User-friendly website with information on facilities, fees, and booking options.
- Partnerships: Collaboration with freight forwarders, customs agencies, and logistics companies.

Customer Relationships:

- Account Management: Dedicated teams for key airlines and freight forwarders.
- Performance Reporting: Regular reports on cargo handling times, security breaches, and service level agreements (SLAs).
- Customer Service: 24/7 support for inquiries and troubleshooting.

Revenue Streams:

- Landing Fees: Charges based on aircraft weight and size.
- Storage Fees: Charges for warehousing and storing cargo.
- Value-Added Services Fees: Revenue from on-site services like repackaging, labeling, and insurance.
- Concession Fees: Revenue generated from on-site businesses like catering, ground handling services, and maintenance facilities.

Key Resources:

- Runways and Landing Areas: Infrastructure designed for large cargo aircraft.
- Cargo Terminals: Warehouses equipped for efficient sorting, processing, and storage.
- Ground Handling Equipment: Forklifts, conveyor belts, specialized vehicles for cargo handling.
- Information Technology Systems: Cargo management systems, tracking software, security monitoring systems.

Key Activities:

- Airport Operations: Maintaining runways, facilities, and air traffic control systems.
- Cargo Handling: Receiving, sorting, storing, and dispatching cargo shipments.
- Security: Ensuring the safety and security of cargo and personnel.
- Marketing and Sales: Attracting new airlines and freight forwarders.
- Customer Relationship Management: Building and maintaining relationships with key clients.

Key Partnerships:

- Airlines: Agreements with airlines to establish cargo hubs or freighter routes.
- Freight Forwarders: Partnerships to offer integrated logistics services.
- Government Agencies: Collaboration with customs and security agencies to streamline clearance processes.
- Ground Handling Service Providers: Companies specializing in cargo loading, unloading, and handling.

Cost Structure:

- Infrastructure Costs: Maintenance of runways, terminals, and cargo handling equipment.
- Personnel Costs: Salaries for air traffic controllers, security personnel, cargo handlers, and administrative staff.
- Marketing and Sales Costs: Expenses associated with promoting the airport's cargo services.
- Technology Costs: Maintaining and upgrading cargo management and security systems.
- Landing Fee Sharing: Sharing a portion of landing fees with airlines as incentives.

B.3. Business Model Canvas - Cargo Aircraft Manufacturer

Customer Segments:

- Cargo Airlines (Passenger airlines with cargo operations)
- Express Delivery Companies
- E-commerce Giants
- Military (For strategic airlift)
- Government Agencies (For humanitarian missions)
- Logistics companies and shipping companies
- Government agencies and military for transport and logistics purposes.

Value Propositions:

- High Payload Capacity: Ability to transport large quantities of cargo.
- Long Range: Efficient operation over extended distances.
- Fuel Efficiency: Minimizing operational costs for airlines.
- Reliability: Minimizing downtime and maintenance needs.
- Advanced Avionics: Enhancing safety and navigation capabilities.
- Customization Options: Offering configurations for specific cargo needs.
- High-quality and reliable cargo aircraft tailored for specific needs.
- Efficient and cost-effective transportation solutions for cargo logistics.
- Compliance with aviation regulations and safety standards.
- After-sales support and maintenance services.
- Innovation in aircraft design and technology for improved performance.

Channels:

- Direct Sales Force: Dedicated teams interacting with airlines and major cargo operators.
- Airshows and Industry Events: Showcasing new models and capabilities.
- Online Sales Platform: Providing information and facilitating communication.
- Partnerships with Leasing Companies: Expanding reach and financing options for customers.
- Partnerships with aviation brokers and agents.
- Participation in industry trade shows and events.

Customer Relationships:

- Dedicated Account Managers: Providing personalized support and after-sales service.
- Training Programs: Educating airline staff on efficient operation and maintenance.
- Maintenance and Parts Supply Network: Ensuring global support for aircraft.
- Customer Relationship Management (CRM): Building long-term relationships with clients.
- Pre-sales consultancy and customization according to customer requirements.
- Efficient and reliable delivery of aircraft orders.
- Feedback collection and continuous improvement based on customer input.

Revenue Streams:

- Aircraft Sales: Selling new cargo aircraft to airlines and cargo operators.
- After-Sales Services: Maintenance contracts, parts supply, and technical support.
- Customization Services: Modifying aircraft to meet specific cargo needs.
- Leasing Options: Partnering with leasing companies to offer financing solutions.

- Sales revenue from selling cargo aircraft.
- Revenue from after-sales services such as maintenance, repair, and spare parts.
- Licensing and royalty fees for technology transfer or use of intellectual property.

Key Resources:

- Highly Skilled Workforce: Engineers, designers, and manufacturing personnel.
- Advanced Manufacturing Facilities: Equipped for complex aircraft assembly.
- Supply Chain Network: Reliable suppliers of aircraft components and materials.
- Intellectual Property: Patents for innovative cargo aircraft designs.
- Skilled engineers and aviation experts.
- Manufacturing facilities equipped with advanced machinery.
- Supply chain for sourcing raw materials and components.
- Sales and marketing team.
- Financial resources for investment and operations.

Key Activities:

- Research & Development: Continuously improving aircraft performance and efficiency.
- Design & Engineering: Creating new cargo aircraft models with advanced features.
- Manufacturing & Assembly: Building high-quality cargo aircraft.
- Sales & Marketing: Promoting cargo aircraft to potential customers.
- Customer Service: Providing support to airlines throughout the aircraft lifecycle.
- Testing and quality assurance to ensure compliance with safety standards.
- Marketing and sales of aircraft to potential buyers.
- Providing after-sales support and maintenance services.
- Research and development for innovation and product improvement.

Key Partnerships:

- Engine Manufacturers: Suppliers of reliable and efficient aircraft engines.
- Avionics Suppliers: Providers of advanced navigation and communication systems.
- Materials Suppliers: Delivering high-quality components for aircraft construction.
- Leasing Companies: Offering financing solutions for airlines to acquire cargo aircraft.
- Regulatory Authorities: Collaborating to ensure compliance with aviation safety standards.
- Suppliers of aircraft components and parts.
- Aviation regulatory bodies for certifications and approvals.
- Logistics companies for distribution and delivery partnerships.
- Maintenance and repair organizations (MROs) for after-sales services.

Cost Structure:

- Research & Development Costs: Investments in new technologies and aircraft designs.
- Manufacturing Costs: Labor, materials, and overhead associated with aircraft production.
- Marketing & Sales Costs: Expenses related to promoting and selling cargo aircraft.
- Customer Service Costs: Providing support to airlines after aircraft purchase.
- Supply Chain Management Costs: Maintaining relationships with suppliers and ensuring parts availability.
- Manufacturing and production costs.

- Distribution and logistics costs.
- Administrative and overhead expenses.
- Regulatory compliance costs.

B.4. Business Model Canvas - Freight Distributor

Key Partnerships:

- Suppliers: Partnerships with manufacturers and suppliers for transportation and storage solutions.
- Technology Providers: Collaborations with technology firms for advanced tracking, routing, and management systems.
- Government Agencies: Partnerships for regulatory compliance and customs clearance.
- Freight carriers (airlines, trucking companies, shipping lines): Collaborations for transportation management.
- Customs brokers and trade compliance specialists: Partnerships for customs brokerage and trade compliance.
- Insurance companies: Partnerships for offering value-added services such as insurance.
- Local partners in international markets: Collaborations for expanding global reach and operations.

Key Activities:

- Transportation: Managing global transportation networks including air, ground, and sea freight.
- Warehousing and inventory management: Operating storage facilities for inventory management and distribution.
- Tracking and tracing: Providing real-time tracking and tracing of shipments.
- Customs brokerage and trade compliance: Facilitating customs procedures to ensure smooth cross-border movement of goods.
- Technology development and integration: Developing and integrating information technology systems for logistics operations.
- Network management and optimization: Optimizing transportation networks and managing partnerships.
- Customer service and support: Providing personalized support and proactive communication.

Key Resources:

- Transportation Fleet: Aircraft, trucks, ships, and other vehicles for cargo transport.
- Warehousing Facilities: Distribution centers and warehouses for storage and fulfillment.
- Information Technology: Software systems for tracking, routing, and managing logistics operations.
- Skilled Workforce: Trained personnel for logistics operations, customer service, and IT support.

Value Proposition:

- End-to-end logistics solutions: Seamless integration of warehousing, transportation, customs brokerage, and fulfillment.
- Global Reach: Offering extensive international networks for fast and reliable delivery anywhere in the world.
- Visibility and tracking: Real-time shipment tracking and inventory management.
- Scalability and flexibility: Ability to handle fluctuating volumes and diverse shipment needs.
- Cost efficiency: Optimized transportation networks and economies of scale.
- Reduced complexity: Single point of contact for all logistics needs.

- Industry expertise: Compliance and knowledge of specific industry regulations.
- Speed and Reliability: Providing fast and dependable delivery services with trackable shipments.
- Supply Chain Solutions: Offering end-to-end supply chain solutions including warehousing, distribution, and fulfillment.
- Customized Services: Tailoring logistics solutions to meet the specific needs of individual customers.

Customer Segments:

- E-commerce Companies: Online retailers and marketplaces requiring efficient shipping solutions.
- Businesses: Small, medium, and large enterprises needing reliable logistics services for their supply chains.
- Individuals: Consumers requiring parcel delivery services for personal items and gifts.
- Manufacturers
- Retailers (e-commerce & brick-and-mortar)
- Distributors
- Businesses requiring international trade

Channels:

- Online Platforms: Website portals and mobile apps for booking shipments, tracking packages, and managing accounts.
- Sales Teams: Direct sales teams for acquiring and managing corporate clients.
- Partnerships: Collaborations with e-commerce platforms, retailers, and other businesses for customer acquisition.
- Network of warehouses and distribution centers

Customer Relationships:

- Self-Service: Providing online tools and resources for customers to manage their shipments and accounts.
- Personalized Support: Offering customer service representatives for assistance with inquiries, issues, and special requests.
- Proactive Communication: Sending notifications and updates to customers regarding shipment status and delivery schedules.
- Dedicated account managers
- Customer service hotlines
- Performance reporting and analytics

Revenue Streams:

- Shipping Fees: Charging customers for the transportation of goods based on factors like weight, size, and destination.
- Warehousing Fees: Generating revenue from storage and handling services for inventory stored in warehouses.
- Value-added Services: Offering additional services such as insurance, customs brokerage, and packaging for an extra fee.
- Subscription fees for tracking and visibility tools

C Summaries of Expert Interviews

C.1. Summary Expert Interview with AM1

AM1, a representative of [aircraft manufacturer] in the Netherlands, spoke about his role at [aircraft manufacturer] in the field of sustainable aviation and his involvement in projects promoting Sustainable Aviation Fuel (SAF). He emphasised that the adoption of SAF has already begun and that clear guidelines from the European Union are encouraging the use of SAF. The USA aims to meet a large portion of its SAF demand through agricultural production, which could be challenging. AM1 highlighted the increasing demand for SAF and stressed the need to boost SAF production and build the necessary capacities.

He explained that political pressure, particularly from the European Union's Green Deal, is crucial in advancing SAF production. Additionally, he pointed out that the decarbonization of aviation is now a priority, in contrast to previous years when this issue was neglected.

AM1 also discussed the impact of SAF on the business model of aircraft manufacturers like [aircraft manufacturer]. He emphasised that modern aircraft can use both conventional kerosene and SAF. Ongoing technical improvements are also leading to fuel consumption savings of up to 20-25% compared to older aircraft and a reduction in CO2 emissions. He explained that aircraft manufacturers like [aircraft manufacturer] are developing planes that can run on both conventional kerosene and SAF. This is important because aircraft are used for about 30 years, and their operators must drive decarbonization efforts.

Overall, AM1 stressed the urgency of increasing SAF production and usage to make the aviation industry more sustainable and achieve climate goals.

AM1, from [aircraft manufacturer], talked about the possibility of retrofitting older aircraft models to be certified for 100% SAF, which is feasible for newer models. He emphasized that the certification is for the aircraft model and thus applies to all aircraft of that series. Similar to the automotive sector, initial concerns about the use of SAF have been addressed through certifications.

Expanding SAF certification beyond 50% requires the involvement of regulatory authorities like EASA and FAA, as well as sufficient available SAF. [aircraft manufacturer] is working closely with partners to promote SAF production and availability.

[aircraft manufacturer] is conducting projects with various partners such as Neste, Sasol, Linde, and Uniper to advance SAF production.

Regarding customer inquiries, AM1 noted that there is currently more political pressure to use SAF, even though the fuel is three times more expensive than conventional kerosene. He also mentioned the future potential of hydrogen and electric aircraft, noting that further technological advancements are needed.

In relation to the business models of aircraft manufacturers like [aircraft manufacturer], the possibility of charging higher prices for aircraft that can operate on SAF was discussed. Reducing the emission footprint is expected to be crucial for the industry.

C.2. Summary Expert Interview with AP1

The interview with AP1 focuses on the significance of sustainable fuel for […] Airport and its collaboration with [logistics company]. [Logistics company] has ambitious sustainability goals, specifically aiming for CO2 neutrality by 2030, and plans to use sustainable aviation fuels (SAF). [Logistics company] is targeting a 30% SAF blending ratio by 2030, even though the EU mandates only 5-6%.

AP1 emphasizes that […] Airport is working with [logistics company] to establish local SAF production. This effort is in collaboration with industry partners such as Airbus, Sasol, EDL, and HH2E. The goal is to create a feasibility study to examine the technical and economic viability of SAF production. Factors being analyzed include infrastructure, hydrogen pipelines, and financial viability.

A significant focus is on political support and ensuring that Germany not only imports SAF but also produces it domestically. The German government has committed to SAF production in Germany, which allows the [project name] project to advance further.

AP1 explains that SAF production requires enormous electricity capacities, and it is crucial that these come from green energy sources. Politics plays a central role in financing and pricing SAF to make production economically viable. The project is one of the most advanced in Germany, involving numerous industrial partners and comprehensive political coordination.

The long-term goal is to enable climate-neutral flying and retain the entire value chain in the region. In addition to [Bundesland] and [Bundesland], similar initiatives are underway in other federal states, which have the potential to drive sustainable aviation forward in Germany overall.

In the interview with Carsten Höwelhans, AP1 states that besides plant builders, aircraft manufacturers, hydrogen producers, and politicians, large consumers like [logistics company] are crucial for the development of SAF at […] Airport. [Logistics company] has a strong interest in SAF, even though no firm contracts exist yet.

AP1 stresses that the planned SAF production is based on Power-to-Liquid (PtL) technology, as biofuels are not an option due to limited resources and ethical concerns. The airport sees itself competing with other global locations and aims to offer unique value through investments in SAF infrastructure. This is intended to attract not only [logistics company] but also other potential customers.

An early investment in SAF infrastructure is expected to make the [airport's] location attractive to businesses and politicians and to position the airport as a key economic player. AP1 sees the development of SAF as a way to strengthen the airport's competitiveness, particularly compared to other locations.

In the discussion, AP1 explains that […] Airport is currently not directly affected by political and regulatory measures such as the EU Emissions Trading System or CORSIA, as these mainly impact airlines. However, the airport plans to build a ”multi-blend” facility for SAF production, which would require significant investments. This facility is to be built near existing kerosene infrastructures to ensure logistical efficiency.

Currently, the share of SAF at the airport is 0%, and there are no specific commitments for the airport regarding emissions reduction. AP1 emphasises that societal pressure and independent goals from companies like [logistics company] play a more significant role than statutory quotas. The airport relies on its own initiatives, such as expanding PV installations and using an electric fleet, to achieve CO2 neutrality by 2030.

AP1 clarifies that the decarbonization of the airport also serves as a communication tool to encourage customers to purchase SAF and thus contribute collectively to emissions reduction.

C.3. Summary Expert Interview with AP2

In the interview, Carsten Höwelhans and AP2 discuss the current state and future development of Sustainable Aviation Fuel (SAF). AP2 identifies two main challenges for SAF: its general availability and its local supply. He notes that the industry is also working on verifying SAF's credibility, which he believes will be resolved sooner than supply issues.

AP2 explains that increased political and societal pressure for decarbonization is driving SAF adoption. This pressure has grown over the past decade, pushing the aviation industry to seek immediate solutions. SAF is currently the most feasible option for reducing carbon emissions compared to technologies like electric or hydrogen-powered engines, which are not yet fully developed.

Regarding the role of airports in SAF adoption, AP2 clarifies that airports traditionally do not own the fuel infrastructure, which is usually managed by airlines and fuel producers. Therefore, airports have limited influence over SAF implementation. They can only facilitate and support the efforts of airlines and fuel producers, rather than directly driving the adoption of SAF.

AP2 also addresses the potential societal backlash against the aviation industry for its environmental impact. He notes that while Europe might push for degrowth due to societal costs, other regions with different tax structures and regulations might not face the same pressure. This regional variation complicates the global approach to SAF adoption and decarbonization efforts in aviation.

In the next segment of the interview, Carsten Höwelhans and AP2 discuss the potential of air cargo to drive the adoption of SAF compared to passenger traffic. AP2 agrees that air cargo, driven by corporate customers' sustainability goals and scope 3 emission targets, might have a higher incentive to adopt SAF. However, he notes that the costs of SAF will ultimately be handed on to the end consumer, likely raising consumer prices.

The interview explores how the green premium associated with SAF might be distributed across the supply chain. AP2 suggests that while airlines operate on slim margins, cargo handlers have higher margins and might initially absorb some of the additional costs. However, this will result in cost reduction efforts by freight forwards in other areas of their business such as R&D. He also mentions potential cost savings from reduced fossil kerosene use such as the need to buy fewer emissions allowances.

AP2 points out that the adoption of SAF might help companies with employee retention by demonstrating a commitment to sustainability. This, in turn, could enhance the company's image and contribute to long-term benefits.

Regarding the value proposition for customers, AP2 discusses the challenge of making SAF attractive despite its higher cost. He suggests that SAF credits could be marketed similarly to frequent flyer programs for businesses, emphasizing the contribution to meeting carbon reduction targets. Companies like DHL have initiatives like Go Green Plus to communicate their sustainability efforts, but there are difficulties in labelling and promoting these efforts due to regulatory constraints on terms like ”green” and ”sustainable.”

Finally, AP2 addresses the involvement of new stakeholders in the SAF value chain. He notes that major fuel producers are rebranding as energy companies and moving into the SAF space, but he doesn't foresee significant new players outside of small startups entering the ecosystem at this stage.

C.4. Summary Expert Interview with AG1

AG1, Director of Ground Operations at [airline], discusses the airline's role in sustainable aviation fuel (SAF) integration and the challenges facing the industry in adopting SAF. [Airline], as a subsidiary of the [airline] Group, aligns with the group's SAF blending practices. AG1 highlights the complexities of SAF adoption, including its higher cost compared to traditional fuel and limited availability, especially in remote destinations.

He emphasises the high industry acceptance of SAF as crucial for transitioning to sustainable aviation but notes the considerable challenges ahead, such as scaling up production and infrastructure development. AG1 discusses [airline's] approach to belly cargo operations, which primarily involves collaboration with [airline] Cargo.

Regarding SAF adoption, AG1 discusses the reluctance of customers to bear the additional costs associated with it. He also touches on regulatory pressures highlighting the need for effective policies that do not unfairly disadvantage airlines. AG1 discusses regulatory factors, particularly focusing on CORSIA, emphasizing its potential discrimination against airlines operating in non-CORSIA states. He stresses the need for transparent legal frameworks to drive SAF adoption while avoiding market distortions. AG1 emphasizes the industry's commitment to addressing climate change.

The interview also delves into the feasibility of EU quotas for SAF usage, noting challenges due to limited production and the energy-intensive nature of current SAF production methods. In terms of SAF quotas proposed by the EU, AG1 acknowledges their importance in providing planning certainty for airlines but stresses the current limitations in SAF production capacity and the need for further incentives and infrastructure development.

The interview discusses [airline's]belly cargo business, where [airline] Cargo manages freight capacity. Currently, customers are barely willing to pay a premium for low-carbon transportation. AG1 underscores the importance of transparency in communicating the environmental impact of air travel to customers, cautioning against greenwashing. AG1 takes a critical stance towards selling air transport based on SAF as a "green" mode of transportation to the end customer and suggests an open but honest communication of the benefits of SAF. He discusses the need for partnerships to advance SAF production and infrastructure, particularly with companies focused on reducing energy consumption in SAF production.

The conversation shifts to operational aspects, highlighting the minimal need for new infrastructure to incorporate SAF into existing airline operations. AG1 emphasises the importance of collaborative efforts to increase SAF production capacity and reduce costs. Regarding investments in sustainability, AG1 suggests that the responsibility lies not solely with airlines but with all stakeholders in the aviation industry. He emphasises the need for joint efforts to develop sustainable travel products and share responsibility for reducing carbon footprints among value chain members. Additionally, the interview explores the challenge of balancing sustainability initiatives with airlines' financial constraints, suggesting industry-wide partnerships to address emissions collectively.

C.5. Summary Expert Interview with FD1

FD1 explains the current state and future prospects of Sustainable Aviation Fuel (SAF) adoption in the industry. FD1, a partner at [freight distributor], highlights SAF as a crucial technology for decarbonizing aviation due to its compatibility with existing infrastructure. While being the only viable option for a significant decarbonization of air transport presently available, SAF faces challenges such as high cost and limited availability. [Freight distributor], committed to Science Based Targets, aims to reduce emissions from all sources (e.g. electricity, road fleet), but growth in business may offset these efforts without decarbonizing flights. Increasing customer willingness to pay for SAF is essential, requiring clear value propositions. However, allocating SAF costs between [freight distributor] and customers poses complexities. While [freight distributor]aims to offer SAF-blended flights, explaining the varying SAF percentages to customers and organisations like the SBTi remains challenging. The ultimate goal is to reduce emissions throughout the network, even if not directly on every flight.

Carsten Höwelhans and FD1 discuss the challenges and implications of SAF adoption, particularly concerning emissions reporting and market dynamics. FD1 elaborates on the complexities of including SAF emissions reductions in reporting frameworks like the Green House Gas Protocol, highlighting the need for transparency and standardised approaches. FD1 underscores SAF certificate trading as an absolute prerequisite for an uptake in SAF adoption. They also explore the potential for communicating emissions reductions to end customers while avoiding accusations of greenwashing. Political developments, such as SAF mandates and market regulations, are seen as crucial drivers for SAF adoption, with SAF quotas being seen as a potentially beneficial mechanism by FD1. The conversation underscores the importance of consistency in regulations across the industry and the role of companies like [freight distributor] in leading the transition to sustainable aviation practices.

Carsten Höwelhans and FD1 discuss various aspects of SAF adoption, including the need for new partnerships, certification processes, and alternative fuel technologies. FD1 emphasises the importance of collaborating with organizations like Science Based Targets and Smart Trade Centre for certification and market access. While SAF remains primarily derived from biofuels, they explore the potential of alternative production methods like Power to Liquid (PtL) but FD1 notes the current focus on biofuels due to technological limitations. The conversation also touches on [freight distributor's]fleet renewal strategy, where new Boeing 777 aircraft are being acquired for long-haul flights to improve efficiency and reduce emissions. Despite the challenges of SAF's high cost and limited efficiency, leading to higher abatement cost compared to other technologies, FD1 acknowledges the strategic necessity of investing in SAF, emphasising the need to commercialise SAF to achieve a successful transition.

Carsten Höwelhans and FD1 delve into the implications of SAF initiatives on business operations. Carsten explains how some companies are considering shifting a portion of their air freight to sea freight to save costs, which can then be redirected to purchasing SAF, thereby achieving carbon reductions. However, FD1 remarks that such changes may result in service level reductions, potentially impacting customer satisfaction. FD1 highlight industries with high-profit margins, like luxury goods and pharmaceuticals, as prime candidates for SAF adoption due to their ability to absorb additional costs. Additionally, FD1 explains the challenges of achieving end-to-end green solutions, especially in complex logistics networks, where ensuring the use of sustainable transportation methods at every stage poses significant operational and financial challenges. They also touch upon the pressure from investors for companies to become more sustainable. FD1 notes that while European investors tend to prioritize sustainability, US investors may be less concerned. Ultimately, FD1 emphasises the need for companies to balance profitability with sustainability goals and anticipates that success in sustainability efforts could eventually lead to market differentiation and competitive advantage.

C.6. Summary Expert Interview with FD2

FD2 from [freight forwarder] explains his role in the company's sustainability efforts, particularly focusing on Sustainable Aviation Fuel (SAF). He highlights his work on [freight forwarder]'s sustainability strategy, emphasising SAF as a key element in reducing emissions. Despite the low adoption rate, there is optimism about the future, expecting rapid increases in SAF usage with a company internal goal of [double digit]% SAF by 2030.

FD2 clarifies misconceptions about SAF production, particularly the role of palm oil, stating that most SAF is derived from waste oils like used cooking oil, not palm oil. He acknowledges challenges in scaling up due to the limited availability of these waste oils and competition with other industries. To address this, he discusses various production pathways such as HEFA, Alcohol-to-Jet, Fischer-Tropsch, and Power-to-Liquid technologies. Each has its pros and cons, with HEFA being currently the most viable but limited in raw materials availability in the long term. Power-to-Liquid, although promising, is still not technologically and economically competitive. FD2 anticipates that significant quantities of Power-to-Liquid SAF may not be available until around 2030, depending on market incentives and technological advancements. However, once this technology is commercially available it will likely outcompete other production pathways in the long term.

FD2 discusses how the company's [product for sustainable transportation], which allows customers to opt for SAF usage and receive emission reduction certificates, fits into their business model. Although the SAF isn't necessarily used on the exact flight carrying the shipment, it is accounted for within [freight forwarders]'s network. Customers show a willingness to pay a premium for reduced emissions through this initiative, but the scalability of this model remains to be seen. [Freight forwarder] initially incurs the cost of purchasing SAF and hopes to recoup this through the new product.

FD2 notes that while large firms, particularly those in high-margin industries like pharmaceuticals and luxury goods, are adopting this premium service to meet their climate goals, it's unclear how these efforts align with the current Greenhouse Gas Protocol Framework and the accounting of Scope 3 emissions. There is an ongoing debate about the legitimacy and reporting of these emissions reductions, but both [freight forwarder] and its customers assume they will be recognized in the future.

Carsten Höwelhans and FD2 discuss the challenges of marketing SAF without falling into greenwashing. FD2 emphasizes the importance of transparency and accurate communication, acknowledging that aviation has a higher environmental footprint than other modes of transport but can reduce its environmental impact by using SAF.

Additionally, [freight forwarder] evaluates partner airlines for their sustainability and efficiency, favouring those with better environmental practices and SAF usage – if operationally feasible. They adhere to strict internal policies on acceptable SAF, excluding options like palm oil due to unsustainable practices in the past. These efforts aim to ensure that all partners meet high sustainability standards, reinforcing [freight forwarder]'s commitment to reducing emissions responsibly.

C.7. Summary Expert Interview with FD3

In this interview, FD3, an employee of [freight distributor's] corporate development team working in the decarbonization strategy area, is questioned. He explains his responsibilities, which primarily involve analysing the market for Sustainable Aviation Fuel (SAF). He identifies potential strategic partners that produce SAF and conducts initial screenings and discussions with various stakeholders. The results of these analyses are then discussed within a team and, if positively evaluated, presented to the leadership team.

Collaboration with SAF producers takes place through long-term purchase agreements without directly investing in their projects to minimise risks. These contracts are carefully negotiated to consider price and political risks. Additionally, reputational risks in the sustainability field are considered, excluding certain raw materials like palm oil. There is, however, ongoing discussion about the acceptance of different types of biofuels and their sustainability.

In the interview, FD3 and Carsten Höwelhans discuss the challenges and strategies in distributing the additional costs of SAF along the value chain. [Freight distributor] is willing to absorb more costs in the short term to stimulate the market and position itself well. However, in the long term, these costs need to be partially passed on to end customers to ensure economic viability. Lückhof emphasizes that high-priced products in the air cargo market exhibit higher price elasticity, so end customers might be willing to pay a small premium for sustainable transport.

There is a discussion about whether the air cargo sector can be a driving force for the adoption of SAF, as it might be easier to convince business customers of the benefits than individual passengers in passenger air travel. [Freight distributor] sees an advantage over competitors, who have not yet invested in SAF. However, the development and communication of "green" products to end customers require patience and education.

Another topic is the risk of greenwashing accusations. There are established accounting standards that are audited by independent auditors to ensure transparency. Nevertheless, communication remains a challenge, as simple messages often omit details and thus become vulnerable to criticism. FD3 notes that many airlines are currently facing legal challenges due to allegedly misleading communication. It is emphasised that a balance between clarity and accuracy is necessary to provide transparency while minimizing vulnerability.

It is then stressed that despite the challenges, clear communication is necessary to ensure the commercial viability of SAF. Without passing on the costs to end customers, airlines and logistics companies could not finance the adoption of sustainable fuels in the long term.

The interview extensively discusses the issue of additional costs due to the use of SAF at [freight distributor] and the willingness of customers to bear these additional costs.

Currently, the use of SAF is significantly more expensive than fossil kerosene, about three to four times higher. When the SAF share is only 6%, the additional costs for the company are still relatively low. However, [freight distributor] aims to reach a 30% SAF share by 2030. This would lead to significantly higher costs. Last year, [freight distributor] already spent a three-digit million amount solely on the additional costs of SAF, directly impacting the EBIT (Earnings Before Interest and Taxes). This amount only covers the additional costs for a 3% SAF share. Increasing this share tenfold to 30% could result in costs reaching the billions, significantly affecting the company's profitability.

Predicting the willingness of customers to cover the additional costs of SAF is difficult. A possible indicator is that companies in high-margin industries, such as the pharmaceutical industry or the luxury goods sector, might be more willing to bear these costs. A key driver for companies' willingness to invest in SAF is internal sustainability goals or publicly communicated environmental ambitions they want to meet. Companies that have firmly anchored sustainability in their corporate culture and whose management bonuses are tied to achieving sustainability goals show a higher willingness to pay for the green premium costs.

C.8. Summary Expert Interview with CO1

Carsten Höwelhans interviews CO1, Director of Climate and Energy for Supply Chain at [apparel company]. CO1 explains her role in decarbonizing transportation and distribution centres globally, focusing on reducing air freight, increasing efficiency, and transitioning to sustainable options like electric or renewable fuels. She discusses the challenges of partnering with logistics service providers and justifying the costs of sustainable aviation fuel, despite its higher price point. Despite barriers like the greenhouse gas protocol, [apparel company] has significantly reduced air freight usage, aiming for a more sustainable transportation model.

Carsten Höwelhans asks CO1 about the discrepancy between the European carbon emissions trading program and the greenhouse gas protocol regarding sustainable aviation fuel. CO1 explains that [apparel company] follows the greenhouse gas protocol for carbon reporting, which currently doesn't allow for claiming carbon reductions from SAF in scope 3 emissions. The protocol doesn't accept market-based reductions where companies purchase certificates for SAF, as it lacks a clear chain of custody. While such reductions are allowed in scope 2 emissions for electricity, they're under review for scope 3. Until changes are made, [apparel company] focuses on sustainable fuels for road and maritime transport but can't claim reductions from SAF use in air travel, despite its potential to significantly reduce emissions.

Carsten Höwelhans questions CO1 about whether using sustainable aviation fuel on a flight from Asia to North America, where it's physically linked, could reduce scope 3 emissions. CO1 explains that it's possible if proven, but difficult due to the blend of SAF used in planes and the limited availability of SAF at airports globally. CO1 elaborates on the challenges of justifying the expense of SAF and suggests considering the context of specific products, like customised footwear, which necessitates air transport for quick delivery. [apparel company] explores options like consolidating shipments and using SAF on bulk air shipments to reduce overall emissions while compensating for costs, aiming for solutions that pay for themselves and make emission reduction more feasible in a challenging business environment.

Carsten Höwelhans discusses with CO1 the challenges of creating a value proposition for using sustainable aviation fuel in cargo shipments. CO1 explains that due to the disaggregated nature of transportation and the limited availability of sustainable fuels, it's difficult to claim a green delivery throughout the entire supply chain. While [apparel company] buys carbon offsets for some e-commerce orders, they're transitioning away from this strategy towards reducing their carbon footprint directly. CO1 emphasises the importance of being transparent and conservative in messaging to consumers, avoiding greenwashing. The value proposition for [apparel company] lies in its commitment to sustainability as a global brand with the resources to lead the industry towards more environmentally friendly practices, hoping to create momentum for others to follow suit.

Carsten Höwelhans inquires about the prerequisites for [apparel company] to purchase sustainable aviation fuel and any requirements imposed on shipping companies. CO1 explains that while the procurement department handles contracts, the Sustainability Department provides the requirements. A sustainable fuels policy guides these decisions, outlining criteria such as the fuel being at least second generation, free from land use change and palm oil, and meeting verification standards like RSB or ISCC certification. [Apparel company] reserves the right to reject fuels that don't meet these criteria.

Carsten Höwelhans discusses with CO1 the impact of sustainable transportation options on [apparel company's] partner network. CO1 explains [apparel company's] annual survey process, the Sustainable Chain Sustainability Index, used to benchmark logistics providers based on their sustainability efforts. Providers are rated and given feedback, with the goal of improving sustainability performance collaboratively. CO1 emphasises the role of regulation in driving the widespread adoption of sustainable aviation fuel, which could lead to cost reductions through increased demand and economies of scale. Currently, [apparel company] is investing more in sustainable marine fuel due to its closer price parity with traditional fuel. They aim to reduce air freight usage overall while waiting for SAF to become more economically viable. They discuss the technical and cost differences between sustainable marine and aviation fuels, highlighting the complexities of transitioning to more sustainable transportation options.

C.9. Summary Expert Interview with EX1

EX1, head of the Berlin office at the [interest group] and expert for eFuels in maritime and air transport, explains that the [interest group] is an initiative with 180 members along the eFuels value chain, promoting the adoption of synthetic fuels for industrial usages as well as road, maritime and air transport. The goal is to create a market for eFuels through good regulatory frameworks, particularly at the EU level.

When asked about the progress and future development of SAFs in aviation, EX1 states that regulations like the ReFuelEU Aviation Regulation dictate the timeline for adoption. This regulation includes fixed quotas for SAFs that start in 2025 and increase until 2050. There is also a sub-quota for synthetic SAF. These quotas and associated penalties create an incentive for the industry to ramp up SAF production.

EX1 further explains that the penalties are at least double the price difference between SAF and conventional kerosene. This regulation sets a maximum premium that airlines have to pay for SAF, which caps price increases as demand for SAF rises. Airlines are thus motivated to buy SAF, as the penalties and obligations would result in much higher costs.

EX1 indicates that the first larger industrial production facilities for eFuel SAFs are expected to be operational from 2027. Pioneers in this field include Arcadia eFuels from Denmark, Nordic Electrofuel and Norsk e-fuel, both from Norway. The ramp-up of production heavily depends on the EU's certification of eSAFs, which has not yet been completed or is significantly delayed. This delay has considerably hindered progress in recent years.

EU certification, based on the Renewable Energy Directive, requires eFuel SAFs to achieve at least a 70% CO2 reduction compared to fossil fuels. Other technical details, such as the source of green electricity and timelines for commissioning production facilities, are also part of the certification requirements. The lack of certification leads to investor uncertainty and slows down the supply chain. The entire ramp-up process is thus heavily dependent on the speed of certification, as without it, the products will not have significant value for SAF buyers and the higher price cannot be justified.

EX1 explains that the development and adoption of SAF have gained significant momentum in recent years due to new EU regulations, such as quotas. Regulation is key, as it creates obligations that force companies to switch to sustainable fuels.

EX1 emphasises that without mandatory measures, it would be difficult to create a market for SAF, as there is insufficient willingness to pay for sustainable transportation. However, there are mechanisms to pass the costs on to end customers. In air cargo, customers' willingness to pay more for climate-friendly options is higher than in passenger transport.

Another issue is the competitive distortion caused by the EU Emissions Trading System and ReFuelEU Aviation, which only affects flights within the EU. Companies could avoid emission charges by flying through third countries like the Middle East, potentially disadvantaging European airports. While there are solutions for shipping, there is no comparable regulation for aviation yet. The regulatory solution in shipping is A stopover within 300 nautical miles of the EU is not counted as a stopover, thereby reducing the risk of carbon leakage.

EX1 sees the IATA's CORSIA system as having little impact on fuel choice, as CO2 prices are too low to force a switch to SAF. A global emissions trading system would be ideal but is difficult to implement. The EU is a pioneer here, posing challenges for European airlines, but mechanisms like the Innovation Fund and free certificates help offset the additional costs.

The development of SAF is costly and complex but necessary for climate protection. Despite regulatory and market challenges, EX1 remains optimistic that continued political support and adjustments can make a significant contribution to reducing CO2 emissions in aviation.

EX1 emphasises that airports and OEMs (Original Equipment Manufacturers) like Boeing and Airbus conduct technical tests but have little influence on promoting SAF production. The infrastructures and supply chains to airports are relatively monopolised, posing a challenge for new producers specialising in renewable fuels.

SAF is blended with conventional kerosene before it is delivered to the airport. Therefore, the delivery of SAF-kerosene mixtures must occur at a preceding terminal. This poses a challenge as terminal structures are relatively rigid and current owners often have little incentive to adopt SAF and the construction of redundant infrastructure is not feasible. Overall, it is in the airlines' interest to have SAF available, as otherwise there will be penalties.

Besides production, the buyer is the most important. Without a buyer, projects cannot move forward and securing further funding is difficult. For many EU grants, it must be proven that part of the products is secured through purchase agreements.

The industry must plan long-term, which is challenging. It is no longer about making a purchase agreement and then looking for something new after six months. Instead, long-term planning is required. Some airlines are taking alternative routes by securing stakes in SAF production companies. This allows them to secure quantities for future facilities and be part of the joint venture.

C.10. Summary Expert Interview with EX2

In this interview, Carsten Höwelhans asks EX2 from [certification organisation] about his role and the certification process for Sustainable Aviation Fuels (SAF). EX2 explains that he joined [certification organisation] in October 2022, focusing on the certification for SAF in both regulated and voluntary markets, including the EU RED and CORSIA frameworks. [certification organisation] provides three main certification schemes: [certification organisation] EU, [certification organisation] CORSIA, and [certification organisation] Plus, allowing companies to be certified under multiple schemes simultaneously.

EX2 notes a growing interest in SAF certification from both EU and international markets, driven by regulatory pressures and incentives like Quotas in the EU and the IRA in the US. Airlines outside the EU spear of EU Quotas, such as those in the US, are also keen on SAF due to potential incentives/subsidies and the need to meet EU regulations when flying to Europe. He emphasises that certification can be done in non-EU countries where the fuel is produced and then shipped to be used within the EU.

The discussion touches on the preference for waste and residue-based SAF over feed crops due to sustainability concerns. EX2 explains that waste residues, such as used cooking oil and tallow, do not compete with food production and are more widely available globally. In contrast, feed crops can lead to high carbon intensity scores due to possible induced land use changes. He mentions that certain certifications, like the low land use change certification, can mitigate these disadvantages, but they require more effort and resources. Overall, EX2 indicates that most SAF certified by [certification organisation] are based on waste and residues.

Further, Carsten Höwelhans and EX2 discuss the development of eFuel SAFs and their certification process. EX2 explains that currently, eSAFs can only be certified under the voluntary market ([certification organisation] Plus scheme). The European Commission is in the process of recognising renewable fuels of non-biological origin (RFNBOs), primarily hydrogen-based fuels, which will soon be certifiable. The eSAF market is still developing, with significant technological and infrastructural challenges compared to established biofuel supply chains. The production of eSAFs involves setting up electrolyzers, which are still in their early stages.

Regarding the sub-quota for eSAFs, EX2 acknowledges that while the initial target for 2030 is low (around 0.6-0.7%), it will still be challenging to meet. However, mechanisms within the EU, like the flexibility mechanism, can help balance SAF distribution among member states. He also highlights the increasing interest from companies in the eSAF space, driven by upcoming regulatory requirements.

EX2 clarifies that [certification organisation] provides certification frameworks rather than partnerships. Companies can form associations like FuelsEurope or WindEurope to have a stronger regulatory impact.

Regarding the cost and availability of SAFs, EX2 notes that SAF is currently 2 to 5 times more expensive than conventional jet fuel. While prices are decreasing, they are not doing so sharply. Incentives and regulatory multipliers might help, but ultimately, the market will have to adjust to SAF prices. Availability and price are interconnected; as SAF production increases, prices should decrease. However, feedstock availability remains a concern. EX2 sees potential in eFuels, especially since they are not linked to food production, and in other alternatives like recycled carbon sustainable aviation fuels and low-carbon gases, which could provide viable feedstock solutions. More research is needed to explore multi-cropping and other innovative approaches to increase feedstock availability.

Carsten Höwelhans and EX2 touch on the challenges and developments in the SAF sector, focusing on carbon accounting, regulatory complexities, and market dynamics. A significant issue is the difficulty in claiming reductions in Scope 3 emissions (indirect emissions from a company's value chain) under current protocols, which hinders SAF adoption. EX2 highlights [certification organisation's] new transfer system designed to transfer carbon credits from airlines to corporate customers, piloted with DHL and Neste, as a potential solution.

Regarding the willingness to pay for a green premium, EX2 notes that [certification organisation] does not influence companies' pricing decisions for SAF; it is up to the companies themselves to decide whether to charge a premium for green services. The industry's sentiment towards EU regulations is mixed, described as ”hate and love.” While regulations provide certainty through mandates for SAF usage, their complexity and lack of harmonization (e.g., RED2, RED3, refuelEU aviation, EUETS) can delay investment decisions.

Greenwashing is another significant concern, where companies might make exaggerated environmental claims. [certification organisation] certifies the production, traceability, and custody of feedstock up to the point of airport delivery but does not oversee airline claims. It is crucial for airliners to comply with regulations to avoid misleading customers about their green credentials. While [certification organisation] Plus can support credibility and help avoid greenwashing allegations, it is a voluntary scheme. The transportation sector requires regulatory schemes to achieve zero-emission claims.

Global developments influencing SAF include various countries like Singapore and Japan introducing internal mandates for SAF usage and airline initiatives from companies such as IAG, Virgin Atlantic, and Alaska Airlines. The main global initiatives driving SAF adoption are the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and the Inflation Reduction Act (IRA) in the U.S., which promote local feedstock production through incentives. Despite these efforts, complexities in regulations and the risk of greenwashing remain critical issues to address for broader acceptance and effectiveness of SAF in reducing aviation emissions.

D

Interview Guide

Adapted from: Dodd and Yengin (2021)

Introduction:

Who am I, What is the goal of the study, What do I want from you Why are you offering green transportation products if you can not make money from them?

Question 1: Context

Please tell me about yourself and your role in the company or the role that your organization plays in the air cargo industry.

Rationale:

Establishes the context for the interview. Initial interview questions should be broad and then funnelled down.

Probes:

- Interesting, can you elaborate? (Elaboration probe)
- What brought you to that conclusion or strategy? (Evidence probe)

Question 2: SAF Diffusion

How would you describe the current state of SAF adoption in the industry?

Rationale:

Open-ended ways to explore factors that help or hinder the adoption. Following a broad introduction interview questions become to be more pointed to the research questions.

Probes:

- That's interesting. Can you elaborate on the specific areas where you see the most progress in SAF adoption? (Elaboration probe)
- Conversely, what are some of the biggest obstacles hindering wider adoption of SAF? (Elaboration probe)
- How does the current state of SAF adoption compare to your expectations for this stage in the development of the technology? (Elaboration probe)

Question 3: Socio-political Pressure

How do you think Government policy or regulation influences the adoption of SAF?

Rationale:

Open-ended way to explore external factors beyond the industry value chain that influence the adoption of SAF. Aims to create an understanding of the role of governments in SAF adoption.

Probes:

- Can you elaborate on specific policies or regulations that you think would be most effective in driving SAF adoption? (Elaboration probe)
- In your experience, how responsive has the government been to industry concerns regarding SAF policy? (Slant probe)
- Are there any international efforts to harmonise regulations around SAF that you're aware of? (Elaboration probe)

Question 4: Value Chain Dynamics

Within the air cargo industry who is driving the adoption of SAF or how do you think could potentially take a leading role?

How do you assess the importance of your own company in influencing the trajectory of SAF adoption?

Rationale:

Explores the power dynamics within the air cargo industry. Who are leaders and lagers/followers when it comes to the introduction of new innovations?

Probes:

- What factors do you think are most important for a company to take a leading role in SAF adoption? (Elaboration probe)
- Can you give some examples of how your company is influencing other stakeholders in the value chain to adopt SAF? (Evidence probe)
- How do you see the role of different stakeholders (e.g., airlines, fuel producers, cargo owners) evolving in the future with regard to SAF adoption? (Elaboration probe)

Question 5: Financial Perspective

In your opinion how significant do you think is the impact of large-scale use of SAF on the cost structure of airlines?

Can additional costs be recouped through new revenue streams?

Rationale:

Questions explore if airlines can cover the additional costs from SAF through higher revenues. If not the interviewer will follow up to explore if there is potential to increase revenues from green transportation services in the future.

Probes:

- Are there any potential cost-saving measures that could be implemented to make SAF more affordable for airlines? (Elaboration probe)
- How do you see the price of SAF evolving in the coming years? (Elaboration probe)
- Besides the willingness to pay a premium, are there other ways cargo owners might be incentives to support the use of SAF? (Elaboration probe)

Question 6: Product Perspective

What value can SAF provide to cargo owners?

How do you assess the importance of low-carbon transportation for cargo owners and is there a willingness to pay a premium for "green" transportation services?

Rationale:

Following up on the previous questions about additional revenues, this question explores how a compelling value proposition will look so that higher transport prices are justified to the cargo owner.

Probes:

- Can you give some specific examples of how cargo owners are currently communicating the use of SAF to their customers? (Elaboration probe)
- What are the biggest challenges in raising awareness about the benefits of SAF among cargo owners? (Elaboration probe)
- Beyond environmental benefits, are there any other potential advantages of using SAF that could be attractive to cargo owners? (Elaboration probe)

Question 7: Activity Perspective

Who do you think needs to be included in the partner network to drive the adoption of SAF?

How will this impact the routines and tasks executed by an airline?

Rationale:

Understand which organisations will play an important role when deploying SAF at a large scale. Generate an understanding of how key activities are impacted by the use of SAF.

Probes:

- Can you elaborate on specific types of partners that you think would be most beneficial to include in the SAF network? (Elaboration probe)
- Beyond the partners you mentioned, are there any other stakeholders whose involvement would be crucial for successful large-scale SAF deployment? (Elaboration probe)
- Can you give an example of a specific activity within an airline's operation that would be impacted by the use of SAF? (Elaboration probe)
- In your experience, have there been any challenges or unforeseen issues that arose when airlines transitioned to using SAF? If so, how were they addressed? (Evidence probe)

Question 8: Customer Perspective

Unchanged according to conceptual model.

Rationale:

Not applicable.

Probes: