BLOCKCHAIN IN VOLUNTARY CARBON MARKETS

- A CASE STUDY IN THE SCANDINAVIAN AVIATION INDUSTRY

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Abstract

As a result of the substantial growth in environmental awareness amongst the public over the past decades, the demand for sustainable business practices has contributed to an insurgence of climate-supporting initiatives across corporations and industries. One such initiative is found in the aviation industry, where airlines are implementing voluntary carbon offsetting schemes that provide passengers with the ability to counteract the carbon emissions of their flights. Despite the introduction of measures aimed at mitigating the carbon footprint in this industry, studies show that the adoption amongst air travellers is low. In light of this, the purpose of this research is to identify the most prominent area of improvement in the current practice of voluntary carbon offsetting, and subsequently analyse how blockchain technology can facilitate an improvement of the issue.

Viewing the Scandinavian aviation industry as a single case study, this research employs embedded cases to allow for a more detailed level of inquiry. These sub-units of analysis consist of two Scandinavian airlines: SAS and Widerøe, and a carbon offsetting partner: Chooose. In order to provide a comprehensive analysis of the area of research, this thesis makes use of a mixed-methods approach incorporating qualitative semi-structured interviews with the aviation-related actors and blockchain experts, in addition to a consumer-oriented questionnaire.

This research identifies the lack of transparency from a consumer perspective as the most prominent area of improvement in the practice of voluntary carbon offsetting in the Scandinavian aviation industry. At present, the extent of information visible to the end-consumer reaches no further than the airline, with all subsequent linkages of the supply chain being obscured. It is uncovered that the inhibited transparency is contributed to the non-existent interoperability between data systems and lack of granularity of information. Founded upon these insights, this research proposes a conceptual design aimed at alleviating the identified pain points. Exploiting the inherent properties of blockchain technology, this solution is found to possess the capabilities necessary to facilitate increased transparency from a consumer perspective.

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1. Introduction

"Global warming has emerged as one of the most important environmental issues ever to confront humanity" (Patwardhan, 2000, p.1). Increasingly, individuals and organizations are making everyday choices with the intent of actively benefitting the environment rather than damaging it. This environmental awareness has developed over a century but has gained rapid momentum in the past decades. There is a growing expectation amongst the public that organizations must acknowledge and accept their environmental responsibility, and adjust their business practices accordingly (Juholin, 2004; McIntosh, Thomas, Leizinger, & Coleman, 2003). At a time where the attention towards the environment is heightened, several studies demonstrate how consumers are not only demanding sustainable and environmentally-friendly products and services (Harris, 2007; Whelan & Kronthal-Sacco, 2019), but are reportedly willing to pay a premium for them (Kang, Stein, Heo, & Lee, 2012; Sörqvist et al., 2013; Long, Hart, & Guerriero, 2019). This demand for sustainable business practices has contributed to an insurgence of climate-supporting initiatives across corporations and industries.

In the aviation industry, anthropogenic climate change is being driven through the emittance of substantial quantities of greenhouse gases (GHG), including carbon dioxide (CO_2) (Scheelhaase, Maertens, Grimme, & Jung, 2018). In response to the increasing environmental awareness, industry actors are employing measures aimed at lessening the impact of their carbon footprint. One such initiative is the implementation of voluntary carbon offsetting programs, with the purpose of mitigating the emissions of passenger flights through the support of an emission-reducing activity at a different location (Hamrick, Goldstein, & Thiel, 2015). In essence, air travellers are provided with the ability to counteract the carbon emission of their flight itinerary by funding the reduction or avoidance of an equivalent amount of CO_2 elsewhere.

Despite the proposed environmental benefits of carbon offsetting programs, studies demonstrate that there is a low degree of interest in these schemes in the aviation industry, with only 1%-10% of air travellers taking advantage of the opportunity (Mair, 2011; Choi & Ritchie, 2014; Zhang, Ritchie, Mair, & Driml, 2019). The low adoption rate has been attributed to several causes, with the key reasons found to be the lack of awareness and knowledge of carbon offsetting programs (Kim, Lee, & Ko, 2016), and the public perception of the schemes as having poor credibility and transparency (Babakhani, Ritchie, & Dolnicar, 2016). With a focus on the aviation industry in Scandinavia, this research identifies the lack of transparency from a consumer perspective as the most prominent challenge in the current practice of voluntary carbon offsetting in the Scandinavian aviation industry.

Over the past years, numerous investigations have been conducted on how the capabilities of blockchain technology can enhance transparency across supply chains. Olive Trace, a project facilitated by IBM Spain, is one such successful example. Here, each stage of extra virgin olive oil production and distribution is traced using blockchain technology, all the way from the olive tree to the customer (Gonzales-Lamas, 2019). Similarly, WWF adopted blockchain technology for tracing tuna across the supply chain. By simply scanning the tuna packaging, the consumers are able to access information regarding where and when the fish was caught, fishing method, and vessel (Cook, 2018). In light of such successful cases, this research is set to analyse whether the transparency-enhancing properties of blockchain technology can similarly facilitate improved transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry.

1.1 Purpose of Research

The purpose of this research is to explore whether blockchain technology can facilitate increased transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry. The issue of low transparency is founded upon the perceptions of the actors in the industry, and the relevance of this identified challenge will be assessed in the course of the research. To understand where and how the information flow is currently being inhibited, the research is designed to gain an in-depth insight into the supply chain of voluntary carbon offsetting in the Scandinavian aviation industry. Viewing the aviation industry in Scandinavia as a single case study, insights are to be achieved by employing embedded cases which allow for a more detailed level of inquiry. These sub-units of analysis consist of two Scandinavian airlines: SAS and Widerøe, and a carbon offsetting partner: Chooose.

It is important to note that this research has been constructed in a manner where the specific issue of analysis – the lack of transparency from a consumer perspective - is not evident from the outset. The first sub-research question is formulated to uncover which issue the actors in the Scandinavian aviation industry perceive as most prominent in the current practice of voluntary carbon offsetting. The identification of this issue, based on the analysis of primary data collection, serve to inform and direct the subsequent research. However, it has been deemed necessary to include the specific issue in the main research question despite it not being determined from the outset, in order to facilitate a more meaningful and comprehensive introduction to the thesis.

1.2 Research Question

In line with the purpose of this research, the following research question has been formulated. Furthermore, four sub-questions have been composed to facilitate the development of the insights required to sufficiently answer the main research question.

How can blockchain technology facilitate improved transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry?

a) *Which area of improvement in the practice of voluntary carbon offsetting is perceived as most prominent by the actors in the Scandinavian aviation industry?*
b) *How does the identified issue correspond with consumer demand?*
c) *Where in the supply chain, and how, is transparency currently being inhibited?*
d) *How can the properties of blockchain technology alleviate the pain points inhibiting consumer transparency?*

1.3 Scope and Delimitation

The practice of carbon offsetting has been placed under considerable scrutiny and subject to controversy in the media over the years. However, it is important to note that this research is not concerned with assessing the actual environmental impact of voluntary carbon offsetting. Rather, the purpose is to understand whether blockchain technology could feasibly be incorporated to reduce the issue of low transparency from a consumer perspective. As such, examining whether carbon offsetting is an efficient means of neutralising pollution activities is beside the scope of this research. In addition, this research is concerned with carbon offsetting employed for voluntary purposes. Consequently, efforts will not be made to assess issues relating to carbon offsetting with the intent of meeting regulatory targets.

Furthermore, the area of improvement in this research is uncovered based on the perceptions of the actors in the industry. The researchers found that the best way to facilitate a precise and relevant analysis of the current situation in Scandinavia was to focus on an issue founded upon up-do-date insights from individuals with hands-on experience and inside information on that specific area. The current practice of voluntary carbon offsetting likely embodies additional areas of improvement; however, this research is only concerned with analysing the issue recognized as most prominent at this time. This is a necessary delimitation in order to facilitate a more comprehensive, in-depth assessment of the particular issue.

Moreover, the geographical market of this research is limited to Scandinavia in order to narrow down the scope and provide a more focused view. The similarities between the countries in terms of factors including technological development, geographical proximity, market size, economic prosperity, high average wages, and even language makes it appropriate to view the countries as one single market (Lynes & Andrachuk, 2008). This is particularly suitable for a case covering the aviation industry in Scandinavian, as the major airlines in this region generally have a significant presence in all three countries. In addition, the researchers originate from a Scandinavian country, providing them with deeper insights from the outset and a larger network which will likely prove useful. Furthermore, the scope of this research is limited to passenger transport since this segment makes up the market of voluntary carbon offsetting. As such, when referring to the aviation industry, freight transport and military flights are excluded.

The scope of this research is limited to analysing how the incorporation of blockchain technology can improve the identified issue. The authors recognize that there might exist other technologies that could facilitate enhanced transparency, however, efforts will not be made to assess these in detail. This limitation has been made to narrow down the scope of this research, and as such ensure a more comprehensive analysis of the relevant aspects. Moreover, this research will not focus on the legal and regulatory aspects of adopting blockchain technology. This decision has been made as the scope is to assess how the technology and its properties may increase transparency from a consumer perspective, where the legal and regulatory means do not contribute to the general purpose of this investigation.

Finally, it is important to note that the authors of this research do not have a technical background. In line with the purpose of this thesis, the research is delimited to the general suitability and properties of the technology. As such, a detailed analysis based on the mapping of the technical landscape will not be attempted.

1.4 Disposition

In order to facilitate a smooth and coherent reader experience, this section is concerned with guiding the reader through the structure of this research. To start off, due to the inherent complexity of the area of research at hand, the Background section is constructed to provide the reader with foundational knowledge on carbon markets and the practice of carbon offsetting. Subsequently, a brief overview of the aviation industry is presented in the Aviation Industry section, in order to facilitate an understanding of the current offsetting partnerships in Scandinavia.

After the contextual information has been presented and described, the research will continue onto the Methodology section. Here, the methodological choices underpinning the thesis will be presented and justified, employing the *research onion* framework of Saunders, Lewis, and Thornhill (2016). Since this research is constructed in a manner where the specific issue of analysis is not evident from the outset, it is necessary to include a section early on addressing the first sub-question. As such, Identification of Challenges is concerned with pinpointing the most prominent area of improvement perceived by the Scandinavian aviation actors. This section essentially functions to narrow the scope of the research to a particular problem inherent in the industry today and must be included prior to the theoretical section in order to allow for the selection of relevant theories and concepts underpinning the subsequent analysis. Following the identification of this issue, the Theoretical Framework may commence.

The Analysis will present the results from the primary data collection and analyse these findings in combination with relevant secondary data. This section is concerned with answering the three final sub-questions, thereby developing the relevant insights required to sufficiently answer the main research question. In the Discussion, the findings of the analysis will be evaluated in order to understand whether blockchain technology is suitable for the purposes of this research. Furthermore, the challenges of adopting the technology will be examined in an attempt to either substantiate or discredit the findings of the analysis. Finally, the Conclusion will incorporate the insights from the analysis and the discussion in order to arrive at and present a well-considered answer to the main research question of this thesis.

2. Background

The following section will provide a foundation of knowledge regarding the research at hand. To start off, the concept of carbon offsetting will be described, before moving the focus to the two distinguished markets where carbon credits may be traded, elaborating on their purpose and function. In alignment with the purpose of this thesis, emphasis will be placed on the voluntary carbon market.

2.1 Carbon Markets

Carbon markets are one of the instruments that have been established in order to combat the accumulated GHGs in the atmosphere (Dufrasne, 2019). There are two forms of carbon markets schemes, the *cap-and-trade scheme*s, where regulated entities sell or buy allowances for emitting CO_2 (Dowdey, 2007), and the *baseline-and-credit mechanisms*, which enables the purchase of CO_2 reductions (Dufrasne, 2019). Baseline-and-credit mechanisms are more commonly referred to as offsetting endeavours and will be referred to as such in this research. The fundamental difference between the two relates to what is being sold and bought in the market. Either case refers to the trading of one tonne of CO_2 equivalent (CO_2eq). However, in a cap-and-trade-scheme, entities trade *permits* allowing them to pollute in the future, whilst in offsetting mechanisms, companies trade *offsets* which represent a reduction that has already occurred (Dufrasne, 2019).

Placing a price on emissions forces stakeholders to consider their emissions when making operational commitments (Joskow, 1992). From an economic perspective, the environmental cost that the world faces from anthropogenic emissions is categorized as an externality. This cost is internalized as each polluter is forced to pay for the right to emit, or as a party is paid to emit less. The desire is to fully and efficiently internalize the externalities in order for the remaining environmental impacts to be economically efficient (Joskow, 1992). (Joskow, 1992).

2.2 Carbon Offsetting

Carbon offsets can be defined as "*measurable, quantifiable, and trackable units of GHG emissions reductions"* (Hamrick & Gallant, 2018, p. 1), and are commonly measured in metric tonnes of CO_2eq. In essence, offsetting allows carbon to be reduced in the global atmosphere by means of compensating excess emissions in one location through the reduction of CO_2 in another (Lovell & Liverman, 2010). The effectiveness of carbon offsetting is reliant on the concept of GHG being a *global pollutant.* As such, it is irrelevant if the CO_2 is emitted from a factory in Norway or an area of deforested land in Brazil. This provides a corporation with the ability to neutralize one tonne of their released emissions through the support of an emission-reduction project at an entirely different location (Hamrick, Goldstein, & Thiel, 2015).

Carbon offsets may either be traded on the *compliance carbon market,* where establishments subject to regulation acquire and surrender emissions permits or offsets so as to meet predetermined targets, or the *voluntary carbon market,* where trading occurs for incentives other than satisfying a regulatory requirement (Hamrick & Gallant, 2018). Increasingly, it is found that the lines between compliance and voluntary markets are blurring, with standards that were once established for the voluntary practice progressively is being considered for inclusion in the compliance market (Donofrio, Maguire, Merry, & Zwick, 2019).

Offsetting may provide a more cost-efficient and convenient alternative for a company reducing its own carbon consumption. However, some critics question whether offsets really do represent actual emission reductions. The factor that has proven most vexing relates to *additionality,* which is key in determining a project's eligibility to sell credits (Gillenwater, Broekhoff, Trexler, Hyman, & Fowler, 2007). Additionality entails that a project or activity that reduces carbon should not have taken place without carbon finance in a business-as-usual scenario and is typically acclaimed as one of the most important qualities of carbon offset projects (Center for Resource Solutions, 2016). A major limitation in the offsetting schemes of project-based mitigations is that the reduction must be measured in relation to a counterfactual reality. This entails that the emission that would have taken place in the market if the offsets did not exist must be estimated in order to determine the quantity of emission reductions a project actually achieves. This hypothetical reality must be inferred and cannot be proven, and as such is always to some extent subjective (Kollmuss, Zink, & Polycarp, 2008).

In carbon market literature, two distinctive aspects closely related are *carbon credits* and *carbon offsets*. Although these terms are often used interchangeably, they convey two different meanings. Carbon offsets enable CO_2 to be reduced in the global atmosphere, whilst carbon credits are tradable certificates signifying the right to pollute an amount of CO_2. Consequently, carbon offset projects can be described as producing carbon credits (Lovell & Liverman, 2010; Singh, Jha, Bansal, & Singh, 2011).

2.3 Compliance Carbon Markets

Compliance carbon markets, also referred to as regulatory carbon markets, are the result of government regulations to reduce CO_2 emission. In these marketplaces, entities that are subject to regulations acquire and surrender emissions permits or offsets to meet a predetermined regulatory target (Hamrick & Gallant, 2018). Unless a distinction is specifically made, the discussion regarding carbon markets in literature generally refers to compliance carbon markets.

In compliance carbon markets, a government agency establishes the rules concerning what types of offsets are acceptable, as well as what rigour they must prove in order to be included in the market. Customarily, offsets are only allowed in limited quantities due to their ability to act as cost-containment mechanisms by providing cheaper alternatives than emissions reductions within regulated sectors (Hamrick & Gallant, 2017).

2.3.1 Market-based Measures

Two market-based climate measures have been established to reduce the carbon footprint of the aviation industry. These include the European Union Emissions Trading Scheme (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (Maertens, Grimme, Scheelhaase, & Jung, 2019).

The aviation industry has been subject to the EU ETS since 2012, with the scheme currently being applicable to all intra-EEA flights. It is based on a cap-and-trade system where a cap is placed on the total amount of certain GHGs that may be emitted by covered entities (European Commission, n.d. a). This cap ensures that the total amount of GHG emissions are kept below a predefined level in the period for which the cap applies. Within the cap, entities receive or purchase emissions allowances, and may trade with other participating sources. If an installation is likely to emit more than its allocated allowance, it must either take measures to reduce its emissions or purchase additional allowances (Department for Business, Energy, & Industrial Strategy, 2013). Should an entity fail to surrender a sufficient amount of allowances to cover its emissions, heavy fines are imposed (European Commission, n.d. a). Moreover, participants are provided with the ability to buy limited amounts of international offset from emission-reducing projects.

In 2016, the International Civil Aviation Organization (ICAO) adopted a global market-based measure for aviation emissions, referred to as CORSIA. This measure obliges the aviation industry to offset its post-2020 growth in CO_2 emissions on international flights by means of purchasing carbon offsets (Maertens et al., 2019). CORSIA consists of three implementation phases, with a *pilot phase* of application beginning in 2020[1]. Following is the *first phase* spanning from 2024 through 2026. In these initial phases, the scheme is reliant on the voluntary participation of states, with all EU states having pledged their engagement. The final phase, referred to as the *second phase* applies from 2027 through 2035 and is mandatory for all ICAO Member States, with minor exceptions (ibid).

The fundamental difference between the two schemes relates to how CORSIA is a global offsetting scheme, while the EU ETS is a cap-and-trade system applicable to the EU. This entails that under the EU ETS, the government has control over the total amount of CO_2 emitted as companies are not allowed to emit more than the predetermined level (Scheelhaase et al., 2018). Under a pure offsetting mechanism like CORSIA, a theoretical emissions limit is set, however, companies will be free to emit any amount they like so long as they purchase carbon offsets to compensate (Dufrasne, 2019).

2.4 Voluntary Carbon Markets

The voluntary carbon market has developed without the influence of a regulatory regime (Lovell & Liverman, 2010), and encompasses all carbon offset transactions which are not acquired with the intent of being surrendering into an operational compliance carbon market. As the participants of the voluntary carbon markets are not mandated by law to offset their emissions, they are able to determine for themselves who to interact with and the terms of the trade (Broderick, 2008). Demand is driven by organizations and individuals that independently claim responsibility for their own emissions, in addition to entities purchasing pre-compliance offsets in anticipation of emissions reductions being required by a regulator (Ecosystem Marketplace, n.d.). Most often, voluntary offsetting is performed as a tool for social responsibility in order to improve a company's public image (Dufrasne, 2019).

Voluntary offsets are generated from on-the-ground activities and projects aiming to reduce or avoid carbon emissions. Developers can employ an array of activities to produce carbon offsets, from low-carbon energy production to planting trees that remove carbon from the atmosphere (Hamrick & Gallant, 2018). In addition to the global reduction of carbon in the atmosphere, carbon offsetting activities might include additional non-carbon impacts referred to as "*co-benefits*". Such benefits may relate to the preservation of biodiversity, health, or employment, typically in line with aspects of sustainable development (Hamrick & Gallant, 2017). In recent times, many project developers have aligned their co-benefit metrics with the Sustainable Development Goals (SDGs) of the UN (appendix 1; Hamrick & Gallant, 2018), involving anything from gender equality to providing access to clean water and sanitation (UN, n.d.).

2.4.1 Pricing

From its inception, the purpose of the voluntary carbon markets has been to contribute to the transition into a lower-carbon world. One aspect that varies a lot within the voluntary carbon market is how much one should pay for a carbon credit. While prices in the compliance markets are fairly stable, the prices recorded in the voluntary carbon markets vary significantly (Hamrick & Gallant, 2018). In 2008 the average price of $7.34 per metric tonne of CO_2 was recorded, whereas in 2018 it was only $3.01 (Donofrio et al., 2019). However, the actual prices have spanned from under $0.1 per tonne of CO_2 to just over $70 (Hamrick & Gallant, 2018).

One factor that may influence the price volatility in the voluntary market is the historically excess supply, which could in part due be to the fact that there is a distinct time lag between supply and demand. Although interest in offsets drives the creation and continuation of projects, it may take some time before a project produces a single offset (Hamrick & Gallant, 2018).

There have been discussions regarding what the price of a carbon credit should be based upon, whether it is by utilizing market dynamics as a guide, the project expenses, or the outcome of a project. Furthermore, the prices vary based on the project type and where it is located. As the prices of credits are optional to disclose, historical data for prices in the voluntary carbon market are quite rare (Gold Standard, n.d. a).

Currently, there are several methods for calculating the price of carbon. One such model is the Fairtrade Minimum Pricing Model (Gold Standard, n.d. b). The model is cost-based as it considers the cost of implementing a project, with the objective of ensuring that a project remains viable. The price consists of a calculated minimum price that covers the average costs of the projects and an additional "Fairtrade Premium". This premium goes directly to the local community to ensure funding for activities securing more resilience to an already changing climate (Gold Standard, n.d. b). Although the model is a step toward ensuring sustainable projects, it does not account for any additional value or co-benefits the projects may deliver in sustainable development (Gold Standard, n.d. b). Critics argue that the price per tonne of offset is currently significantly lower than the estimated costs of damage that an equivalent amount of carbon pollution causes through ocean acidification and global warming (David Suzuki Foundation, n.d.).

2.4.2 Voluntary Carbon Offset Life Cycle

Ecosystem Marketplace (Hamrick & Gallant, 2017) detail the lifecycle of carbon offsets, from the project development to the retirement of a credit. Figure 1 depicts the common steps required by several standard bodies, though not all. The process begins with a Project Idea Note which estimates the risks and feasibility of a particular project, followed by the Project Design Document describing how a project will reduce or avoid emissions and how they are to be calculated. The first two steps are subject to third-party *validation*, as well as another auditing process referred to as *verification* which evaluates the delivery of GHG mitigation after implementation. Once the carbon offset is ready for issuance, the journey takes the offset from the project developer to a buyer in the form of carbon credits. A buyer may include intermediaries, such as brokers or retailers who take on the responsibility of marketing the offsets to a final buyer, or the offset can be sold directly to the end buyer. Finding a buyer can be a complicated process, as there is currently no single marketplace for trading voluntary carbon credits. Once an offset has been permanently sold to an end-user who wishes to claim its impact, it must be retired to ensure that it can no longer be resold. The carbon offset is then effectively taken out of circulation and its unique serial number is placed on a registry of retired credits(ibid).

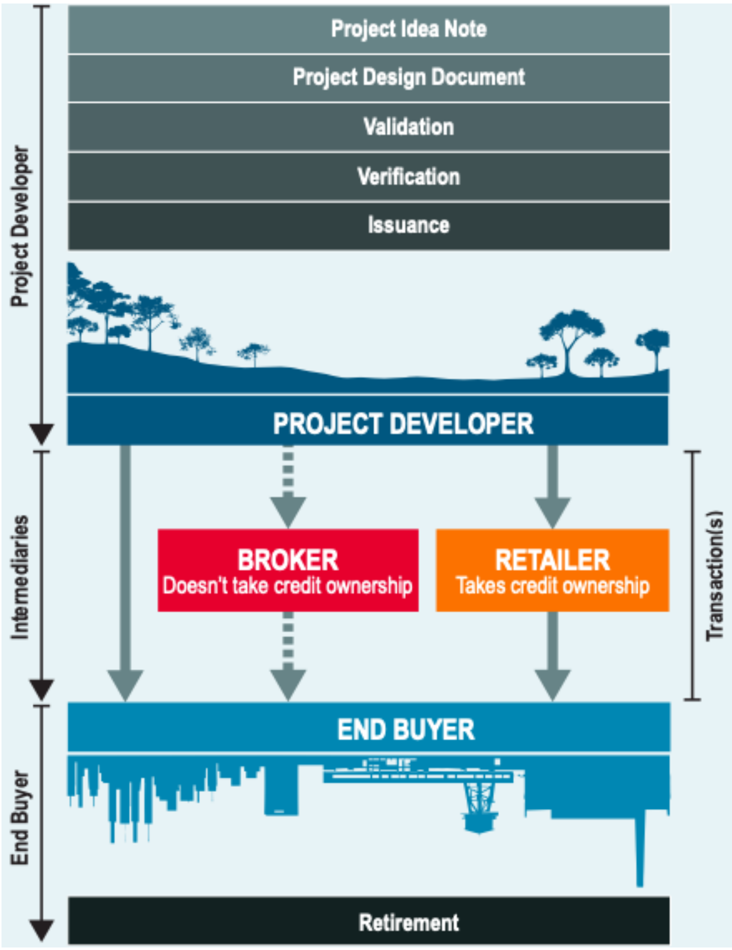

Figure 1: Ecosystem Marketplace's Life Cycle of Voluntary Carbon Offsets (Hamrick & Gallant, 2017).

2.4.3 Voluntary Standards

The vast majority of project developers adhere to procedures and rules established by a third-party voluntary carbon standard (Hamrick & Gallant, 2017). This is to ensure and be able to demonstrate that the voluntary offsets produced by a project are genuine and additional. These standards may differ based on the project type and activity allowed, however, all voluntary standards require that offsets are real, additional, measurable, and verifiable (Hamrick & Gallant, 2018). Being *real* entails that there must be evidence of the project's removal or prevention of emissions, whilst *additional* as previously described relates to how the reductions must not occur without the activities of the emission-reducing project. Further, an accurate *measure* of the volume of emissions reductions should be possible, and finally, a neutral, third-party auditor must have *verified* the reduction of emissions (Hamrick & Gallant, 2018).

Although numerous voluntary standards offer frameworks for project development and third-party verification, only a handful consolidate the majority of the market share. The two that have been dominating for some time is Verified Carbon Standard (VCS) and Gold Standard (GS) (Hamrick & Gallant, 2018). GS is generally accepted as the highest global standard for offsets and is widely considered the leader for stringent quality criteria in the voluntary carbon markets (ICAO, 2019). The establishment of voluntary standards has enabled the market to experiment with novel project types and methodologies, which have later influenced the protocols of emerging compliance schemes (Hamrick, Goldstein, & Thiel, 2015). As governments are increasingly turning to voluntary mechanisms, standards and registries are being used to inform and develop compliance instruments (Ecosystem Marketplace, n.d.). As an example, the VCS has recently been approved to supply carbon credits under CORSIA (Verra, 2020).

Previously, outside confirmation was non-existent or at best barley being used by project developers. Today, verification standards have become an unquestionable requirement for several sellers seeking to trade high-quality credits (Bayon, Hawn, & Hamilton, 2009). As a consequence, the markets now embed several schemes for verification, validation, and certification of voluntary carbon offset projects. Based on the formation of standards, carbon credit registries have emerged with the intent of tracking the exchange of credits and overseeing proprietorship to enhance transparency in the marketplace (ibid).

3. Aviation Industry in Scandinavia

The purpose of this section is to provide the reader with a brief overview of the aviation industry in Scandinavia. This research is concerned with the activities of three of the major airlines within commercial aviation; Scandinavian Airlines (SAS), Norwegian Air Shuttle (Norwegian), and Widerøe.

Air traffic has become an important means of transportation in all the Scandinavian countries. This is largely due to the relatively long distances between major cities, and the surrounding sea and mountainous topography resulting in few road connections to the rest of Europe (Stroll, 2020). SAS is currently the leading air transport company in Scandinavia in terms of turnover, accounting for approximately one-third of all flights to, from, and within the region (ibid). Norwegian is a close second, with a turnover amounting to almost three billion euros as of August 2019. However, SAS made headway with over four billion euros over the same period (ibid). In the past decade, both players have shifted focus to more international operations, and have experienced significant growth in these markets (CAPA, 2016). In contrast, Widerøe is the largest regional airline in Scandinavia, mainly operating within the region (Widerøe, n.d.).

3.1 Carbon Offsetting in the Aviation Industry

Currently, both SAS and Norwegian are engaging in voluntary carbon offsetting, whilst Widerøe is not. SAS started providing its passengers with the ability to offset the carbon emissions of their flights in 2006 (SAS, 2020). In the beginning, the customers were offered the opportunity to purchase carbon credits on top of their tickets (SAS Group, 2007), however, this practice has since been eliminated. In 2018, SAS launched an initiative where the CO_2 emissions of all passengers in the Youth customer segment and its own business travels would be carbon neutralized (SAS, 2018). Additionally, it was announced in February 2019 that EuroBonus members would be included in this scheme as well. This entails that SAS is personally funding the emissions-reducing efforts of all passengers in these segments.

In 2019, Norwegian implemented an opt-in solution in their booking process, providing the consumer with the option to purchase carbon credits to offset the emissions of their flight on top of their ticket (Norwegian, 2019). Here, it is the passenger who carries the cost of the emissions reductions, not the airline.

Both SAS and Norwegian are partnering with a provider of carbon offsets. Essentially, these partners act as an intermediary between the airlines and the carbon offset project developers. Their purpose is to conduct quality assurance and secure the reliability of projects, curating a portfolio of CO_2-reducing projects from which the airlines can select (Chooose, n.d. a; SAS, n.d. a). Figures 2 and 3 illustrate the different offsetting partnerships in the Scandinavian aviation industry today.

Figure 2: Offsetting Partnership: SAS

Figure 3: Offsetting Partnership: Norwegian

As depicted above, SAS is currently partnering with Natural Capital Partners to facilitate its offsetting program. Originating in London, Natural Capital Partners has operated within carbon offsetting for over 20 years (Natural Capital Partners, n.d.). On the other hand, Norwegian Air Shuttle is in a partnership with Chooose, a Norwegian-born technology company founded in 2017 aiming to reduce and remove air pollution from the atmosphere (Chooose, n.d. a; b). Both partners facilitate the trading of carbon credits, enabling the purchase of more reliable carbon projects and credits.

This research employs embedded cases to allow for a more detailed level of inquiry into the aviation industry in Scandinavia. Insights in the current offsetting practices are developed from one actor from each of the aforementioned partnerships, respectively SAS and Chooose. Efforts were made to collect data from the remaining actors, Natural Capital Partners and Norwegian, however, this was not possible. As such, this research gains insight into the aviation industry in Scandinavia based on perceptions from an airline in the first partnership (SAS), an offsetting partner from the second partnership (Chooose), in addition to an airline that does not practice voluntary carbon offsetting (Widerøe).

4. Methodology

In order to outline the research planning and development of this project, Saunders et al.'s (2016) *research onion* has been employed (appendix 2). This tool embodies the process of designing the research, in addition to the views and beliefs of the researchers. Illustrated through the six layers of the onion, the method begins from the outer layer working inwards, with the choices in each layer influencing the next (Saunders et al., 2016). This section will describe the application of each stage of the onion to the objective of this study.

4.1 Philosophy of Science

The outer layer of the research onion considers the underlying philosophies of the research. Research philosophy relates to a set of assumptions and beliefs concerning the development of knowledge (Saunders et al., 2016). In order to ensure an adequate approach to the research question, both ontology and epistemology need to be considered. Ontology refers to the interpretation and perception one has of the world, where the perspective of subjectivism and objectivism must be considered (Eriksson & Kovalainen, 2008). Epistemology is concerned with how knowledge is obtained and interpreted, and what constitutes valid and legitimate knowledge (Saunders et al., 2016).

The ontological perspective selected for this thesis is social constructivism. This focus is deemed appropriate as the aim of the research is to examine how blockchain technology can improve the performance of voluntary carbon offsetting in the Scandinavian aviation industry, with the analysis being founded on knowledge of the industry today in combination with the subjective perceptions of the actors in the industry and blockchain experts, as well as the attitudes and preferences of the consumers (Saunders et al., 2016). Social constructivism centres on the notion that knowledge is constructed through interactions with others (McKinley, 2015), which aligns with the purpose of this thesis.

Pragmatism focuses on the reconciliation of subjective interpretations, objective facts, and contextualized experiences, allowing different perspectives to interpret data and answer the research question (Saunders et al., 2016). This research intends to combine the objectivity of secondary data with the subjectivity of qualitative and quantitative data, and thus pragmatism has been selected as the epistemological choice and philosophical position. This allows the researchers to utilize different techniques of data collection and analysis procedures in order to develop nuanced answers to the research questions.

As the pragmatic view emphasizes the practical outcomes of specific contexts rather than abstract distinctions, extensive variations can be found in regard to how subjective or objective the research is (Saunders et al., 2016). When analysing the qualitative data of this thesis, the subjective perspective is incorporated through an applied version of the interpretivist approach. This approach implies that reality is dependent on the spectator, as there is not one unbiased reality (Bryman, Bell, Mills, & Yue, 2011). As such, this research subscribes to an overall pragmatist approach and incorporates characteristics of the interpretivist approach for the qualitative data analysis.

4.2 Reasoning Approach

The second layer of the onion is the reasoning approach. The reasoning approach is essential in defining how data is handled, in addition to explaining how theory is connected to the research. The two elemental approaches utilized when conducting research are *deduction* and *induction*. Additionally, there exists an approach in which the researchers apply both elemental approaches: the *abductive* approach (Bryman & Bell, 2015). This research subscribes to the abductive approach, as it incorporates elements of both deduction and induction.

The inductive approach is employed when an uncharted phenomenon is explored (Malhotra, Nunan, & Birks, 2017), and examined through the perceptions of research participants

(Bryman & Bell, 2015). This aligns with the overall purposes of this research. In the inductive approach, observations are made without underlying theoretical knowledge, with general principles established from the observations made and thereafter linked to theory. This reasoning approach is most appropriate for qualitative analysis, as it warrants profound insights through the observation of participants in a particular context (Bryman & Bell, 2015).

The deductive reasoning approach starts with a hypothesis, founded upon previously developed theory from empirical data, which are subsequently tested in order to determine whether the assumption should be confirmed or dismissed (Malhotra et al., 2017; Bryman & Bell, 2015). This approach is employed when the aim is to adopt a clear theoretical position that is to be tested through data collection (Saunders et al., 2016). Although an inappropriate approach for the qualitative data analysis of this research, the deductive reasoning approach aligns with the purposes of the quantitative data analysis in this mixed-methods approach. As such, abductive reasoning is found to be suitable for this research, incorporating aspects of both elemental approaches. Moreover, this allows the researchers to move back and forth between theory and empirical data (Saunders et al., 2016), which is essential in this thesis.

4.3 Research Design Classification

The research design constitutes a plan or framework for how data is to be collected for a research project and can broadly be categorized as either *conclusive* or *exploratory* (Bryman & Bell, 2015*)*. Conclusive research design is employed when information is clearly defined for the purpose of testing hypotheses or examining relationships. The research process is typically characterized by structure and large, representative samples. For this research, an exploratory design has been found to be more suitable, as it provides insights and understanding as opposed to measuring hard facts. The approach is not as structured as the conclusive design, rather it allows for a more flexible research process that may be altered throughout the project. The exploratory design commonly embodies smaller sample sizes, making it less representative. Instead, it provides greater insights, which is essential for the purpose of this research study.

4.4 Methodological Choice

The third layer of the research onion consists of the methodological choice, which is concerned with whether a research study follows a *quantitative, qualitative,* or *mixed-methods* research design. A quantitative research design intends to examine relationships between different variables, which are measured numerically and analysed by utilising an array of graphical and statistical techniques (Saunders et al., 2016). This method is generally most appropriate for deductive reasoning approaches. On the other hand, a qualitative design is more suitable for inductive reasoning approaches and aims to gain depth, insight, and understanding (Bryman et al., 2011). Similar to quantitative research, a qualitative design aims to uncover correlations, however, these are based on logic, reasoning, and estimations rather than numerical data (Blumberg, Cooper, & Schindler, 2011).

This research incorporates both qualitative and quantitative techniques to collect both statistical and non-statistical data. In other words, the research is designed with a mixed-methods approach. This approach has been found suitable with the aim of providing a comprehensive conclusion to the research questions, further elaborated in section 4.7 Data Collection. Utilizing a sequential exploratory design, the qualitative data is first collected and analysed followed by the collection and analysis of the quantitative data. As such, the qualitative phase will inform and direct the subsequent quantitative phase, allowing the authors to elaborate on and explore initial findings (Saunders et al., 2016).

4.5 Research Strategy

The fourth layer of the research onion relates to the research strategy of the thesis. A *case study* is a research strategy that investigates a phenomenon or topic within its real-life context through an in-depth inquiry (Yin, 2014). According to Dubois & Gadde (2002), *"the interactions between a phenomenon and its context is best understood through in-depth case studies"* (p. 554). For this thesis, a case study strategy has been adopted using the aviation industry in Scandinavia as a single case within which the Scandinavian airlines and their offsetting-partners are embedded cases. Embedded cases act as sub-units of analysis, allowing for a detailed level of inquiry (Yin, 2014). The phenomenon under examination in this thesis is voluntary carbon offsetting and the researchers seek to understand this phenomenon in its real-life context in the Scandinavian aviation industry. This objective coincides with the characteristics of a case study. Additionally, case studies frequently draw on both qualitative and quantitative data in order to fully comprehend the dynamics of a phenomenon (Saunders et al., 2016), which supports the mixed-method approach of this research.

It is important to note that there exists disagreement about the ability of a case study to produce generalizable knowledge. The prevailing view of case studies is that they produce weak generalisability, notably due to the widespread use of qualitative research methods. Such methods are usually not intended for replication due to the socially constructed interpretations of a smaller sample of participants in a specific context. However, this notion is increasingly losing favour as the value of mixed-methods research is becoming more prevalent (Saunders et al., 2019).

4.6 Time Horizon

The fifth layer of the research onion relates to the time horizon of the research and whether a *cross-sectional* or *longitudinal* perspective is utilized. In cross-sectional studies, a phenomenon is studied at a particular time (Saunders et al., 2016). This perspective is often used in research projects for academic purposes, due to the typical time constraints experienced. On the other hand, longitudinal studies are more akin to a diary or series of snapshots and have the capacity to examine change and development (Saunders et al., 2016). This research is a case study based on primary data collected over a limited period of time and existing research. As the purpose is not to study change, but rather to understand the current performance of voluntary carbon offsetting in the aviation sector, a cross-sectional perspective is found to be more applicable. This aligns with the primary data collection being conducted in a short timeframe. Although a longitudinal study might provide further insights from conducting research at multiple points in time, this research is time-constrained, and thus a longitudinal perspective was simply not feasible.

4.7 Data Collection

The sixth and final layer of the research onion is data collection and data analysis. The process of data collection starts with examining readily available *secondary data* to gain an understanding of the area of study and facilitate in identifying and defining the primary data collection. Analysing secondary data may grant valuable insights for the researchers, and is essential for problem diagnosis, planning, and verification of qualitative research (Malhotra et al., 2017). The secondary data in this study is collected after careful selection processes to ensure the accuracy and relevancy of the material.

The *primary data* of this research is both qualitative and quantitative in nature, gathered with the purpose of coping with the particular research problem of the thesis (Malhotra et al., 2017). The qualitative data collection starts off with semi-structured interviews with two of the major airlines in Scandinavia: SAS and Widerøe, as well as one offsetting partner: Chooose. The purpose is twofold: first, to identify the most prominent area of improvement perceived by the industry actors. Secondly, to obtain deeper knowledge about the supply chain and how offsetting currently functions in the Scandinavian aviation industry. The findings from the semi-structured interviews are then utilized to inform and direct the subsequent quantitative phase, consisting of an online questionnaire directed at uncovering the preferences and attitudes of air travel consumers in Scandinavia.

The primary data collection also consists of several qualitative semi-structured interviews with blockchain experts. These are conducted in order to provide the researchers with a deeper insight into blockchain technology, as well as benefits and potential challenges of implementation and operation in the supply chain of voluntary carbon offsets in the Scandinavian aviation industry. Finally, semi-structured follow-up interviews are conducted in order to gain further insight and elaborate on the initial interviews. Taking into account the circumstances of the COVID-19 outbreak, it was deemed a necessary trade-off to conduct these through email. This will be further elaborated on in section 4.8.2 Design & Execution.

4.8 Qualitative Data

4.8.1 Semi-structured Interviews

The qualitative data collection of this thesis is conducted using a *semi-structured interview* technique. An interview may be classified somewhere between *structured* and *unstructured* (Denscombe, 2010). At one end, a structured interview is made up of questions that are pre-arranged and defined, generally leading to standardised answers with little to no variation (Qu & Dumay, 2011). At the other end, unstructured interviews function without predetermined questions of any sort. Rather, they tend to be more informal and more open in their questions, where it is up to the interviewer to be mindful of the subject they want to explore as the free-flowing conversation unfolds (Malhotra et al., 2017).

Semi-structured interviews fall in between the two opposites, giving the interviewer a higher level of control over the subject than in an unstructured technique, yet questions may still be open as there are no fixed ranges of responses (Saunders et al, 2016). This method has been found to be suitable as this research has predefined areas regarding the information required from the participants and a vision of how the data should be interpreted in an analysis.

The aim of conducting qualitative research interviews is to explore the respondents' experiences and perceptions of a specific topic. As such, the purpose is to extract meaning through interpretations, not necessarily facts (Malhotra et al., 2017). When selecting this method, the element of representativeness is somewhat set aside in favour of the quality of the targeted respondent. The focus of a qualitative interview is on the depth and detail of the collected data, and to a lesser degree on the broadness of the interviewees (ibid).

4.8.2 Design & Execution

Semi-structured interview techniques are applied to provide in-depth insights into both the Scandinavian aviation industry and blockchain technology. The method builds on a prepared question guide, where fixed themes have been established and organized in a consistent and systematic fashion (Bryman & Bell, 2015). Three interview guides are initially created for the purposes of this research: one for the airlines, one for the offsetting partner, and one for the expert blockchain interviews (appendix 3; 4; 5). The interview guides allow for new questions to be developed during the interview as new information unfolds and gives the interviewers the opportunity to probe responses where a further explanation could prove insightful. The question order can also vary depending on how the conversation flows (Saunders et al., 2016). This is a suitable environment for the researchers to learn and develop deeper knowledge throughout the dialogue and as such appropriate for the qualitative data collection of this research.

The semi-structured interviews have been carried out as face-to-face interviews where this was possible. Nevertheless, where this was not feasible, the researchers intended to conduct internet-mediated interviews by utilising communication tools that allow for the sharing of both audio and video. This reduces potentially adverse effects of utilising a listening-mode only, as the researchers are able to observe some of the non-verbal cues and behaviours of the respondents (Saunders et al., 2016). However, the COVID-19 pandemic has had a large impact on the work and daily life in Scandinavia in general, and the aviation industry has been heavily impacted. Consequently, the researchers found themselves having to adapt the data collection. Where respondents were no longer able to participate in follow-up video interviews, electronic interviews were carried out through email where possible. This form of written interview is not conducted in real-time, and as such carries certain limitations (ibid). Individual interview guides were created for additional email interviews (appendix 6; 7).

4.8.3 Sampling Method & Size

Bryman & Bell (2015) suggest purposive sampling for qualitative research. Also referred to as non-probability sampling, this technique allows researchers to strategically select participants suitable for the research problem rather than sampling on a random basis (Bryman & Bell, 2015). Two target groups are identified as appropriate for the qualitative data collection of this study. For the first target group, it is of great importance to select participants who have relevant positions and substantial knowledge of carbon offsetting in the Scandinavian aviation industry. In the second target group, individuals with expertise in blockchain technology are essential, particularly those with an insight into the usage of blockchain for environmental and sustainable purposes or leveraging the technology across a supply chain.

Seven initial semi-structured interviews were conducted with an average duration of approximately 45 minutes, three of which with the aviation-related target group, and four with the blockchain expert target group (table 1). Furthermore, three follow-up interviews were conducted through email with two of the blockchain experts and the offsetting partner in order to gain deeper insights and elaborate on the findings of the previous interviews. Efforts were made to conduct follow-up interviews with all aviation-related actors, however, these were cancelled or rejected in light of the COVID-19 circumstances. According to Saunders et al.

(2016), it is recommended to continue collecting qualitative data until data saturation is reached and that additional data collected provides little to no new knowledge or themes.

It proved difficult to secure individuals from the respective organizations in Scandinavia for interviews. As the COVID-19 pandemic has heavily impacted the aviation sector, the researchers found the quest for additional interview subjects and interviews to difficult. Nonetheless, the researchers managed to conduct interviews with one party in each of the major offsetting partnerships in the Scandinavian aviation industry, as depicted in section 3.1 Carbon Offsetting in the Aviation Industry, in addition to an airline that does not conduct carbon offsetting. As such, the researchers found the insights and perceptions provided by the participating actors to be sufficiently representative of the industry, providing value to the case study of this research.

The blockchain interviews were found to be sufficient in generating enough data on the possibilities of blockchain technology implementation for voluntary carbon offsetting and to gain an adequate saturation of the topic.

Interview Subject	*Target Group*	*Supply Chain Stage*	*Initial Interview*	*Follow-up*
SAS	Aviation industry	Airline	18/02/20	N/A
Widerøe	Aviation industry	Airline	19/02/20	N/A
Chooose	Aviation industry	Offsetting partner	04/02/20	14/05/20
Jacob Pouncey	Blockchain	N/A	20/02/20	01/05/20
Ian Choo	Blockchain	N/A	21/02/20	N/A
Kristoffer Just & Radu Teodorescu	Blockchain	N/A	26/02/20	02/05/20
Thomas McMahon	Blockchain	N/A	27/02/20	N/A

Table 1: Overview of Interview Subjects

4.8.4 Transcription

The audio-recordings of all the interviews are subsequently transcribed in order to facilitate a more thorough examination, as well as to conduct a repeated analysis of the findings (Bryman & Bell, 2015). The decision regarding whether and how an interview is transcribed depends on how the qualitative data is intended to be analysed (Saunders et al., 2016). This research utilizes *intelligent verbatim transcription* for the interviews with the actors in the aviation industry. This method entails transcribing every word but excluding expression of emotions including hesitations such as "uh", laughing, and stuttering (Streefkerk, 2019). It was deemed that details such as measuring pauses or evaluating how the interviewee articulated their answers were not necessary and would not enhance the quality of the findings. As this research aims to uncover the most prominent area of improvement perceived by the actors in the Scandinavian aviation industry, these interviews had to be analysed and coded to identify patterns and relationships. As such, it was necessary to transcribe the whole of each interview (Saunders et al., 2016).

For the expert blockchain interviews, the *data sampling* method of transcription proposed by Saunders et al. (2016) was utilized. In this method, only the parts of audio-recordings that are pertinent to the research are transcribed. This was deemed as sufficient as these interviews were not intended to be encoded or for identifying patterns, but rather for the researchers to gain expert knowledge on blockchain in relation to the topic of the research.

4.8.5 Qualitative Data Analysis

The process of *Thematic Analysis* is utilized in the initial analysis of the data collected from the airline-related interviews. This approach involves the researchers coding the qualitative data, in this instance a series of interviews, in order to identify patterns or themes for further exploration related to the research question (Saunders et al., 2016; Braun & Clarke, 2006). This makes it possible to integrate related data from individual transcripts as well as to draw and verify conclusions. This method is applied to the interviews with the actors in the aviation sector in order to recognize patterns in relation to issues perceived by the different actors, allowing the researchers to identify the most prominent area of improvement.

The procedure of a Thematic Analysis has been divided into four steps. First, *becoming familiar with your data* involves the act of familiarizing oneself with the data by producing transcripts, and reading and re-reading the data during analysis. The next step is *to code your data*. Coding entails labelling the units of data within a transcript with a code symbolising the meaning of the extract. This is essential to ensure that each unit of relevant data is accessible for further analysis (Saunders et al., 2016). The codes in this thesis consist of an initial framework of predefined codes derived from conceptual and theoretical work, as well as codes devised during the process where the predefined codes were deemed inadequate. This approach aligns with the deductive approach of this research. The software NVivo is utilized to facilitate the coding process.

The third step consists of *searching for themes and recognising relationships*. Although seen as a distinct stage, this step will in practice occur simultaneously as data is being collected and coded. This step essentially involves seeking out patterns and relationships in the developed codes, in order to create a shortlist relevant to the research question. A theme may consist of several codes with similarities but also often single codes that are found to be essential for the research and as such are elevated from a code to a theme-status (Saunders et al., 2016). Finally, it is necessary to *refine themes and test propositions.* The devised themes should be part of coherent sets, and their meaningfulness might require revaluation. This process is typically developmental, occurring by re-reading and re-organizing the data. Propositions that have emerged from the data should also be tested by searching for alternative explanations and negative examples of non-conformity to the patterns being tested. Doing this will facilitate the development of valid and well-grounded conclusions (ibid).

For the blockchain expert interviews, the aim is not to develop patterns or relationships in the datasets. Rather, the goal is to develop knowledge and insights relevant to the research subject which might be difficult to gain otherwise. Specifically, the researchers are seeking to uncover insights pertaining to how blockchain technology could be utilized in the specific case of voluntary carbon offsetting in the Scandinavian aviation industry, as well as the experts' opinions on the benefits and challenges to potential implementation. As such, conducting a process of Thematic Analysis is deemed as unnecessary and of low added value. Instead, the researchers will individually interpret the collected data after each interview, followed by a discussion in order to uncover key findings for a specific interview.

4.9 Quantitative Data

4.9.1 Questionnaire

A questionnaire is designed in order to collect the quantitative data of this research. The aim is to provide insight into consumer preferences regarding carbon offsetting, using the findings from the thematic analysis of the aviation industry to inform and direct the topic and questions. Essentially, this questionnaire is developed in order to examine whether the area of improvement identified in the preceding qualitative aviation interviews corresponds with consumer demand. The questions are formulated to analyse whether the mitigation of the uncovered issue would increase the demand and add value to the process of voluntary carbon offsetting from a customer perspective.

The questionnaire is designed as an online self-completed questionnaire with a structured form, which entails that the respondents record their own answers to a pre-specified set of response alternatives (Saunders et al., 2016). It is devised in English to ensure that it is apprehensible to the whole target group. The questions are formulated in a manner aimed to be easily understandable and minimise bias, further adjusted following pilot-testing (Malhotra et al., 2017). All the data gathered from the questionnaire is anonymous in an attempt to reduce potential social influence (Söderlund & Öhman, 2005). Anonymity is found to be of great importance in this questionnaire, as the topic relates to sustainability and environmental consciousness, and individuals might otherwise be inclined to portray themselves as more environmentally responsible than they necessarily are.

4.9.2 Design

The online questionnaire is designed with three sections (table 2), with the purpose of collecting distinct information to contribute to the research questions (appendix 8).

	Questions	**Purpose**
Section 1	Questions 1-4	Collect demographic and behavioural data on the participants. Essential to explore how attitudes and perceptions differ across the population (Saunders et al., 2016).
Section 2	Questions 5-9	Attitude and opinion variables related to participants' perceptions about the topic (Saunders et al., 2016). Aims to gain insight into consumer awareness and attitudes towards the environment and carbon offsetting.

Section 3	Questions 10-11	Attitude and opinion variables related to preferences on application (app) design and cost.

Table 2: Sections of the Online Questionnaire

The questionnaire consists of 11 structured questions, arranged in a predefined order. It is generally found that if the majority of questions are *structured* in a self-administered questionnaire, participant cooperation increases (Malhotra et al. 2017). Distributing the questionnaire online has several advantages, including speed, quality of response, and the reduction of researcher bias. However, recruiting participants through social media sources entails that they are self-selecting to participate and thus the researchers cannot be certain of whether the respondents are actually representative of the target population (ibid). In order to reduce this uncertainty, the initial question of the questionnaire is designed as a control question with the purpose of filtering out any respondents who do not currently live in Scandinavia (Saunders et al., 2016). This is essential as the research is interested in the perception and attitudes of current and potential customers in Scandinavia.

Several types of question formats have been applied in the questionnaire of this research. *Dichotomous* questions are utilized for simple statements where the researchers are looking for clear answers and little depth, such as for filtering the respondents. This format includes two response alternatives, such as “yes” and “no”, and are usually supplemented by a neutral option to provide the respondent with an alternative if they feel indifferent to the question asked (Malhotra et al., 2017). Further, multiple-choice questions provide the participants with a fixed list of answer options and ask them to select one (ibid). In this research, single-answer questions were utilized, where the respondents are required to select only one unique choice. This is particularly effective when the researchers have a clear set of alternatives in mind, as it requires the participants to select the option that is closest to their opinion. The participants are however provided with a neutral alternative and respondents are thus not forced to pick a side (Saunders et al., 2016).

Likert-scale rating questions are applied to the questions where the purpose is to understand the participants’ attitudes in relation to a particular phenomenon. Each rating question consists of five response options, requiring the participant to indicate a level of agreement or disagreement with a statement (Malhotra et al., 2017). *Likelihood* response categories are applied when the objective is to uncover the respondents' level of interest in relation to a particular phenomenon, entailing that the response options are scaled from "not at all interested" to "extremely interested" (Saunders et al., 2016). Another relevant response category is the *amount* category, incorporated in a question where the aim is to understand whether a particular phenomenon is more or less appealing following a change. The amount response category entails scaling the alternatives from "a lot less interested" to "a lot more interested" (ibid). With a Likert-scale rating of five alternative responses, the middle option provides the respondent with a neutral choice.

A final variation of rating-style questions utilized in this questionnaire is the *matrix* question. This is a grid of questions that allows the researchers to record the answers to several similar questions simultaneously (Malhotra et al., 2017). Similar to the Likert-scale rating questions, respondents are provided with five alternative responses, where they are required to indicate their level of agreement to three different aspects related to a phenomenon. The likelihood response category is also utilized here, with responses ranging from "not at all important" to "extremely important". The purpose is to uncover the level of importance the participants' place on different aspects connected to a phenomenon.

4.9.3 Sampling Method

A version of non-probability sampling referred to as *convenience sampling* is utilized in the questionnaire of this thesis. This method has been found to be the most suitable due to the constrained time, resources, and monetary factors of this research. It involves obtaining participation based on availability (Saunders et al., 2016) and has been performed in this research by publishing the questionnaire in various social media groups in Norway, Sweden, and Denmark. Such sampling is however prone to bias and influences beyond the researchers' control, and thus interpretation must be treated with caution (ibid). If there were no constraints, the ideal approach would have been to incorporate simple random sampling by reaching out to individuals through a database. The selected sampling approach can however still provide comprehensive findings from the questionnaire.

To ensure that all respondents belong to the target population, a control question is included to filter out any respondents who do not currently reside in a Scandinavian country. Although it would be possible for individuals living outside of these three countries to travel using a Scandinavian airline, the researchers found this control question to be a necessary trade-off to filter out irrelevant responses.

4.9.4 Target Population

The target population of the quantitative research consists of individuals who travel with, or would potentially travel with, a Scandinavian airline. Although individuals residing outside of Norway, Denmark, and Sweden could also be customers of these airlines, it has been found necessary to exclude these in order to simplify an otherwise complex data collection process. As such, the questionnaire is directed at individuals who are currently living in Scandinavia. The sampling frame utilized consists of respondents active in various Facebook groups in Norway, Denmark, and Sweden. Note that this does not exclude individuals who do not currently travel by airplane, as their opinion could still prove valuable. Even if individuals do not currently fly, the option to counteract the emissions of their flight might make them more interested.

4.9.5 Pilot-Test

The questionnaire of this research was pilot tested in order to spot and solve potential problems or unclarity before proceeding with the finished survey. The test was completed on a small-sized group of participants, corresponding to the actual target group (Malhotra et al., 2017). Although pilot-testing has proved to be most beneficial when conducted face to face (ibid), it was not possible to meet up due to the COVID-19 pandemic. As such, the questionnaire was tested online by having a group of pre-selected respondents take the unpublished questionnaire and provide feedback on aspects relating to the wording and clarity of the questions and descriptions, as well as how they interpreted them. Although interviewers were not able to observe the reactions and attitudes of the participants themselves, testing was still deemed to be vital as it helps reduce the chance of misinterpretation by incorporating the feedback (Malhotra et al., 2017).

The results of the pilot-test unveiled a few formulations that might be interpreted in multiple ways, so minor changes were incorporated to clarify the universal meaning of these questions. Apart from this, it was found that there were no issues concerning the layout, descriptions, or the questions' difficulty. These results established that the questionnaire was clear and understandable, and after incorporating the minor changes the actual questionnaire was ready for distribution.

4.9.6 Quantitative Data Analysis

The quantitative data is processed and analysed in order to convey meaning, as questionnaire data in its raw form often provides little understanding (Saunders et al., 2016). In order to convert the raw data into information, the survey design and analysis tool Qualtrics is utilized. This tool has been selected as the questionnaire was originally designed and published through Qualtrics, making it an effective and suitable choice for further processing. After cleaning the data for partial responses, the quantitative data is processed into visualisable information through graphical and statistical techniques.

4.10 Data Limitations

There are several limitations in terms of both the qualitative and quantitative data of this research. To start off, the time frame restricts the number of respondents to both the questionnaire and the semi-structured interviews. A total of 220 respondents contributed to the questionnaire, which allows for a margin of error of 6.61% calculated with a 95% confidence level. The calculation is based on the total population size in Scandinavia as of April 2020, specifically 21 312 703 residents (Worldometers, 2020). The margin of error indicates how many percentage points the results of the questionnaire may vary from the actual population value. Hence, a 95% confidence interval with a 6.61% margin entails that the results will be within ± 6.61% of the actual population value 95% of the time (StatisticsHowTo, n.d.).

As previously mentioned, the convenience sampling technique is utilized for the questionnaire. This technique is limited in that it does not necessarily represent the population of interest with accuracy, and therefore is a source for potential bias (Saunders et al., 2016). Indications of this are found in the demographic section of the questionnaire, where the age group of individuals between 21-29 years old represents 60.37% and female respondents represent 70.97% of participants. This demonstrates an overrepresentation of these groups. However, considering the constraints on time and resources of this research, it was found to be a necessary trade-off in order to gain access to respondents in the target population.

An additional limitation relates to the response alternatives available in the questionnaire. Attempts were made to ensure clarity and inclusion of responses through a thorough review and pilot testing. However, the researchers' lack of expertise means that the results may not account for all desired response alternatives and individual opinions may have been indirectly discarded.

It is also important to be aware of the limitations of the qualitative interviews conducted. As previously mentioned, it proved difficult to secure the envisioned participants from the aviation sector. In the end, three companies were able to participate, and only one of these was available to answer scheduled follow-up questions. The time restrictions added to this issue, but largely it was a consequence of the outbreak of the COVID-19 pandemic. The aviation industry has been heavily impacted, and the researchers experienced several cancellations and rejections attributed to the pandemic. However, as there are relatively few players in the Scandinavian aviation industry, it is found that the insight provided is valuable nonetheless.

Furthermore, there is a risk of the interviewers affecting the interview subject through comments, tone, or non-verbal behaviour, often referred to as interviewer bias (Saunders et al., 2016). This should be considered in the findings as the interviewers are not experts. However, attempts were made to combat this by designing interview guides and having both researchers partake in each interview to reduce the potential distorted judgment.

Further, response bias entails that respondents may be willing to participate in the interview but are sensitive to the exploration of certain subjects. As such, they may prefer not to discuss a topic if they are unable or unwilling to divulge particular information. The outcome is often that the interviewees only provide a partial picture, potentially casting themselves or the organization from which they are a delegate in a positive fashion (Saunders et al., 2016). This aspect is of particular importance in the interviews with the aviation industry, as the main topic discussed relates to sustainability and the environment. Such subjects could be considered rather sensitive, and an organization might want to portray themselves as more environmentally responsible than they actually are. This must be taken into account when interpreting the results.

An additional limitation relates to the fact that the interviews have been conducted in several languages: Norwegian, Swedish, and English. This choice has been made to facilitate the most natural and accurate communication possible. As such, several interviews have had to be translated. Although efforts have been made to ensure that the meanings contained in the original language are repeated authentically, there exist certain limitations. The translation is an inherently interpretive act, and as such meaning may become lost in translation (Nes, Abma, Jonsson & Deeg, 2010). In order to reduce this limitation, interviews have only been conducted in languages in which the researchers are fluent, and the utmost care has been taken to facilitate accurate interpretation.

Finally, there are limitations to be considered regarding the way in which the interviews have been conducted. The ideal option would have been to carry out all interviews as face-to-face, in-person interviews. However, this was not always possible due to geographical location, as well as the advice of social distancing in light of the COVID-19 outbreak. As such, several interviews have been carried out as internet-mediated interviews, either by means of web conferencing or email. This extends access to participants but also exposes the research to trade-offs in relation to the limited ability of the researchers to pick up on social cues and non-verbal behaviour (Opdenakker, 2006). Additionally, communication through email interviews is not spontaneous in nature as it provides the interviewee with extended time to reflect on their answers (ibid). However, it was determined that the additional insight provided by the supplementary interviews outweigh the potential negative impacts of conducting the interviews online.

4.11 Reliability, Validity & Credibility

4.11.1 Reliability

Reliability refers to the ability to replicate the design of previous research and achieve the same results. In other words, it relates to the consistency and replicability of the research (Saunders et al., 2016). Several measures have been taken to facilitate the reliability of both the qualitative and quantitative data of this thesis.

To mitigate the threat of participation error in the qualitative data collection, the interviews were conducted during office hours at a time considered most convenient by the participants. Furthermore, all interviews were conducted in a closed space to ensure that the interviewees were able to speak freely without being overheard (Saunders et al., 2016). For the internet-mediated interviews, it is assumed that the interviewees were able to find a closed space themselves. Moreover, potential social influence affects the interviews in situations where the participants are reluctant to divulge information on certain topics. There is a risk that the interviewee is inclined to cast their respective organization in a positive fashion, which in turn reduces reliability.

For the quantitative data, measures were taken to facilitated reliability through the utilization of methods, parameters, and measurements established in previous research. In order to examine the phenomena thoroughly and avoid misinterpretations, questions were designed with rating-scales, as well as matrix-scales (Bryman & Bell, 2015). The clarity and universal meanings were enabled through pilot-testing. The pilot-testing was performed in an attempt to minimize any potential bias. Furthermore, all the information retrieved from the questionnaire was anonymous in order to mitigate potential social influences (Söderlund & Öhman, 2005). This was considered particularly important due to the topic of this questionnaire, as respondents might otherwise be inclined to portray themselves as more environmentally responsible than they actually are.

4.11.2 Validity

Validity is concerned with the accuracy and generalisability of research and can be interpreted as the integrity of the conclusions derived from the findings (Bryman & Bell, 2011). The validity of this research has been facilitated through *internal* and *external validity* (Saunders et al., 2016).

Internal Validity

The internal validity of the quantitative data refers to the ability of the questionnaire to measure the aspects that it intends to measure, referred to as the measurement validity (Saunders et al., 2016). The intent of the questionnaire was to analyse whether the area of improvement identified in the preceding qualitative aviation sector interviews corresponded with consumer demand. Furthermore, the purpose was to gain insights into the attitudes and perceptions of the consumers in regard to carbon offsetting, as well as whether or not a proposed digital solution could improve their perception. It was found that the questionnaire produced valuable insight into the intended aspects, as such, measured what it intended to measure. The responses collected from the questionnaire provided the researchers with the data required to fulfil the research objective, and as such establishes measurement validity.

External Validity

External validity refers to whether the findings of the research can be generalized to other relevant groups or cases (Saunders et al., 2016). In relation to the qualitative data, the interview participants have been carefully selected with a purposive non-probability sampling method in an attempt to achieve generalisability. The main criteria for the interview subjects within the Scandinavian aviation industry were substantial knowledge within the current carbon offsetting and environmental practices of their respective companies. Furthermore, it was deemed appropriate to conduct interviews with both airlines and their offsetting partners in order to ensure that the data collected was from different perspectives. The participants of the blockchain expert interviews were selected based on their knowledge and experience within blockchain technology, with a particular focus on individuals with an insight into the usage of blockchain for environmental purposes or supply chains.

In an effort to facilitate external validity in the questionnaire, the data was gathered from a large sample of respondents. However, the application of a convenience sampling method is not able to ensure the representativity of participants, and as such the data are not necessarily generalizable (Malhotra et al., 2017). Evidence of this can be seen in the distribution of responses in terms of both gender and age, which essentially reduces the external validity of this research. However, as a sequential mixed-methods approach has been utilized in an attempt to validate and substantiate the previous findings of the qualitative data collection in the aviation industry, the findings of the questionnaire are considered to generate some degree of external validity.

Nonetheless, this thesis is a single case study on the specific circumstances of voluntary carbon offsetting in the Scandinavian aviation industry, which entails that the findings are rather specific to the present conditions. As such, it is difficult to establish the generalisability of this research (Saunders et al., 2016). It could, however, be argued that the findings may be generalizable to voluntary carbon offsetting practices in the aviation industries elsewhere, assuming that the professional actors and consumers share similar perceptions and attitudes like those in Scandinavia.

4.11.3 Credibility

Credibility is considered to be the most crucial criterion in establishing the trustworthiness of the research. The main purpose of credibility is to guarantee the connection between the findings of the research and the socially constructed realities of the participants of the research (Saunders et al., 2016). The *triangulation method* has been applied in order to ensure the credibility and trustworthiness of this thesis. The research has been carried out by two researchers, who explored and analysed the findings from individual perspectives. Furthermore, the primary data was collected from two sources in order to attain consistency in the findings and increase representability: qualitative semi-structured interviews and a quantitative questionnaire. The collected data was combined with a range of theoretical perspectives and secondary data in order to analyse the findings. Utilising more than one source of data through the triangulation method, the multiple researchers, data sources, methods, and theories help in ensuring the credibility of the collected data, analysis, and subsequent interpretation(ibid).

5. Identification of Challenges

In order to facilitate a precise and relevant analysis of the current situation in the Scandinavian aviation industry, qualitative data was collected from three aviation-related actors in order to uncover their perceptions of the present areas of improvement in the current practice of voluntary carbon offsetting. Based on the themes and patterns identified in the data analysis, this section will attempt to answer the following sub-question:

a) *Which area of improvement in the practice of voluntary carbon offsetting is perceived as most prominent by the actors in the Scandinavian aviation industry?*

To be able to recognize themes and patterns in the three data sets, the interviews were coded following the Thematic Analysis approach described in section 4.8.5 Qualitative Data Analysis. The main theme of relevance for this section is the "*Challenges of Voluntary Carbon Offsetting*". The criteria for a code to be included in this overarching theme was for it to consist of a comment from the interview subject relating to an issue or area of improvement in the practice of voluntary carbon offsetting. This could include either aspect they had identified when conducting voluntary carbon offsetting themselves or from the observation of other companies. As such, it was relevant to understand the perceptions of the actors who currently do not practice voluntary carbon offsetting as well as those who do.

Under the overarching theme, three sub-themes were uncovered: *transparency, pricing,* and *reporting.* These themes were identified by accumulating related codes, as well as by elevating single codes of importance into a theme-status. All the individual codes consist of sentences or paragraphs which relay the same meaning. The themes and the codes they consist of can be viewed in table 3.

Theme	**Codes**	**Frequency**
Transparency	Transparency, traceability	3/3
Pricing	Low price, volatility	2/3
Reporting	Reporting	1/3

Table 3: Overview of the Developed Themes Coherent to the Challenges of Carbon Offsetting.

Further, the themes have been ranked in accordance with the number of data sets they occurred in. Reporting was indicated as a challenge connected to carbon offsetting in one out of the three data sets, specifically in the interview with SAS.

"It is great that everyone has to report (to EU ETS and CORSIA), and that all airlines have to be transparent in their emissions. However, I would like it to be easier… If we fly to one country it must be reported, but if we fly to another it does not... The descriptions (of the CORSIA framework) are quite vague… I hope that in the future there is only one system, so we do not have to keep doing double reporting". - SAS

In addition to this aspect only being indicated as an issue in one out of the three interviews, it is related to carbon offsetting practices conducted for regulatory purposes, such as under the EU ETS or CORSIA. As this thesis is concerned with voluntary carbon offsetting, this issue falls outside of the scope. As such, reporting as an area of improvement will not be pursued further in this research.

5.1 Pricing

The next theme identified is the issue of pricing, which consists of the codes "*low price*" and "*volatility*". This theme has been recognized in two of the three data sets.

"The price is volatile. It depends on how many projects exist – some are cheaper, and some are more expensive… Some of the cheaper ones are very low quality and should be stayed away from. This stuff is complicated… Some clients believe it's too cheap, making it seem like (carbon offsetting) has no value." – Chooose

"We have seen a lot of variation with the different airlines, and which providers they use and how the price of these projects are. Two companies can sell carbon compensation from the same project in a developing country, and price it from 6 euro per tonne to 29 euro per tonne." – Chooose

"We would like to see CORSIA with a much larger cost attached to emissions. We find this solution to be relatively weak… The solution is actually a compromise which makes you pay way too little for emissions." – Widerøe

The two respondents found the prices of carbon credits to be volatile and typically too low. The perception was that if the prices of credits are too low, the customer could interpret the quality and value of the initiative as poor. However, the offsetting partner argues that low prices do not necessarily equal low quality, which complicates the matter further. Either way, a client might assume that a low price signifies low quality.

5.1.1 Discussion of Pricing

In order to gain a deeper insight into the findings, the interviews with the blockchain experts who have knowledge of the application of blockchain technology for environmental purposes will be incorporated, in addition to relevant secondary data.

As stated earlier in the thesis, the significant price fluctuations regarding carbon credits entail that the voluntary carbon market is quite volatile (Donofrio et al., 2019). Giving an exact outline of the current prices in the voluntary carbon market is nearly impossible, as the market is extensively fragmented for the reason of an assortment of potential measures, types, and location of projects, offset qualities, and so forth (Bisore & Hecq, 2012). Critics argue that the price of carbon credits is currently far below the estimated costs considering the damage that emissions inflict on the world (David Suzuki Foundation, n.d.).

One of the blockchain interviewees detailed how the market structure can be characterized as an *oligopsony*. This entails that the market consists of relatively few buyers with a great deal of control over the huge number of sellers. The suppliers in the voluntary carbon markets are faced with extensive competition in order to sell their products, a situation that enables the buyers to drive prices down significantly (Kenton, 2018).

> *"The last bit of it, which I think is a problem with the structure of the market is what they call, oligopsony, where you have very few buyers with a lot of market power and a lot of sellers who basically cannot do anything... The asset owner is totally outclassed because of their share size. It is a very uneven industry."* – Ian Choo

Due to the excess supply of carbon credits in the voluntary market, it may prove challenging to stabilize the prices. Furthermore, the lack of a single marketplace makes it difficult for project developers to find a buyer for their carbon credits (Hamrick & Gallant, 2017). These two factors contribute to the current volatility of prices in the voluntary carbon market.

"There are a lot of existing projects that do not have a marketplace or have been operating in a private placement kind of venue …" – Thomas McMahon

Even though the demand influences the supply, there is a definite time gap between the two which is hard to change before the project verification and validation process is effectivized. It usually takes about 2.5 years from the project idea note to the issuance of an offset (Hamrick & Gallant, 2017), which indicates very inefficient process. This was further backed up by one of the respondents.

"Carbon certification in itself is a very inefficient process… Which is quite problematic. Which I'm not sure we can solve yet" – Ian Choo

5.2 Transparency

The Transparency theme consists of the codes: "*transparency*" and "*traceability*". These terms that are often referred to in the same context but are in reality distinct concepts. The reason for this ambiguity even amongst scholars is that there exists a correlation between the two, which will be described further in section 6.1 Supply Chain Transparency. As such, these two codes have been incorporated into one overarching theme. The theme of Transparency has been recognized in all three data sets.

"There are some customers who contact us and want a receipt, who want evidence (of the offset emissions). There are even those who state that they want to travel to Asia themselves to check (the projects) out. Obviously, we cannot offer a trip to our projects, we have 31 million travellers each year, that would not be possible". – SAS

"We do not offer receipts per passenger, that would be a lot more work. On business trips, however, it is possible… The company gets a receipt periodically for their purchases of (climate) compensations… But this is for significantly larger quantities, we are not able to give out a receipt per person… It would be cool to be able to show the other passengers as well… What we have now is more like a delivery report, and you cannot track or follow the sum. You only get one lump sum". – SAS

The airline that currently conducts voluntary carbon offsetting, SAS, emphasized the importance of transparency from a consumer-perspective. They experience a demand from customers to provide evidence of their emissions reduction claims. However, they are currently only able to provide business clients with a periodic receipt of how much carbon emissions their organization has mitigated through carbon offsetting. The general consumers are not able to access information pertaining to the emission-reducing efforts of their particular flight, and as such are not able to track or verify the claims of carbon compensation. Rather, they can only access generic information on the emission reduction claims of the airline through the airlines' public websites. According to SAS, they are not able to provide this service to the general consumer at this time, as it would entail "a lot more work".

> *"...It (blockchain) might ease the uncertainty of the effects of (carbon offsetting), and whether it is documentable from A to Z... There might be less greenwashing (if blockchain is utilized)."* – Widerøe

> *"Airline x[1] have quite low transparency in relation to (which carbon-reducing initiatives) they actually spend their money on... So, there are few who know".* – Chooose

Currently, Widerøe does not provide its customers with the option to offset the carbon emissions of their flights. This decision is reportedly based on their view of carbon offsetting as a form of greenwashing, i.e. the practice of making unsubstantiated claims or misleading consumers about the environmental impact or benefits of a service (Delmas & Burbano, 2011). The interview uncovered that their perception of carbon offsetting as greenwashing is owed to the "uncertainty of the environmental effects" and the inability to document the emission reduction from one end to another. These statements have been interpreted as perceived challenges relating to the transparency and traceability of the current voluntary carbon offsetting practices. The offsetting partner, Chooose, substantiates the perception of low

[1] *A major airline in Scandinavia*

transparency in the Scandinavian aviation industry by directly claiming that one of the major airlines in Scandinavia shows little transparency in their offsetting practice.

5.2.1 Discussion of Transparency

Over the years, the practice of voluntary carbon offsetting has been placed under considerable scrutiny and subject to controversy. According to various research, lack of transparency and quality assurance are frequently described as the main areas of improvement in the voluntary carbon markets (Mair & Wong, 2010). The cause of the scepticism and lack of transparency are reportedly numerous, particularly relating to uncertainties regarding the measurement and impact of emissions reduction efforts (Mair, 2011).

Furthermore, research has also been conducted in the field of carbon offsetting in the aviation sector. The studies demonstrate how there is a low degree of interest in voluntary carbon offsetting schemes, with an adoption rate of only 1%-10% of air travellers (Choi & Ritchie, 2014; Mair, 2011; Zhang et al., 2019). The main causes of this low adoption rate have been recognized as the lack of awareness and knowledge about these schemes among customers (Choi, Ritchie, & Fielding, 2016), and the low degree of transparency and credibility giving a poor impression of the voluntary carbon offset projects (Babakhani, Ritchie, & Dolnicar, 2016). According to Zhang et al. (2019). The perceived lack of transparency and credibility might influence the attitudes and purchase intentions of the consumers. However, this has not yet been examined in a carbon offsetting context.

5.3 Most Prominent Challenge

To determine the direction of the subsequent research, the most prominent area of improvement is selected based on the number of interviewed actors who perceive it as an issue. This research is delimited to one single issue in order to facilitate a more comprehensive analysis. Based on the perceptions of the aviation-related actors in Scandinavia, transparency is identified as the most prominent challenge in the current practice of voluntary carbon offsetting of the industry. In particular, the interviews identified the importance of increased transparency in relation to one stakeholder segment: air-travel consumers. With the theme reoccurring in all three interviews, the researchers find that a potential enhancement would likely prove beneficial to not only the actors in the supply chain but for the end-consumers as well. As such, this research will proceed with the intent of understanding how blockchain technology can be utilized to improve the transparency of voluntary carbon offsetting in the Scandinavian aviation industry. This entails that the issue of pricing is put aside for future research.

6. Theoretical Framework

This chapter aims to provide an overview of the academic literature relevant to this research topic. Two main themes have been identified as essential for further analysis. To start off, the concept of supply chain transparency will be discussed before the authors dive deeper into how the term is impacted by traceability and visibility. The chapter will continue onto a detailed literature review of blockchain technology, with the purpose of establishing knowledge of the characteristics, challenges, and applications of the technology. Finally, the discussion will be completed with a brief overview of the current literature gap in the research literature.

6.1 Supply Chain Transparency

In order to fully grasp the concept of supply chain transparency, the term *supply chain* must be understood. The scope of the supply chain starts at the source of supply and culminates at the point of consumption (Stevens, 1989). Although there exist several definitions, this thesis subscribes to the notion of a supply chain as:

> "*A network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer"* (Christopher, 1992, pp, 320).

Awaysheh & Klassen (2010) define transparency as the degree to which information is available to both parties in an exchange, in addition to outsiders. In a supply chain context, transparency captures the extent to which stakeholders have access to, and a shared understanding of, product-related information on request "*without loss, noise, delay or distortion*" (Beulens, Broens, Folstar, & Hofstede, 2005, p. 482). This includes end-users, as well as other firms in the supply chain. As such, supply chain transparency requires a company to be aware of what is occurring upstream in the chain and further communicate this information both internally and externally (Bateman & Bonanni, 2019).

Increasingly, consumers, governments, and other stakeholders are demanding more information about the supply chains of a company (Bateman & Bonanni, 2019). Transparency is demanded in aspects such as production practices, labour conditions, food integrity, and environmental sustainability. As the consumer expectations of product origins are increasing, consumers are becoming more insistent on verifying the claims of a company (Francisco & Swanson, 2018). Although all products have a history, much of this history is often obscured. With the increasing awareness, the reputational costs of failing to meet the demands and expectations of transparency have often grown high (Bateman & Bonanni, 2019), and the exposure of negative or deceitful practices rapidly lead to financially crippling proportions (Francisco & Swanson, 2018).

Historically, motives of quality and safety, and the resulting legal requirements, have been the main drivers of transparency efforts. However, in the past decade, the interest has shifted to the benefits of transparency in relation to cooperative operational optimization and performance within ethical and socially sound supply chains (Bastian & Zentes, 2013).

Although often mentioned in the same setting, transparency and traceability are distinctive concepts carrying different meanings. Traceability may be defined as the ability to identify and verify the different components in every stage of a process, as well as the chronology of events (Skilton & Robinson, 2009). It allows companies to deliver more credible social and environmental claims by being able to track and verify the origin and journey of a product and their inputs.

Scholars have recognized a correlation between optimizing transparency and traceability, which might explain why the concepts are often used interchangeably. Francisco & Swanson (2018) describe how supply chain traceability leverages transparency in order to *"operationalize organizational goals related to raw material origins and provide context to a final product or service"* (p. 2). Being transparent, i.e. having more information available, has been found to lead to increased traceability. However, traceability is limited if material information is found to be missing or incomplete, or when the complexity of a supply chain results in concealed elements. Higher complexity can be found in supply chains where there is not a single source producer, but rather several producers located in different countries (Francisco & Swanson, 2018).

As previously mentioned, supply chain transparency requires a company to be aware of what is occurring upstream in the supply chain (Bateman & Bonanni, 2019). Without possessing knowledge internally of the activities occurring across the chain, it will prove impossible to communicate timely and accurate information externally. As such, *supply chain visibility* can be seen as a prerequisite in obtaining supply chain transparency. This research subscribes to the definition of supply chain visibility as:

> *"The extent to which actors within a supply chain have access to or share the information which they consider as key or useful to their operations and which they consider will be of mutual benefit"* (Barratt & Oke, 2007, p. 1230).

The concept of supply chain visibility does not entail that each stage should share all information with all parties across the supply chain, but rather that the data shared is perceived as relevant and meaningful (Kaipia & Hartiala, 2006). As such, end-to-end visibility involves sharing all relevant information with the appropriate actors in the supply chain. According to Gates, Mayor, & Gampenrieder (2016), end-to-end visibility reduces the risk of supply chain failure, as it translates into more reliable information across the chain. The most significant barriers to supply chain visibility are described by Butner (2010) as organizational factors as opposed to technological factors. This includes organizational data systems, lack of time, increased levels of work, and reluctance to share information (Somapa, Cools, & Dullaert, 2018).

Although supply chain visibility and supply chain transparency are distinct concepts, they can be expressed as mutually supportive of one another (Bell, Mollenkoph, Meline, & Burnette, 2016). Shay Scott, the managing director of Global Supply Chain Institute, describe the relationship as following:

> *"Visibility provides a company with knowledge of activities across its supply chain: transparency is what and how it communicates that knowledge to customers, partners, and stakeholders."* (Inbound Logistics, 2017, p. 4).

Kaipia & Hartiala (2006) identifies five development areas in data sharing from a visibility point of view. One of these is the "*benefit from a collaborative relationship with customers"* (p. 386). As consumers are increasingly demanding access to more information regarding product origin and aspects surrounding the production of a product, it has become important for companies to focus on a transparent relationship with their consumers. In order to generate more transparency, both visibility in the supply chain and disclosure of information to the end-consumer is essential (Kraft, Valdés, & Zheng, 2018).

Although the relationships between supply chain visibility, transparency, and traceability are arguably closely related and interconnected, understanding the difference will support the accomplishment of a comprehensive analysis in this research. In essence, visibility refers to the extent to which the actors in a supply chain are able to view and access accurate and timely information upstream and downstream (Somapa et al., 2018), whereas traceability relates to the ability to track and trace products across the supply chain. Finally, transparency shifts the focus from an internal supply-chain perspective to external stakeholders and is concerned with proactive engagement and communication with customers, NGOs, governments, and other stakeholders (Bell et al., 2016).

In this research, visibility is seen as a prerequisite for transparency. If the actors in the supply chain are not able to communicate relevant information internally, it will prove problematic to communicate it externally. As such, when discussing the extent to which the different parties are able to access information across the supply chain, it translates to supply chain visibility. Moreover, any information communicated externally is interpreted as supply chain transparency. In this research, providing the consumers with enhanced transparency simultaneously entails facilitating the ability to trace assets in the supply chain.

6.2 Blockchain Technology

Satoshi Nakamoto, the pseudonym of the developer or developers of bitcoin, introduced the world to blockchain technology in 2008. For the first time, a solely peer-to-peer network allowed users to trade electronic assets between themselves without relying on an intermediary (Nakamoto, 2008). As such, the system provided a solution for establishing trust in an uncertain environment, without the reliance on a middleman (Ølnes, Ubacht, & Janssen, 2017). While blockchain technology was introduced through Bitcoin, its applications have gone beyond cryptocurrencies. Today, blockchain is being described as capable of transforming several fields, amongst others bookkeeping, management, and law. Consequently, three generations of blockchain technology have been formed, "*Blockchain 1.0 for digital currency, Blockchain 2.0 for digital finance,* and *Blockchain 3.0 for digital society*" (Zhao, Fan, & Yan, 2016, p.1).

There are numerous ways of defining the concept of blockchain. One of the most extensive descriptions has been formulated by Seebacher & Schüritz (2017), who provided a definition based on peer reviewed literature:

> "*A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by public-key cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity."* (Seebacher & Schüritz, 2017, p.3).

In simpler terms, blockchain is a database that is shared with and accessible to every participant in the network, constantly synchronized and with consensus across different domains to enable the integrity of data. With that, blockchain is also referred to as a distributed ledger technology (DLT) (Ølnes et al., 2017). With the shared, reliable, and public register of transactions, a blockchain enables users to examine the transactions without controlling them. Blockchain is described as offering transparency and accountability of information, with one of its main attributes being its ability to keep track of the full lifecycle of each transaction through a decentralized method of ownership (Foerstl, Schleper, & Henke, 2017).

The term blockchain is derived from its inherent architecture, consisting of a list of records, i.e. blocks, that are rapidly growing and linked through cryptography. Hashing, a method of cryptography, is essentially taking any length of an input string which returns a fixed-length output combined of text and numbers. Each block is connected with preceding blocks through a hash of the previous block: the parent block. The blocks in the chain store transaction information and a new block is created once a transaction is validated (Rosic, 2016). The validation of the broadcasted blocks happens through computers referred to as nodes. Nodes are critical components within the blockchain architecture, as they are what makes the data accessible. A node can be seen as a participant in the network (Franco, 2014). As illustrated in figure 4, after a transaction is validated, the block is added onto the chain. In that regard, the blockchain is a resourceful yet simple method of transferring information from one entity to another in an automatic manner (Rosic, 2016).

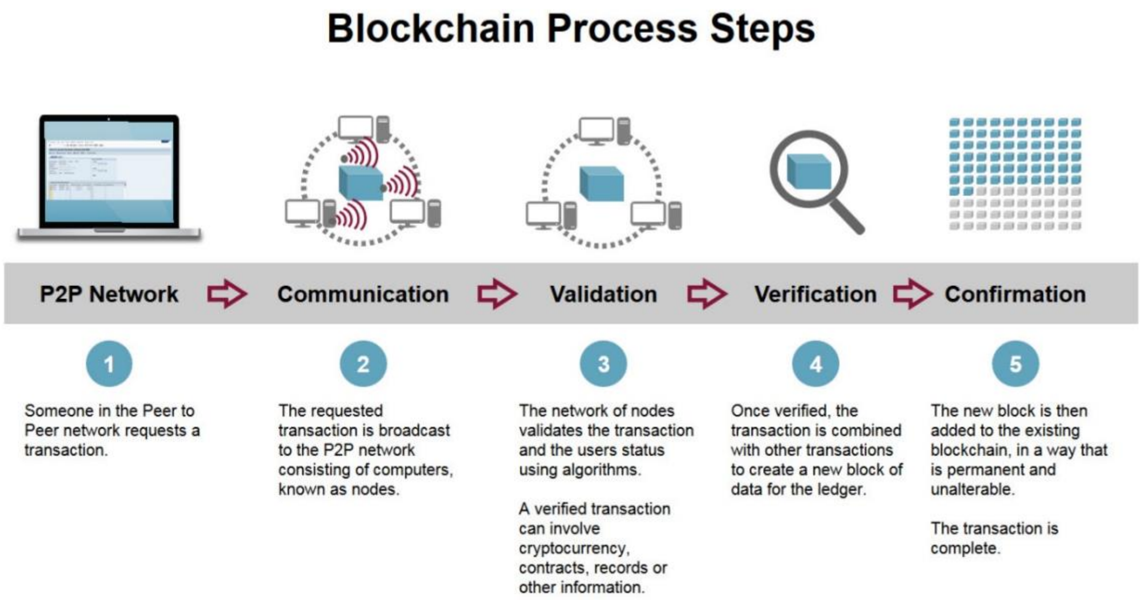

Figure 4: Blockchain Transaction (Kommana, n.d.).

Contrary to traditional databases, users are not able to update or delete existing data in a blockchain. Rather, it utilizes an append-only data structure, where users are allowed to add further data in the form of blocks, or access existing data. As such, the two operations within a blockchain are *read* and *write* abilities. The read ability refers to operations where the goal is to retrieve and question data from the blockchain. On the other hand, the write operation entails contributing to the blockchain by adding more data onto it (Ray, 2018).

6.2.1 The Three Pillars of Blockchain Technology

Rosic (2016) defines the three pillars of blockchain technology as *decentralization*, *transparency*, and *immutability*. These aspects are referred to as the three most fundamental characteristics of blockchain technology.

Decentralization

One of the key features of blockchain technology is its decentralized network, enabled by several core attributes. Figure 5 illustrates the difference between centralized and decentralized systems. Contrary to a conventional centralized system, a decentralized framework has no core entity that controls and dictates the other involved parties. This entails that all members of a fully decentralized blockchain network have the ability to confirm new transactions and access the history behind past transactions (Wang, Zheng, Xie, Dai, & Chen, 2018). By enabling any two peers of the blockchain to conduct a transaction without a third-party authority, the technology has the ability to diminish bottlenecks at the central server (ibid). Furthermore, the data in a decentralized system is not stored in one spot, as information is owned by all participants. This characteristic makes the system harder to hack (Rosic, 2016).

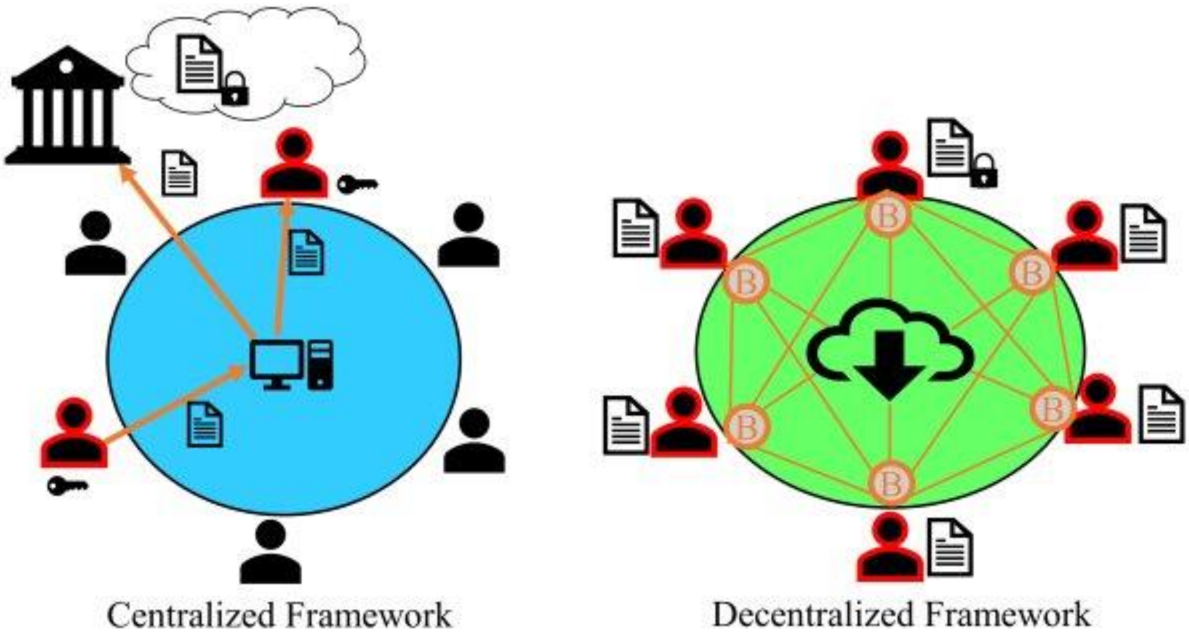

Figure 5: Centralized Framework vs. Decentralized Framework (Puthal, Malik, Mohanty, Kougianos, & Yang, 2018).

While the traditional Blockchain is decentralized, several newly emerging platforms have implemented one or more leader nodes with the sole responsibility of collecting, validating, and broadcasting transaction information (Superoneio, 2018). Although these systems are less decentralized, they are a great deal faster. Consequently, there exists a trade-off between speed and decentralization, which will be detailed further in section 6.2.7 Blockchain Challenges.

Transparency

Arguably one of the most interesting features of blockchain technology relates to its ability to enable privacy in combination with transparency. This aspect has led to some confusion regarding how transparency and privacy can coexist in an efficient manner. The identity of a person is concealed through complex cryptography, and the person is exclusively represented by their public address. Linking a public address to an individual is quite hard to accomplish, which in turn secures the individual's real identity. On the other hand, the moment the public address can be linked back to them, all transactional information the entity has engaged in becomes accessible (Seebacher & Schüritz, 2017).

Blockchain is said to increase transparency as information is made public between participants without the influence of a third-party (Seebacher & Schüritz, 2017). With the embodied element of transparency, blockchain increases trust as transaction details are broadcasted to the entire network. As a consequence, it forces companies to be more straightforward when conducting business, something they may not have had to deal with previously. As such, the technology allows for transparency and traceability across the supply chain, by providing stakeholders with the ability to monitor and track transactions and information across the supply chain (Rosic, 2016).

Immutability

Blockchain is said to be immutable in the sense that once data has entered the blockchain, it cannot be interfered with. This is due to the cryptographic hash function blockchain embodies, which enables the traceability of change (Abeyratne & Monfared, 2016). Even if minor changes are made to the input variable, the changes reflected in the hash will be vast. Further, as the blocks are linked through hash pointers of the previous blocks, changes made to the data in one block will be manifested in the hash stored in the previous blocks (Rosic, 2016). This permits procedures and mechanisms empowered by blockchains technology to work with an elevated level of certainty since the network provides a complete and unaltered history of actions (Bogard & Rice, 2015). As a result, it becomes more difficult for companies to "work the books" (Rosic, 2016).

6.2.2 Capabilities of Blockchain Technology

The capabilities of blockchain technology go beyond just transferring and storing money. The technology may replace processes that rely on transaction costs and embodies the ability to cut out the middleman, eliminating the need for a match-making platform (Rosic, 2016). To gain a deeper insight into Blockchains technology, it is necessary to shed some light on certain aspects closely related to the technology.

Digital Signature

A digital signature is a mathematical scheme that utilizes cryptography to implement electronic signatures to ensure the authenticity of digital messages (Agrawal, 2018). Each user within the network has both a private and a public key, with the purpose of encrypting and decrypting data. The public key is shared with everyone in the blockchain and is essentially a hashed version of the user's unique public address (Frankenfield, 2018a). In contrast, the private key is withheld and kept secret. In essence, a transaction is signed using the private key and broadcasted to a peer-to-peer network, whilst the public key is used by the other parties to verify and access the transaction (Wang et al., 2018; Agrawal, 2018).

Consensus Mechanism

In a decentralized system, there exists no central authority with the task of maintaining the database. As such, mechanisms must be in place to guarantee that each transaction is genuine and that all peers achieve agreement on the state of the network (Frankenfield, 2019). Consensus mechanisms can be described as algorithms that allow nodes to cooperate in a distributed system, essentially ensuring that all participants reach a consensus on a single source of truth (Binance Academy, n.d.).

There exist many ways to reach consensus, depending on the intended purpose and type of blockchain. The original and most recognized consensus mechanism is the *Proof-of-Work*

(PoW) approach. The PoW approach ensures authenticity and verifiability by requiring a complicated computational task to be solved, such as identifying hashes with specific patterns, in order to confirm transactions and thereby generate new blocks (Casion, Dasaklis, & Patsakis, 2018). This approach is also referred to as a mining process, where nodes (miners) compete to complete puzzles in order to be the one to establish a consensus point (Hammerschmidt, 2017). The process is incentivized to facilitate broad participation, with the first miner to solve the puzzle receiving a monetary reward (Berke, 2017). A notable disadvantage of the PoW approach relates to the massive computational power and expenditures necessary to run the complicated algorithms. As a consequence, PoW mining has been described as *"consuming more energy than many small countries"* (Skalex, n.d., p. 2).

An alternative consensus mechanism is *Proof-of-Stake* (PoS). This method is often described as a more environmentally friendly approach, due to the significant decrease in power consumption relative to PoW. While PoW requires users to repeatedly run complicated hashing algorithms, the PoS allows a user to validate block transactions by providing their stake of the network. The highest stake gets to validate the transaction (Voshmgir & Kalinov, 2017). The algorithm employs the idea that if a peer has invested a sufficient amount of funds in the network, the loss related to performing a damaging attack on the network outweighs any potential gain (Bashir, 2017). Similar to the PoW, the PoS also provides incentives to the leader of the new block, thereby facilitating the broadest network participation possible, and as such the most robust security achievable (Hammerschmidt, 2017). Increasingly, traditional PoW networks are transitioning into PoS, generally contributed to the increased energy efficiency caused by the elimination of high-powered computing. Ethereum is one platform reportedly transitioning into PoS (Won, 2020).

An additional consensus mechanism is the *Proof-of-Elapsed-Time* (PoET) approach. Although newer and not as recognized as the previous two, this mechanism has been included in this research due to its insignificant resource usage and energy consumption. Furthermore, one of its most recognized usage areas is for the Hyperledger Sawtooth, which will be further described in section 6.2.4 Ethereum & Hyperledger. Contrary to PoW and PoS, PoET functions like a fair lottery system where each node in the network has an equal chance of being selected as the leader. As such, this mechanism is founded upon the notion of spreading the winning chances fairly across participants (Frankenfield, 2018b). Each individual peer in the blockchain network must wait for a random amount of time, with the time being determined by a sample containing a random variable. The first participant finishing the waiting time is selected as the leader of the new block (Hyperledger, n.d. a). In other words, the participant with the smallest sample, and as such the shortest waiting time, wins. The PoET consensus mechanism is frequently utilized for permissioned networks, which requires participation access to be granted (Wang et al., 2018).

Smart Contracts

"*A smart contract is a computerized transaction protocol that executes the terms of a contract*" (Szabo 1994, p. 1). Originally coined by Szabo in the 1990s, the term *smart contracts* embed all sorts of property assessed by digital means (Szabo, 1997). The concept of smart contracts has progressed since the 1990s, particularly following the introduction of blockchain technology. These contracts are running pieces of codes on top of the blockchain network, where the digital assets are controlled by arbitrary rules implemented by these pieces of code. A smart contract will automatically execute a transaction when all parties of a contract fulfil the predetermined arbitrary rules (Voshmgir & Kalinov, 2017). These predetermined rules allow for the performance of credible transactions without the need for a middleman or third-party intervention. As such, smart contracts have the potential to enhance efficiency and reduce costs (Hu et al., 2019), in addition to increasing transparency as the information and logic of the contract are visible to all participants in the network (Kukkuru, n.d).

As smart contracts are devised for and implemented within blockchains, they assume certain properties of the technology. That is, they are immutable and distributed. As such, the contract cannot be changed, and it is not possible for parties to break a contract following its creation (Tania H., 2020). Moreover, the distributed nature entails that the result of the contract is validated by all network participants, and no single entity or person has control of the transactions (ibid). The incorporation of smart contracts on permissioned blockchains are increasingly recognized for business collaborations (Hu et al., 2019). With supply chains growing more complicated and fragmented, smart contracts can reduce delays, human errors and trust between parties (Holder, 2018).

Tokenization

Within blockchain technology, tokenization is the procedure of issuing blockchain tokens that digitally represent real-world exchangeable assets (Laurent, Chollet, Burke & Seers, 2018). Following the issuance of a token, the blockchain records and maintains a ledger of every individual movement the token undertakes, proving its usefulness in facilitating the storage and transfer of cryptographic tokens in a frictionless manner (Uzsoki, 2019). A vital attribute of tokenization in blockchain relates to the double-spending problem. Previously, digital assets such as documents or images could be replicated a limitless number of times. However, the permanent and immutable record of blockchain transactions entails that this problem can conceivably be overcome (CoreLedger, 2019).

In essence, tokenizing an asset, whether intangible or tangible, entails issuing a digital token on a blockchain, where the blockchain will keep a record of the issuance and maintaining a distributed ledger of each and every movement of that unique token. Moreover, blockchain proves its usefulness when an intangible asset, such as a carbon credit, exchanges hands. Issuing the carbon credit as tokens on the blockchain entails that these tokens can be "*registered, tracked, and traded*" (Francisco & Swanson, 2018, p. 3). With these features, enhanced supply chain traceability and transparency could be achieved through the utilization of tracking technologies, such as barcode scanners (Francisco & Swanson, 2018).

6.2.3 Different Types of Blockchains

Blockchains are constructed differently depending on the area of use. Buterin (2015) describes blockchain-like database applications to fall within three main categories: *public*, *consortium*, and *fully private* (table 4). The original blockchain underlying Bitcoin is an example of a public blockchain. Anyone in the world can contribute to the core activities of a public blockchain, making it the most decentralized network available (Wang et al., 2018). Operating on an incentivizing scheme, the public network encourages new entrants to join and facilitate in the agility of the network. One of the most prominent disadvantages of a public blockchain relates to the heavy power consumption that is critical in maintaining a public distributed ledger (Seth, 2018).

The consortium network type embodies a blockchain where the consensus process is controlled by a pre-screened set of nodes. The systems can be described as quasi-private, as it has a controlled user group but simultaneously possesses the ability to work across different organizations (Yafimava, 2019). Within a fully private blockchain, the permissions to write are concentrated within one organization, whilst the read permissions may either be public or limited to a certain number (Buterin, 2015).

Property	**Public Blockchain**	**Consortium Blockchain**	**Private Blockchain**
Consensus determination	All miners	A selected set of nodes	One organization
Read permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Centralized	No	Partial	Yes
Consensus process	Permissionless	Permissioned	Permissioned

Table 4: Public Blockchain, Private Blockchain & Consortium Blockchain (Wang et al., 2018, p. 358).

In a public blockchain, there are no restrictions regarding who is permitted to join the network. As such, a public blockchain can be classified as *permissionless* (Wang et al., 2018). Furthermore, there does not exist an administrative unit controlling the network, overseeing memberships, or prohibiting illegitimate users. When a ledger has this degree of openness, it entails that the written content is readable by the general public as well as all peers (Wüst & Gervais, 2018). In contrast, a *permissioned* blockchain implies that only a limited number of users are authorized to join and partake in the core activities, as is the case with both consortium and private blockchains. As such, a node must be verified to be a part of the consensus process in a permissioned blockchain (Wang et al., 2018). An administrative unit assigns permissions, whether it is read, write, or both, to the right individual peers allowing them to partake (Wüst and Gervais, 2018).

6.2.4 Ethereum & Hyperledger

Although there exist several blockchain networks, Ethereum and Hyperledger have been described as having conquered their respective domains of public and permissioned blockchains (Blockgeeks 2019a). Furthermore, both have historically been utilized in supply chains to improve transparency and traceability (Provenance, 2015; Sawtooth, n.d. a). As such, this research intends to exclusively focus on these platforms in the subsequent analysis. The most prominent distinguishing feature between the two platforms relates to the purpose they have been designed for. On one hand, Ethereum is an open-sourced and public platform. It runs smart contracts for applications that are created for decentralization and mass consumption (Prerna, 2019). On the other hand, Hyperledger is designed to leverage blockchain for business-to-business (B2B) transactions, created with the requirements of organizations in mind (Sahu, 2020). Table 5 illustrates several differences between the two platforms in relation to the aforementioned aspects surrounding blockchain technology.

Ethereum

"Ethereum is a global, open-source platform for decentralized applications" (Ethereum, 2020a, p. 1). What distinguishes Ethereum from other cryptocurrencies and blockchains is its programmable capability. This capability entails that developers may utilize the platform to build new kinds of applications that are capable of doing things their traditional counterparts may not be (Ethereum, 2020b; Ethereum, 2020c). Applications built on Ethereum, known as decentralized applications (dapps), are open-source software that leverage blockchain technology (Blockgeeks, 2019b). Essentially, dapps are web applications supported by Ethereum smart contracts; codes running on Ethereum that can control digital assets (Ethereum, 2020c).

Ethereum has been created specifically for the purpose of executing smart contracts, with these contracts constituting the core of the platform (Oliva, Hassan, & Jiang, 2020). In essence, Ethereum allows developers to build applications (dapps) consisting of multiple smart contracts, which are executed following the rules programmed by the developer (Brock, 2018). As such, developers may benefit from utilizing Ethereum's existing infrastructure rather than creating a completely new blockchain from scratch (Xie, 2017). The platform is able to support financial applications as well as non-financial applications, enabling the decentralization of close to any service (Brock, 2018).

Hyperledger

Contrary to Ethereum, Hyperledger does not support a cryptocurrency, but rather operates as a hub for the development of open industrial blockchains (Rosic, 2017). "*Hyperledger is an open-source community focused on developing a suite of stable frameworks, tools, and libraries for enterprise-grade blockchain deployment"* (Hyperledger, n.d. b, p. 1). Hyperledger leverages a permissioned blockchain, which entails that all the participants are known to one another, and as such have an inherent interest in contributing to the consensus making process. All participants, once accepted into the network, share the ledger system. Additionally, participants are able to share information with a higher degree of security than what one could expect from a normal database (Hyperledger, n.d. b). Common amongst enterprise blockchain applications is the reliance on real-world trust between the parties involved. The objective is setting up entities in an adaptable ecosystem with the needed insurance of the boundaries being flexible enough to include additional participants in the future (ibid).

As information is mirrored accurately across all the nodes in a network, every entity keeps a duplicate of the common system of records where the data cannot be eradicated or altered (Hyperledger, n.d. b). Hyperledger projects are divided into six distributed ledgers: Hyperledger Besu, Hyperledger Burrow, Hyperledger Fabric, Hyperledger Indy, Hyperledger Iroha, and Hyperledger Sawtooth. Considering the purposes of this research, it is found that the Hyperledger Sawtooth could be a suitable platform, having been implemented in supply chains "*to trace the provenance and other contextual information of an asset*" (Hyperledger, n.d. c, p. 47).

"Hyperledger Sawtooth is an enterprise blockchain platform for building distributed ledger applications and networks" (Hyperledger, n.d. c, p. 1). Its primary objective is to maintain ledgers in a distributed manner and produce safe smart contracts. The system allows developers to decide on several aspects that best suit their unique business requirements, such as transaction rules, permissioning, and consensus algorithms (Hyperledger, n.d. c). A distinctive feature with the Sawtooth system is the separation between the application system and the core

system. Sawtooth is attempting to solve challenges surrounding private permissioned networks, by having no centralized service that might leak classified data (ibid). Since its implementation, Sawtooth has among other things been utilized for marketplace transaction tracking where exchange for a digital asset is tracked using smart contracts allowing for consistent data records between different parties, enabling immutable transactions records (Sawtooth, n.d. b). Additionally, the platform has been utilized for enabling supply chain traceability and accountability (Sawtooth n.d. c). It is acknowledged that other Hyperledger platform could similarly provide suitable alternatives, however, this research is delimited to analysing one of them.

Ethereum vs. Hyperledger Sawtooth

	Sawtooth	**Ethereum**
Ledger type	Permissioned and permissionless	Permissionless
Nodes	Fully decentralized	Fully decentralized
Consensus	PoET	PoS, PoW
Cryptocurrency	No	ETH
Smart contract	Yes	Yes
Transaction structure	Custom transaction structure	Single transaction structure
Transaction per second (TPS)	1300	15-20

Table 5: Hyperledger vs. Sawtooth (Mason, 2018; Caro, Ali, Vecchio & Giaffreda, 2018; Hyperledger, n.d. c; Anwar, 2019; Mahatma, 2019; Anwar 2020; and Sitoh, 2018).

6.2.5 Internet of Things

Internet of Things (IoT) relates to the interconnected network of everyday objects to empower the collection and exchanging of data (Xia, Yang, Wang, & Vinel, 2012). IoT has become a prominent path in endorsing the smart world, creating a connection between the physical and virtual environment in order to support its users in their undertakings. The true value of IoT is described as realized when communicating devices are able to successfully integrate with other technological applications (Lee & Lee, 2015). According to Gartner (2014), the information sharing and collaboration facilitated by IoT will transform the way supply chains operate, and the information available to parties in the supply chain.

Most IoT applications are based on a centralized architecture intertwined with the cloud servers through the internet. Although these systems have their advantages, such as flexible computation and data management capabilities, they face an assortment of security issues. Amongst others, blockchain technology may assist with monitoring, governing, and securing IoT devices (Hang & Kim, 2019). IoT devices are attached to a specific item that works through the web, empowering the exchange of information among items or individuals consequently without human mediation (HLC, n.d.). Merging IoT and blockchain technologies could be prevailing, and consequentially may change serval industries. Through the utilization of smart contracts, IoT devices may carry out self-governing transactions (Kshetri, 2017).

6.2.7 Blockchain Challenges

In light of the relative immaturity of blockchain technology, there are several bottlenecks and challenges inhibiting widespread adoption. This section is concerned with presenting some of the most prevalent ones relevant to this research.

To start off, the lack of awareness and understanding of the technology is often described as one of the principal challenges to adoption. Many organizations still associate blockchain with Bitcoin, only accepting it as a means of payment (Anwar, 2018). Misinformation and knowledge gaps are common (Nguyen, 2019), which often results in organizations not fully understanding the capabilities of blockchain and its application outside of cryptocurrencies. Moreover, at the point when organizations receive new technology, the context of that innovation assumes a significant position. How individuals manage the material properties of the new technology is influenced by their past experience of utilizing similar technologies before. As such, how organizations adopt blockchain is reliant upon how existing and related obstacles are resolved (Rijmenam, 2019).

The aforementioned energy consumption of numerous blockchain platforms is extensive, with the process of mining under PoW using colossal amounts of electricity (Wachal, 2019). This challenge, however, is reduced drastically when employing more environmentally friendly consensus mechanisms, such as PoS or PoET, and permissioned blockchains, as the computational power required to support smaller networks is highly reduced (Marr, 2019).

An additional challenge of adopting blockchain is the substantial initial costs. Although cost reductions are often accredited as one of the long-term benefits of blockchain, the implementation of the technology can require extensive investments. This includes the development of software and specialized hardware (Surjanto, 2018), however the final price will vary with project requirements. Furthermore, the successful adoption of blockchain technology requires qualified personnel to be employed to handle the network internally. In addition to the added costs of salaries for the new personnel, this can prove challenging due to the recency and rapid growth of the technology. Numerous organizations are demanding qualified personnel, but not that many individuals possess the required skill set (ibid).

Furthermore, the value created by blockchain technology is most apparent when organizations work together towards a shared goal, such as an industry-wide initiative (Swanson, n.d.). Currently, several industries contain different blockchains and applications built independently. In any one industry sector, different organizations are building their chains to dissimilar standards (ibid). This lack of standardisation amongst blockchains has resulted in an inability to create interoperability between networks. Numerous blockchains have been developed as standalone platforms, with different protocols, consensus mechanisms, privacy measures, and coding languages (De Meijer, 2020). The lack of universal standards prevents the different networks from communicating with one another efficiently, and the challenge will likely not be overcome before industry-wide standards are established (ibid).

Moreover, there are challenges relating to the utilization of blockchain technology in the context of personal data, which is defined as information regarding an identified or identifiable natural person. Enforced in May 2018, the General Data Protection Regulation (GDPR) is a regulation in EU law on data protection and privacy for citizens of the EU and EEA. One particular challenge relates to the assumption of the GDPR that it must be possible to modify or erase personal data to comply with legal requirements (Finck, 2019). This is fundamentally incompatible with the append-only data structure of blockchains, as users are not able to update or delete existing data. Rather, it is only possible to add further data or access existing data. As such, aligning the GDPR's principles of storage minimization with the immutability of blockchain is challenging (ibid).

Furthermore, whilst blockchain is more secure than its traditional centralized counterparts, it is still possible to breach systems, apps and businesses supported by blockchain technology (De Meijer, 2020). Several recent studies have investigated whether blockchain is as secure and private as it is claimed to be. Zhang, Xue, & Liu (2019) found that only a limited number of blockchain platforms can truly achieve the attributed set of security goals in practice.

Finally, a major challenge to the widespread adoption of blockchain technology is described through the *blockchain trilemma*. This trilemma addresses the notion that it is impossible to scale a blockchain network without compromising either decentralization, security, or both (Febrero, 2020; figure 6). It is believed that blockchains are only able to achieve two out of these three traits at any one time (Ometoruwa, 2018). As such, the trilemma refers to the trade-offs that blockchain developers must make when determining how to advance the fundamental design of their blockchain (NeonVest, Viswanathan, & Shah, 2018).

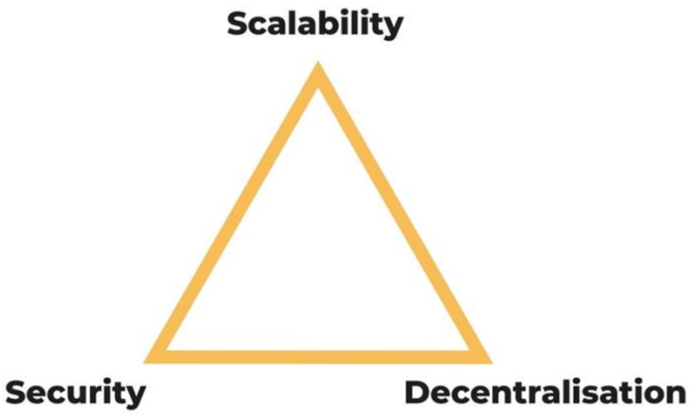

Figure 6: The Blockchain Trilemma

Scalability has long been recognized as perhaps the most prominent technical challenge needed to tackle for the technology to be implemented in various fields (Buterin, 2018). The scalability aspect is perceived as especially difficult to tackle due to the fact that the traditional blockchain requires every node in the network to process every single transaction. As such, the processing capacity of the entire network is limited to the capacity of a single node (Buterin, 2018). If the blockchain was to be secure and decentralized, like Bitcoin, it would be costly and slow to run global services efficiently. In contrast, achieving scalability and security comes at the cost of decentralization, which would entail that the system has central nodes that may suppress the network and manipulate its governance. Finally, having a blockchain that is decentralized and scalable involves a lack of security, which inevitable is an unacceptable trait for most blockchain networks (Vazz, 2019).

The challenges related to scalability of blockchain platforms are however not as prevalent for permissioned networks (De Meijer, 2020). This is due to the generally higher transaction throughputs possible in a permissioned blockchain. Scaling a network that is more static and with pre-agreement is more affordable and less demanding than scaling an open, dynamic network (Lyons, Courcelas & Timsit, 2019). As such, these blockchains are more scalable and faster than their permissionless counterparts, but also less decentralized as a consequence.

6.3 Literature Gap

This thesis is concerned with areas of research that are relatively young: blockchain technology and voluntary carbon offsetting in the aviation industry. More specifically, incorporation blockchain technology in order to improve supply chain transparency in the practice of voluntary carbon offsetting. In light of the recency of the phenomena, the existing literature is limited.

Existing research concerned with the transparency-enabling features of blockchain within the supply chain is frequently related to the manufacturing of tangible assets. Abeyratne & Monfared (2016) reviewed the adoption of blockchain technology in the supply chains of manufacturing businesses and found that the technology has the potential to improve transparency and traceability. This is attributed to blockchains inherent capabilities of immutable data records, distributed storage, and controlled user access (ibid). Similarly, Galvez, Mejuto, and Simal-Gandara (2018) suggest that the implementation of blockchain technology can facilitate food traceability by allowing all stakeholders to access the full history and current location of a product. Moreover, the same premises can create transparency for all participants, thereby strengthening relationships with existing customers and attracting new ones (ibid).

Scholars have also explored the application of blockchain technology in sustainable and green supply chains. Rane & Thakker (2020) describe how the properties of the technology can facilitate increased visibility and process control in green procurement, through the ability to track product information from supplier to customer. As such, blockchain can ensure that the suppliers and consumers in a supply chain are well connected. Incorporating IoT sensors and monitoring technology allows for immediate information relating to real-world objects to be gathered, which in combination with blockchain may facilitate increased transparency, efficiency, and reliability (ibid). Moreover, the researchers found that merging blockchain and IoT has the ability to ease the tracking of greenhouse emissions across the supply chain. However, they emphasize that not all actors in a supply chain are equipped for, or comfortable with, sharing information on a platform accessible to all parties (ibid).

In relation to the literature on the application of blockchain for carbon markets, this thesis finds that existing research is generally concerned with regulatory markets (Jackson, Lloyd, Macinante, & Hüwener, 2018; Dong et al., 2017; Hartman & Thomas, 2020), or with a focus on the creation of new carbon market schemes (Kawasmi, Arnautovic & Svetinovic, 2015). As such, the available data to draw upon is limited. To the best of the knowledge of the authors, there exists no previous literature on utilizing blockchain to enhance supply chain transparency in the voluntary carbon market of the aviation industry. In light of this, this research identifies the aforementioned topic as an area that is underexplored, constituting a literature gap.

7. Analysis

In this section, the findings from the qualitative and quantitative data collection will be introduced and combined with the theoretical framework to answer the main research question:

How can blockchain technology facilitate improved transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry?

b) *How does the identified issue correspond with consumer demand?*
c) *Where in the supply chain, and how, is transparency currently being inhibited?*
d) *How can the properties of blockchain technology alleviate the pain points inhibiting consumer transparency?*

In section 5 of this research, transparency was identified as a challenge of voluntary carbon offsetting in all three aviation-related interviews and subsequently determined to be the most prominent area of improvement in the Scandinavian aviation industry. As previously mentioned, transparency captures the extent to which stakeholders have access to, and a shared understanding of, product-related information on request (Beulens et al., 2005). In particular, the interviews identified the importance of increased transparency in relation to one stakeholder segment: air-travel consumers. In order to answer the research questions above, this study will proceed with the intent of understanding how technology can be utilized to improve the transparency in the practice of voluntary carbon offsetting in the Scandinavian aviation industry from a consumer-perspective.

To be able to increase the accessibility of information relating to end-consumers, the company itself must be aware of what is occurring upstream in the supply chain (Bateman & Bonanni, 2019). Without possessing knowledge internally of the activities occurring across the chain, it will likely prove impossible to communicate precise and timely information externally. In other words, supply chain visibility can be seen as a prerequisite in order to increase transparency towards the consumer.

7.1 How Does the Identified Issue Correspond with Consumer Demand?

In order to understand whether the perceptions of the actors in the aviation industry coincide with consumer demand, quantitative data collection has been conducted through an online questionnaire. The data collection primarily provides insight into the general interest in carbon offsetting among air-travel consumers, in addition to the perceived importance of several aspects related to transparency. The primary objective is to uncover whether enhanced transparency can increase the appeal, and thus demand, of voluntary carbon offsetting amongst air-travel consumers in Scandinavia. The intent of this research is to facilitate enhanced transparency through the implementation of an app that allows air-travel consumers to access the individual offsetting activities pertaining to his or her flight. As such, the questionnaire has been designed with this app in mind.

The questionnaire received 283 recorded responses. After cleaning the data of partial responses, 220 responses were deemed valid for further analysis. Out of the participants, 70.97% are female, 28.57% are male, and 0.46% prefer not to divulge this information. Further, the majority of respondents, 60.37% to be exact, are between the ages of 21-29. The questionnaire was unsuccessful in gathering data from respondents aged 17 and younger, therefore this category has been excluded from the analysis. Although not unexpected considering the convenience sampling of this questionnaire, it does entail that the findings might not be representative of the whole population.

Following a short description of carbon offsets and the offsetting practice in Scandinavian airlines (appendix 8), participants were asked to rate their general interest in offsetting the carbon emission of their flights.

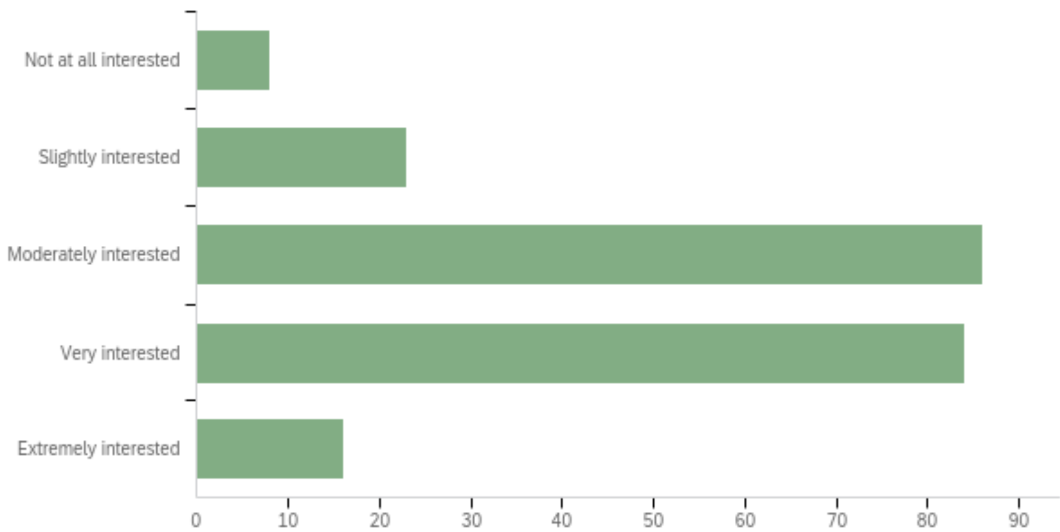

Figure 7: Results of Q6: "Based on what you just read, is offsetting the carbon emissions of your flight something you would be interested in?".

According to the results in figure 7, the participants' initial interest in offsetting the carbon emission of their flights can be described as moderate, with a mean of 3.35. Further, the relatively low standard deviation of 0.9 entails that responses are generally concentrated around the average result, reflecting a lower amount of variation in the answers.

Moreover, the researchers are looking to understand which aspects of transparency the consumers perceive as most important. The actual term transparency was not mentioned in the questionnaire, as the concept can be ambiguous even for scholars (Francisco and Swanson, 2018). Rather, it was introduced through the terms: *origin, journey,* and *environmental impact* accompanied by a short explanation for each (appendix 8).

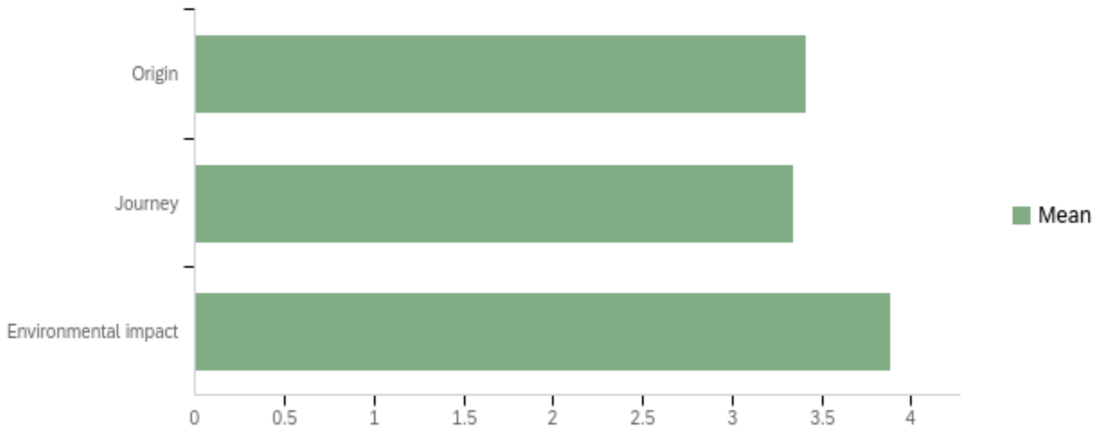

Figure 8: The Result Mean of Q7: "If the carbon emissions of your flight were offset, how important would it be for you to have access to and be able to verify information regarding:".

The findings of Q7 reveal that having access to and the ability to verify information regarding the environmental impact of the carbon emissions reduction is deemed as the most important feature. With a mean of 3.89, the participants rated this aspect as very important. However, as displayed in figure 8, the consumers rated all three areas as of relative importance, with the lowest average being 3.34 for the offsets' journey. This indicates that the respondents find this aspect to be moderately important even though it was rated last amongst the three. Similarly, being able to access and verify information regarding the origin of the offsets was also perceived as moderately important, with an average scored of 3.41.

Building on the previous question, the purpose of Q8 was to uncover whether consumers would be interested in an app where the origin, journey, and environmental impact could be tracked.

Figure 9 displays the distribution of responses, which represents a mean of 3.20 and a standard deviation of 1.11.

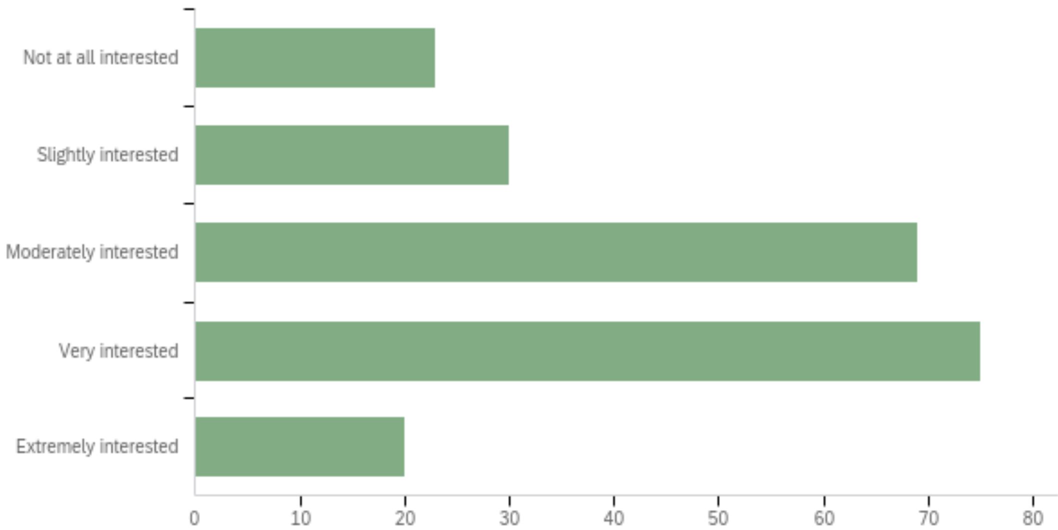

Figure 9: Results of Q8: "How interested would you be in an app where you could track the origin, journey, and environmental impact of your flight's emission reduction efforts?"

These findings indicate that responses are moderately interested in an app that provides the users with the ability to track the origin, journey, and environmental impact of their flights' emission-reducing efforts. This is interpreted as the participants showing moderate interest in increasing the transparency of the practice of carbon offsetting in the Scandinavian aviation industry. Although a substantial number of individuals reportedly are either very interested (77 respondents) or moderately interested (68 respondents), the number of participants not at all interested or only slightly is also quite significant, with 52 individuals in total. This variation is reflected in the standard deviation, which scores 1.11.

The participants were then asked to rate how the availability of the proposed app would affect their interest in offsetting the carbon emissions of their flight. The objective of this question was to understand how increased transparency affects the consumers' interest in carbon offsetting. The findings indicate that introducing the app, which is interpreted as increasing transparency, is perceived as adding some value to the practice of carbon offsetting conducted by airlines. By calculating the average change in interest amongst consumers, a positive change is detected: an increase of 0.68 was found when utilizing a scale of -2 to 2, where -2 equals "a lot less interested" and 2 "a lot more interested" (figure 10). This entails that the consumers can on average be described as more interested in carbon offsetting the emissions of their flight in the presence of an app that grants them access to information regarding the origin, journey, and environmental impact of the carbon offsets.

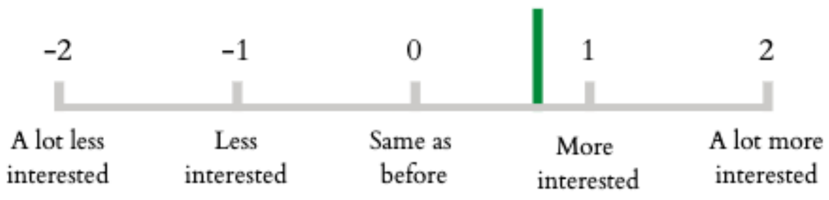

Figure 10: Mean Result of Q9: "Would you be more or less interested in carbon offsetting your flight if such an app was available?"

Initially, the participants of the questionnaire were moderately interested in carbon offsetting, with an average score of 3.35. According to the findings, the respondents can be described as more interested in offsetting the carbon emissions of their flights following the implementation of an app that increases transparency. Based on these findings, it is deemed that the lack of transparency perceived by the Scandinavian aviation industry is corroborated by air-travel costumers. As such, this research recognizes transparency from a consumer-perspective as an area of improvement in the current practice of voluntary carbon offsetting in the Scandinavian aviation industry. Subsequently, it is interpreted that enhancing transparency could add value to the practice.

7.1.1 Market Segment Analysis

After having established that enhanced transparency in the practice of voluntary carbon offsetting is substantiated by consumer demand, this section is concerned with gaining an insight into the customer segment that shows the most promise in relation to the implementation of the app.

The findings of the market segment analysis provide a certain insight into the target group of carbon offsets in the aviation industry, moreover, the potential market of the proposed app for tracking the origin, journey, and environmental impact of carbon offsets. It is apparent from the questionnaire that the younger age group shows the most interest in both the practice and the app (appendix 9). As such, the implementation of the app might prove more successful if designed with this customer segment in mind. Furthermore, it seems that the interest increases with the average annual flight frequency up to a certain level (appendix 10). Unsurprisingly, the interest in the app correlates with the level of concern for air pollution (appendix 11). Considering that the significant growth of environmental awareness the past decades shows few signs of ceasing, this finding might indicate that the market for voluntary carbon offsetting and the app has the potential to grow larger and more stable in the future.

7.2 Where in the Supply Chain, and How, is Transparency Currently Being Inhibited?

The purpose of this section is to map out the supply chain of voluntary carbon offsetting in the Scandinavian aviation industry today. This is necessary in order to recognize the current extent of consumer transparency, in addition to where and why this transparency is being inhibited. This will be accomplished by combining the primary data collected from the aviation-related actors with the secondary data of the voluntary carbon offset lifecycle presented in section 2.4.2.

The voluntary carbon offset lifecycle provided by Ecosystem Marketplace (Hamrick & Gallant, 2017) describes the different ways project developers are able to reach buyers. One option is to promote the projects directly to the end-consumer. Otherwise, it is possible to utilize the services of intermediaries, including brokers and retailers, who take on the responsibility of marketing and promoting the carbon credits to an end-buyer. According to the interview conducted with SAS, airlines in Scandinavia utilize the services of intermediaries in order to offset their carbon emissions. These partners essentially act as brokers in the sense that they purchase carbon credits on behalf of organizations or individuals based on the agreement of commission when the trade is executed.

> *"We see how much CO_2 a trip generates… Then we turn to them (our offsetting partner) and tell them how much (carbon offsetting) we want to purchase. We have an agreement*

with them so that they make the purchase and then we get a confirmation of the delivery… So, we get proof that the work has been completed." – SAS

Employing the services of an intermediary entails that the airlines do not interact with the project developers themselves. Rather, the responsibility of quality assurance and selecting reliable projects fall on the offsetting partner. Chooose currently relies on an independent team of so-called "enablers" to secure the reliability of its carbon credits. According to their website, this team of enablers consists of carbon registries, payment providers, project developers, and third-party verifiers (Chooose, n.d. a). However, the specific process of determination and criteria likely varies between different brokers.

"What we do is that we have an independent, neutral carbon-team that evaluates the projects we have available… That really assesses the projects continuously, and can advise us…" - Chooose

Although the airlines are not in control of the project-selection themselves, they are able to request certain criteria that the carbon reduction projects should fulfil. These criteria could relate to factors such as the project type, location, price, and whether the project should provide any particular co-benefits that support the values of the company, such as gender equality or other non-carbon impacts.

"We tell them how many kilos of CO_2 we want to purchase, and then there is a negotiation process... We have expressed that we are interested in (purchasing offsetting from) wind energy projects in Asia." – SAS

"The client can tell us "it is important for us to purchase a project from this market because we are expanding to e.g. Asia" … Are there any other SDGs that are pertinent to the airlines' values? We can, for instance, find a project which supports three SDGs in addition to climate change." - Chooose

One of the major differences in the process of voluntary carbon offsetting in the Scandinavian aviation industry today relates to *who* is carrying the cost of emissions reductions. Currently, this is done in one of two ways. Either, the consumer is presented with an alternative at the check-out process when purchasing a flight ticket, where they are able to “opt-in” and purchase carbon credits to neutralize the environmental impact of their flight. Here, the cost is carried by the consumer - the passenger who will be travelling by airplane – and only if he or she decides to pay an additional fee on top of the original ticket price. This service is provided by Chooose, and as such Norwegian:

> *“We have a platform that can be implemented in the check-out process, a so-called “opt-in” ... This makes it (emissions reductions) more of a joint effort between the airline and its consumers. This is a seamless process so that you as a customer do not have to go to a third-party to offset but can simply “opt-in” there and then.”* – Chooose

The other option currently practised in the Scandinavian aviation industry is for the airline to personally carry the cost of the carbon credits. In this situation, the airline pays for a portion of carbon credits equivalent to the emissions of the flight pertaining to certain customer segments. As such, the consumers do not pay an additional fee, but it is a prerequisite for them to belong to a certain customer group for the emissions to be offset, such as membership customers or the youth segment. This is currently being practised by SAS:

> *“We CO_2 compensate the flights of all our Eurobonus members (membership customers) and youth tickets… We identify the amount of CO_2 emissions a trip generates, take that sum, and add up all the Eurobonus and youth trips (on the different flights) ... Then we turn to our partners, and tell them we want to purchase this amount… This does not mean that our emissions are reduced, rather they are reduced in another sector… This (cost of emissions reductions) is something we want to carry as a corporate responsibility”* – SAS

However, SAS is reportedly developing a solution where consumers are able to purchase additional carbon offsetting as an opt-in alternative through their check-out process:

> *“We are actually in the process of developing a solution on our page, where individuals who choose not to be Eurobonus members will also be able to purchase (carbon credits)*

directly from our website… And of course, if you are a youth (or a member) and purchase a ticket then you can select to add additional carbon offsetting if you want… But we will still carbon offsetting those tickets." – SAS

Either way, the transaction goes through the airline. As such, the consumers do not interact with intermediaries or project developers themselves. Hence, they do not currently have a say in project selection nor the ability to access further information regarding the emissions reduction than that provided by the airline. According to Chooose, their selection process is based on several criteria and continuous evaluation. This includes requirements with regard to the certification of a particular project. Reportedly, they only purchase projects which have at least Gold Standard verification.

"We have an independent carbon-panel who constantly evaluate the best projects. We have several criteria - not all (projects) are UN-verified, but then they have Gold Standard verification" – Chooose

Based on these insights, the supply chain of voluntary carbon offsetting in the Scandinavian aviation industry has been mapped in figure 11.

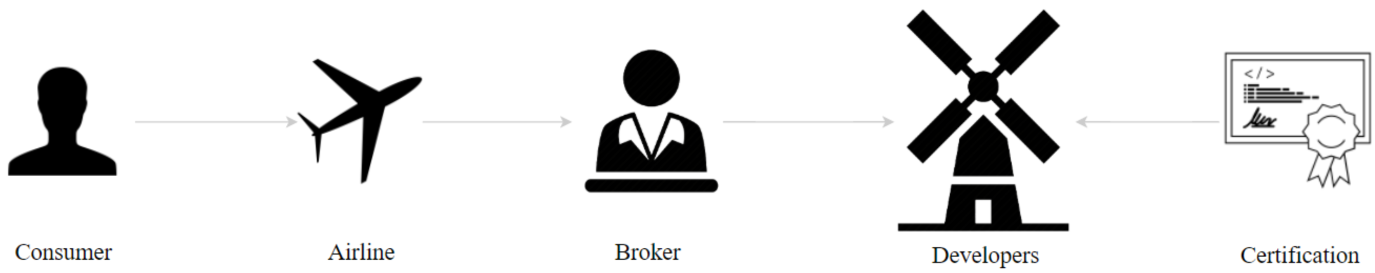

Figure 11: Simplified Supply Chain of Voluntary Carbon Offsetting in the Scandinavian Aviation Industry from a Consumer-Perspective.

Figure 11 illustrates a simplified version of the current supply chain of the practice of voluntary carbon offsetting in the Scandinavian aviation industry from a customer perspective. Essentially, the process is set in motion when a consumer purchases a flight ticket and either selects to opt-in and pay an additional fee in order to offset the emissions of their flight or when the individual belongs to a customer segment that grants carbon offsetting. The airline calculates the number of carbon credits required to neutralize the emissions of these customers based on factors such as the number of tickets in a particular flight eligible for offset, distance flown, and aircraft weight. This information is reported to the offsetting partner periodically, either monthly (Norwegian) or quarterly (SAS). On behalf of the airline, the partner then purchases an equivalent amount of carbon credits from project developers fitting the particular criteria of the airline in addition to the requirements of verification.

7.2.1 Supply Chain Transparency from a Consumer Perspective

This section is concerned with the extent to which the process of voluntary carbon offsetting in Scandinavian airlines is currently visible to the end-consumer. In the previous section, it was established that any transaction related to the purchase of carbon credits goes through the airline, regardless of whether the consumer personally pays for the offsetting or if the cost is carried by the airline. Furthermore, the interviews revealed that the airlines in Scandinavia are currently not providing the individual passenger with a receipt of the specific emissions reductions purchased to offset their flight, as discussed in section 5.2 Transparency. Rather, the consumers have to seek out information pertaining to the carbon offsetting practices of the specific airline through public sources, such as the company website, the website of their offsetting partner, or their annual sustainability report (SAS 2020; Norwegian, n.d.). When questioned about the possibility of providing passengers with individual receipts related to their purchase of carbon credits through Norwegian's "opt-in" function, their offsetting partner replied:

> *"This is presented on (the airline's) informational pages prior to the purchase."* – Chooose

After having established that the consumers are not provided with any receipt or additional information following their purchase, this research is interested in understanding the extent of information communicated prior to purchase. As such, the researchers have completed the respective check-out processes of both Norwegian and SAS. In Norwegian's check-out process, passengers are able to opt-in and pay a premium to "*support CO_2-reducing projects* *certified by the United Nations and the Gold Standard*" (appendix 12). If a passenger decides to "read more", they are still not provided with information relating to the specific project in pursuit of support, but rather a generic project information. This includes *"offsetting is performed through a portfolio of CO_2 reducing projects"* (appendix 12). Information regarding the amount of CO_2 to be offset is equally vague, described as *"an amount equal to or greater than the calculated carbon footprint of your itinerary"* (appendix 12).

In SAS's check-out process, the information provided is even more scarce, consisting of a brief statement proclaiming that the trip of EuroBonus members will be offset (appendix 13). However, this finding is not surprising, seen as it is SAS themselves who carry the cost of offsetting the consumers' flights. As such, the average passenger can be assumed to be less demanding regarding the extent of information they are provided with. Nevertheless, SAS will likely be under pressure to incorporate more information in the future if the new opt-in solution described in section 7.2 is developed.

As a result, consumers are neither provided with information specific to their flights prior to purchase, nor any information ensuing the purchase. Rather, they only have access to the airline's generic offsetting information, and a lump sum average or percentage of the total emissions reductions over a certain period (SAS, 2020; SAS, n.d. b; Norwegian n.d.). Still, this information is not readily available and would require the consumer to actively seek it out. As such, they are unable to obtain evidence of what actually occurs following their purchase. This includes information regarding when the carbon emissions are effectively offset, the origin of the particular carbon credit, the offsets' journey, and the actual environmental impact of the offsets pertaining to their particular flight. In relation to the simplified supply chain illustrated in figure 11, the extent of the information visible to the end-consumer reaches no further than the airline, with all subsequent linkages being obscured.

7.2.2 Pain Points

To facilitate a potential solution to the issue of low transparency from a consumer perspective, it is necessary to understand exactly how and why transparency is being inhibited. As such, this section will attempt to uncover the pain points of the current offsetting practices in the

Scandinavian aviation industry, by interpreting the findings from the aviation-related interviews in combination with secondary data.

Based on extensive research and communication with several actors in the supply chain of voluntary carbon offsets in the Scandinavian aviation industry, this research identifies the main contributing factors to the lack of transparency from a consumer perspective to be the lack of granularity of information and the non-existent interoperability between information systems. According to SAS, their offsetting partner is not able or willing to accept micro-transactions, i.e. individual purchases from air-travel consumers. Rather, they exclusively work with organizations that are capable of ordering far larger volumes of carbon credits periodically in bulk.

> *"Previously, it was possible for individuals to utilize the (carbon emission) calculator on our website to calculate how much CO_2 is generated from their particular trip… and go directly to Natural Capital Partners' website to purchase CO_2 offsetting themselves. However, this is no longer possible, as Natural Capital Partners only want to work B2B."* – SAS

The decision to solely operate B2B likely relates to an issue of scale. To illustrate this challenge, a flight from Oslo (OSL) to Copenhagen (CPH) for one single passenger would emit 54.6 kg CO_2 to the atmosphere, according to the emissions calculator provided by SAS (SAS, n.d. b). In comparison, SAS offset 1.2 million tonnes of passenger-related CO_2 in the fiscal year 2019 (SAS, 2020). This would amount to an average of 300 000 carbon credits purchased in bulk quarterly considering that one tonne of CO_2 is equivalent to one carbon credit. Handling individual transactions amounting to this volume would require a lot more work. As such, individually fulfilling purchases for single journeys instead of operating with lump-sum purchases would increase complexity substantially, as it would require a significantly deeper level of granularity of information. Granularity refers to the degree of detail in the information. Hence, greater granularity entails a deeper level of detail (Business Dictionary, n.d.).

The way carbon offset registries are designed today, carbon credits have to be manually retired for the buyer to be able to claim its impact (appendix 14). Inquiries were made to Chooose concerning their specific process of retiring carbon credits; however, this information is reportedly deemed sensitive and could not be divulged (Chooose 2). As such, the insights are based on the Gold Standard registry, as the CO_2-reducing projects of the offsetting partner in this research are verified by this standard (Chooose, n.d. a). However, it is possible that the methods of registering and retiring carbon credits vary slightly across standards.

As airlines are currently purchasing carbon credits in bulk, the individual passenger has no means of identifying the specific carbon offsets pertaining to his or her particular flight. The partner would be required to retire the carbon credits of each particular passenger separately if wanting to provide the consumers with access to information regarding the journey, origin, and environmental impact of their emissions-reducing efforts. This would undoubtedly be a cumbersome and resource-intensive process in the current registries, where retirement must be performed manually. As a consequence, common practices have been established consisting of periodic lump-sum purchases and the external communication of general information only.

Furthermore, for the partner to be in the position of retiring the credits of each particular passenger separately, it is a prerequisite for the airlines to report information separately and for it to be traceable to each passenger, as opposed to the current lump-sum practice. This brings the analysis to the subject of interoperability between IT systems. Interoperability enables different information systems to access, integrate, exchange, and cooperatively utilize data across organizational boundaries, effectively enabling timely and seamless portability of information (Luna, Campos, & Otero, 2019). To the best of the authors' knowledge, there exists no technical interoperability between the data systems of the airlines and their offsetting partners. This is evident as the current processes rely on human intervention to facilitate the exchange of data between actors.

At present, the airlines have to manually report the amount of carbon credits to be purchased periodically in bulk, either monthly or quarterly. If the systems were interoperable, it would be possible for the offsetting partners to access information directly, allowing them to purchase and retire offsets on the airlines' behalf in a timelier manner. The current practice is time-consuming and more prone to errors as information is manually transferred between systems, and as such interpreted as insufficient for the instantaneous data requirements of modern demands.

7.3 How Can the Properties of Blockchain Technology Alleviate the Pain Points Inhibiting Consumer Transparency?

This section is concerned with assessing how the properties of blockchain technology can alleviate the identified factors currently inhibiting transparency. As such, the purpose of incorporating blockchain is to facilitate enhanced transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry. To start off, the suitability of blockchain technology in addressing the aforementioned pain points will be examined, in order to understand whether blockchain possesses the properties appropriate to improve supply chain transparency in the area of this research. Subsequently, a proposed conceptual design supported by blockchain technology will be presented and described, with the aim of enhancing transparency for the end-consumer. Finally, an assessment will be made considering the underlying features of blockchain necessary to support this potential solution.

7.3.1 Suitability of Blockchain Technology

Enabling transparency of information is one of the most prominent characteristics of blockchain technology. This section aims to understand whether the transparency-enhancing properties of the technology are applicable to the voluntary carbon offsetting practices in the Scandinavian aviation industry, with the help of insights from the interviews with the blockchain experts. As such, this section is not concerned with the challenges of adopting blockchain, but rather to elaborate on the capabilities of blockchain that may contribute to enhanced transparency. The trade-offs and challenges of the technology will be considered and discussed in depth in subsequent sections.

In section 7.2.2 Pain Points, it was determined that the main contributing factors to the low consumer transparency in the practice of voluntary carbon offsetting relate to the lack of granularity of information and the non-existent interoperability between systems. As such, alleviating these pain points is key to achieving increased transparency from a consumer perspective. Although a wide array of blockchain properties have been designed with the intent of enhancing transparency, this research is concerned with those that have the potential of solving the identified restrictions in the practice of voluntary carbon offsetting.

To start off, blockchain technology possesses the ability to accommodate a deeper level of granularity of information than has been feasible and cost-effective previously. This is enabled through the technology's ability to create interoperability between information systems, facilitated by its properties as a DLT (Mittal & Thakur, 2018). The network of replicated databases is visible to anyone within the network, updated continually to ensure that each ledger has identical information. Furthermore, the decentralized database provides parties with the ability to trust one another without the need for intermediaries, making seamless information-sharing across platforms and stakeholders possible (ibid).

> *"That is when blockchain can really shine, in that granularity… I gave you two dollars, but you do not know which of the two are being spent on this project, you just throw them in one bucket. However, with blockchain, you can actually tokenize it… You can see that "oh this particular dollar from this particular purchase has now gone to this particular project". That level of transparency and granularity is something you do not get with the traditional system."* – Jacob Pouncey.

Incorporating blockchain technology in the supply chain of voluntary carbon offsetting would allow parties to access and exchange information directly and automatically, drastically reducing human interference. The accessibility of updated information across cooperating actors would eliminate the need for airlines to manually purchase credits periodically, and potentially eliminate the necessity of intermediaries in general. Furthermore, a shared network allows for deeper levels of granularity as it enables the traceability of credit and offset information directly to individual passengers. In essence, blockchain technology possesses the ability to provide interoperability between the databases in the supply chain, essentially mitigating the pain points currently restricting transparency from a consumer perspective.

In addition to the ability to create interoperability between systems, blockchain technology is able to provide a verifiable and auditable history of information since all records stored in this distributed ledger require consensus to be reached by an absolute majority of peers (Caro et al., 2018). As such, any data recorded in the chain is next to impossible and highly costly to edit. This immutable trait is frequently described as one of the key benefits of blockchain technology (Kuo, Kim, & Ohno-Machado, 2017), and allows for provenance tracking as all data and records can be verified. The practice of voluntary carbon offsetting has been placed under considerable scrutiny over the years, with numerous instances of low-quality and even questionable credits being traded. Each uncovered instance has the potential of reducing the credibility of the practice as a whole. As such, the immutability feature is essential as it facilitates the communication of reliable and accurate information.

> *"The single source truth from a distributed ledger solution will allow for the actors involved in the supply chain to coordinate, audit, and report the details of their operations in a fully transparent and immutable way".* – Jacob Pouncey

Another feature supporting the ability of blockchain technology to facilitate enhanced transparency in the practice of voluntary carbon offsetting in the Scandinavian aviation industry relates to the potential of incorporation of smart contracts.

> *"This distributed ledger, blockchain, can remove the need for reconciling each and every transaction with a supplier, implement business rules, by applying smart contracts or the like. That transaction only takes place if two or more participants endorse them, or if another transaction has been completed first, due to the built-in method (hashing)"* – Kristoffer Just

> "*Smart contract gives you the ability of registration, certification, and standardization of how the product looks and also all the smart contracts can find every project that is behind it in perpetuity*" - Thomas McMahon

From the interviews with the blockchain experts, it is found that smart contracts are widely considered a prominent feature of blockchain technology which could provide value to this particular research. As previously mentioned, smart contracts enable the creation of algorithms and programs that can be enforced when certain conditions transpire, without the need for human intervention (Francisco & Swanson, 2018). Incorporating smart contracts in the digital layer of the supply chain of voluntary carbon offsetting would enforce a relationship through cryptographic code, allowing the creation of trust based on the logic and data being visible to all participants in the network. As such, information can be transferred directly between actors in the supply chain without the need for human intervention and manual processes. This would allow for the current bulk-purchase practices between the airline and offsetting partner to be eliminated, by facilitating the automatic transfer of data pertaining to individual customers.

This section finds that blockchain technology embodies the capabilities necessary for facilitating interoperability and granularity of information in a supply chain. However, it should be noted that this ability is not exclusive to blockchain technology, as traditional database structures can often solve similar tasks. With the incorporation of application programming interfaces (APIs) in traditional databases, it is possible to automate workflows and processes between databases (Vasu, 2020). This could similarly allow for the different actors' data systems to communicate directly without human interference. Considering the costs associated with implementing blockchain technology, the traditional approach could be perceived as the most cost-effective alternative (Singh, 2019).

7.3.2 Conceptual Design

In this section, the potential blockchain solution to the lack of transparency from a consumer perspective will be presented and described. As previously mentioned, the information flow in the practice of voluntary carbon offsetting is inhibited by the non-existent interoperability between systems, which contributes to the low level of granularity of information. As such, creating interoperability between the different data systems in the supply chain is a prerequisite in order to facilitate transparency.

This research proposes the introduction of an app that allows the passenger to access the individual offsetting activities pertaining to his or her flight. As such, the consumers will be provided with the ability to trace the provenance of the carbon credits purchased to offsets the carbon footprint of their itinerary, in addition to verifying the environmental impact of the emissions-reducing efforts. This will be made possible by employing blockchain technology in the supply chain of voluntary carbon offsets in the Scandinavian aviation industry, thereby facilitating interoperability between data systems. Moreover, this interoperability will allow for a deeper level of granularity of information, making it possible to trace the information back to an individual passenger.

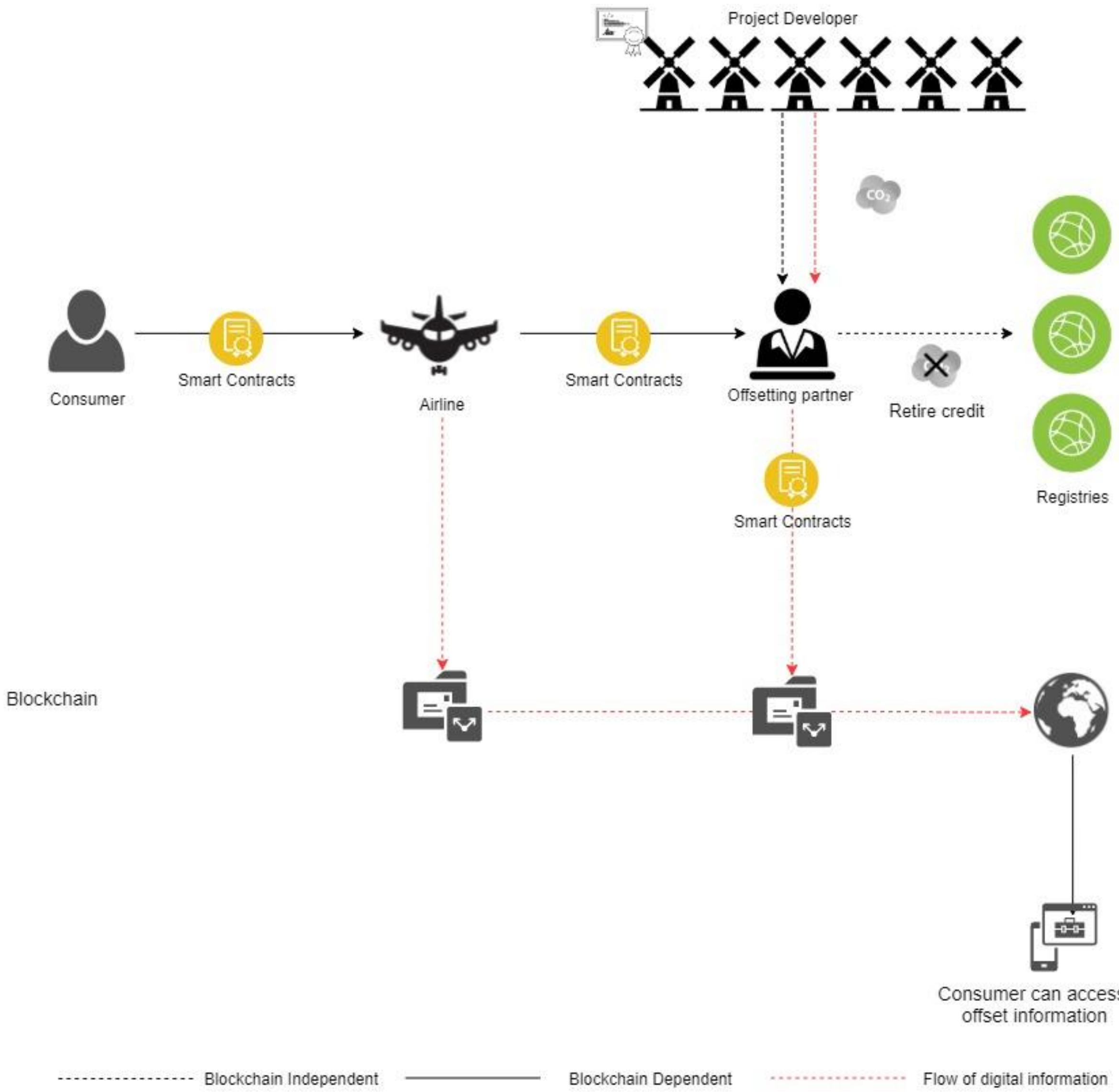

Figure 12: Blueprint of Proposed Conceptual Design

To start off, the process will commence when a passenger scans their flight ticket upon boarding. This indicates that the passenger will in fact, partake in the flight, which warrants the purchase of carbon credits. Once the ticket has been scanned, the money will be released from the airline's account and automatically transferred to the offsetting partner. This quantity will be earmarked for the purchase of an amount of carbon credits equivalent to the CO_2 emitted as a result of the passenger's itinerary. The transaction will be executed by utilizing a smart contract, where the fulfilment of predetermined arbitrary rules initiates an automatic transaction between parties. The ticket, whether it is on an app or a hard copy, contains a barcode that essentially sets of the smart contract. In this instance, the predetermined rules could include aspect such as; 1) the airline must have received a purchase of carbon credits from the passenger, alternatively, the passenger must be in a customer segment eligible for offsetting, and 2) the tickets of these passengers must be scanned upon boarding. This is based on the assumption that the airline is able to match the ticket number with the carbon credit purchase.

Through tokenization, the value of a carbon credit is converted into a token that can be manipulated and transferred on the blockchain (eToroX, n.d.). This entails that the credit can be broken down into digital increments, allowing a specific amount of offsetting equal to the emissions of a passenger's itinerary to be linked directly back to them.

In order to simplify the implementation of blockchain technology in the supply chain, it has been deemed necessary to exclude the project developers from the blockchain solution. Due to the inherent complexity of having numerous individual suppliers, it is found to be sufficient for the offsetting partner to purchase credits from the developers in bulk, essentially acting as retailers instead of brokers. Furthermore, as many project developers are located in developing countries where technology might not be as evolved, incorporating them in the blockchain could be problematic considering the potential technological barriers. In order for a consumer to claim the environmental impact of a carbon offset, it has to be retired on their behalf. However, it does not have to be purchased at the time of retirement. As such, bulk-purchases between the offsetting partners and the project developers will not reduce the transparency from a consumer perspective, since the relevant credits will still be linked to the specific passenger. This entails that the offsetting partner interacts with the project developers independently of the blockchain.

Furthermore, the offsetting partner will also have to interact with the registries and retire carbon credits independently of the blockchain. Ideally, the registries would have been incorporated in the blockchain, facilitating an automated retirement process. This could potentially have eliminated the need for intermediaries in general. However, due to the lack of incentives in the current business models of the registries, this has been deemed unrealistic at present. The way carbon registries are structured today, their source of income is reliant on an annual fee placed on platform users, complementary services, and donations (appendix 14; Gold Standard, n.d. c). This entails that the registries are not responsible for the sales of carbon credits, and as such have no incentive to further increase demand through improved transparency. Moreover, the apparent lack of technical capabilities possessed by the registries serves as an additional barrier to the integration of blockchain technology. As such, it has been deemed necessary to retain the manual process of retirement in this solution.

Once the money has been transferred from the airline to the offsetting partner, an amount of carbon credits equivalent to the CO_2 emitted from the passenger's itinerary will automatically be reserved. This will again be accomplished through a smart contract. Here, the predetermined rules that must be satisfied might include: 1) the offsetting partner must possess a sufficient number of carbon credits to complete the order, and 2) a transfer of money earmarked for the purchase of carbon credits must be received from an airline. Once these requirements are met, the carbon credit will be reserved for the particular passenger and placed aside for subsequent retirement. At this point, the passenger will be able to access all information pertaining to the emissions reductions of his or her flight in the app, such as the type of offset, origin, project developer, and environmental impact. Additionally, they will be informed about the current status of the reserved credit, allowing them to stay up to date on when the credit is retired.

As the retirement of credits will continue to occur manually, the process will transpire periodically in bulk. Every so often, the offsetting partner will retire all the reserved credits accumulated over a certain period. A smart contract will be incorporated to notify all relevant passengers of the status update of their carbon credits. The contract will be executed following the fulfilment of predetermined rules, which might involve: 1) there exists carbon credits reserved for retirement in a certain period, and 2) the partner manually retires the credits. Following retirement, the credit will be marked as retired in the passenger's app. Consequently, the passenger may officially claim the impact of the particular carbon offsetting, effectively neutralizing the emissions of their itinerary.

The application of smart contracts will allow different data systems to transfer relevant data automatically and without human interference. As such, interoperability is created between systems where this previously was non-existent. Furthermore, the direct data transfer allows for greater granularity of information, providing the actors in the supply chain with the ability to process passenger-specific information as opposed to accumulated lump sums. After it has been made possible to link a portion of carbon credits to a particular passenger, the information can be communicated to the relevant end-consumer to facilitate transparency.

Figure 12 depicts the blockchain solution from the point of view of a single airline, and as such a single offsetting partner. In practice, all actors with a voluntary carbon offsetting scheme in the Scandinavian aviation industry will be able to participate in the network. This industry-wide solution is facilitated by blockchains inherent ability to create a distributed server with no central authority. When designed as a permissioned platform, it is possible to grant access to relevant industry actors only, as discussed in section 7.3.4. Once the initial architecture has been created, it can be accessed by other actors in an easy and seamless manner. This allows relevant data to be shared in a way that no single entity is in control of it, however, all parties have access to it. As such, multiple airlines and offsetting partners can be granted access to the blockchain network, entailing that there is not one obvious party eligible to manage the platform. This challenge will be considered in the discussion.

7.3.3 Customer Application

After enabling the possibility of linking relevant information to the specific passenger, the information must be communicated to the end-consumer in order to facilitate transparency. As previously mentioned, the goal is to achieve this through the implementation of an app that allows the passenger to access the individual offsetting activities pertaining to his or her flight. It is essential for this app to incorporate a user-friendly interface, in order to ensure a straightforward and manageable experience for the consumer. As such, the consumer should not have to understand the principles of blockchain technology to utilize the app.

The granular information facilitated by blockchain technology will be incorporated into the app to provide the individual passenger with access to the offsetting activities pertaining to their particular itinerary. For adoption to occur among consumers, access to information must be intuitive and not complicated by blockchain jargon. To enable this, a user interface (UI) layer will run on a local database, which in turn is mirrored into the blockchain system. This essentially provides the consumer with a window into the system, that has undergone customization to facilitate a more straightforward experience for the average user.

Essentially, the app will function as a way of visualizing the data in the system in a user-friendly manner. It must include information that could be perceived as essential to the consumer, such as the origin of the offset, project type, journey, and retirement status. In section 7.1, the ability to verify the environmental impact of the carbon offsets was found to be perceived as most important by the public, and thus emphasis must be placed on information that allows for this verification. In this way, the app will provide a means for the passenger to track and maintain an overview of all the flights they have undertaken and the emissions-reducing efforts pertaining to each one. As such, the extent of information accessible to the end-consumer would no longer be inhibited at the point of the airlines, but extended to include all subsequent stages in the supply chain, as depicted in section 7.2.

The final section of the questionnaire was concerned with collecting data on the preferences and attitudes of the consumers in regard to the design and costs of the proposed user app. To start off, participants were queried on their preference in relation to the design of the app. On one hand, it could function as a stand-alone specialized app, independent of other apps. This would require the consumer to download an independent app, where all information pertaining to the carbon offsetting activities of their flights would be stored. Alternatively, the app could be integrated into existing applications, such as frequent-flyer apps. The results in figure 13 were uncovered.

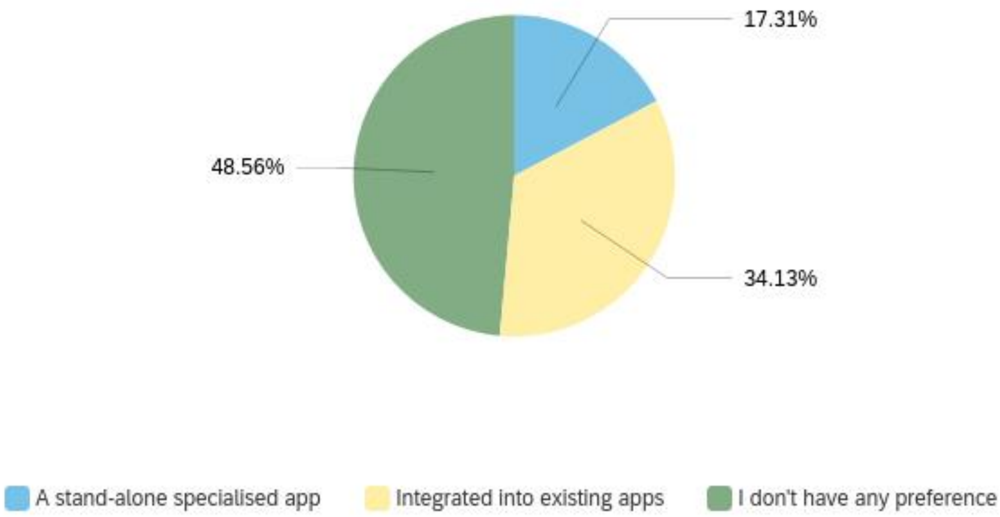

Figure 13: Results of Q10 - Design; "Would you prefer the app to be:".

Based on the findings of Q10, it is found that the majority of participants do not have any preference in regard to the design of the consumer app. Out of those who have a preference, the most preferred alternative is integrating the service into an existing app. As such, integrating the service is found as an appropriate solution to the design of the proposed app. This research suggests that the service should be integrated into the existing apps of the respective airlines, as this could reduce the barrier to adoption in that a substantial amount of passengers likely already possess the app, and as such allow for more convenience to the consumers. However, this would entail that the respective airlines must be willing to govern this service.

In order to further assess the demand of the app, the respondents of the questionnaire were asked about their willingness to pay a small price for such a service. According to the findings, 47.12% of the participants responded negatively. Only 12.02% were willing to pay for the service, however, 40.87% answered "maybe" (figure 14).

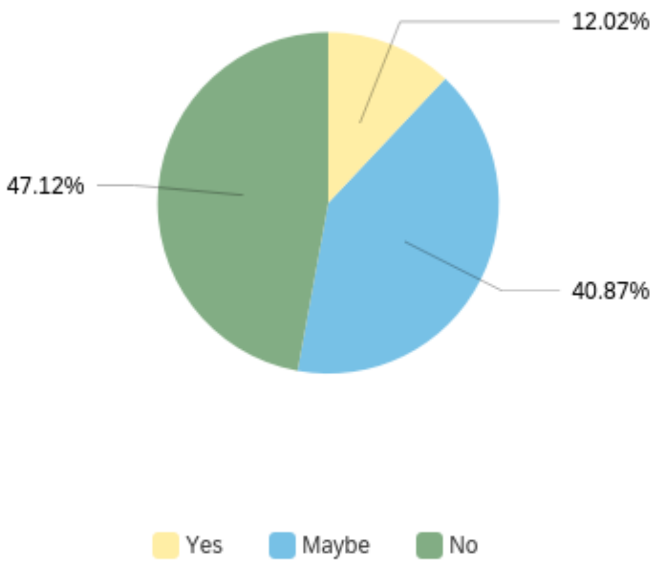

Figure 14: Results of Q11: "How would you be willing to pay a small price for such an app?".

This finding is perhaps not surprising. There is still a substantial lack of awareness about the offsetting schemes of airlines among consumers (Choi et al., 2016). This is substantiated by the fact that the practice in Scandinavia is quite new, with the current programs of SAS and Norwegians having been launched in 2018 and 2019. Section 7.1 identified that there does exist a consumer-demand for an app that increases the transparency of the practice of voluntary carbon offsetting in the aviation industry. As such, this service has the potential of providing a value-enhancing addition to the practice. However, based on the findings of this section, the airlines must consider their willingness to carry any costs associated with the integrated service themselves, particularly in the early stages where awareness is still relatively low.

7.3.4 Underlying Features of the Conceptual Design

After having established a potential blockchain solution to the non-existent interoperability between data systems and the lack of granularity of information, it is necessary to consider the underlying features of blockchain. As the inherent purpose of voluntary carbon offsetting is to reduce and avoid CO_2 from the atmosphere, one of the main concerns of a potential technological solution relates to its environmental impact. It would be detrimental to the practice if the solution attempting to enhance transparency results in superfluous energy consumption. As such, decisions regarding blockchain design must take into consideration the energy consumption of different features.

The aforementioned consensus mechanism, PoW, involves massive computational power and expenditures in order to run the complicated algorithms. This energy expenditure is vital in providing a safe and secure network, as it allows the blockchain to maintain a record of the transactions which are honest and trustworthy. However, the exponential energy use consequentially makes this consensus mechanism ill-suited for use in environmental purposes. As such, PoW is found to be inappropriate for the proposed blockchain solution of this research.

The two consensus mechanisms presented in this research that provide more environmentally-friendly solutions are PoS and PoET, as described in section 6.2.2. A commonly cited disadvantage of the PoS relates to the "rich get richer" concept, where participants who have the ability to place large security deposits are allowed to have control of consensus in the chain (Jenks, 2018 a). Furthermore, there exist inherent costs associated with PoS to partake in a consensus, which is not apparent in the PoET. However, PoS has a high transaction rate, as platforms are able to confirm transactions immediately, and as such reach consensus fast. In contrast, the PoET is described as having medium transaction latencies (Kulkarni, 2018). Nevertheless, the decision of consensus mechanism, and subsequently which trade-offs to accept, must be reached in consideration of other factors, such as the level of privacy required.

In order to ascertain which blockchain type will prove most beneficial, it is necessary to evaluate the different drawbacks and benefits of public and private blockchains in light of the purpose of this research. To start off, it is not desirable for all internet users to be able to participate and contribute to the consensus. Rather, only a controlled group of participants, consisting of the actors in the supply chain should be able to access write operations. This is necessary to ensure that only relevant information is stored on the blockchain. As such, a fully public blockchain would prove ill-suited, as this would allow anyone in the world to read, write, and contribute to the core activities of the blockchain (Wang et al., 2018). This finding is substantiated by the massive energy consumptions required for maintaining a public distributed ledger, contradicting the purpose of this research. The vast expenditure relates to the frequent utilization of PoW as a consensus mechanism for public blockchains, such as in the case of Bitcoin. As such, it is found that a permissioned blockchain is suitable for the purpose of this research, which requires access to be granted in order to participate (ibid).

Furthermore, it is essential for the transactions in the chain to be publicly viewable in order to facilitate transparency. As such, consumers, stakeholders, and other internet-users with the desire to view this information should have access to read operations, yet without the ability to contribute. This coincides with the features of a public permissioned blockchain, which can be referred to as a type of consortium blockchain. As previously mentioned, a consortium blockchain is a quasi-private blockchain in which reading permissions can be private or public (Yafimava, 2019). Since it is vital for the public to have access to read operations, a consortium blockchain with public reading permissions has been found to be most suitable for this research. This finding is substantiated by the need for multiple actors from different organizations to contribute to write operations in the blockchain (Wang et al., 2018).

A consortium blockchain has low energy consumption in its consensus mechanisms (Williams, 2020), which is appropriate for a technological solution underpinning the practice of voluntary carbon offsetting in the Scandinavian aviation industry. Furthermore, it can be described as having higher efficiency, as the volume, size, and number of nodes is vastly lower in comparison to a fully public blockchain (Kulkarni, 2018). However, a consortium blockchain is only partly decentralized, due to the inherent properties of both private and public blockchains. In contrast to a public blockchain where every node contributes to the consensus process, the consortium blockchain utilizes a pre-determined set of nodes in order to control this process (Zheng, Dai, Tang, & Chen, 2019).

When determining the suitable blockchain platform for a specific purpose, trade-offs have to be made between decentralization, scalability, and security. As previously mentioned, this decision is referred to as the blockchain trilemma (Buterin, 2016). In relation to the amount of data the platform must be able to process, the aspect of scalability is deemed as of importance. If each passenger is going to be provided with an individual receipt of their particular journey, the amount of data the system must handle will be substantial in comparison to the current bulk-purchase practices. However, the challenges related to scalability of permissioned blockchain platforms are not as prevalent as in their permissionless counterparts, due to their restricted set of users (Scherer, 2017). In relation to the security of the network, it is essential for the cryptographic algorithms to be robust against failure. As the purpose of adopting a blockchain network in the voluntary carbon offsetting supply chain is to increase transparency, it is vital for the information in the chain to be immutable and protected from attacks. In light of the permissioned nature of the potential blockchain solution, decentralization has been given a lower priority.

After determining the permissioned public blockchain as the most suitable blockchain governance architecture, it must be considered whether to use an existing platform or build a customized one. Utilizing an established platform makes it possible to take advantage of capabilities and resources that have been developed over time, such as well-established global networks and native cryptocurrencies. Existing platforms will already have undergone extensive trial and error and continuous upgrades, allowing for a more convenient implementation. In contrast, building a custom blockchain requires the developers to create a tailored code and build a network of users from scratch. Furthermore, the responsibility of updating and maintaining the code falls on the developer (Shilov, 2018). As such, building a customized blockchain platform is usually far too time-consuming and costly.

Nevertheless, there does exist certain advantages of building a custom blockchain. Doing so provides ultimate flexibility in regard to the option of consensus algorithm, a customized balance of decentralization, scalability, and security, and control of the codebase (Shilov, 2018). Furthermore, dependency on an existing blockchain creates certain operational risks, in that the users become vulnerable to potential security breaches, malware, or system outages occurring in the underpinning blockchain platform.

> *"When you are using someone else's blockchain, like Ethereum… You are vulnerable to whatever happens there. If one day something happens, then the whole thing goes up in flames."* – Radu

In this research, it has been determined that the benefits of a well-established platform far outweigh the flexibility of a customized platform. After considering the blockchain trilemma, it is found that there currently exist platforms providing suitable properties as those required in the supply chain of the practice of voluntary carbon offsetting. As such, the massive costs of developing a customized platform would be unnecessary and impossible to justify. As previously mentioned, both Ethereum and Hyperledger Sawtooth have historically been utilized across supply chains to improve transparency and traceability. As such, this research is limited to assessing the suitability of these two platforms, however, it is acknowledged that there might exist other potential networks.

Ethereum and Hyperledger Sawtooth have been designed with distinct intentions. To start off, Ethereum is a public, permissionless blockchain, where all internet users can access transaction data and engage in transaction validation. However, it is possible to apply permissioning on the application layer (Friebe, 2017). The permissionless operation and total transparency of the Ethereum platform come at the price of scalability and privacy (Prerna, 2019). If each passenger is going to be provided with an individual receipt of their particular journey, the amount of data the system must handle will be substantial in comparison to the current bulk-purchase practice. Currently, the Ethereum platform is not able to handle large amounts of data (Chittoda, 2019), which will likely result in extensive bottleneck issues. Furthermore, the costs of utilizing the Ethereum platform will likely prove prohibitive, as each transaction and smart contract execution entails a cost (Rosic, 2018). This cost will be particularly damning due to the number of individual transactions required to achieve consumer transparency.

Plans are being made to convert Ethereum from a PoW to a PoS blockchain. Initially, the launch was scheduled for January 2020 (Won, 2020), but has been postponed indefinitely. As such, this research will not consider the suitability of the PoS Ethereum, although it would likely be more appropriate compared to the current version due to the reduced resource consumption.

In contrast to Ethereum, all transactions on the Hyperledger Sawtooth platform are free of charge. As this platform is specifically designed with organizations in mind, it functions as software for originations to develop personalized blockchains fitting the requirements of their business. The platform operates as a permissioned network by default (KindGeek Software, 2018), allowing for a control layer that permits access and certain actions to only be performed by particular participants (Frankenfield, 2019). Furthermore, Hyperledger Sawtooth offers high scalability, which allows for efficient transaction throughput of data (Regueiro, 2018). This feature has been described as highly suitable for supply chain purposes, where it is typically necessary for a substantial amount of data to be transferred frequently. The platform's particular attention to security, modularity, and scalability (Olson et al., 2018), correlates with the aforementioned requirements of this research in relation to the blockchain trilemma; high scalability, high security and less emphasis on decentralization. As such, the Hyperledger Sawtooth has been deemed most appropriate for the purposes of this research.

8. Discussion

After having established how a potential blockchain solution could facilitate transparency, it is essential to assess the feasibility of adopting it in the supply chain of voluntary carbon offsetting in the Scandinavian aviation industry. This section is concerned with evaluating the interoperability and granularity of information facilitated by blockchain technology, in order to understand whether the proposed blockchain solution could prove favourable for the purposes of this research. Furthermore, the challenges of adopting the technology will be discussed, in an attempt to either substantiate or discredit the proposed blockchain solution.

The favourability of the proposed solution is dependent upon whether blockchain technology is more appropriate for enhancing transparency from a consumer perspective in comparison to other non-blockchain solutions. To start off, it is necessary to ascertain whether the blockchain solution fulfils the intended purpose. In the analysis, it was established that the incorporation of blockchain-enabled smart contracts in the supply chain will allow for the automatic transfer of passenger-specific offsetting information without human interference. Additionally, the tokenization of carbon credits enables the credits to be broken down into digital increments, allowing the offsetting pertaining to a particular customer to be linked directly back to them. As such, it is made possible to link passengers to their specific emissions-reduction efforts, rather than accumulating all the carbon offsetting endeavours related to an airline in one generic bundle. With this information, the airlines will be able to communicate passenger-specific information to the relevant end-consumer, effectively enhancing transparency from a consumer perspective. As such, this research finds that the proposed solution fulfils the intended purpose of improving the issue identified as the most prominent in the current practice of voluntary carbon offsetting in the Scandinavian aviation industry.

The question then becomes whether traditional non-blockchain technologies are able to facilitate equal solutions to the lack of transparency in the industry. As previously mentioned, it would be possible to eliminate the current bulk-purchase practice by facilitating software integration between the different data systems in the supply chain. This could allow data transfer to be automated between an airline and its offsetting partner, enabling passenger-specific information to be communicated. However, this would require each airline to separately connect their data systems with their specific offsetting partner in order to enable automated workflows and processes. From an industry perspective, this would essentially become a process of performing individual software integration multiple times.

With blockchain, it is possible to develop an industry-wide solution that all relevant actors can adhere to. Once the initial blockchain architecture is established, it can easily be employed by other actors in a seamless and straightforward fashion. This allows relevant data to be shared with no single entity in control, but with all parties having access to it. In the aviation industry, this feature would be especially valuable as the different airlines may utilize the same suppliers, both in regard to project developers and offsetting partners. Moreover, with only a handful of voluntary standards consolidating the majority of the market share, the same registries are generally employed to retire credits. Allowing the relevant actors to leverage one common platform eliminates the need to separately integrate numerous different IT systems across supply chains. Furthermore, the distributed and immutable properties of blockchain technology may contribute to enhanced security and data protection across the network, with each participant holding a secure copy of all records and changes (Schlapkohl, 2019). As such, the adoption of blockchain technology would prove favourable if the aim is to enhance consumer transparency as a shared initiative across the industry.

To successfully implement blockchain technology in the supply chain of voluntary carbon offsetting, it is important to assess the challenges and barriers that must be considered and managed. To start off, a major challenge relates to the willingness and ability of actors in the supply chain to adopt a blockchain solution (Jacob Pouncey 2). For the proposed solution to work, both the airlines and the offsetting partners must be willing to share more information and as such create transparency in their practices. This research finds that certain actors, particularly the offsetting partners, are reluctant to share relevant information, including the current process of retirement (Chooose 2). As such, it is questionable whether they would even be interested in participating in a solution that would require a significant enhancement of transparency and visibility in the supply chain. If they are not willing to participate, this would prove a major limitation to the proposed solution. However, the offsetting partners are reliant on provisions as a source of income (Chooose, n.d. a), which provides an incentive to participate in a solution facilitating consumer demand of voluntary carbon offsets.

Furthermore, the implementation of blockchain technology requires significant monetary costs and knowledge of certain key areas of the technology. The inherent costs related to blockchain makes it more expensive than the traditional central database (Jenks, 2018b). Furthermore, the actors in the supply chain will likely not have sufficient experience or knowledge concerning the adoption of blockchain technology and might choose to outsource this operation, which will entail additional monetary costs. Moreover, the application of blockchain technology for supply chain purposes is quite new, and as such the knowledge about employing the technology is also quite insubstantial. With the lacking awareness of the technology, misinformation and knowledge gaps in relation to its capabilities are rather common (Nguyen, 2019). As such, companies do often not fully comprehend how the technology can be used to facilitate transparency and traceability, and how this can improve their business processes.

A further challenge to the implementation of blockchain technology relates to the relatively low external pressure. Although consumers are increasingly showing interest in accessing information regarding the offsetting practices of the airlines, the pressure has still not resulted in any change in the current operation. This might relate to the lack of awareness and knowledge about offsetting schemes among customers. An additional factor to the lack of change in the current practices is that pressure regarding transformation is not amounting from a sufficient number of people (Choi et al., 2016). If customers increase the pressure on organizations to operate with full transparency, it might make supply chains more likely to adopt blockchain technology.

Since the proposed blockchain solution is intended for the aviation industry in Scandinavia, it is subject to the GDPR. As previously mentioned, there are challenges relating to the utilization of blockchain in the context of personal data. The current best practices entail storing all personal data off the blockchain, or "off-chain", which can subsequently be connected to the ledger by a hash (McMahon, 2019). In this research, only the ticket number of the passenger would be stored on-chain, whilst all personal data is stored in the airlines' local database. However, there are still uncertainties regarding whether the hash constitutes personal data (ibid). Nevertheless, the European Parliamentary Research Service recognizes that permissioned blockchains generally raise fewer compliance issues than their permissionless counterparts (Finck, 2019).

Moreover, it is important to consider the laws applicable to the transactions of a public blockchain system. When a ledger spans over multiple jurisdictions, it can prove challenging to establish which jurisdictions' laws and regulations should be followed. However, within a permissioned blockchain, it is simpler to develop internal governance structures and legal frameworks (Salmon & Myers, 2019). Furthermore, since all Scandinavian countries are subject to EU laws, some of the difficulties relating to legal jurisdictions may be lessened. If the network is to be extended outside of Scandinavia or the EU in the future, it will prove more difficult to establish which jurisdictions' laws and regulations apply.

This research finds that blockchain technology can facilitate the improvement of the issues related to transparency in the supply chain of voluntary carbon offsets. However, it is not able to solve the "last mile" problem, often referred to as the "garbage in, garbage out" conundrum (Jacob Pouncey 1; Kristoffer Just 1). The process of digitizing the carbon offsets will still rely on trust, as the real-world asset needs to be manually converted into its digital representation. As such, it is still reliant upon the project developers and auditors conveying accurate information, which in turn is incorporated in the blockchain. In essence, "*any information system is only as good as the quality of its dat*a" (MIT Supply Chain, 2017, p. 1). This issue is especially prevalent in blockchains, due to their unalterable quality (MIT Supply Chain, 2017).

An additional challenge relates to how to best manage the blockchain solution. As previously mentioned, all actors with a voluntary carbon offsetting scheme in the Scandinavian aviation industry will be able to participate in the network. This entails that there is not one obvious party eligible to manage the platform. The blockchain solution is designed to support transparency in the entire industry, and thus it is not the sole responsibility of one particular entity or supply chain. As such, this research identifies two potential options. Either, the industry would have to work together in a consortium approach, with each individual actor pitching in. Alternatively, a third party could take on the responsibility of building the blockchain infrastructure for actors to plug into. In relation to the consortium approach, the conflicting incentives of the different actors in the industry would likely entail a lengthy implementation, hindering and stalling the adoption of the technology. Potentially, the conflicting – and lack of – incentives could result in failure to commence the implementation altogether.

As such, this research finds the optimal approach to be a third party taking on the responsibility of implementation and management of the blockchain solution. This would entail that an external party develops the infrastructure of the network, allowing the relevant actors in the industry to connect to it. Furthermore, a suitable third-party will likely possess the technical capabilities and experience necessary to successfully design and develop the blockchain solution, which the actors in the industry likely lack. Potential alternatives include organizations with an interest in the application of blockchain for environmental or supply chain purposes, however, this research will not attempt to determine specifically who the third party should be.

As the technical aspects of implementing the proposed solution is out of the scope of this research, further assessments should be made regarding such aspects. The Hyperledger Sawtooth platform is relatively new, and as such is far for being perceived as a mature application at the level of other more established platforms. Moreover, it could be that other platforms will prove more beneficial when divining into the more technical aspects of the different platforms. The researchers acknowledge that there exist numerous further technical aspects that needs to be considered before full adoption.

9. Conclusion

The objective of this thesis has been to investigate blockchain technology and how its properties could be adopted in the practice of voluntary carbon offsetting in the aviation industry to enhance transparency from a consumer perspective. This has been achieved by analysing the following research question in a Scandinavian setting:

> *How can blockchain technology facilitate improved transparency from a consumer perspective in the practice of voluntary carbon offsetting in the Scandinavian aviation industry?*

Viewing the aviation industry in Scandinavia as a single case study, this research employs embedded cases to allow for a more detailed level of inquiry. These sub-units of analysis consist of two airlines within the region: SAS and Widerøe, in addition to a carbon offsetting partner: Chooose. In order to facilitate a comprehensive investigation into the main research question, four sub-questions were formulated and subsequently examined in the analysis. Here, the findings from the analysis will be tied together to fulfil the overall purpose of this research.

In the initial part of the analysis, the lack of transparency from a consumer perspective was recognized as the most prominent area of improvement based on the perception of the actors in the Scandinavian aviation industry. The identification of this issue served to direct and inform the subsequent research. Secondly, a questionnaire was developed to examine whether the lack of transparency was corroborated by consumer demand. It was uncovered that respondents were more interested in offsetting the carbon emissions of their flight following the enhancement of transparency. As such, this research finds that improving transparency could add value to the practice of voluntary carbon offsetting in the Scandinavian aviation industry.

The third component of the analysis was concerned with recognizing the current extent of information available to the consumer, in addition to how and where in the supply chain transparency is being inhibited. This was essential in order to develop an insight into the abilities required to facilitate a solution to the identified challenge. Founded upon semi-structured interviews with the aviation-related actors and relevant literature on supply chain transparency, it was found that the information accessible to the end-consumer reaches no further than the airline, with all subsequent linkages being obscured. In the current practice, consumers have no means of identifying the specific carbon offsets pertaining to his or her particular flight. Rather, they only have access to the airlines' generic offsetting information, such as a lump sum average of the total annual emissions reductions.

This research finds, based on extensive research and communication with several actors in the industry, that the main contributing factors to the lack of transparency from a consumer perspective relate to the lack of granularity of information and non-existent interoperability between data systems. The current practice is highly reliant on human intervention, which is reflected in the periodic bulk purchases and manual retirement of carbon credits. At present, all carbon offsetting endeavours related to an airline is accumulated into one generic bundle. This is what creates the inability to link specific emissions-reduction efforts to a particular customer, depriving the consumer of the ability to access information pertaining to their particular itinerary. As such, this research identified the creation of interoperability between data systems and the deeper level of granularity of information to be the key to enhance transparency from a consumer perspective in the Scandinavian aviation industry.

Building on the preceding findings, the fourth and final component of the analysis was concerned with investigating the ability of blockchain technology to alleviate the pain points currently inhibiting consumer transparency in the supply chain. Founded upon insights from the semi-structured interviews with the blockchain experts and an extensive literature review on blockchain technology, this research finds that blockchain possesses the properties necessary to allow the carbon offsetting efforts pertaining to a particular customer to be linked directly back to them. A conceptual design has been developed illustrating the potential application of blockchain in the supply chain of voluntary carbon offsetting in the Scandinavian aviation industry. With the inherent environmental and organizational requirements of a platform underpinning data transfers in a carbon market supply chain, a public permissioned blockchain has been deemed most appropriate. This restricts the participation and contribution abilities to the consensus to a controlled group of relevant actors, whilst simultaneously providing the public with read abilities – essential for facilitating transparency. This research arrived at the Hyperledger Sawtooth as a fitting alternative, substantiated by its historic applications in supply chains for transparency and traceability purposes. Moreover, this platform meets the requirements of an environmental consensus mechanism and the blockchain trilemma essential for the purposes of this research.

The proposed conceptual design incorporates blockchain-enabled smart contracts in the supply chain, which allows the automatic transfer of information without human interference. Moreover, by converting the value of carbon credits into tokens, the credits can be broken down into digital increments. Combined, these features allow the automatic and separate transfer of passenger-specific information in the supply chain, effectively enabling a specific amount of offsetting equal to the emissions of a passenger's itinerary to be linked back to them. As such, it has been found that the conceptual design is able to solve the identified challenges contributing to the current bulk purchases and external communication of generic information. Furthermore, the implementation of the proposed blockchain platform would allow all actors with a voluntary carbon offsetting scheme in the Scandinavian aviation industry to participate in a shared network. This would provide an industry-wide solution, enabled by blockchain's inherent ability to create a distributed server with no central authority.

Finally, the passenger-specific information facilitated by blockchain technology must be communicated to the end-consumer in order to facilitate transparency. This research proposes the introduction of an app that provides passengers with access to the individual offsetting activities pertaining to his or her flight. To enable this, a user interface (UI) layer will run on a local database, which in turn is mirrored into the blockchain system. Essentially, this provides the consumer with a customized and user-friendly window into the system. Based on the findings from the questionnaire, this research proposes the integration of this service into the existing apps of the respective airlines. Following the introduction of such a service, the extent of information accessible to the end-consumer would no longer be confined to the airline but extended to include all subsequent supply chain stages.

9.1 Feasibility

This research finds that the proposed conceptual design is a favourable solution if the intent is to enhance transparency as a shared initiative across the industry. The benefits of developing one common platform to be leveraged by all industry actors will likely increase with the number of participants in the industry. In the Scandinavian aviation industry, the dominant actors are rather few, and the airlines that have adopted a voluntary carbon offsetting scheme are even fewer. This entails that the costs and efforts associated with implementing a blockchain network might be perceived as large relative to the benefits of the industry-wide solution. In light of this, this research concludes that the properties of blockchain technology are able to facilitate transparency from a consumer perspective in the Scandinavian aviation industry, but that the favourability of employing a shared platform will increase with the number of the actors involved. As such, a broader geographical scope, or even incorporating other industries with voluntary carbon offsetting schemes, would increase the suitability of blockchain technology as a solution to the lack of transparency from a consumer perspective.

Nevertheless, the feasibility of adopting blockchain technology is dependent on a wide range of other factors, with certain key obstacles being described in this research. To start off, this research finds that there might exist a reluctance of certain industry actors to share relevant information, which would constitute a barrier to a solution facilitating transparency. Moreover, the current pressure from end-consumers might not be substantial enough to warrant the adoption of blockchain technology for the purposes of enhancing transparency. However, the findings of the questionnaire could arguably serve as an incentive to engage relevant actors in the proposed solution, as it demonstrates that there does exist a potentially value-adding demand amongst consumers. Furthermore, the lack of awareness and understanding of blockchain technology is one of the principal challenges inhibiting widespread adoption. Seeing as several actors in the supply chain are not technically inclined, it is likely that they do not fully comprehend how the technology can be beneficial in facilitating transparency and traceability, and how this can improve their business processes.

The findings of this thesis must be considered in lights of its scope and limitations. As a case study, the findings are rather specific to the present conditions in the Scandinavian aviation industry, making it difficult to establish their generalizability. However, it could be argued that the findings may be applicable to voluntary carbon offsetting practices outside of Scandinavia, on the condition that the professional actors and consumers share similar perceptions and attitudes. Beyond the scope of this research, there exist several additional challenges to adoption that must be considered in order to ascertain the feasibility of implementing blockchain technology to enhance transparency in the area of this research. These relate to aspects such as regulatory factors and integration with legal systems. In particular, this research has been delimited from assessing the technical aspects surrounding blockchain technology, which would be vital in ascertaining the feasibility of the proposed conceptual design.

10. Further Research

There are substantial areas where further research can contribute to the support of the findings of this research. To start off, this thesis finds that the favourability of developing one common platform to be leveraged by all relevant actors will likely increase with the number of participants in the network. As such, it would prove interesting to examine the adoption of the blockchain solution in a broader geographical scope, so as to analyse the feasibility of incorporating the offsetting practices of additional aviation industries into one large platform. Potentially, an investigation could even be made into the incorporation of blockchain technology for voluntary carbon offsetting practices outside of the aviation industry, facilitating a single solution for multiple offsetting endeavours.

Additionally, this research excludes the carbon registries from the proposed blockchain solution. This decision was found to be necessary due to the current business models of these actors, where a lack of incentive is preventing their participation in the network. At a later time, where resources and insights allow for it, an in-depth exploration of the potential to incorporate the registries on the blockchain may provide an interesting subject. This might constitute extensive research, as it would likely require a vast change in the business model. Moreover, this thesis identified the most suitable management approach of the blockchain solution to be a third-party taking on the responsibility of developing the blockchain infrastructure. However, attempts were not made to identify said third-party. To facilitate a more comprehensive understanding of the adoption of blockchain technology in the area of this research, this aspect should be further examined.

Finally, two additional areas of improvements in the practice of carbon offsetting in the Scandinavian aviation industry were recognized in this research: reporting and pricing. It might prove interesting to conduct further studies to assess whether these issues could be mitigated through the adoption of blockchain or other technologies.

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