Blockchain takes to the skies

An assessment of blockchain applications in the airline industry

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Abstract

Recently, the airline industry increasingly turned towards blockchain technology and started investigating potential use cases. Despite the clear interest in the emerging technology, academic contributions in this field remain scarce. This dissertation strives to close this research gap and explore promising blockchain use cases and their value for the airline industry. Moreover, factors important for the successful implementation of the use cases are discussed. The research questions were answered following a qualitative approach in the form of ten expert interviews, supplemented by the examination of secondary literature. A quantitative approximation of the qualitative insights was adopted to capture the value of the use cases. An order of relevance was established for the initial 14 use cases based on which four promising blockchain use cases, namely "loyalty points", "aircraft parts provenance", "travel distribution landscape" and "passenger ID management" were identified. Quantitative approximation of qualitative insights indicated that the use case "loyalty points" is likely to create the most value as compared to the remaining three use cases. For successful implementation, it is vital to avoid considering the technology as a solution searching for problems to be solved and clearly identifying the measurable economic impact of a given use case. Additionally, strategic implications, enablers and roadblocks, as discussed in this study, must be considered. Looking ahead, mainstream adoption of blockchain technology in the airline industry is only expected by approximately 2024. Future research could be directed towards the individual analysis of promising use cases presented in this study.

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***Keywords*:** Blockchain; Blockchain technology; Airline industry; Blockchain applications; Blockchain use cases; Use case evaluation; Blockchain implementation

Resumo

Recentemente, o setor das companhias aéreas direcionou-se cada vez mais para a tecnologia "blockchain" e começou a investigar possíveis casos de uso. Apesar do claro interesse pela tecnologia emergente, as contribuições academicas neste campo permanecem escassas. Esta dissertação procura diminuir a escassez de pesquisa e explorar casos promissores do uso de "blockchain" e o seu valor para o setor aéreo. Além disso, são discutidos fatores importantes para uma implementação bem sucedida dos casos de uso. As perguntas do estudo foram respondidas seguindo uma abordagem qualitativa na forma de dez entrevistas com especialistas, complementadas pelo exame de literatura secundária. Uma aproximação quantitativa dos insights qualitativos foi adotada para capturar o valor dos casos de uso. Uma ordem de relevância foi estabelecida para os 14 casos de uso iniciais, com base nos quais foram identificados quatro casos promissores de blockchain, como "loyalty points", "aircraft parts provenance", "travel distribution landscape" e "passenger ID management". A aproximação quantitativa das informações qualitativas indicou que o caso de uso "loyalty points" provavelmente criará o maior valor em comparação com os restantes três casos de uso. Para uma implementação bem-sucedida, é essencial evitar considerar a tecnologia como uma solução, procurando problemas a serem resolvidos e identificando claramente o impacto economico mensurável de um determinado caso de uso. Além disso, implicações estratégicas, facilitadores e obstáculos, como discutido neste estudo, devem ser considerados. Olhando para o futuro, a adoção convencional da tecnologia "blockchain" no setor de transporte aéreo é esperada apenas em aproximadamente 2024.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BC4A	–	Blockchain for Aviation Initiative
CAPA	–	Centre for Aviation
DLT	–	Distributed Ledger Technology
EASA	–	European Aviation Safety Agency
ETAC	–	Emerging Technology Analysis Canvas
FSNC	–	Full-Service Network Carrier
GDS	–	Global Distribution System
GDPR	–	General Data Protection Regulation
ICAO	–	International Civilian Aviation Organization
IAG	–	International Airlines Group
IATA	–	International Air Transport Association
LCC	–	Low-Cost Carrier
LHLC	–	Long-Haul Low-Cost
OTA	–	Online Travel Agency
PBFT	–	Practical Byzantine Fault Tolerance
PoC	–	Proof of Concept
PoS	–	Proof of Stake
PoW	–	Proof of Work
SITA	–	Société Internationale de Télécommunications Aéronautiques

1 Introduction

Introduced to the wider public through the cryptocurrency Bitcoin, blockchain is an emerging digital technology that can be described as a decentralized public ledger in which transactions are stored in a chain of blocks (Zheng et al., 2018). Cryptocurrencies, however, are only one of the many potential applications of blockchain technology and people have started to realize that the most profound opportunities of this emerging technology lie within organizations and industries (Schneider et al., 2016). Beyond this, the impact of blockchain is often characterized in analogy to the internet. While the internet enabled the sharing of information across the world, blockchain technology promises to enable the digital exchange of value without friction (Goudarzi & Martin, 2018). Despite its potentially transforming impact on multiple industries, much of the hype surrounding blockchain was initially focused on the financial sector (Tapscott & Tapscott, 2016). Nonetheless, the emerging technology eventually attracted the attention of leaders across various industries, of which one is the airline industry (Accenture, 2018). The airline industry is characterized by a complex ecosystem of stakeholders, oftentimes required to share operational and customer data across various entities, largely archaic and siloed system structures storing the data as well as highly fragmented distribution channels (Bouffault et al., 2019). Blockchain's capability of facilitating accurate, auditable and secure transactions across a dispersed group of stakeholders fits well to the airline industry's needs of sharing data and connecting players from the complex ecosystem in a trustful, secure and auditable manner (Gottlieb, 2017). Going beyond the initial use of blockchain technology, purely financial transactions, this creates a compelling value proposition for the industry. Accordingly, blockchain was identified as one of the emerging technologies that are expected to have a profound impact on the future of aviation (IATA, 2018b).

The airline industry's strong interest in blockchain technology is reflected in the foundation of dedicated blockchain departments and working groups investigating and developing potential use cases (Whitby, 2018), the establishment of industry-wide blockchain initiatives (SITA, n.d.) as well as increased investments in the emerging technology (SITA, 2019). While there is evidently interest in blockchain technology, little empirical effort to systematically capture its potential for the airline industry has been made to date.

The few contributions available focus on specific case studies or the discussion of individual use cases (compare Madhwal & Panfilov, 2017 or Ying et al., 2018). Comprehensive documentation of emerging applications and use cases allowing for systematic comparisons, as existent for other industries, such as the chemical, healthcare, pharma or logistics industry

(compare Bocek et al., 2017; Hackius & Petersen, 2017; Petre, 2017 or Sikorski et al., 2017), are not available for the airline industry. In an attempt to fill this knowledge gap and contribute to the academic relevance of blockchain technology in the airline industry, this dissertation endeavors to explore current developments of potential use cases. Hence, promising blockchain use cases are identified and analyzed in terms of their value for the industry before practical recommendations for the implementation of blockchain technology are provided. This dissertation is guided by two research questions:

Research Question 1: What are promising use cases for blockchain in the airline industry and what is their associated value?
Research Question 2: What factors must be considered to ensure the successful implementation of blockchain in this industry?

The remainder of this dissertation is structured as follows: Chapter 2 introduces the airline industry by pointing out general characteristics, typical airline business models and current economic developments and challenges. This section is followed by a review of blockchain technology, including advantages as well as limitations that are yet to be solved. Combining the two previous topics, the chapter ends with a characterization of current developments of blockchain technology in the airline industry. The literature review is followed by an outline of the methodology in chapter 3, presenting the research design and data collection. Chapter 4 is devoted to the analysis and discussion of the insights collected through the literature review as well as expert interviews and answers the two research questions guiding this dissertation. First, blockchain use cases are structured according to an order of relevance for the airline industry, allowing to identify four promising use cases. These blockchain applications are discussed and analyzed in detail based on their potential value for the airline industry. In a second step, practical recommendations are provided in the form of suggestions discussing important factors to be considered for successful implementation. The focus lies on strategic implications, enablers and roadblocks, as well as an industry outlook for the emerging technology. Eventually, chapter 5 draws final conclusions regarding the two research questions and discusses potential limitations. The dissertation ends with an outlook for future research opportunities.

2 Literature Review

2.1 The Airline Industry

2.1.1 Industry Characteristics

The airline industry is part of a tightly connected ecosystem of various players including aircraft and aircraft component manufacturers, lessors, airports, freight forwarders, Global Distribution System (GDS) provider, and Online Travel Agencies (OTAs) (Cassar, 2018). At the very heart of this ecosystem lie the airlines, with the five largest organizations worldwide (measured by capacity and number of aircrafts in an ascending order) being Ryanair, United Airlines, Southwest Airlines, Delta Airlines and American Airlines (Zhang, 2019). The airline industry is heavily government-regulated (Ethiraj & Zhou, 2019), and security and safety are further ensured through institutional industry bodies like the International Air Transport Association (IATA), the International Civilian Aviation Organization (ICAO), or the European Aviation Safety Agency (EASA) (Akmeemana, 2017). Airlines are usually large in complexity and face geographically dispersed operations due to the nature of the business. Markets are characterized by dynamic competition (Ethiraj & Zhou, 2019) and consequently, financially-ill organizations regularly become insolvent, as the recent defaults of Thomas Cook, Jet Airways or WOW Air showcased (O'Mara, O'Brien & Croke, 2020). Additionally, the industry is characterized by low profit margins (on average US$ 6.85 per passenger in 2018) (IATA, 2019a) and as a result of high fixed costs and demand variability, profitability is largely determined by efficient operations, favorable fuel prices and the overall health of the global economy (Ethiraj & Zhou, 2019; IATA, 2019a).

2.1.2 Airline Business Models

Services provided by airlines can generally be categorized as domestic and international air passenger transportation as well as cargo transportation (IATA, 2019b). Academic scholars, policy makers and business professionals typically distinguish between two major types of airlines, depending on its business model and the respective market position occupied. On the one hand, there is the traditional Full-Service Network Carrier (FSNC) model, as known from major airlines such as Lufthansa or American Airlines. This legacy model is characterized by adopting multi-hub-and-spoke route structures, operating larger planes and thus higher numbers of first- and business-class seats as well as providing a greater variety of services to the passenger (Ethiraj & Zhou, 2019). Low-cost Carriers (LCCs), such as Ryanair or Southwest Airlines, usually operate limited point-to-point networks and generate ancillary revenues by charging its customers for enhanced service (Soyk, Ringbeck, Spinler, 2017). However, the

past years showed a homogenization of business models across the airline industry with LCCs adopting approaches previously exclusive to the FSNC model, making the boundaries less obvious. As such, LCCs continue expanding into FSNC markets by adopting Long-Haul Low-Cost (LHLC) approaches, using GDSs or offering frequent-flyer-programs. Conversely, FSNCs increasingly implement cost-efficiency practices typically used and pioneered by LCCs (IATA, 2018a).

Another aspect primarily adopted by FSNCs, yet more recently also used by some LCCs, is the formation of airline alliances. These cooperative agreements allow for efficiencies as well as enhanced customer benefits by sharing frequent flyer programs, flights and operational costs, such as maintenance facilities, lounges, or personnel among alliance partners (Beresnevicius, 2019). The practice of sharing flights across different airlines is referred to as code-sharing. Oftentimes, it is included within alliance agreements, however, an airline may also have arrangements with other airlines beyond its respective alliance. In code-share agreements, multiple airlines each use their own code to offer a flight. While only the operating carrier actually operates the flight, the other airlines, called marketing carrier, can also offer the same flight (Wiener et al., 2007). Airlines typically engage in these collaborative code-sharing agreements to increase passenger load factors (A Yimga & Gorjidooz, 2019), widen their market presence as well as enhance customer reach and offer (Wiener et al., 2007).

2.1.3 Current Economic Development and Challenges

During the last decade, the airline industry experienced a period of growth and high profitability, peaking in the years 2015 to 2017 (IATA, 2019b). Given however, that the airline industry typically develops cyclically, experts expect the end of this "supercycle" and foresee the advent of an economic downcycle (O'Mara et al., 2020). Despite growing revenues in 2019, global airline profitability of US$ 25.9 bn was short US$ 1.4 bn as compared to 2018 (IATA, 2019b). Similarly, passenger traffic growth sunk from 7.4% to 4.2% and capacity growth was at 3.5% down from 6.9% in the previous year (IATA, 2020a). According to experts, the predicted downturn of the upcoming years was expected to be a rather soft landing (O'Mara et al., 2020). In light of the current development of the Covid-19 pandemic however, it is important to highlight that the airline industry faces an unforeseen exogenous shock with an expected impact between US$ 63 bn and US$ 113 bn in global revenue losses (IATA, 2020b). Likewise, other experts even forecasted most airline's bankruptcy by the end of May 2020 in case of uncoordinated or lacking government intervention (CAPA, 2020).

Beyond that, industry headwinds may evolve from geopolitical tensions, technological innovations, environmental concerns, terrorism or natural disasters (IATA, 2018b). Another

challenge for the global airline industry is its low profitability. Considering the previously mentioned high fixed costs, the airlines' dependency on oil prices as well as the overall health of the global economy, financial profitability largely relies on operational efficiency (Branagan, 2019). Processes, however, oftentimes are outdated and cumbersome (Bouffault et al., 2019). An example, where this becomes apparent is aircraft maintenance. Data on parts and aircrafts, crucial to keeping the plane airborne and ensuring safety for passengers, is often collected manually, prone to loss and rarely available digitally (Lemasson et al., 2019). Yet another factor influencing airline profitability is attributable to the large number of players within the airline ecosystem, each claiming their share of value. Resultingly, airline dependencies on intermediaries, such as GDS providers and OTAs, jeopardize the margins (OpenJaw Technologies, 2019). In addition, the airline industry is characterized by an "archaic and siloed system landscape" (Bouffault et al., 2019), where sensitive information related to customer, product or operational data is stored (OpenJaw Technologies, 2019). As a result of these fragmented data silos, fast and seamless exchange of data within airlines, as well as between involved parties from the airline ecosystem, is hindered (Bouffault et al., 2019).

2.2 Blockchain

The idea of blockchain was first conceptualized and described by Stuart Haber and Scott Stornetta (1990) but only gained broader public attention through the publication of a whitepaper written by the pseudonym Satoshi Nakamoto (2008) introducing Bitcoin. Broadly classified, blockchain is a type of distributed ledger technology (DLT). Distributed ledgers are decentralized archives of data, managed and controlled by participants sharing the same rights and control (Di Francesco Maesa & Mori, 2020). They allow participants to share, synchronize and report data or transactions on a peer-to-peer basis without the need for a trusted third party. (Natarajan, Krause & Gradstein, 2017).

Blockchain differentiates itself from other DLTs by its use of cryptographic and algorithmic methods to create and verify a permanently growing data structure in the form of blocks, which are linked to each other in a chain (Natarajan et al., 2017). As such, blockchain can be defined as *"*a peer-to-peer, distributed ledger that is cryptographically-secure, append-only, immutable and updateable only via consensus or agreement among peers*"* (Bashir, 2018).

At the core of blockchain technology lie peer-to-peer interactions, or transactions. Users engage in digitally signed transactions with other network participants, called nodes, using public-private-key cryptography and disseminate them to all other nodes in the network. These transactions represent agreements between both parties and "may involve the transfer of physical or digital assets, the completion of a task" or others (Casino, Dasaklis & Patsakis,

2018), meaning that not all transactions need to involve the exchange of a monetary value. New transaction records are bundled together to a block and verified against a strict set of rules. These newly created blocks are validated collectively by members of the network according to a pre-defined algorithmic validation method, called consensus mechanism. Upon validation, the new block is appended to the existing chain and an updated, fully identical copy of the entire chain is saved to every node (Natarajan et al., 2017). Rejected blocks are not added to the chain.

2.2.1 Taxonomy of Blockchains

Blockchain technology is usually categorized according to the network's management and permission structures, distinguishing between public, private and federated/consortium blockchains (Casino et al., 2019; Zheng et al., 2018). Public, or permissionless blockchains are open to anyone willing to participate in the network, with every user being able to read and write transactions and hence perform operations on the blockchain. Prominent examples of public blockchains include Bitcoin, Ethereum, Litecoin and most other cryptocurrencies (Haferkorn & Diaz, 2014).

Private and federated, or consortium blockchains can be categorized as permissioned blockchains. In this type of blockchain, a whitelist of permitted users along with certain characteristics and permissions is defined. Severe attacks on permissioned blockchains are much less likely, due to the known identity of users among others (Androulaki et al., 2018), and hence lighter consensus mechanisms can be adopted. Private and federated/consortium blockchains distinguish themselves from one another based on how transactions are verified. Whereas private blockchains deploy a single entity that is responsible for the verification of transactions, leader nodes are selected in federated/consortium blockchains to share this responsibility. These leader nodes may grant further permissions to other nodes. Thereby, a partially decentralized design is achieved, while maintaining the privacy and scalability benefits of a private blockchain (Casino et al., 2019). Thus, a federated/consortium blockchain can be considered a hybrid blockchain with features of both, the open and private protocols. While private blockchains are mostly applied for efficiency and auditing purposes, federated, or consortium blockchains find their use mostly in industry and business environments (Zheng et al., 2018) and enable multiple stakeholders to access a single blockchain. A prominent application of a federated blockchain architecture is the open source Hyperledger Fabric, which is part of the Hyperledger Project of Linux. It can be considered a blockchain operating system, that enables companies such as IBM, Microsoft and Oracle to offer cloud-based "blockchain-as-a-Service" solutions and allows firms to build their own permissioned blockchain

(Androulaki et al., 2018). Table 1 provides a structured classification of the characteristics of public, private and federated/consortium blockchain technologies.

Table 1: *Characteristics of Public, Private and Federated/Consortium Blockchains*

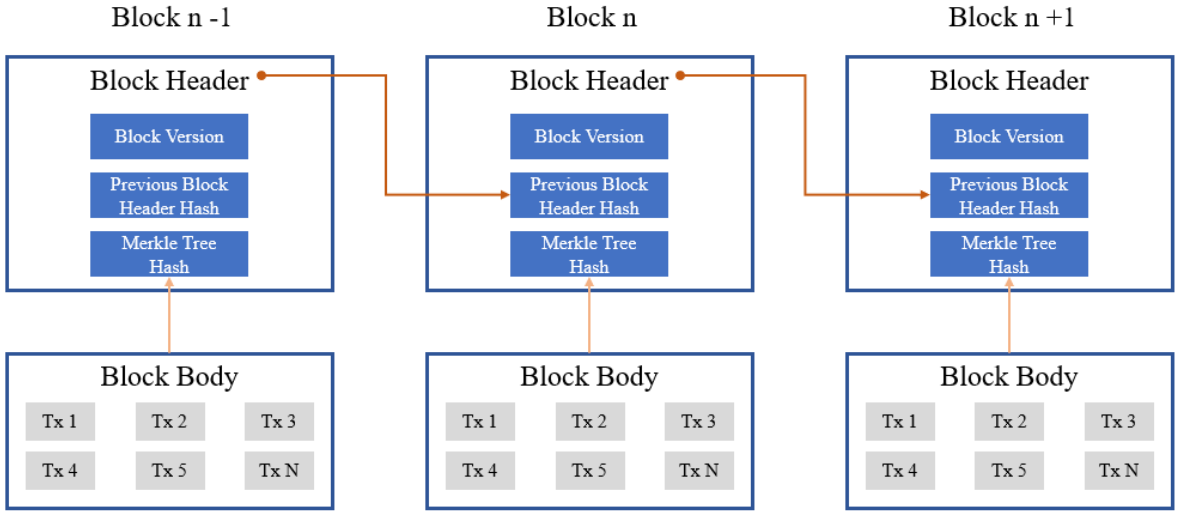
Property	***Public***	***Private***	***Federated/Consortium***
Consensus determination	All miners	Single entity	Permissioned nodes
Consensus process	Decentralized	Centralized	Semi-centralized
Energy efficiency	Low	High	High
Identity	Anonymous	Identified users	Identified users
Read permission	Public	Public or restricted	Public or restricted
Write permission	Public	Restricted	Restricted
Immutability	Nearly impossible	Collusion attacks possible	Collusion attacks possible
Transaction approval	Order of minutes	Order of milliseconds	Order of milliseconds

Note: Own illustration; adapted from Casino et al. (2019) & Zheng et al. (2018).

2.2.2 Basic Structure of a Blockchain

Depending on the type of blockchain network, there is a degree of variation regarding the information stored in each block. The basic structure of blocks, however, is similar across different blockchains and is depicted in Figure 1. A block typically consists of the block header and the block body. The former contains the block version, the previous block's header hash, the Merkle tree hash and other varying information such as the nonce, the difficulty target, or the timestamp. The latter stores information on the transactions inside the block (Bashir, 2018). A block's hash can be considered the digital fingerprint of a block that is automatically created through a cryptographic hash algorithm that takes into account the entire information stored in the header of the block (Bashir, 2018; Di Francesco Maesa & Mori, 2020). The Merkle tree hash is an aggregated hash created from all the transactions within the block body (Bashir, 2018). Through this hash cryptography, every block has a unique identifier, which allows to distinguish any block from others. As outlined above and visible in Figure 1, every block contains the previous block's hash, which links the blocks in a backward direction. This linkage creates an interdependence to all previous blocks and their respective contents to the very first block created, called the genesis block (Di Francesco Maesa & Mori, 2020). As the hash of a block changes automatically once there is any alteration to the content of the block, all hashes of the following blocks would change as well. The chain of the block that was tampered with would thus mismatch all the other chains in the network and would be rejected by its users (Nakamoto, 2008).

Figure 1: *Basic Blockchain Structure*



Note: Own illustration; n = number of the block; Tx = transaction; adapted from Bashir (2018).

2.2.3 Consensus Mechanisms

As outlined earlier, each block needs to be verified. To establish a single version of truth and to circumvent the need for a trusted third party for this validation, a consensus mechanism is utilized. Over time, different types of blockchain have emerged which also gave rise to different consensus mechanisms (Saleh, 2020). The most widely adopted approach remains the one introduced with the Bitcoin protocol, namely Proof of Work (PoW) (Casino et al., 2019). PoW is typically used in public, permissionless blockchains and the nodes responsible for verifying transactions and validating new blocks are called miners. Miners compete against each other to solve a complex mathematical equation, that results in finding a hash that is below or equal to a certain target specified in the block structure. This is achieved by iteratively changing the nonce, an arbitrary number only used once (Bashir, 2018), until a hash that matches the criteria is found. The block is added to the chain once the correctness of the hash is confirmed by all other nodes. The first miner that successfully manages to solve the equation receives a reward, usually in the form of the blockchain's cryptocurrency (Casino et al., 2019; Zheng et al., 2018).

The computing power required for this process is immense and since many miners simultaneously try to create a new valid block, this consensus mechanism results in high levels of energy consumption. For example, the Bitcoin blockchain alone is expected to have similar electricity consumption levels like the countries Ireland or Austria (de Vries, 2018). The most widely used alternative approach to PoW is the more energy efficient concept of Proof of Stake (PoS). Competition among miners existing in PoW is replaced by offering randomly selected validators the authority to update the blockchain, based on their stake, i.e. wealth. The chosen

validator creates a new block in the similar manner as in PoW, except that there is only one node expending computing power to solve the puzzle (Saleh, 2020). Other notable consensus mechanisms include Practical Byzantine Fault Tolerance (PBFT), Delegated Proof of Stake (DPoS), or Ripple (Zheng et al., 2018, offers a comprehensive review of different consensus mechanisms).

2.2.4 Smart Contracts

With the advent of more advanced blockchain architectures, such as Ethereum or Hyperledger Fabric, new capabilities and functionalities arose. One of these new capabilities are smart contracts, which essentially are code, or computer programs, stored on a blockchain that "secure, enforce and execute settlement of recorded agreements between people and organizations" (Bashir, 2018). As such, two or more parties can use smart contracts to determine mutually agreed upon outcomes to a certain digital asset, that are triggered automatically once pre-defined conditions are met (Tapscott & Tapscott, 2018). Smart contracts are therefore capable of drastically reducing costs of contracting, enforcing contracts and making payments (Tapscott & Tapscott, 2016). In the long term, smart contracts may even transform traditional firm structures that are built on contracts to create decentralized enterprises without intermediaries, such as accountants or lawyers and only little management required (Iansiti & Lakhani, 2017; Tapscott & Tapscott, 2016).

2.2.5 Advantages of Blockchain

It can be summarized that blockchain technology has some key characteristics. Data processed on a blockchain is append only, time stamped and immutable (Zheng et al., 2018), meaning that it can only be added in a sequential order at the end of the chain as well as that transactions feature built-in audit trails and cannot be altered upon addition. Furthermore, blockchain is administered by algorithms using public-private key encryption, thereby decreasing the risk of fraud and ensuring security of transactions (Drescher, 2017). It is decentralized and transparent, allowing for enhanced data accuracy and consistency across the whole network as well as reducing the possibility of a single point of failure (Drescher, 2017; Zheng et al., 2018). Lastly, blockchain networks are consensus-driven, ensuring that any update or change is agreed upon by all involved parties (Bouffault et al., 2019; Casino et al., 2019; Zheng et al., 2018).

Considering these core characteristics, several distinct benefits result from the implementation of blockchain. Given its decentralized structure, blockchain replaces trust in humans with trust in technology and its respective protocols and rules (Hughes et al., 2019).

Along with its consensus-driven nature, this allows for the disintermediation of trusted third parties, like banks or notaries, to validate transactions which allows for faster processing of transactions. Beyond this, blockchain allows multiple stake-holding entities to access a single version of truth and hence function as a shared ledger, effectively reducing the complexity of managing separate databases and the need for reconciliation and verification of data (Bashir, 2018). Allowing for high levels of process automation, smart contracts can be utilized to replace manual, labor-intensive tasks (Hughes et al., 2019). As such, the utilization of smart contracts may lead to completely trustworthy systems, which, beyond significant cost reductions and automation, provide benefits of flexibility, speed and security (Bashir, 2018).

Overall, cost reduction is another significant benefit of blockchain, as all previously mentioned advantages go hand in hand with savings. These may be directly visible, for example as reduced fees payable to intermediaries or indirectly, for example through more efficient operations resulting from automation (Akmeemana, 2017; Hughes et al., 2019). Moreover, benefits may emerge in the form of more transparent, standardized and streamlined processes as they must be redesigned when transitioning from traditional technology to blockchain (Hughes et al., 2019).

2.2.6 Limitations of Blockchain

Despite its advantages, it must be acknowledged that blockchain is an emerging technology and as such still lacks technological maturity (Bashir, 2018), constituting in the form of several limitations.

Especially permissionless blockchains are characterized by scalability issues in terms of limited transaction speed as well as increasing transaction volumes (Natarajan et al., 2017). Bitcoin, for example, is only capable of processing up to 7 transactions per second (Zheng et al., 2018), whereas Visa's credit card processing network is able to handle up to thousands of transactions per second (Casino et al., 2019). Additionally, blockchains become bigger with every new transaction and as such require large amounts of storage capacities on each node's computer. The Bitcoin blockchain, for example, has already exceeded 100 gigabyte storage (Zheng et al., 2018). Nonetheless, potential solutions to scalability issues include the use of "planes", "sharding" or "sidechains" (Bashir, 2018; Casino et al., 2019) (Bashir, 2018, provides an extensive discussion of possible scalability solutions).

Privacy and confidentiality issues are considered another significant limitation of blockchain technology, as information is stored on a shared, public ledger. Especially, transactional privacy in relation to the traceability of transactions and smart contract operations are concerns for businesses as well as individuals as the use of pseudonyms, common for public

blockchains, is not sufficient to guarantee transactional privacy (Casino et al., 2019; Zheng et al., 2018).

Despite the considerably high security levels of blockchain, some issues must be addressed in this regard. Public blockchains are susceptible to so-called 51% attacks. This means, that in a case in which at least 51% of the network nodes are controlled by a single entity, consensus could be manipulated. As a result, a faulty, tampered-with chain could be accepted as the true chain, whereas the actual true chain would be rejected (Natarajan et al., 2017; Zheng et al., 2018). Similarly, private consortium blockchains may fall victim to collusion attacks, where parties collaborate to manipulate consensus and thereby override immutability (Zheng et al., 2018). Owing to recent breakthroughs in quantum computing, quantum resilience is considered another limitation. Especially public-private key encryption, may be vulnerable once a strong enough quantum computer is built (Casino et al., 2019). In relation to security issues, it is important to mention the reliability of smart contracts. Since smart contracts are coded programs, they are not immune to technical vulnerabilities or human-induced errors (Natarajan et al., 2017). Additionally, smart contracts differ from traditional programming environments, making their operations harder to understand, and thus easing opportunities of hiding illegal behaviors like the implementation of Ponzi schemes (Casino et al., 2019).

Sustainability is another significant constraint to the technology's wider adoption. Especially public blockchains using the PoW consensus mechanism have very high levels of energy consumption due to mining operations and as such are wasteful in terms of resource usage (Casino et al., 2019). Alternative consensus mechanisms, enabling more energy-efficient operations, are thus adopted increasingly. For example Ethereum, the world's second largest blockchain, is expected to fully move to the PoS consensus mechanism in 2020 (Murtaza, 2020).

Apart from technological challenges, a set of non-technical limitations exist. These manifest for example in the form of lacking legal, regulatory or user acceptance, as well as open questions pertaining to issues regarding the General Data Protection Regulations (GDPR) (Hughes et al., 2019).

It is important to highlight that not all the aforementioned issues affect all blockchain designs in the same manner. Especially critical limitations in the form of scalability, sustainability or privacy largely pertain to permissionless blockchains as compared to permissioned ones (Bashir, 2018; Natarajan et al., 2017).

2.3 Blockchain in the Airline Industry

Looking beyond cryptocurrencies and applications within the financial sector, blockchain technology is attracting the attention of leaders across various industries, one of which is the airline industry. Considering the industry's previously outlined characteristics and challenges, the airline industry provides an environment fitting well with many of the capabilities of blockchain technology (Accenture, 2018). For example its capability of facilitating accurate, auditable and secure transactions across various stakeholders meets the industry's need to share data in a trustful, secure and auditable way (Gottlieb, 2017). In line with this, the technology has been identified to have a major impact on the airline industry in the future and the potential of becoming a central driver of change (IATA, 2018b).

Consequently, airlines started investing in this emerging technology over the past years. Whereas in 2017 only 52% of surveyed airlines invested in blockchain (SITA, 2018a), this figure was up to 72% in 2019. Of this, 57% of the airlines invested in R&D, or piloted programs, and 15% triggered investments in major blockchain programs (SITA, 2019). In addition to investing in the technology, airlines are looking for partnerships with third party tech specialists to deploy blockchain and embrace its opportunities. 27% of airlines surveyed stated to already have had partnerships in place in 2018. By 2021 this number is expected to nearly double to 49% (SITA, 2018a). In addition to partnerships with technology specialists, the airline industry has recently experienced the emergence of multiple initiatives that aim at fostering blockchain adoption. The Société Internationale de Télécommunications Aéronautiques (SITA), for example, launched the Global Blockchain Alliance, which evolved from their previous initiative, the Aviation Blockchain Sandbox, and focuses on use-case assessment, business benefits, government, business cases and industrialization (SITA, n.d.). Similarly, Lufthansa Industry Solutions launched the Blockchain for Aviation Initiative (BC4A) to research and assess potential blockchain applications, create joint standards for its use, as well as bring relevant players from the industry together (Evers, n.d.). Furthermore, Lufthansa partnered with SAP in 2018, to launch their first Aviation Blockchain Challenge, aiming to tackle three distinct fields: (i) passenger experience, (ii) airline operations and processes as well as (iii) maintenance and the aviation supply chain (Lufthansa Innovation Hub, n.d.).

SITA Lab, SITA's technology research team, in collaboration with Heathrow Airport Holdings Limited and International Airlines Group (IAG), initiated a blockchain project to provide a single version of truth for flight status data, called 'FlightChain'. The consortium was later joined by Geneva Airport and Miami International Airport, underlining the project's success and demonstrating scalability of the solution (SITA, 2017). In 2018, SITA invited more

airlines and airports to join the project and received more than 50 expressions of interest from airlines, airports and other industry players (SITA, 2018b). Singapore Airline focused its direction towards blockchain differently and implemented a digital wallet, called KrisPay, which is the first airline loyalty program based on blockchain technology. It enables its customers to have real-time access to their miles and use it for payment at various retail partners in Singapore (Singapore Airlines, 2018). Other Airlines venturing into blockchain technology include Lufthansa, Air Canada or Air France-KLM, for example, who established partnerships with Winding Tree, a Swiss blockchain start up, that focuses on providing an open-source travel distribution platform (Chavez-Dreyfuss, 2019).

3 Methodology

3.1 Research Design

The initial approach was to acquire and consolidate academic literature, as well as qualified insights from other credible sources in blockchain and the airline industry. Complementing, validating and extending insights from this first step, qualitative interviews with experts from both fields were conducted.

In order to answer the first research question, insights and information accumulated during the prior steps were analyzed. Considering that this dissertation has a time restriction, in combination with the purpose of this study, to explore promising applications of blockchain in the airline industry, (i) only a limited number of use cases and (ii) only those use cases providing specific benefits, for example in the form of improved processes, were analyzed in detail in a second step.

As a first step of the analysis, an order of relevance for the use cases mentioned in literature and interviews was established. For this, interviews and articles were analyzed in terms of emphasis put on each use case. Meaning that for the interviews the time spent talking about a specific use case and for the literature the portion of the article dedicated to a use case was assessed. While emphasis put on a use case is a good starting point to sort use cases, it could lead to the inclusion of use cases that are discussed extensively based on their limitations only. Therefore, the assessment was complemented using a second criterion, namely potential of the use case for the airline industry. It should be noted that this assessment of potential is merely meant to mitigate the beforementioned issue and not to provide an in-depth analysis of benefits, which will follow in the second step. The two criteria were merged into a single scale as only those use cases which were emphasized could be assessed in terms of their potential. Accordingly, the use cases mentioned in literature and interviews were evaluated on a scale from 1 (= Interviewee/ author(s) did not mention use case) to 5 (= Interviewee/ author(s) mentioned use case, put emphasis on it and regarded it as very promising). Appendix 1 includes a detailed description of the two scales used for the assessment of literature and interviews, thereby showing how the scores were allocated to the use cases.

After the use cases were assessed individually, a final order of relevance was established by calculating an aggregate score for each use case based on a weighted average of the two individual scores from expert interviews and literature. Considering that the experts were explicitly questioned to point out benefits of potential use cases, insights from the interviews are better suited for an assessment of the use cases. Beyond this, expert opinions better reflect current developments of potential blockchain applications in the airline industry, as compared

to insights from literature which may be outdated. As a result, the scores based on the expert interviews received a weight of 75%, whereas the scores based on literature received the remaining 25%. This methodological approach of screening the use cases first, before proceeding with more granular analysis of selected use cases, as well as the scales used for this first assessment were validated by the experts during the interviews.

In a second step, the potential value of the use cases with the highest aggregate scores from the order of relevance was evaluated based on a quantitative approximation of the insights from the interviews based on the three criteria "efficiency and cost savings", "customer benefit" and "trust, data sharing and auditability". In addition to being validated by the experts, secondary literature provides several reasons why the chosen criteria are suitable to evaluate the use cases. As the strategic value of blockchain will mostly be in the form of cost reduction and increased efficiencies in the short term (Carson et al., 2018), the criterion "efficiency and cost savings" is well suited to capture use case impact. Similarly, the criterion "customer benefit" is legitimized as an important measure since blockchain is expected to drastically improve the customer experience (Bouffault et al., 2019). The last criterion, "trust, data sharing and auditability" reflects key benefits of blockchain (Hughes et al., 2019). Yet, depending on the respective use case, these characteristics may result in different levels of value and accordingly are an important measure to consider.

As it was expected that no or only little quantifiable insights on the benefits of blockchain could be provided by the interviewees, the scales of the three criteria were deliberately designed in a way to allow for an assessment of the use cases based on their description and benefits outlined by the interviewees. Accordingly, the interviews were analyzed using a scale from 1 (= The use of blockchain does not increase operational efficiencies and does not result in cost savings) to 5 (= The use of blockchain drastically increases operational efficiencies and results in substantial cost savings) to assess the first criterion "efficiency and cost savings". Similarly, "customer benefit" was measured using a scale from 1 (= The use of blockchain does not impact the customer experience at all) to 5 (= The use of blockchain has a substantial impact on the customer experience). Also, the last criterion "trust, data sharing and auditability" was measured using a scale from 1 (= The use of blockchain does not impact trust, data sharing and auditability) to 5 (= The use of blockchain has a substantial impact on trust, data sharing and auditability). "Explanations" in Appendix 2 includes a detailed description of the three scales and thereby allows to understand the allocation of scores.

Every interview which included at least one of the highest scoring use cases from the previous analysis, was analyzed individually per use case and scores for each of the three criteria were allocated according to the respective scale. In case an interview lacked sufficient information for a criterion, no score was provided for this criterion. Having assessed each interviewee's insights on the use cases individually and according to the outlined methodology, an average score for each criterion was calculated for the use cases. Based on these scores, the total aggregate value of each use case was calculated using equal weights across the criteria. Evenly distributed weights were chosen over a weighted average, as the experts indicated the three criteria to be equally important in terms of assessing use case value for the airline industry.

The second research question was answered based on a qualitative analysis of the interviews, which was complemented with insights from literature. Building on the Emerging Technology Analysis Canvas (ETAC) (Figure 1 in Appendix 3), which is a framework used to characterize important factors for the success of emerging technologies (Fremantle et al., 2018), comprehensive suggestions for the implementation of blockchain technology in the airline industry were provided. The focus here lay on the discussion of strategic implications, enablers and potential roadblocks critical for a successful implementation. An outlook for blockchain technology in the airline industry complemented this. Insights from the interviews were analyzed and aggregated into clusters of the respective factors under discussion.

3.2 Data Collection

Given the exploratory nature of this dissertation, exhaustive secondary research was undertaken to collect information on the topics under study, namely the airline industry, blockchain, as well as the use of the latter on the former. The process involved the review of relevant academic literature and other qualified sources such as general management magazines, reputable newspapers, whitepapers and institutional or consulting publications. Complemented with industry fact sheets, the secondary data collection provided relevant insights of both qualitative and quantitative nature and laid the groundwork of this study.

To validate and extend the findings from the secondary data collection, primary research was conducted through expert interviews. Given the exploratory nature of this study, the interviews were conducted in a semi-structured way, allowing for enhanced flexibility and better understanding of the personal opinion of the interviewee (Bryman & Bell, 2011). An interview guide was used to broadly structure the interview process and, if requested, provided to the interviewee in advance, as a means to strengthen the dependability of the research (Bryman & Bell, 2011). Given the limited number of experts in this particular area under study, a convenience sample was used, and potential candidates were identified using literature, web-

search and LinkedIn. To ensure legitimacy and relevance of the insights, only people with significant expertise in blockchain technology, for example in the form of previous work experience or projects, were considered.

A total of ten candidates was interviewed. Interviewees included current and former airline executives, airline line managers, founders of blockchain start-ups and consultants. The interviewees all possess solid experience within the airline industry and represent various areas of the industry. Table 2 provides an overview of the participants' backgrounds as well as basic information about the interviews. Insights from each interview were consolidated in a summary. The interview guide can be reviewed alongside the interview summaries in Appendices 4 and 5, respectively.

Table 2: *Expert Interviews*

Expert	Industry	Profession	Range of revenues	Interview duration	Interview date
1	Airline	Head of Corporate Strategy	US$ 1-5 bn	45 min	31.03.2020
2	Airline	Senior Aviation Consultant	/	60 min	08.04.2020
3	Airline (Maintenance)	Founder and CEO blockchain start up	/	70 min	10.04.2020
4	Airline (Maintenance)	IT Consultant/ Project Manager	US$ 40-45 bn	45 min	16.04.2020
5	Airline (Cargo)	Senior Project Manager Digital Transformation	US$ 40-45 bn	40 min	20.04.2020
6	Airline	VP Enterprise Effectiveness/ Head of internal Consulting Division	US$ 25-30 bn	45 min	21.04.2020
7	Airline	Head of Incubators and Accelerators	US$ 25-30 bn	50 min	22.04.2020
8	Travel	Founder and COO blockchain start up	/	55 min	24.04.2020
9	Airline (Loyalty)	Head of Innovation Lab/ Manager IT	US$ 40-45 bn	50 min	28.04.2020
10	Management Consulting	Managing Director/ Global Head of Blockchain	US$ 5-10 bn	35 min	01.05.2020

Note: Own illustration; "/" = no disclosure of financial information.

4 Analysis and Discussion

Blockchain technology is expected to have a strong impact on the airline industry and the potential to improve customer experiences, operational efficiencies and cost-savings within various areas of the industry (Bouffault et al., 2019). The expert interviews complement these theoretical expectations from literature and provide legitimacy from a practical point of view. When asked about the potential of blockchain for the airline industry on a scale from 1 to 10, with one being low potential and 10 being high potential, the average rating of the interviewed experts was 7.8 (Figure 2 Appendix 3). In line with this, one former airline official indicated, that "most airlines look at blockchain as a technology for the future, as there are obviously benefits to it" (Expert 6, 2020).

Despite this, academic attention on the application of blockchain in the airline industry is considerably low and only a limited number of scientific contributions are directed towards the discussion of use cases. Other sources, such as publications from leading consulting firms or institutions, like IATA or the Blockchain Research Institute, discuss blockchain use cases for the airline industry, yet lack a sufficient level of detail required to make appropriate and comparable judgements about the potential value of these use cases. A structured documentation of emerging use cases allowing for comprehensive discussion and comparison is not available. Filling this gap in academic research, the aim of this study is to explore promising use cases and providing practical recommendations for the implementation of blockchain technology in the airline industry. Accordingly, this section will be devoted to discussing and answering the two research questions guiding this dissertation:

Research Question 1: What are promising use cases for blockchain in the airline industry and what is their associated value?
Research Question 2: What factors must be considered to ensure the successful implementation of blockchain in this industry?

4.1 Blockchain Use Cases in the Airline Industry

Opportunities for blockchain in the airline industry typically cluster around five areas of application, namely tokenization of assets, provenance of virtual and physical assets, digital IDs, certification for safety and security as well as smart contracts (Goudarzi & Martin, 2018). Analyzing insights from literature and expert interviews according to the methodology outlined in the previous chapter, a total of 14 use case were identified. Whereas 11 use cases were described by both, literature and experts, three use cases mentioned by experts were not covered in the literature.

Table 3: *Order of Relevance of Use Cases*

Use case	Experts *(75% weight)*	Literature *(25% weight)*	Weighted average
Loyalty programs	3.1	3.8	3.3
Aircraft parts provenance	3.1	3.8	3.3
Travel distribution landscape	2.3	2.6	2.4
Passenger ID management	2.4	2.0	2.3
Crew/Workforce ID management	1.9	2.2	2.0
Baggage tracking	1.6	2.4	1.8
Cargo tracking	1.7	1.8	1.7
Revenue & payment reconciliation	1.6	1.5	1.6
Flight planning & ATC charges	1.1	1.5	1.2
Ground operations	1.0	1.6	1.2
Connecting travel providers	1.3	1.0	1.2
Refueling of aircrafts	1.2	1.0	1.2
Tokenization of aircrafts	1.3	1.0	1.2
Automated passenger compensation	1.0	1.2	1.1

Note: Own illustration; based on analyses found in Tables 1 and 2 of Appendix 1.

Table 3 presents an order of relevance for the identified use cases based the emphasis put on the use case by literature authors and interviewees as well as its potential for the industry. Overall, the scores from literature and experts are to a large degree consistent, resulting in similar levels of relevance placed on the respective use case. However, the use case “baggage tracking” shows an unusual divergence, indicating that literature assesses this use case as more promising as compared to the interviewed experts.

As the scope of this dissertation is restricted by time constraints, only a limited number of use cases could be analyzed in detail. Considering the evaluation scale of 1-5, use cases with a weighted average score of 2 or less indicate a lower relevance for the industry. Accordingly, the four use cases with scores higher than 2, namely “loyalty programs”, “aircraft parts provenance”, “travel distribution landscape” and “passenger ID management” seem to be promising for the airline industry and thus well suited for further evaluation. Moreover, these four use cases reflect different areas of the airline industry and are therefore exemplary for the wide applicability of blockchain in this field. Going forward, the four mentioned use cases will be analyzed and discussed in detail in the following section with special emphasis put on their potential value add for the airline industry.

4.2 Promising Use Cases

The use cases will be discussed by first describing the current process and existing pain points and in a second step introducing the potential blockchain solution. This brief description is followed by a discussion of the potential value of the respective use case for the airline industry, taking into consideration the three criteria used to analyze the use cases, “efficiencies and cost savings”, “customer benefit” and “trust, data sharing and auditability”. Provided that this study focuses on the potential value add of blockchain use cases for the airline industry, technological aspects of solutions or its implementation will not be discussed in detail. Eventually, this part will conclude with a comparison and discussion of the value of the use cases as established through an approximation of quantitative analysis of qualitative insights.

4.2.1 Loyalty Programs

A central part of airlines’ customer relationship management are loyalty programs (IATA, n.d.). For every flight taken with the airline or within its alliance, participating travelers are rewarded with digital points that can be spent at a network of partners or redeemed for new tickets. Currently however, airlines’ frequent flyer programs are oftentimes characterized by high levels of manual overhead and cumbersome or even manual processes in terms of earning, redemption, and reconciliation (Experts 7 & 10, 2020). Especially transferring points between airlines and customers, airlines and retail partners or airlines and airlines is a very time-consuming and non-transparent process (Experts 2, 7 & 10, 2020). Moreover, loyalty points represent liabilities on the airlines’ balance sheets and as a result provisions must be set aside to account for the financial value of the miles (Expert 2, 2020).

Using blockchain, many of the these problems associated with airline loyalty programs may be solved, as the technology is able to ”significantly streamline the earning, spending, accounting and reconciliation of frequent flyer points” (Goudarzi & Martin, 2018). Essentially, loyalty points would be tokenized on a blockchain and transferred to a cryptocurrency, carrying a similar financial value as the traditional frequent flyer points (Experts 2, 3, 6, 9 & 10, 2020). Multiple stakeholders, including airlines or retail partners would have access to a single point of truth for frequent flyer points in such a consortium blockchain and would be provided with a “clear understanding, that the data they transfer and reconcile is correct” (Expert 10, 2020).

The potential value add in terms of enhanced efficiencies is highly promising. Especially administrative backend processes, like mileage accrual and redemption, updating customer accounts or reconciling frequent flyer points between airlines can be automated heavily using blockchain (Experts 6 & 10, 2020). Considering only the latter in isolation, alliance-wide cost savings of up to US$ 1 mn annually would be possible, if a consortium blockchain was

implemented (Expert 10, 2020). Traditionally involving high administrative overhead, the process of onboarding new partners would be drastically improved using blockchain by enabling them to simply subscribe to the new platform (Expert 7, 2020).

Next to potential efficiency gains, this use case allows airlines to substantially increase customer benefits (Experts 2, 3, 6, 7 & 10, 2020). Due to the technological features of blockchain, miles would be provided in a "secure and real-time way, allowing for immediate usage and redemption of points" (Expert 2, 2020). This ability to "earn-and-burn" does not only allow for high levels of user engagement (Expert 7, 2020), but also enables customers to experience instant gratification (Expert 2 & 6, 2020). Furthermore, the enhanced onboarding process of partners would result in an increased availability of retail partners for customers to redeem their loyalty points at.

Moreover, benefits prevail in terms of trust, data sharing and auditability. Data transferability and auditability would be enhanced drastically, as every participant of the consortium blockchain would have access to the same version of accurate, agreed upon data (Expert 10, 2020). Accordingly, this would result in increased trust into the data quality as well.

Additionally, the overall burden of managing the financial liability of loyalty points could be reduced, and provisions may be steered more accurately, as a combined result of increased spending incentivization of customers and real-time information on how many points are issued and redeemed (Experts 2 & 7, 2020).

4.2.2 Aircraft Parts Provenance

Considering the airline industry's strong focus on security and safety due to strict regulatory oversight, it is critical to know the exact origin and ensuring the quality of all components and parts an aircraft is composed of. As such, airplane maintenance is characterized by extensive documentation on works and quality checks performed for every individual part (Expert 7, 2020). In light of the technological finesse of modern airplanes, one is drawn to think these maintenance processes are characterized by similar technological sophistication. In reality however, processes are time-consuming and generate "dozens of folders of paper-based records with maintenance history" (Expert 3, 2020). Data, crucial to ensure planes remain airborne, is often collected manually (Lemasson et al., 2019). For aircraft parts to be considered airworthy, a gapless history of all maintenance records must be provided. Considering the largely manual and paper prone procedures, part provenance can become an issue, and if not provided without disruption, even result in long and costly processes to establish airworthiness of the part. In the worst case, airworthiness cannot be established, and the airline is forced to scrap the respective part (Expert 4 & 5, 2020). Although some airlines have initiated digitization efforts to collect

data on spare part maintenance digitally (Expert 4, 2020), these are mostly stored in isolated databases characterized by heterogeneous data standards, hindering seamless data transfer across different systems (Lemasson et al., 2019).

Using blockchain technology, every part of an aircraft may be equipped with its own digital identity, providing back-to-birth traceability and a complete history for every maintenance step conducted (Experts 3, 5 & 7, 2020). Furthermore, the use of smart contracts could ensure that only certified engineers and mechanics provide services for the parts and aircraft they are licensed for (Expert 3, 2020).

Eliminating friction and drastically reducing paperwork involved in airline maintenance processes, the introduction of blockchain allows for strong increases in efficiencies (Experts 3, 4, 5 & 7, 2020). Furthermore, scheduling and tracking of maintenance events could be enhanced, while more accurate data collected on aircraft parts could be used to provide insights into previously unknown inefficiencies within various maintenance processes (Expert 7, 2020). Additionally, fewer parts would be discarded due to the completely auditable back-to-birth traceability (Experts 4 & 5, 2020). Beyond this, the creation of a digital twin for each part impacts and improves other airline processes that are dependent on accurate parts provenance, such as lease-back transitions of aircraft or the secondary spare parts market (Expert 4 & 5, 2020). In conclusion, the value of this use case is substantial, with the implementation of blockchain potentially resulting in maintenance cost reductions of approximately 5% (Lemasson et al., 2019), which translates into savings worth US$ 3.5 bn on the industry level.

Unlike its impact on efficiencies and cost savings, however, this use case does not carry much value in terms of customer benefit. Merely the increased security, through the avoidance of unofficial spare parts sold by unauthorized resellers (Expert 5, 2020), may be considered to have an indirect beneficial effect on the customer.

Next to drastically reducing and managing the load of documentation required for aircraft parts, blockchain could help to offer independent availability of the documentation and enable direct access to data for relevant parties (Expert 7, 2020), resulting from its decentralized, immutable and consensus-based nature. Thus, data shareability across various entities is enhanced. Moreover, complete life-cycle part provenance could be established, providing every player from the ecosystem with trust in and transparency about every aircraft part's history (Expert 1, 3, 4 & 5, 2020).

4.2.3 Travel Distribution Landscape

Today's travel distribution landscape is widely shaped by three GDS providers, Amadeus, Sabre and Travelport, which are responsible for tracking bookings and distributing

available inventory within the travel industry. They function as intermediaries within the travel supply chain by connecting OTAs and travel providers, like airlines (Singhal, 2018). As a result, airlines have become highly dependent on these GDS providers, which "consolidate much of the industry's decision making power and charge substantial fees and commissions for their services" (Bouffault et al., 2019). Considering the industry's thin margins, airlines are looking for solutions to reduce dependencies on the intermediaries.

A promising alternative to the existing structures could be leveraging blockchain technology to disintermediate the whole travel distribution landscape and shift back value traditionally captured by GDS to the original providers of travel inventory, the airlines (Experts 1, 2 & 8, 2020). Ideally, this would be a completely decentralized public blockchain environment, directly connecting travelers with travel providers.

Considering an average fee of around US$ 10 per ticket paid to GDS providers (Expert 2, 2020), a disintermediation of these middlemen could result in substantial cost savings for airlines. The full magnitude of the value behind this use case becomes even more apparent when considering an estimation, according to which the total amount of GDS fees paid by airlines were approximately US$ 7 bn in the year 2012 (The Economist, 2012). Furthermore, due to the potentially direct transactions with customers, airlines would be enabled to instantly collect fare revenues and access proceedings quicker. This process is currently very time-consuming for airlines to manage and involves IATA as a third party. Typically, one or two weeks after a ticket is sold by an OTA, it is declared to the Billing Settlement Plan, managed by IATA, from where payments between OTAs and airlines are cleared. Additionally, airlines could achieve efficiencies by reducing the management overhead required to handle the current process (Expert 2, 2020).

Despite potentially slight reductions in fare prices, the customer presumably will not enjoy many benefits from this use case. Large organizations with high travel expenses like global consulting firms, however, may potentially directly connect to airlines via blockchain and may benefit from more advantageous fare prices (Expert 8, 2020)

A main feature of this solution is the disintermediation of GDA providers, who as middlemen, claim a large portion of the industry's value. The involved entities could rely on the consensus-driven nature of blockchain as well as its governing protocols and rules to provide trust and transparency to the travel distribution ecosystem, thereby making GDAs widely redundant. Furthermore, the distribution capabilities of the airlines could be enhanced due to the improved transferability of data and potential access to OTAs or customers worldwide, as an open blockchain would allow anyone to participate. Especially in relation to

the verification of OTAs, smart contracts may be used to legitimate those participants (Expert 8, 2020).

A major issue for this use case, resulting from its permissionless design, is scalability. Current transaction processing speed of public blockchains cannot compete with existing GDS capabilities (Experts 1 & 8, 2020). Therefore, the non-profit start up Winding Tree, driven by the motivation to liberalize the travel industry, has shifted their efforts to focus on the two main capabilities of GDS providers, namely aggregation of OTAs and providing trust in their legitimacy. Instead of following their initial idea of executing all transactions of the distribution landscape on a blockchain, they created an environment based on Ethereum, which only provides the vetting of businesses, as currently done by GDAs and thus scalability issues resulting from limited transaction rates are avoided. Once a business or OTA proved their legitimacy via "verifiable claims", they can connect with the airlines' APIs directly based on traditional technology, which allows for the appropriate transaction speed required (Expert 8, 2020).

4.2.4 Traveler ID Management

Long queues and unpleasant experiences before and after flights are a common characteristic of air travel troubling travelers. There are multiple points across the customer journey, where the traveler must verify and share his or her identity to clear legal processes and access services. In the process, many intermediary parties, like airlines, airports, customs and immigration authorities are involved and validate customer identities individually. Typically, the customer interacts with multiple centralized systems, resulting in a very time-consuming, inefficient and unpleasant process (Experts 6 & 7, 2020).

Blockchain could be used to connect the various players involved in this process and instead of validating the passenger's identity repetitively at every touchpoint, it would only be validated once in the beginning of the process and potentially linked to biometric data, serving as a unique identifier throughout the journey. Relevant entities would be provided with access to the traveler's data and the customer could move smoothly through the whole ecosystem (Experts 6 & 7, 2020). Furthermore, additionally required travel documentation, such as visas, could be directly attached to the passenger identity and thereby easily accessed by relevant authorities (Expert 7, 2020).

Considering the largely manual processes of validating passenger identities at various points across the customer journey, this solution could increase efficiencies by reducing time required for validation of travelers (Experts 6 & 7, 2020). Moreover, due to human error, passengers without valid visas may sometimes board flights but are denied access at the

destination country. The involved costs for repatriation and fees incurred are born by the airline and may be avoided using a blockchain system, which provides complete information on all required travel documents (Expert 7, 2020).

Customers could benefit tremendously from this use case. Streamlining the processes and making them more efficient allows to drastically increase the throughput time and thereby reduce time travelers spent queuing. The overall travel experience could be enhanced, providing customers with more flexibility and allowing them to seamlessly move through the various check points from departure to arrival (Experts 7 & 8, 2020).

Leveraging its ability to enable various entities to access decentralized data in a trustful and secure manner, a blockchain solution enhances data transferability across the whole passenger identity ecosystem.

4.2.5 Comparison of Use Cases

As per the previous discussion on individual use cases, the implementation of blockchain can help solve many pain points or improve existing processes and thereby generate value for the airline industry. Complementing these findings with an approximation of quantitative analysis of the insights from the interviews, allows to achieve enhanced comparability and a better evaluation of the use cases in terms of their value and industry impact. The results of the analysis for every individual use case can be found in the Tables 1 to 4 in Appendix 2. The findings from this analysis are summarized in Table 4, providing a structured overview of the quantitative approximation of the potential value of the use cases for each criterion as well as the total aggregate value. It was calculated using evenly distributed weights across the three criteria.

Overall, the use case “loyalty programs” with a total value score of 3.8 out of 5 seems to carry the greatest value for the industry, confirming findings from literature, that the potential of blockchain is highest in customer-related activities (Bouffault et al., 2019). As discussed in the previous section, blockchain can be especially beneficial in terms of increased efficiencies and resulting cost savings. Beyond that, customers are able to enjoy instant gratification through the immediate transfer of loyalty points and thus benefit greatly. Eventually, the impact of this use case is expected to be even stronger, as “a lot of value and new opportunities will be discovered along the way when experimenting with the technology or after implementing it” (Expert 3, 2020).

Table 4: *Comparison of Use Case Value*

Criteria	Loyalty programs	Aircraft parts provenance	Travel distribution landscape	Passenger ID management
Efficiencies & cost savings *(33% weight)*	4.0	3.8	4.0	3.3
Customer benefit *(33% weight)*	4.0	1.2	2.5	3.6
Trust, data sharing and auditability *(33% weight)*	3.5	4.0	3.7	3.3
Total value:	**3.8**	**3.0**	**3.4**	**3.4**

Note: Own illustration; based on analyses of interviews found in Tables 1 to 4 in Appendix 2.

Next, the use cases "travel distribution landscape" and "traveler ID management" both have a total value score of 3.4. Whereas the former scores highest on the criteria "efficiencies & cost savings" and "trust, data sharing and auditability", the latter has a higher impact in terms of enhanced customer value. The strongest value driver of the use case "travel distribution landscape" is the prospect of disintermediating GDS providers and claiming back large amounts of financial value that has been captured by the middlemen for decades. The use case "traveler ID management" seems to have its strongest impact on the customer value, allowing for reduced waiting times and increased flexibility.

Finally, the use case "aircraft parts provenance" received the lowest total value score, namely 3.0 out of 5. Despite its considerably high impact in terms of efficiencies as well as enhanced data transferability and auditability, this use case does not impact customer value, which is not surprising, considering the purely operational nature of aircraft maintenance.

4.3 From Theory to Practice: Suggestions for Implementation

By outlining critical factors to consider when implementing blockchain applications in the airline industry, the second research question is addressed. The suggestions are structured according to the ETAC (Figure 1 in Appendix 3), a framework outlining important success factors for the implementation of emerging technologies. Its four main categories involve (i) the identification of a problem, (ii) the need of the technology to have a significant impact, (iii) technical feasibility and (iv) the navigation of potential risks, which are broken down into 13 distinct factors (Fremantle et al., 2018). Due to the limited scope of this dissertation, it is not feasible to discuss the ETAC framework in its entirety. Instead, only factors that correspond

with those identified by experts during the interviews will be discussed. Accordingly, this section starts with a discussion of strategic implications, highlighting the importance of a strong business case and potential strategy opportunities. In conjunction with the following part about important enablers supporting the successful implementation of blockchain technology in the airline industry, which closely reflect the factor "Drivers" the first two categories of the framework are covered. Next, potential roadblocks as addressed as "Risks" in the ETAC framework are discussed. Eventually, this section will conclude with an outlook of blockchain for the airline industry, including a potential starting point for an airline's blockchain endeavors. Together with the roadblocks, this covers the fourth category of the framework.

4.3.1 Strategic Implications

4.3.1.1 Making the Business Case. Sometimes, organizations want to implement emerging technologies to better understand and learn about the technology (Expert 5 & 10). These experiments typically do not have a justifiable business use and are rather driven by the interest in the technology. Typically, those projects are shut down and may even result in resistance towards the technology within the organization (Expert 10, 2020). Similarly, problems sometimes tend to be approached by organizations with blockchain as the appropriate solution on their mind already (Expert 5, 2020). It is important, however, to always remain solution-oriented and approach a specific problem with an open mind regarding various potential solutions and technologies. Otherwise, one may easily fall victim to the fallacy of blockchain becoming a solution, that is looking for a problem. Fortunately, there are various frameworks available, helping to assess whether blockchain may be an appropriate solution for a problem at hand (for example Goudarzi & Martin, 2018). These frameworks can be utilized to pre-screen the viability of using blockchain, before assessing the potential value of use cases.

Once blockchain could be confirmed as an appropriate solution to a given problem, the denominator of use case success lies in the ability of airlines to clearly pinpoint its economic value. As this dissertation showed, an extensive number of potential blockchain use cases within the airline industry exists and is likely to increase with time progressing and the technology maturing. However, airlines may navigate through this by taking a structured approach, combined with a healthy dose of skepticism towards use cases, allowing them to determine whether sufficient accessible value is at stake for the respective use case. Pain points addressed by the solution must be identified and defined clearly to enable granular analysis of the potential commercial value of the use case (Carson et al., 2018). Without proving a real, measurable economic impact, airlines should neither consider a given use case for

implementation nor think about options of which blockchain strategy to follow, as discussed in the next section (Experts 1, 5, 6, 7, 8, 9 & 10, 2020).

4.3.1.2 Blockchain Strategies. Once a use case has been identified to being capable of solving specific pain points and generating significant commercial value, decision maker must consider strategic implications before blindly testing and implementing a potential blockchain solution.

One framework for blockchain strategy (Figure 3 in Appendix 3), as proposed by McKinsey & Company, differentiates between strategic options based on the two dimensions "Market dominance", defined as the ability to influence key parties of a blockchain environment, and "Standards and regulatory barriers", defined as the requirement for regulatory approval or coordination on standards. Depending on the positioning within the matrix, the four potential strategies are "Attacker", "Follower", "Leader" and "Convener" (Carson et al., 2018). While this framework does not allow for the development of an extensive organization-wide blockchain strategy, it enables organizations to recognize critical factors in determining their respective approach towards a blockchain use case.

Facing high regulatory barriers and standards imposed by national and international air transport organizations or institutions such as IATA, as well as enjoying high levels of market dominance, it can be inferred that incumbent airlines (typically FSNC) should follow the "Convener" strategy. Given the high regulatory barriers and standards required, conveners need to establish consortia and drive conversations to shape new standards. A process, which may be facilitated by existing alliance structures. Moreover, despite enjoying high market power, legacy airlines cannot single-handedly drive blockchain adoption, and should therefore harness their dominance to establish standards within the consortium to optimally position themselves to "shape and capture the value of new blockchain standards" (Carson et al., 2018).

Depending on the magnitude of a use case however, the classification of airlines in terms of the dimension "Market dominance" may vary. As a result, the appropriate strategic approach may differ for use cases that encompass multiple industries and players as compared to blockchain applications that are limited to the airline industry.

4.3.2 Enablers for Implementation

While blockchain technology itself has the capability to serve as a digital enabler to unlock vast amounts of value within the airline industry, the successful implementation of this emerging technology depends on certain critical factors.

Initiating blockchain projects requires various stakeholders from the airline ecosystem, potentially even competitors, to collaborate extensively and share data. Therefore, it is crucial

to leverage existing trustful relationships between these players to form alliances and consortia. This allows to establish governance models that are aligned with each entities' needs and capabilities and lay out how systems, data and investments will be managed. This, however, may only be achieved through exceptional stakeholder management (Expert 2 & 6, 2020) and a certain level of trust existing between participants (Expert 10, 2020). Furthermore, IATA, as an objective institution, could act as a facilitator assisting in the creation of guidelines and global standards (Experts 5 & 7, 2020). This becomes particularly relevant as a lack of standards and clear regulations is a major limitation for the scalability of blockchain applications (Carson et al., 2018).

Next, communication on the organizational level must be very clear. Relevant airline decision makers must be educated and demystified about blockchain, its capabilities and its potential benefits (Experts 2 & 3, 2020). As outlined earlier, clearly pointing out the potential value to be captured by a use case helps convincing executives and reducing opposition towards the emerging technology, eventually allowing for management buy-in. Further relating to the organizational capacities, airlines must possess a certain level of innovation capability. As airlines traditionally are not very innovative (Expert 3, 2020), establishing innovation centers, as for example the Lufthansa Innovation Hub, can help accelerate the development of these capabilities (Expert 10, 2020).

Additionally, airlines must have very strong knowledge about existing IT architectures and how they connect to the outside world, as discussions within blockchain consortia will quickly focus on design questions such as which data is required, what data format should be used or how the blockchain solution can be integrated within the existing IT environment (Expert 5, 2020).

Lastly, current limitations of blockchain, especially in terms of scalability, interoperability and cross-chain functionality, must be resolved in order for the technology to mature and become more widely adopted.

4.3.3 Roadblocks for Implementation

Antagonist to the enablers, there are certain factors that potentially impede the successful implementation of blockchain within the airline industry. Firstly, the airline industry is characterized by a strong legacy mindset towards innovation as well as a high reluctancy to change (Experts 1, 3, 4 & 7, 2020), which is reflected in its considerably slow approach towards adopting new technologies (Experts 1 & 4, 2020). Moving entirely to e-tickets, for example, took the industry approximately 12 years (Expert 1, 2020). Further complicating the implementation of blockchain technology, is the industry's focus on safety, compliance and

regulations (Experts 4 & 7, 2020). Looking beyond general air transport regulation, European airlines are affected even more severely, due to the additional burden to conform with GDPR requirements.

Furthermore, despite being around for more than ten years, blockchain is still strongly associated and often confused with cryptocurrencies, especially Bitcoin (Carson et al., 2018). Resulting from the cryptocurrency's strong fluctuations in value during the past two years, the impression of being unpredictive or unreliable may be extrapolated to blockchain technology in general. However, regulators are slowly beginning to accept blockchain and recognize its industry-wide benefits beyond cryptocurrencies (Experts 3 & 6, 2020).

Currently, however, the largest roadblock for the implementation of blockchain technology is the global airline industry crisis, resulting from the impact of the Covid-19 pandemic. Many airlines face insolvency and are dependent on governmental support. Accordingly, it will require years to regain pre-crisis strength and investments in emerging technologies, such as blockchain, are most likely either halted or stopped entirely (Experts 1,2 & 6, 2020).

4.3.1 An Outlook for Blockchain in the Airline Industry

As of 2019, the Gartner Hype Cycle for blockchain technologies (Figure 4 in Appendix 3) saw blockchain sliding into the "Trough of Disillusionment", a stage characterized by waning interest in the emerging technology due to experiments and proof of concepts (PoC) failing to deliver on expectations (Rimol & Goasduff, 2019). In accordance with this, three interviewees from Lufthansa Group stated that the company's blockchain hype peaked in mid-2018 and most PoCs did not move into production and were shut down (Experts 4, 5 & 9, 2020). Further supporting the findings from Gartner, five interviewees were not aware of any currently implemented blockchain use cases across the airline industry (Experts 2, 3, 5, 8 & 9, 2020). Eventually between 2021 and 2024, blockchain technology is expected to reach the "Plateau of Productivity", the final stage of the hype cycle which is characterized by increased mainstream adoption of the emerging technology (Rimol & Goasduff, 2019).

Despite the predictions of Gartner and Lufthansa's seemingly fading interest, several airlines kept working on blockchain technology and its implementation. Air France – KLM or British Airways, for example, continued operating dedicated blockchain teams that investigate potential use cases and prepare their implementation (Expert 2, 2020), whereas Emirates signed a three-year contract with Loyyal earlier this year, to move the start up's blockchain loyalty solution to production with the airline's Skywards program (Ledger Insights, 2020).

Although it can be argued that permissioned blockchains defeat the purpose of blockchain technology by compromising its decentralized structure and resultingly should not be considered real blockchains after all (Expert 8, 2020), these private networks are expected to build the starting point for most airlines' blockchain endeavors (Expert 1, 5, 6 & 10, 2020). Permissioned blockchains are not only "much closer to how airlines think, work, act and behave" (Expert 10, 2020), in terms of their functionality but also allow for higher transaction rates and better protection of sensitive information (Expert 1, 2020). Only once the technology matures further, permissionless blockchain applications may emerge (Expert 6, 2020).

As demonstrated by the analysis of potential blockchain use cases, airline loyalty programs appear to be a well-suited point of departure to implement blockchain technology. According to an interviewee from Boston Consulting Group, "this use case was discussed with many airlines, as it really enables them to generate high cost-savings" (Expert 10, 2020). Furthermore, it is supported by the actions taken by Emirates and Singapore Airlines, which were first movers in this area. Nonetheless it is important to highlight, that airlines should strive to pursue this initiative on the alliance level instead of embarking on this opportunity individually to entirely reap the associated benefits of blockchain technology and generate the highest amount of value possible for both – the customers and the airlines (Expert 10, 2020).

5 Conclusion

This dissertation aimed at bridging the gap between industry and academic research by providing an overview of current developments in blockchain applications in the airline industry. Promising blockchain use cases were characterized and evaluated in terms of their potential value for the industry and practical recommendations in the form of critical factors for the successful implementation of blockchain use cases were elucidated.

Based on the analysis of secondary literature and primary data collected from expert interviews, it can be concluded that “loyalty points”, “aircraft parts provenance”, “travel distribution landscape” and “passenger ID management” are promising use cases that could benefit from an integration with blockchain technology. Quantitative approximation of the interview insights allowed for enhanced comparison of their value and industry impact. Among the four use cases, the application of blockchain technology to airline loyalty programs has the capacity to yield the highest value for the airline industry in the near future.

For any given blockchain use case to be implemented successfully, it is critical for organizations to clearly identify its economic impact and prove a viable business case that benefits the organization. Doing so, it is crucial to not consider blockchain as a solution that is looking for a problem and to remain open-minded towards alternative solutions. Airlines should typically follow the “Convener” strategy and actively participate in the creation of industry consortia and standards to fully reap the benefits associated with the application of blockchain in the airline industry. Overcoming competitive structures and adopting a collaborative approach among airlines is a key enabler for the successful implementation of blockchain use cases. While there are several roadblocks potentially complicating the adoption of blockchain technology, the largest impediment currently is the Covid-19 pandemic and the associated airline crisis.

Looking ahead, blockchain applications are predicted to be mostly in the form of permissioned blockchain designs, until the technology matures further and allows for permissionless environments. Moreover, mainstream adoption of this emerging technology should not be expected before approximately 2024. As proven by this study as well as recent developments in the industry, the use case “loyalty points” marks an appropriate starting point for the implementation of blockchain technology in the airline industry.

5.1 Limitations of the Study

It is important to acknowledge that the results of this study should be taken in with limitations. Firstly, despite considering input from both literature and experts, the evaluation of the use cases is not exhaustive and should be updated continuously as more potential use cases

are expected to emerge. Moreover, the interviewed experts may be biased towards their own areas of expertise and as a result, put higher relevance on those use cases as compared to potential applications of blockchain in other areas. While steps were taken to mitigate this limitation through a balanced sample of interviewees with different backgrounds within the industry, an increased sample size would have been required to obtain a fully unbiased view on the use cases. Given the turbulent times for the airline industry resulting from the Covid-19 pandemic, in combination with the inherent time constraints of this dissertation project, however, the ten expert interviews were deemed appropriate for providing the required information. Nevertheless, varying amounts of information were available for different use cases, which may have impacted the assessment of its value for the industry.

Another limitation of this research is reflected in the fact that key insights were obtained using an approximation of quantitative analysis through qualitative insights from the interviews. While allowing for enhanced comparison and evaluation of the impact of blockchain use cases for the airline industry, this approximation may be subjective according to the interviewee's insights and opinions, and the way these were translated into the defined methodology. Furthermore, the scales used for assessment are not scientifically validated through academic literature, merely sense-checked by experts.

Besides that, the criteria chosen for the evaluation of use cases may be considered a limitation. Since use cases emerged from various areas within the airline industry, it was difficult to find general criteria to appropriately capture and compare each use case's value. This becomes apparent in the use case "aircraft parts provenance", as the criterion "customer benefit" is not directly applicable to this use case.

5.2 Future Research Recommendations

Given the relative novelty of blockchain application on the airline industry level, scientific work in this area is still in its infancy. This study may serve as a starting point to explore opportunities of blockchain in the airline industry in more detail. To better understand the implications of the results of this dissertation, future studies could address the four use cases on an individual level and conduct more granular analysis in terms of requirements and potential value creation. For example, the integration of blockchain with loyalty programs, as implemented by Singapore Airlines, or Emirates, could serve as basis to conduct further research in the form of a case study approach and thereby contribute to the body of scientific work in this area and increase awareness for airline executives.

From a more methodological standpoint, another potential research avenue could involve the development of a structured evaluation approach of blockchain use cases across various areas of the airline industry.

Lastly, an interesting field of future research entails the exploration and discussion of different blockchain design choices with respect to the use cases introduced in this dissertation.

References

A Yimga, J., & Gorjidooz, J. (2019). Airline Code-Sharing and Capacity Utilization: Evidence from the US Airline Industry. *Transportation Journal*, *58*(4), 280–308.

Accenture. (2018). *Beyond the buzz: The potential of blockchain technology for airlines*. https://www.accenture.com/my-en/insight-potential-blockchain-technology-for-airlines

Akmeemana, C. (2017). *Blockchain Takes Off: How Distributed Ledger Technology Will Transform Airlines*. Blockchain Research Institute. https://doi.org/10.1111/j.1365-246X.2005.02685.x

Androulaki, E., Barger, A., Bortnikov, V., Muralidharan, S., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Murthy, C., Ferris, C., Laventman, G., Manevich, Y., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolić, M., … Yellick, J. (2018). Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains. *Proceedings of the 13th EuroSys Conference, EuroSys 2018*. https://doi.org/10.1145/3190508.3190538

Bashir, I. (2018). *Mastering Blockchain: Distributed ledger technology, decentralization, and smart contracts explained*. Packt Publishing Ltd.

Beresnevicius, R. (2019). *Airline Alliance's Benefits and Drawbacks Explained*. https://www.aerotime.aero/rytis.beresnevicius/23173-airline-alliance-benefits?page=2

Bocek, T., Rodrigues, B. B., Strasser, T., & Stiller, B. (2017). Blockchains everywhere - A use-case of blockchains in the pharma supply-chain. *Proceedings of the IM 2017 - 2017 IFIP/IEEE International Symposium on Integrated Network and Service Management*, 772–777. https://doi.org/10.23919/INM.2017.7987376

Bouffault, O., Burchardi, K., Bender, J. P., Gopalakrishna, D., Gauche, V., & Paboudjian, C. (2019). *What could Blockchain do for Airlines?* Boston Consulting Group.

Branagan, K. (2019). *10 Challenges for the next decade: What airlines need to know to set themselves up for the next 10 years*. OpenJaw Technologies. https://www.openjawtech.com/ebooks/10-airline-challenges-for-the-next-decade/

Bryman, A., & Bell, E. (2011). *Business Research Methods* (3rd ed.). Oxford University Press.

CAPA. (2020). *COVID-19. By the end of May, most world airlines will be bankrupt*. CAPA. https://centreforaviation.com/analysis/reports/covid-19-by-the-end-of-may-most-world-airlines-will-be-bankrupt-517512

Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2018). *Blockchain beyond the hype: What is the strategic business value?* McKinsey&Company. https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond-the-hype-what-is-the-strategic-business-value

Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. In *Telematics and Informatics* (Vol. 36, Issue November, pp. 55–81). Elsevier. https://doi.org/10.1016/j.tele.2018.11.006

Cassar, R. (2018). Distributed Ledger Technology in the Airline Industry: Potential Applications and Potential Implications. *Journal of Air Law and Commerce*, *83*(3), 455.

Chavez-Dreyfuss, G. (2019). *German airline Hahn Air issues first blockchain-based tickets*. Reuters. https://www.reuters.com/article/us-blockchain-airlines-hahn-air/german-airline-hahn-air-issues-first-blockchain-based-tickets-idUSKBN1XS1TC

de Vries, A. (2018). Bitcoin's Growing Energy Problem. *Joule*, *2*(5), 801–805. https://doi.org/10.1016/j.joule.2018.04.016

Di Francesco Maesa, D., & Mori, P. (2020). Blockchain 3.0 applications survey. *Journal of Parallel and Distributed Computing*, *138*(0), 99–114. https://doi.org/10.1016/j.jpdc.2019.12.019

Drescher, D. (2017). *Blockchain Basics - A Non-Technical Introduction in 25 Steps* (1st ed.). Apress.

Ethiraj, S., & Zhou, Y. M. (2019). Fight or flight? Market positions, submarket interdependencies, and strategic responses to entry threats. *Strategic Management Journal*, *40*(10), 1545–1569. https://doi.org/10.1002/smj.3044

Evers, M. (n.d.). *Generating more transparency in aviation with blockchain technology*. Lufthansa Industry Solutions. Retrieved March 29, 2020, from https://www.lufthansa-industry-solutions.com/de-en/solutions-products/aviation/generating-more-transparency-in-aviation-with-blockchain-technology/

Fremantle, P., Perera, S., Leymann, F., & Jenkins, J. E. (2018). *Emerging Technology Analysis Canvas (ETAC)*. https://github.com/wso2/ETAC/blob/master/ETAC.md

Gottlieb, C. (2017). *Blockchain in Aerospace and Defense.* Accenture. https://www.accenture.com/t20170928T023222Z__w__/us-en/_acnmedia/PDF-61/Accenture-Blockchain-For-Aerospace-Defense-PoV-v2.pdf

Goudarzi, H., & Martin, J. I. (2018). *Blockchain in Aviation: Exploring the Fundamentals, Use Cases and Industry Initiatives*. IATA. https://www.iata.org/contentassets/2d997082f3c84c7cba001f506edd2c2e/blockchain-in-aviation-white-paper.pdf

Haber, S., & Stornetta, W. S. (1990). How to time-stamp a digital document. In *Conference on the Theory and Application of Cryptography*. Springer.

Hackius, N., & Petersen, M. (2017). Blockchain in Logistics and Supply Chain: Trick or Treat? In *Digitalization in Supply Chain Management and Logistics: Smart and Digital Solutions for an Industry 4.0 Environment. Proceedings of the Hamburg International Conference of Logistics (HICL), Vol. 23 (pp. 3-18)*

Haferkorn, M., & Diaz, J. M. Q. (2014). Seasonality and interconnectivity within cryptocurrencies-an analysis on the basis of bitcoin, litecoin and namecoin. *International Workshop on Enterprise Applications and Services in the Finance Industry*, 106–120.

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V., & Akella, V. (2019). Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International Journal of Information Management*, *49*, 114–129. https://doi.org/10.1016/j.ijinfomgt.2019.02.005

Iansiti, M., & Lakhani, K. R. (2017). The Truth about Blockchain. *Harvard Business Review*, *February*.

IATA. (n.d.). *Frequent Flyer Program Benchmark*. Retrieved May 12, 2020, from https://www.iata.org/en/services/statistics/intelligence/frequent-flyer-survey/

IATA. (2018a). *Annual Review 2018*. IATA. https://doi.org/10.1515/auto-2017-0118

IATA. (2018b). *Future of the Airline Indrusty 2035*. IATA. https://www.iata.org/policy/Documents/iata-future-airline-industry.pdf

IATA. (2019a). *Annual Review 2019*. IATA. https://www.iata.org/publications/Documents/iata-annual-review-2019.pdf

IATA. (2019b). *Industry Statistics - Fact Sheet December 2019*. IATA. https://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/fact-sheet-industry-facts.pdf

IATA. (2020a). *Air Passenger Market Analysis January 2020*. IATA. https://www.iata.org/whatwedo/Documents/economics/passenger-analysis-oct-2015.pdf

IATA. (2020b). *IATA Updates COVID-19 Financial Impacts -Relief Measures Needed-*. IATA Press Release. https://www.iata.org/en/pressroom/pr/2020-03-05-01

Ledger Insights. (2020). *Blockchain startup Loyyal in three year deal with Emirates for airline rewards*. Ledger Insights. https://www.ledgerinsights.com/emirates-blockchain-loyyal-airline-rewards/

Lemasson, M., Marx, C., Parker Sealy, R., Thompson, S., & Watkins, A. (2019). *Data for the life of the aircraft*. PwC. https://www.pwc.com/gx/en/aerospace-defence/assets/data-for-the-life-of-the-aircraft.pdf

Lufthansa Innovation Hub. (n.d.). *Aviation Blockchain Challenge*. Lufthansa Innovation Hub. Retrieved March 29, 2020, from https://lh-innovationhub.de/projekt/aviationblockchainchallenge/

Madhwal, Y., & Panfilov, P. B. (2017). Blockchain and supply chain management: Aircrafts' parts' business case. *Annals of DAAAM and Proceedings of the International DAAAM Symposium*, *January*, 1051–1056. https://doi.org/10.2507/28th.daaam.proceedings.146

Murtaza, S. B. (2020). *Ethereum PoS is finally on its way to becoming a reality*. Blockchain News. https://www.cryptopolitan.com/ethereum-pos-is-finally-becoming-a-reality/

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*.

Natarajan, H., Krause, S., & Gradstein, H. (2017). Distributed Ledger Technology and Blockchain. In *FinTech note* (Issue 1). World Bank Group. https://doi.org/10.1596/29053

O'Mara, J., O'Brien, K., & Croke, K. (2020). The Aviation Industry Leaders Report 2020: Steering the Supercycle. In *Airline Economics*. KPMG. https://home.kpmg/ie/en/home/insights/2020/01/steering-the-supercycle-aviation.html

OpenJaw Technologies. (2019). *7 Challenges for Airlines*. OpenJaw Technologies. https://www.openjawtech.com/7-challenges-airlines-18/

Petre, A. (2017). Blockchain use cases in healthcare. *LinkedIn Pulse*, *111*, 1–41. https://www.linkedin.com/pulse/blockchain-use-cases-healthcare-anca-petre

Rimol, M., & Goasduff, L. (2019). *Gartner 2019 Hype Cycle Shows Most Blockchain*

Technologies Are Still Five to 10 Years Away From Transformational Impact. Gartner. https://www.gartner.com/en/newsroom/press-releases/2019-10-08-gartner-2019-hype-cycle-shows-most-blockchain-technologies-are-still-five-to-10-years-away-from-transformational-impact

Saleh, F. (2020). Blockchain Without Waste: Proof-of-Stake. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3183935

Schneider, J., Blostein, A., Lee, B., Kent, S., Groer, I., & Beardsley, E. (2016). *Blockchain: Putting Theory into Practice*. Goldman Sachs. https://www.unlock-bc.com/news/2017-05-25/blockchain-putting-theory-into-practice

Sikorski, J. J., Haughton, J., & Kraft, M. (2017). Blockchain technology in the chemical industry: Machine-to-machine electricity market. *Applied Energy*, *195*, 234–246. https://doi.org/10.1016/j.apenergy.2017.03.039

Singapore Airlines. (2018). *KrisFlyer Launches Innovative Miles-Based Digital Wallet, KrisPay*. Singapore Airlines. https://www.singaporeair.com/en_UK/gb/media-centre/press-release/article/?q=en_UK/2018/July-September/ne2518-180724

Singhal, M. (2018). *The Future of Travel: How Winding Tree is Using Blockchain to Transform Its Business"*. Blockchain Research Institute. https://app.hubspot.com/documents/5052729/view/46641401?accessId=fe1a2c

SITA. (n.d.). *New SITA initiative to further explore Blockchain*. SITA. Retrieved March 29, 2020, from https://www.sita.aero/about-us/sita-membership/member-connect/new-sita-initiative-to-further-explore-blockchain

SITA. (2017). *FlightChain White Paper*. SITA. https://www.sita.aero/resources/type/white-papers/flightchain-shared-control-of-data

SITA. (2018a). *Air Transport IT Insights 2018*. SITA. https://www.sita.aero/resources/type/surveys-reports/air-transport-it-insights-2018

SITA. (2018b). *SITA Group Activity Report 2018*. SITA. https://www.sita.aero/about-us/who-we-are/sita-group-activity-reports

SITA. (2019). *Air Transport IT Insights 2019*. SITA. https://www.sita.aero/resources/type/surveys-reports/air-transport-it-insights-2019

Soyk, C., Ringbeck, J., & Spinler, S. (2017). Long-haul low-cost airlines: Characteristics of the business model and sustainability of its cost advantages. *Transportation Research Part A: Policy and Practice, 106*, 215–234.

Tapscott, D., & Tapscott, A. (2016). The Impact of the Blockchain Goes Beyond Financial Services. *Harvard Business Review*, 7. https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services

Tapscott, D., & Tapscott, A. (2018). *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World* (2nd ed.). Penguin Random House.

The Economist. (2012). The ineluctable middlemen. *The Economist*. https://www.economist.com/business/2012/08/25/the-ineluctable-middlemen

Whitby, P. (2018). *Air France-KLM: blockchain to be driven by 'use case' not tech*.

EyeforTravel. https://www.eyefortravel.com/mobile-and-technology/air-france-klm-blockchain-be-driven-use-case-not-tech

Wiener, P., Ellis, S., Scard, L., Balfour, J., & Dobson, P. (2007). *Competition impact of airline code-share agreements*. European Commission Directorate General for Competititon. https://ec.europa.eu/competition/sectors/transport/reports/airlinecodeshare.pdf

Ying, W., Jia, S., & Du, W. (2018). Digital enablement of blockchain: Evidence from HNA group. *International Journal of Information Management*, *39*(October 2017), 1–4. https://doi.org/10.1016/j.ijinfomgt.2017.10.004

Zhang, B. (2019). *The 20 biggest Airlines in the World, ranked*. Business Insider. https://www.businessinsider.com/biggest-airlines-world-oag-2019-3

Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: a survey. *International Journal of Web and Grid Services*, *14*(4), 352–375. https://doi.org/10.1504/ijwgs.2018.10016848

Appendix

Appendix 1: Order of Relevance Analysis

Table 1*: Order of Relevance of Use Cases based on Interviews*

Use case	E 1	E 2	E 3	E 4	E 5	E 6	E 7	E 8	E 9	E 10	Average
Loyalty programs	1	5	4	1	1	5	5	1	3	5	**3.1**
Baggage tracking	1	4	1	1	1	1	1	1	1	4	**1.6**
Cargo tracking	3	1	1	1	3	3	2	1	1	1	**1.7**
Aircraft parts provenance	4	2	5	5	4	1	4	2	1	3	**3.1**
Travel distribution landscape	4	5	1	1	1	1	1	5	3	1	**2.3**
Passenger ID management	3	1	2	3	1	4	4	3	2	1	**2.4**
Crew/Work-force ID management	1	3	3	4	1	1	1	1	3	1	**1.9**
Automated passenger compen-sation	1	1	1	1	1	1	1	1	1	1	**1**
Flight planning & ATC charges	1	1	1	1	1	1	1	1	2	1	**1.1**
Revenue & payment recon-ciliation	1	1	3	1	1	4	1	2	1	1	**1.6**
Ground operations	1	1	1	1	1	1	1	1	1	1	**1**
Connecting travel providers	3	1	1	1	2	1	1	1	1	1	**1.3**
Refueling of aircrafts	1	1	1	3	1	1	1	1	1	1	**1.2**
Tokenization of aircrafts	1	1	1	1	1	1	4	1	1	1	**1.3**

Note: Own illustration; E = Expert.

Use cases from interviews were evaluated on a scale from 1-5 with:
1 = Interviewee did not mention use case (0% speaking time)
2 = Interviewee mentioned use case, but did not put much emphasis on it (0-5% speaking time)
3 = Interviewee mentioned use case and put emphasis on it (>5% speaking time)
4 = Interviewee mentioned use case, put emphasis on it and regarded it as promising (>5% speaking time; 1-2 benefits mentioned)
5 = Interviewee mentioned use case, put emphasis on it and regarded it as very promising (>5% speaking time; >2 benefits mentioned)

Table 2*: Order of Relevance of Use Cases based on Literature*

Use case	IATA: Goudarzi & Martin, 2018	BRI: Akmee-mana, 2017	BCG: Bouffault et al., 2019	PwC: Lemas-son et al., 2019	Accenture: Accenture, 2018	Average
Loyalty programs	5	4	5	1	4	**3.8**
Baggage tracking	3	4	3	1	1	**2.4**
Cargo tracking	3	1	3	1	1	**1.8**
Aircraft parts provenance	3	3	4	5	4	**3.8**
Travel distribution landscape	4	1	4	1	3	**2.6**
Passenger ID management	2	3	1	1	3	**2**
Crew/Work-force ID management	2	1	1	4	3	**2.2**
Automated passenger compen-sation	1	2	1	1	1	**1.2**
Flight planning & ATC charges	1	3	1	1	1	**1.5**
Revenue & payment recon-ciliation	1	1	3	1	1	**1.5**
Ground operations	1	4	2	1	1	**1.6**

Note: Own illustration.

Use cases from literature were evaluated on a scale from 1-5 with:
1 = Author(s) did not mention use case (use case mentioned 0 times)
2 = Author(s) mentioned use case, but did not put much emphasis on it (use case mentioned 1 time)
3 = Author(s) mentioned use case and put emphasis on it (use case mentioned >1 time)
4 = Author(s) mentioned use case, put emphasis on it and regarded it as promising (use case mentioned >1 time; 1-2 benefits mentioned)
5 = Author(s) mentioned use case, put emphasis on it and regarded it as very promising (use case mentioned >1 time; >2 benefits mentioned)

Appendix 2: Analysis of Use Case Value

Table 1*: Use Case "loyalty programs"*

Criteria	E 2	E 3	E 6	E 7	E 9	E 10	Average
Efficiencies & cost savings	4	3	5	4	3	5	**4**
Customer benefit	4	4	4	5	3	4	**4**
Trust, data sharing and auditability	3	/	3	4	/	4	**3.5**
Total value							**3.8**

Note: Own illustration; E = Expert; "/" = Insufficient information available for evaluation.

Table 2*: Use Case "aircraft parts provenance"*

Criteria	E1	E3	E4	E5	E7	Average
Efficiencies & cost savings	3	4	5	3	4	**3.8**
Customer benefit	1	1	1	2	1	**1.2**
Trust, data sharing and auditability	3	4	4	5	4	**4**
Total value						**3**

Note: Own illustration; E = Expert; "/" = Insufficient information available for evaluation.

Table 3*: Use Case "travel distribution landscape"*

Criteria	E1	E2	E8	E9	Average
Efficiencies & cost savings	4	4	5	3	**4**
Customer benefit	/	3	2	/	**2.5**
Trust, data sharing and auditability	3	4	4	/	**3.7**
Total value					**3.4**

Note: Own illustration; E = Expert; "/" = Insufficient information available for evaluation.

Table 4*: Use Case "passenger ID management"*

Criteria	E1	E4	E6	E7	E8	Average
Efficiencies & cost savings	2	/	4	4	3	**3.3**
Customer benefit	3	4	4	3	4	**3.6**
Trust, data sharing and auditability	3	/	4	3	/	**3.3**
Total value						**3.4**

Note: Own illustration; E = Expert; "/" = Insufficient information available for evaluation.

Explanations

For the analysis, only expert interviews that discussed the respective use case were considered. The use cases were evaluated according to three criteria on scale from 1-5, based on the following:

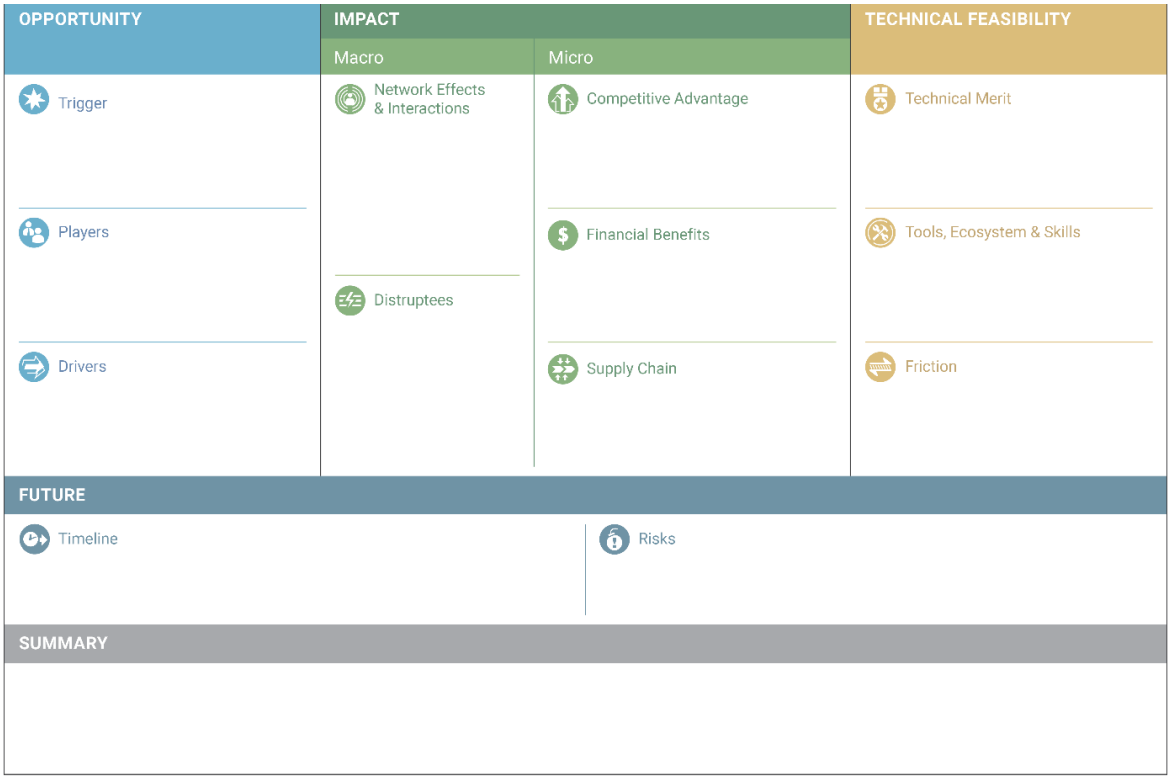
Criterion 1: Efficiencies and cost savings
1 = The use of blockchain does not increase operational efficiencies and does not result in cost savings
2 = The use of blockchain increases operational efficiencies but does not result in cost savings
3 = The use of blockchain increases operational efficiencies and results in moderate cost savings
4 = The use of blockchain increases operational efficiencies and results in high cost savings
5 = The use of blockchain drastically increases operational efficiencies and results in substantial cost savings

Criterion 2: Customer benefit
1 = The use of blockchain does not impact the customer experience at all
2 = The use of blockchain has a minor impact on the customer experience
3 = The use of blockchain has a moderate impact on the customer experience
4 = The use of blockchain has a high impact on the customer experience
5 = The use of blockchain has a substantial impact on the customer experience

Criterion 3: Trust, data sharing and auditability
1 = The use of blockchain does not impact trust, data sharing and auditability
2 = The use of blockchain has a minor impact on trust, data sharing and auditability
3 = The use of blockchain has a moderate impact on trust, data sharing and auditability
4 = The use of blockchain has a high impact on trust, data sharing and auditability
5 = The use of blockchain has a substantial impact on trust, data sharing and auditability

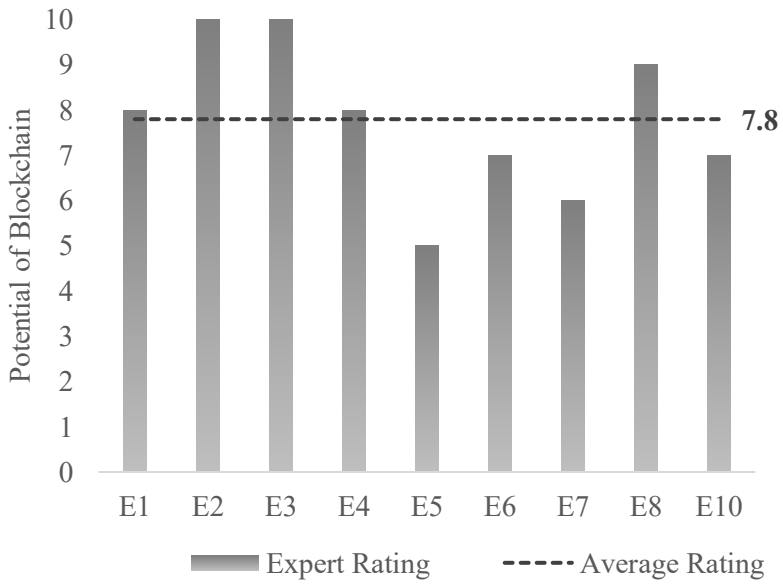
Appendix 3: Figures

Figure 1: *Emerging Technologies Analysis Canvas*



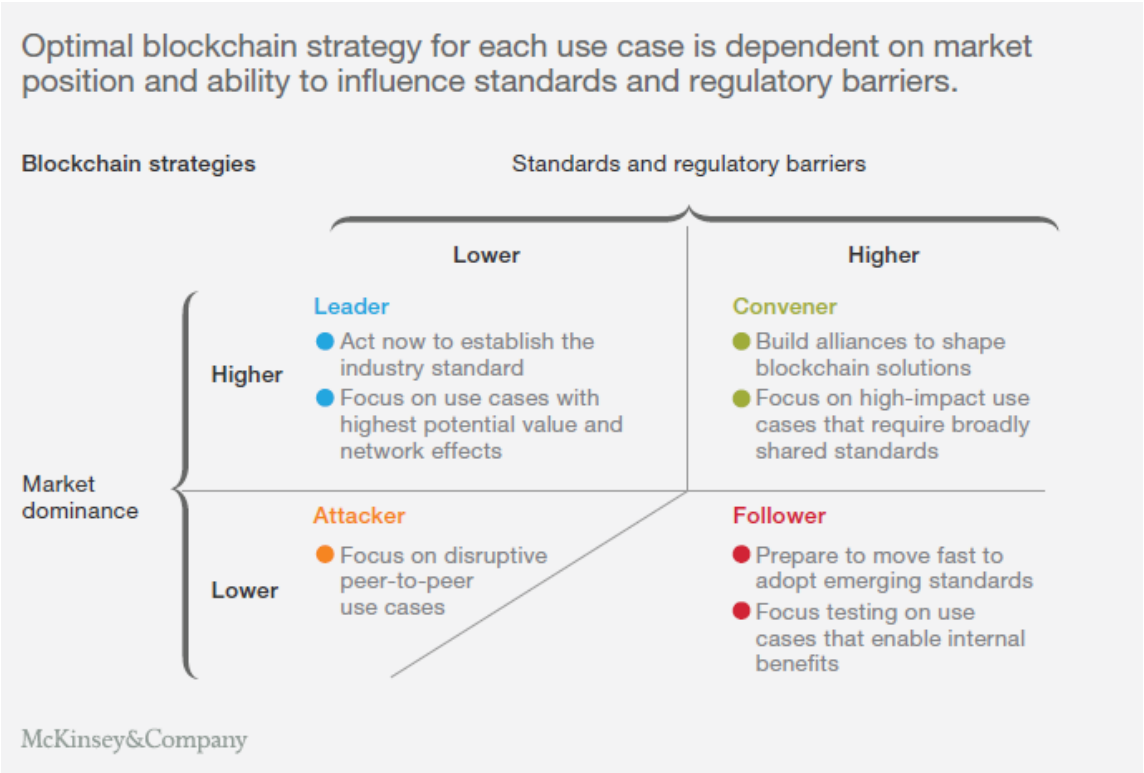
Note: From Fremantle et al. (2018).

Figure 2: *Expert Assessment of Blockchain's Potential in the Airline Industry*



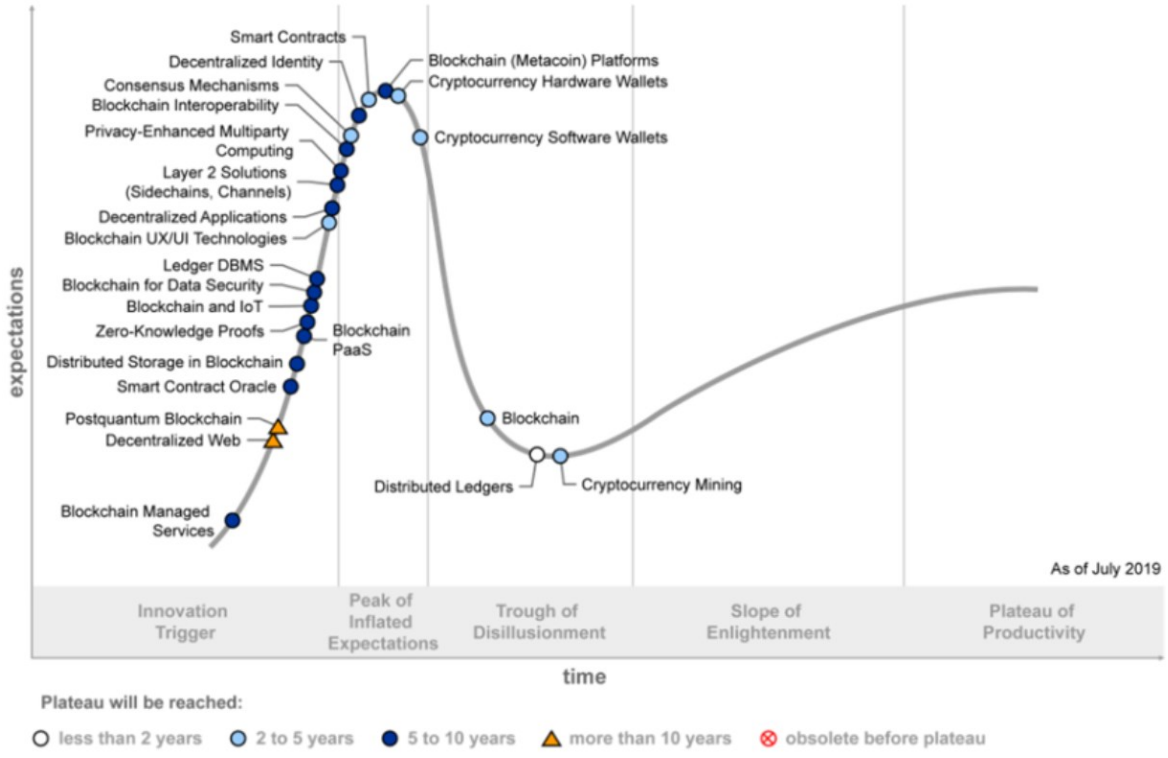
Note: Own illustration; E = Expert; expert 9 declined to provide rating.

Figure 3: *Blockchain Strategies*



Note: From Carson et al. (2018).

Figure 4: *Gartner Blockchain Hype Cycle 2019*



Note: From Rimol & Goasduff (2019).

Appendix 4: Semi-Structured Interview Guide

General Info:

- Introduction of myself, introduction of the project and respective goals
- Interviewee may always abstain from answering a question (e.g. due to lack of knowledge in a certain area)
- Ask interviewee for consent to record the interview and whether anonymization is required
- Ask for any further questions before the interview may begin

Introduction

1. What is your background in relation to blockchain technology as well as the airline industry? How experienced would you consider yourself on a scale from 1-10 in both fields?

RQ 1

1. What are potential applications of blockchain in the airline industry (might be fully implemented solutions, pilots/PoCs or theoretical ideas)?
2. What are their main benefits as compared to the existing process (discuss for every mentioned use case)? E.g. Efficiencies, enhanced transparency or security, cost savings, customer benefit, etc.
3. What are the limitations (discuss for every mentioned use case)? E.g. High upfront costs, low feasibility, high complexity, etc.

RQ 2

4. In a more general way, what enables the successful implementation of blockchain in the airline industry? (e.g. Which capabilities must an airline possess?)
5. What could be major roadblocks that hinder successful implementation?
6. How would a roadmap towards implementation look like? How should airlines go about implementing BC?

Additional information

7. What are possible reasons that slow down the adoption of blockchain across the airline industry?
8. What is your personal opinion towards blockchain, especially in relation to the airline industry? Do you consider the technology ripe for broader implementation? Why?
9. What is the potential of blockchain in the airline industry on a scale from 1-10?
10. Do you know other persons that may be suitable to be interviewed regarding this topic ?

Appendix 5: Expert Interview Summaries

***Expert 1*:** Jörg Troester

Company	Hahn Airlines	**Knowledge Blockchain**	8/10
Title	Head of Corporate Strategy/ Industry & Government Affairs	**Knowledge Airline Industry**	9/10
Background	25 years of experience in the airline industry; Management roles at Hahn Airlines during the past 15 years; Responsible for assessment and strategy development of blockchain and other emerging technologies at Hahn Airlines		

General insights

- Hahn Air proved that it is possible to create a reservation in a blockchain environment and issued the first ticket on a blockchain in late 2019
- Airline industry is at the very beginning of blockchain; Hahn Air does not have an active Blockchain project currently
- Most industry solutions will be on a private blockchain due to sensitive information, and limited numbers of involved participants which allows for increased transaction rates

RQ 1

Use Case 1: Ticketing on BC

- Passenger does reservation with one airline; airline creates token on the blockchain with all relevant information about passenger; payment (ticket) may happen through another airline (e.g. Hahn Air) (e.g. in interlining) who would create a new token based on the previous information; chain of events provides full custody
- Benefits: No need for separate PNR and Ticket systems (IATA initative OneOrder may work on blockchain); information on reservation, payment, airport or accounting are all connected to each other and handled by the respective entity needing access and is thereby transparent and fraud-free. No access of third-party airlines to e-ticket systems required in case of interlining

Use Case 2: Travel distribution via BC

- WindingTree for example provides such a platform on the Ethereum blockchain
- Advantages: makes the airline distribution industry more flexible; direct engagement of customers without middlemen; less monopolized structures in distribution; open platform that is not owned by anyone in the middle of distribution, data is not owned by a single entity
- Limitations: current processing speed of public blockchains cannot compete with GDS transactions; in this industry you have 100/1000s of transactions per second

Use Case 3: Inclusion of various processes from the Distribution Chain in a blockchain environment

- AeroBand limited looking into the Combination of existing parts of the distribution chain in a blockchain environment. Idea of the platform: have an individual connector (xml) that would allow several systems (e.g. reservation system, accounting system, passenger operation system, check-in system) to be connected to the same blockchain environment to have a single information source for all the systems and player that need to operate on the data during the passenger journey

Use Case 4: Passenger ID and automated customer journey

- Fully automated customer journey for passengers from entering the airport to arriving at the destination, renting a car and finding all his luggage already in the car (as all involved players have the respective information required on the customer at hands)

Use Case 5: Air Cargo

- Concept of airway bills is absolutely outdated and manual process, airway cargo bill needs to be printed out multiple times, among others due to complicated customs processes; this area is very little digitized and based on paper documents that need to be carried with the cargo; Blockchain could mean the revolution for cargo documentation in future

Use Case 6: Parts identity and provenance in MRO environment

- Manufacturers, repair shops, airlines involved in a blockchain environment: Aircraft finds out something is wrong and sends an automatic message to the system which knows where the next maintenance is happening and will inform the shop there, which checks if the spare part is available and otherwise orders it; upon arrival the aircraft can get the exact maintenance it needs; manufacturers would learn more about exact product life cycles e.g. if there are certain parts which have a reduced than expected lifecycle; could also enable to have full maintenance history of a plane on blockchain

RQ 2

Enablers for successful Implementation:

- Technology must be ready for huge volumes;
- Enough partners must be on board and connected through the blockchain to really reap its benefits
- Viable business cases for the BC use case must exist (why is it cheaper, faster, more customer oriented); this is currently the biggest issue, abstract benefits are clearly visible, whereas benefits of individual use cases are not yet clearly visible/ understandable

Roadblocks for implementation:

- Higher level: Major industry crises, investments are stopped or drastically slowed down
- Typical and usual reluctance of the industry to change (e.g. e-ticketing took 12 years to be fully implemented, NDC XML took 20 years to be implemented)
- IT complexity of airlines is very high, and thus companies are very careful to change backend systems or technology as they are afraid something goes wrong; Leading thought: “why changing a system that is working pretty well for the moment”

Should airlines pursue BC projects themselves or collaborate with third party providers?

- For cultural and political reasons, it is better to have a 3rd party or consortium “owning” the blockchain environment (example: Lufthansa tried to push all Star Alliance partners on a common distribution platform (Amadeus). Many partners declined, as they would not want to be pushed by Lufthansa, despite many benefits e.g. improved consolidation)

Additional information

Personal opinion towards blockchain

- Blockchain will definitely come earlier or later; makes a lot of sense because the concept of reservation and ticket is based on technology from 60 years ago and is thus just not up to date anymore; there are discussions of remodeling/revamping data models for airline distribution, where blockchain might have a say

Reasons what slows adoption of blockchain

- Airlines are very traditional and typically have a legacy mindset and as such are often resistance to change; especially in relation to their IT systems
- Huge financial investment required for such projects

Potential of blockchain in the airline industry on a scale from 1-10?
- 8/9 out of 10

Expert 2: Ivan Chemtob

Company	Rosa Airlines Consulting	**Knowledge Blockchain**	4/10
Title	Senior Aviation Consultant	**Knowledge Airline Industry**	9/10
Background	Over 25 years of experience in the airline industry with emphasis on the commercial aspect of the industry; various management roles at Air France as well as advisory roles for HNA Group, or Amadeus		

General insights

- Clear idea about the benefits and potential application of Blockchain for the airline industry but no specific technological knowledge of blockchain; rather a user of the technology than an expert
- Air France - KLM & British Airways have teams dedicated to Blockchain; might be worth contacting them
- Finn Air is very innovative in terms of digitalization/ possibly have adopted Blockchain already
- Many airlines where making big announcements that they were investigating and studying blockchain application, however, the interviewee does not know about an airline that has already implemented blockchain technology

RQ 1

Use Case 1: Loyalty Points
- Process today: Loyalty points are a liability for most airlines; for every point given to customers, a financial value is calculated and provisions are made to account for the points; most customer have to few points to actually redeem them for a ticket; process for points to be transferred to customer accounts currently takes quite long (up to 3/4 days)
- Process with blockchain: points would be provided to customer in a secure, real-time way allowing for immediate usage and redemption of points
- Benefits: Reduces overall financial liability as points can be used for smaller purchases; through real-time information about how many points are provided and redeemed provisions can be steered much easier; provide drastically enhanced customer benefits as customers may immediately redeem points and use them for smaller purchases right on the spot (in the airplane/ airport/ taxi etc.) allowing for instant gratification

Use Case 2: Replacing GDS
- Process today: Booking through GDS; travel agencies collect the money; usually after 1 or 2 weeks, the sale is declared to BSP (Billing settlement plan, managed by IATA) and then payments are cleared between OTAs and Airlines; very long process & time-consuming effort for airlines to manage this situation; sometimes double transactions exist in BSP (e.g. if a ticket is refunded)
- Process with Blockchain: Direct and instant payment to the airline, once a ticket is sold; only one single contract between the airline and the customer; customer pays fees to OTA directly (e.g. triggered by smart contract)

- Benefits: Drastically reduced distribution costs and no fees for middlemen (fee to GDS per ticket sold approx. 10€ per booking) resulting in large savings; increased customer benefits (e.g. in case of OTA default and requested refund, the customer may still be reimbursed), quicker access to money for airlines (instead of waiting up to two weeks for clearing); overall reduced overhead costs related to managing the current process; Benefit for OTA: no more need for huge deposits at IATA
- Limitations: implementation takes time and probably is focused on developed countries, as most developing countries have lower levels of technological maturity; Airlines currently may focus on NDC IATA format for enhanced messaging and exchanging information between players from the travel industry) instead

Use Case 3: Baggage Management

- Process today: Lot of luggage gets lost, very old and slow technology is predominantly in place; Airlines only able to inform customer about luggage location with approx. two days delay; lost luggage takes very long to be delivered to customer
- Process with blockchain: luggage is tracked on multiple checkpoints during the journey and (departing airport belts, handlers, airport, arriving airport handlers, arriving airport belts) and data is stored on the blockchain with access provided to every relevant stakeholder; 3 parties must be involved in that process: airlines, handler, and airports
- Benefits: Drastically increased customer experience through nearly real-time location checking of the luggage and thereby drastically reduced times for customer to receive luggage back; airlines have improved knowledge of the status of luggage and as a result less luggage will get lost and fewer passengers must be compensated
- Drawbacks: only provides benefits if many airlines are on board (not every airline serves all routes); therefore, IATA or one of the leading alliances should provide a consistent format that may be adopted by all airlines

Use Case 4: Crew Management

- Benefits: Real-time updated crew planning; information can be pushed without barriers, everyone will have the same information instantly

Use Case 5: Maintenance/ MRO area

- Not discussed in detail

RQ 2

Enablers for successful Implementation:

- Blockchain is the easiest fastest cheapest way to reduce costs overall
- Appropriate communication and clear explanation of benefits of blockchain adoption to board members to guarantee management buy-in
- Creation of small teams with diverse backgrounds and skills
- Proper Stakeholder and relationship management to ensure all required partners are on board

Roadblocks for implementation:

- Finding people with the appropriate skills to join the airlines

Should airlines pursue BC projects themselves or collaborate with third party providers?

- Larger airlines are more likely to create solutions in-house and smaller airlines are more likely to collaborate with third parties

Additional information

Personal opinion towards blockchain

- Expects to see a real use of blockchain soon; most Airline IT is about pushing data, which may be achieved using blockchain; Another big problem that can be addressed with blockchain is inaccurate data

Reasons what slows adoption of blockchain

- Currently it is the crisis, as all airlines have heavy debt issues and therefor no budgets

Potential of blockchain in the airline industry on a scale from 1-10?

- 10/10

Expert 3: Indunil Weerasinghe

Company	SkyChain Laboratories; Virgin Australia	**Knowledge Blockchain**	7/10
Title	CEO & Founder; Contract Engineer	**Knowledge Airline Industry**	8/10
Background	15 years of experience in the airline industry with focus on maintenance; overall knowledge of the commercial aspects of running an airline; Founder & CEO of SkyChain Laboratories, an innovative partner for airlines to explore blockchain solutions; Alumni of Oxford Blockchain Strategy Program		

General insights

- Airline industry is characterized by various stakeholders generating data and other stakeholders relying on accuracy of the data as well as stakeholders relying on a single source of truth (e.g. maintenance records, flight information, location of luggage, etc.), which makes the airline industry a perfect match for blockchain technology; Challenge: decentralized system requires all players to reach consensus on how a shared environment should look like
- True value of blockchain is unlocked and causing disruptive changes only, once the whole industry finds ways to collaborate within the same blockchain environment
- Airlines should already embrace blockchain and explore (small-scale) solutions to prepare themselves to be ready, once technology reaches maturity and causes disruptions; Thus, airlines should have BC strategy in place, to understand opportunities and threats as well as contingency plans that lay out responses to different future scenarios; compared to airlines waiting for technological maturity, early-adapting airlines will have a competitive advantage instead of being disrupted
- Interviewee is not aware of currently fully implemented use cases, most PoC are 1-2 years away from turning into MVP and full implementation
- Overall, blockchain may be applied in areas as diverse as certification of parts and people's qualification to things like protecting the technology on board the aircraft

RQ 1

Use Case 1: Frequent flyer program

- Very natural place for airlines to start experimenting with as loyalty programs are very similar to blockchain; Airlines may transform frequent flyer programs into cryptocurrencies; however, regulatory scrutiny regarding cryptocurrencies may scare airlines away
- Benefits: reduced administrative overhead of giving points "value" (i.e. establishing partner networks, agreements and contracts with retailers, etc.); loyalty points become more liquid and may be traded at the customer's convenience; purchases can be made directly at any shop accepting cryptocurrencies

- Especially in the loyalty area it is hard to predict all possible opportunities of BC and thus, a lot of value/ new opportunities will be discovered along the way when experimenting with the technology or after implementing it

Use Case 2: Payments and Distribution
- IATA Coin: Utilization of a cryptocurrency instead of fiat currencies; Benefits: Only 1% in fees instead of 10% and only 45 min for settlement instead of up to 45 days (cp. Youtube Video)

Use Case 3: Identity of parts
- Every part has its own identity and maintenance record attached to it; combination with certification of engineers/mechanics possible: reduction of friction and paperwork, making the whole documentation very transparent and lean;
- Example: returning aircraft to lessor: dozens of folders of paper-based records with maintenance history; generally very tedious process; could be streamlined with use of blockchain-based records; Benefits of BC vs Database: databases rely on downloading datasets and sharing them, different formats, data standards and quality between entities bring friction, records must be consolidated every once in a while with all involved players

Use Case 4: Certification of Engineers/ mechanics/ pilots
- Not discussed in detail

Use Case 5: Passenger & Crew Identity management
- Not discussed in detail

RQ 2

Enablers for successful Implementation:
- Highly standardized industry through ICAO & IATA; standardization in terms of aircraft homogeneity due to Duopoly of Airbus and Boeing; Industry lacks behind in terms of data standardization
- Org. level: Knowledge & Communication: Many people confuse blockchain with Bitcoin and only very few people truly understand what blockchain is; Correct knowledge about what blockchain is and is not must be provided for relevant decision makers from executive level to relevant heads of X; Communication (also in regard to the respective use cases) must be very clear in order for decision makers to see the genuine benefit from blockchain
- Robust ecosystem with wide network of Blockchain-as-a-Service offerings to choose from

Roadblocks for implementation:
- Shortage of skilled people with blockchain knowledge that can create, connect and maintain the various blockchain ecosystems
- Regulatory acceptance: Slowly, regulators are beginning to accept blockchain and recognize respective industry-level benefits; cryptocurrency-side is not yet widely endorsed

Should airlines pursue BC projects themselves or collaborate with third party providers?
- Airlines typically are not innovative; the best airlines are very good on the operational level; airlines should rather partner with companies that are innovative by nature
- Only very large airlines, e.g. Lufthansa, Air France-KLM, American Airlines, Delta should have dedicated teams with blockchain experts and developers to pursue “in-house” solutions

Additional information

Personal opinion towards blockchain
- Blockchain will be a very disruptive technology, especially for airline industry

- In 15/20 years, people will wonder how everything was done without blockchain technology

Reasons what slows adoption of blockchain
- Biggest impact: regulations

Potential of blockchain in the airline industry on a scale from 1-10?
- 10/10

***Expert 4*:** Thilo Knoop

Company	Lufthansa Industry Solutions/ LH Technik	**Knowledge Blockchain**	8/10
Title	IT Consultant/ Project Manager	**Knowledge Airline Industry**	7/10
Background	15 years of experience in the airline and aviation industry; 9 years as Product Development Consultant at Airbus; 6 years as IT Consultant at LH Ind. Solutions; founded Blockchain 4 Aviation Initiative at LH Ind. Solutions in 2016 focusing on the use of blockchain in aircraft maintenance		

General insights

- Lufthansa stopped all activities in relation to blockchain, as budgets were used up and interest in the new technology seemed to have vanished
- Airlines should not be the driving force behind maintenance related solutions; OEMs should take leader role and create solutions which airlines may then adopt
- Global pandemic may be an initiator for a new order within airline and aviation industry; may trigger thoughts about ways for improvement, rethink existing processes and structures and provide opportunities to implement new solutions
- Airline passenger do not really care about whether latest technology is used by airlines or how processes are handled in the background, unless they feel a benefit (e.g. reduction in price/ enhanced customer centricity)
- Generally, blockchain may always prove useful once a trusted third party comes into play

RQ 1

Use Case 1: Certification of Parts (back-to-birth traceability)
- Current process still very paper-prone; however, airlines start implementing centralized digital database solutions; oftentimes, history of parts cannot be provided without reporting gaps (e.g. paper documents get lost, lifetime of parts is tracked on simple excel sheets prone to error)
- Tracking of parts on blockchain provides trust and transparency to all involved players; drastically increases efficiency of the process
- Benefits: drastic reduction of parts scrapping (often done, once history cannot be provided gapless); once implemented, efficiencies in multiple maintenance processes through reduction of friction and paperless work are generated and opportunities for related processes are provided: e.g. Lease-back transition; transparent secondary spare parts market
- Limitations: project was stopped at LH in 2017 (main challenge was to bring all relevant stakeholders together); Solution threatened to cannibalize services offered by LH Technik

(check-ups of maintenance records/ provision of/ inquiries in parts' history of parts etc. is often outsourced to cheap labor countries like India; Check-ups (especially) of engines through certified engineers is very profitable business for LH Technik)
- Block.Aero, a HK-based start-up in collaboration with Rolls Royce looks at exactly this use case as well *(Note: may provide useful information: https://block.aero/)*

Use Case 2: Refueling of aircraft
- Currently very inefficient process in regard to how payments are made
- Information stored on blockchain in connection with smart contracts could make this process very efficient and eventually provide instant payments

Use Case 3: Identity Management
- This is a huge use case and may be implemented in a multitude of contexts such as identities of engineers, pilots/crew, pilot logbooks (how many hours they have flown/ if they possess the right experience knowledge for an aircraft) or passengers
- Zamna is a startup collaborating with Emirates and Dubai authorities to provide a seamless passenger check-in journey through the airport to the plane based on identities secured on blockchain technology

RQ 2

Roadblocks for implementation:
- Airline industry is traditionally very slow and focused on safety, which limits the implementation of emerging technology such as blockchain
- Customer should not notice the implementation of blockchain technology; user acceptance for the technology is still lacking and trust is not established

Additional information

Reasons that slow down adoption of blockchain in the airline industry
- 8/10
- Since the hurdles currently still outweigh its potential benefits, blockchain technology is not more widely adapted by market players

Potential of blockchain in the airline industry on a scale from 1-10?
- 8/10

Expert 5: Carsten Boehle

Company	Lufthansa Cargo	**Knowledge Blockchain**	7/10
Title	Senior Project Manager Digital Transf.	**Knowledge Airline Industry**	7/10
Background	Worked for 5 years in the airline industry with 3 years as aa Consultant at Lufthansa Industry Solutions and 2 years as Digital Transformation Manager at Lufthansa Cargo; led research group on Blockchain applications at Lufthansa Industry solutions		

General insights

- Blockchain applications have been discussed at Lufthansa when BC was at the top of the hype cycle (mid 2018)
- No blockchain use cases are currently in operation across the industry

- Air France KLM has a dedicated blockchain program
- Blockchain applications were discussed cross-company with Lufthansa and Air France KLM in a joint workshop; however, nothing was jointly implemented
- Consortium blockchains connecting multiple players from the industry could be facilitated by players like IATA, however, they would not provide/ finance the technology

RQ 1

Use Case 1: Cargo Business; trace shipments through supply chain

- The inherent problem in air cargo currently is to get all stakeholders involved in the shipment of goods to provide the same data and records and different standards and formats exist
- By transferring this process to a blockchain, a single source of truth for records with verified information could be established and every stakeholder may be granted access to the required information
- Benefits: creation of transparencies throughout the whole supply chain by having a consistent trace for every good shipped; real-time access to a single set of agreed-upon data and thereby operative efficiencies
- However, Blockchain was concluded to not be the right solution for this issue; It was rather a solution looking for a problem; blockchain is rather about solving trust-issues, which was not the main concern in this respect, instead it was more of an operational problem about technical issues which could better be solved with a database solution
- Use case was buried and most start ups that contacted the airline are out of business by now

Use Case 2: MRO business; digital certificates for parts

- Currently, there are different ways of accessing spare parts for an aircraft; while some airlines have own dedicated spare part pools, which are shared only among their fleet, the majority of airlines have a shared pool of components which are utilized across aircraft from one airline to another;
- When these components are traded and integrated in other pools or aircrafts, you would receive a complete history on the parts describing when and by whom it was produced, where and for how long it was used, etc.; if any documentation is missing, airworthiness has to be confirmed in long/costly processes or the part is scrapped
- The idea was to bring all the information about spare parts on a blockchain and provide a fully digital certificate with complete traceability
- Since most components are serialized, this information would be put on a blockchain once the part is produced by the OEM; from there, ownership could be transferred to the buyer, who in turn provides information on the use (i.e. which aircraft, hours of use, maintenance etc.); when resold again, ownership including all information can once more be transferred easily and consistent asset tracking could take place
- Benefits: life-cycle part provenance could be established and full transparency on part's history could thereby be guaranteed; back-to-birth traceability; increased security through avoidance of fake parts (occurred at U.S. Military for example); increase in efficiencies due to single source of information and one data standard
- However, efficiency gains could also be achieved with a more traditional data base solution, once every involved party would agree to a certain set of standardization with regard to data and records

Use Case 3: Using a single token for the whole travel journey

- Idea is that you could have a ticket and convert this to a token on a blockchain as a way to add more services to it; different aspects from the travel journey like hotels, rental car etc.

would be put on the same token and the customer would identify itself throughout the whole journey
- Whether there is a real benefit of this solution implemented on a blockchain is questionable

RQ 2

Enablers for successful Implementation:
- Success of use cases is purely based on economic factors and no one will be convinced by the technology you are using, nobody cares about the underlying technology; it must be proven that the solution solves a real problem and that it saves money by implementing it this way

Roadblocks for implementation:
- Airline need very good knowledge on its IT architecture as it will quickly get into very detailed discussions on what data is required, what data format is used, how a blockchain solution can be integrated in existing IT environment etc.; overall the airline must possess very good understanding of how they connect to the external world

Should airlines pursue BC projects themselves or collaborate with third party providers?
- Interviewee is skeptical about blockchain as a service offering, since the USP of blockchain still is trust and if this is the underlying issue, why would go turn to one of the big tech companies that is most likely under US regulation and trust them?; these would be solutions for private/consortium blockchain architectures only anyway

Roadmap towards implementation:
- Implementation of a blockchain solution would require lot of cross company discussions on data formats, standardization and these kinds of things; A big part would also involve discussions about which data the airlines are willing to share and how it will be exchanged
- What is important, is that implementation is not driven by the ideology to implement new technologies, in this case blockchain, but to approach a problem from a solution oriented, instead of a technology-focused, perspective; the focus should always be on how problems can be solved and considerations for solutions must always stay objective and open-minded (i.e. not approach a problem with blockchain on your mind as the appropriate solution)

Additional information

Personal opinion towards blockchain
- Two opinions on blockchain: 1) technology driven: it is very fascinating, interesting, clever and cool solution where there must be some applications, use cases or benefits possible; 2) he, and many others, spent many hours/week discussing and investigating potential use cases, where looking for implementations and PoCs but were not able to come up with very promising or real results
- Blockchain right now may be similar to AI in the 80s; there was a big hype but at the time, there were just not the right implementations and use cases for it; however, it came back years later and a multitude of use cases became apparent; as such, there could be possible applications of blockchain which are just not yet very clear see due to the immature state of the technology

Reasons that slow down adoption of blockchain in the airline industry
- There was a window of opportunity to show that blockchain solves some problem in an economic manner during the peak of the hype (2018); yet, no one came up with a good answer and could provide use cases that deliver real value for Lufthansa; and as such it is “a topic not to be mentioned” at the moment, because decision makers believe that the

technology had its chance but could not prove what it is worth; if there are advancements in the technology and broader publicity, there might be new opportunities for blockchain

Potential of blockchain in the airline industry on a scale from 1-10?

- 5 out of 10

Expert 6: Sanjay Naik

Company	Emirates Airlines	**Knowledge Blockchain**	8/10
Title	Vice President Enterprise Effectiveness	**Knowledge Airline Industry**	10/10
Background	Over 25 years of experience at Emirates and the airline industry; Head of internal consulting division at Emirates supporting 80+ of the group companies/brands especially in digital transformation or service innovation projects		

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General insights

- Most airlines look at blockchain as a technology for the future, as there are obviously benefits in the technology; however, the biggest challenge is that use cases must prove value
- Generally, any use case has two main requirements to prove successful: 1.) the project must have a good ROI, or 2.) solve some major technological issue
- Today: technology is not yet fully proven and relatively expensive to implement in comparison to current IT systems that are already used in the industry
- Across the industry blockchain offers a multitude of opportunities for the industry by connecting multiple players like OTAs, GDSs, airlines, passengers, airports, immigration authorities, etc. in one single collaborative system
- Similarly, the benefit from blockchain technology will be highest and most impactful when involving most/all stakeholders from the airline ecosystem
- Generally, most processes at airlines could potentially be on a blockchain-backed system due to the high amounts of players involved in all processes – the question is whether it is worth to invest money in the systems
- GDSs have huge R&D budget (Sabre spends up to 15 bil/year on R&D) and as such may be driving forces behind blockchain research and system implementation
- Currently when talking about blockchain applications at company level, everything is about closed blockchain systems, which are to a certain degree centralized and therefore still prone to fraud; however to connect ecosystem players, immigrations, etc. from all over the world open, truly decentralized blockchain system would be essential, which still face the main limitation of scalability and too low transaction

RQ 1

Use Case 1: Passenger Identification (connecting Airline/ Immigration/ Airport systems)

- Current process: Customer has multiple touchpoints where his data (e.g. passport information) is captured and validated; it moves from the airline systems, to the airport systems; from there to immigrations/authorities/customs and so on; there are many intermediaries involved that facilitate the journey of the customer and check and validate his information individually
- Blockchain use case: Booking takes place via GDSs, OTAs or the airline directly; passport information that typically moves from one validator to the next, is only validated and approved once in the beginning of the customer journey and relevant parties (authorities, airports, airlines etc.) are enabled access to it, it is not required to be checked

over and over again and the customer can move smoothly through the whole ecosystem without showing his passport multiple times
- Benefits: Solves many headaches for the involved players; makes the process very efficient by cutting down lot of manual processes to authenticate and validate documents; Customers do not need to show passports repeatedly

Use Case 2: Cargo Business
- Current process: Shipping of cargo (which especially via air is often high-value goods) requires many approvals and certifications from various authorities and regulators across the cargo supply chain; as such the amount of documentation required is huge; at some airlines already digitized, at some airlines still paper-prone; opportunity for fraud in this process is quite high
- With a blockchain system underlying, certificates and documentation for goods can be stored immutably on the blockchain and access granted to the relevant authorities/ ecosystem players; would reduce inefficiencies within the whole process as well as reducing opportunities for fraud to 0; furthermore, goods could be tracked down across the whole supply chain

Use Case 3: Airline Miles/ loyalty points
- Very good opportunity; when value of the miles is transferred to blockchain/ a cryptocurrency, overhead required to manage backend processes (e.g. mileage accrual and redemption, updating customer accounts etc.) would be drastically reduced and fraud can effectively be eliminated; customers are enabled to immediately spend their earned miles and do not need to accrue them in order for reaping a benefit, which enables instant gratification

Use Case 4: Blockchain automation in code-share agreements
- Emirates cooperated with a FlyDubai, a code-share partner to trial blockchain in code-share agreements;
- Current process: In code share, one ticket will be issued by one airline with the fare being split between the two participating airlines, the processes in the background are not very efficient and reconciliation and fare-splitting is time-consuming
- A blockchain solution could be applied to those kinds of systems, so that the fare is immediately split between the airlines based on rules governed in smart contracts, as soon as the ticket is issued and enters the system

RQ 2

Enablers for successful Implementation:
- On an industry level: Pharmaceutical supply chain will become more and more supported by blockchain technology; Airlines moves 80% of the pharma products and thus processes of airlines need to be aligned with the pharma blockchain processes; the airlines become part of this blockchain ecosystem which could enable airlines to understand blockchain better and turn to their own processes and how blockchain may enhance these

Roadblocks for implementation:
- The biggest limitation would be costs of implementation; there is a shortage of qualified coders capable of designing blockchain environments for the airlines and therefore investments will be high; as such ROI on blockchain systems are not as strong as commercialized current systems, that are cheaper to implement (however, Covid-19 may cause major reskilling of people towards coding/data/technology literacy, which in turn could make BC implementations more cost-effective)

- Regulatory unawareness/ wrong images of blockchain may pose problems as the technology is often confused with cryptocurrencies like Bitcoin (however, regulatory and customer perception of cryptocurrencies may also change, as everything currently moves towards contactless)
- Investment has to be done on a network level instead of on the individual airline level which required strong collaborative efforts and stakeholder management
- Current crises caused major economic impact; airlines will need years to get back on pre-crisis levels and therefore investments will be reduced drastically across the whole industry, not allowing for large investments in emerging, uncertain technologies like blockchain

Additional information

Personal opinion towards blockchain

- Blockchain is a big opportunity; question is only who will fund it; airlines will not invest in new systems in the near future

Potential of blockchain in the airline industry on a scale from 1-10?

- Purely technological potential: 8/10
- Feasibility (practicality of implementing or funding): 4/10
- Overall Potential of blockchain: 7/10

Expert 7: Interviewee requested anonymization

Company	Large international Airline	**Knowledge Blockchain**	4/10
Title	Incubators and Accelerators Manager	**Knowledge Airline Industry**	6/10
Background	12 years of experience in the airline industry; involved in all innovation projects within the group for the past 6 years as manager of its incubators and accelerators program and its innovation lab; Exposure to blockchain solutions through collaboration with start-ups		

General insights

- The whole topic surrounding blockchain use cases is still very theoretical and in its infancy, there are some PoCs and piloted use cases and only very few implementations
- General problem within the airline industry is its legacy business characteristic which are represented in a legacy mindset in terms of innovation and adoption of new technologies
- The mentioned use cases were the only ones considered by the airline the interviewee works for

RQ 1

Use Case 1: Identity Management/ Digital passports/ Digital Identity of passengers

- Current process: Passengers must validate their identity during multiple checkpoints across the customer journey, which is a very time-consuming process and prone to human error
- Solution could be to create an independent source for validating people's identity and moving the whole process from having a physical document at hand towards a fully digital, blockchain-based process and through that facilitate things like clearings/ visas/ etc.

- Some start ups have already started developing value-based solution on this topic; IATA has created a differentiated task force to work on a digital identity initiative, called OneID, which indicates this topic's relevance for the whole airline industry
- Benefits: cost of processing passengers; amount of time checking their passports at different checkpoints; and cost of repatriation and fines airlines receive due to mistakes (airlines are responsible for providing correct documentation of passengers and ensuring they possess correct visas etc.) can be reduced drastically; Governments are provided with more accurate information about the inflow of travelers
- Interviewee worked together with a start up in this area; such a project should rather be driven by an authority (like IATA) or government bodies instead of airlines; airlines would eventually adopt this platform and reap its benefits, but not push its implementation

Use Case 2: Tokenization of aircrafts (*note:* very theoretical use case)

- Most expensive asset of an airline is the airplane and global banks are required to fund these capital-intensive investments.
- Blockchain technology could provide an alternative way to leasing/financing an aircraft: Using security tokens, the airplane could be tokenized and thereby become mass-funded; in that way alternative sources of capital would be attracted, and an airplane could become publicly owned; effectively reducing cost of capital for airlines; this is an interesting project which could make investments more accessible for the public and provide cheaper rates to finance airline fleets; however potential regulatory obstruction and immaturity of the underlying systems are major limitations
- This type of funding through the use of security token was already done in real estate and hotels but not yet in airplane financing

Use Case 3: Digital identity of parts

- Airplane maintenance is characterized by extensive documentation on maintenance work performed for every individual part
- A blockchain-powered system could help to reduce and more effectively manage this load of documentation; Despite working similar to existing maintenance software, which involves tracking of cycles, work history and lifecycles of planes and parts among others, it would bring superior value as it provides independent availability of the documentation and can enable direct access to data for relevant partners; it also provides more accurate and trustworthy data (on all processes related to parts), as it cannot be easily changed by a single entity; furthermore, transferability of ownership of parts and aircrafts is enhanced which facilitates the transfer within the whole ecosystem after for example an aircraft lease ends
- Further benefits include better tracking of maintenance, better scheduling, more (accurate) data; the insights provided by newly generated data could be fundamental to shed light into inefficiencies of all kind of maintenance processes
- This would not be a product, an airline would build on its own initiative; most likely, they would rather opt-in to the system provided by a maintenance provider or OEM, like GE or Honeywell or collaborate with a start up and ensure as a powerful driving force, that other relevant players from the ecosystem would opt-in as well

Use Case 4: Cargo Business

- Shipment of goods involves multiple touchpoints with different providers and agencies for example ground handlers, airlines, customs, clearance and requires large amounts of (often paper-based) documentation; currently, there is no independent source mitigating the whole process in and end-to-end fashion, providing full visibility in the value chain
- Blockchain-based system would enable different entities to collaborate across the value chain; Every entity would provide information on their respective process steps on the chain; Blockchain is superior to shared database solutions because you need the same

independent information available to every involved party without players being able to change data
- Limitation: he is not sure whether there is a financial benefit of a blockchain-based system, which makes it hard to get people on board with such a solution

Use Case 5: Frequent flyer programs
- Current process: In loyalty programs, if customers redeem miles at a partner, the partner has to clear the miles with the airline, which in turn pays the partner and also deducts miles from the customer's account (typically, you get a monthly mail from partners with excel files stating which customer spend how many miles, which then have to be reconciled with airline systems); there is often a lot of manual overhead involved in this process
- The airline launched and implemented an application for loyalty that is completely build on blockchain by working together with a start up that specialized in blockchain for customer loyalty
- Benefits: Instant clearance of miles, which reduces liability; enhanced ability to "earn and burn" for customers, allowing for instant access to points and creation of high user engagement; subscription of partners is much easier and now virtually works without overhead, as partners simply subscribe to the platform
- The start up the airline collaborated with was the main driver of this solution and the airline only had to adapt processes to their own needs

RQ 2

Enablers for successful Implementation:
- Everything comes down to the economic value of the project; if there are direct benefits for the airline, it will subscribe to it and also lead initiatives; if there are rather macro-level benefits, airlines would expect other players/authorities to lead those blockchain initiatives

Roadblocks for implementation:
- Airline industry is very focused on compliance, legal, etc. which can impose high constraints for projects, especially for emerging, not yet proven technologies
- Airlines are traditionally very conservative and the appetite for risk is very low; so as soon as there is the slightest alarm bell rings in regard to a project, it would immediately stand still

Should airlines pursue BC projects themselves or collaborate with third party providers?
- Airlines should definitely collaborate with start ups
- Most likely, in the end it would also be cheaper to buy the start up instead of investing own resources in developing your own blockchain systems

Roadmap towards implementation:
- You always start from the numbers and determine the value of the use case you are working on; then the airline must find the right partner to collaborate with, which is where incubators/accelerators or innovation labs can help a lot; then you PoCs are developed, tested and revisited based on learnings, eventually, when concepts could prove to deliver value, they are handed over for implementation and brought to market, depending on the respective airline's processes

Additional information

Personal opinion towards blockchain

- Definitely ripe for broader implementation, but what is missing is, a global organization, like IATA, playing a bigger role and lead initiatives and bring together different stakeholders to cooperate
- Blockchain projects will always be global-scale projects spanning the whole ecosystem for players to get the real value out of it
- Will always be the chicken-egg situation, unless organizations such as IATA lay out guidelines and create global standards/initiatives to facilitate blockchain projects

Reasons that slow down adoption of blockchain in the airline industry

- Finding the right use cases and the right value in the use cases
- The reason for why the first four use cases discussed are still in theory, is just that. The right value was not yet found and may never be found

Potential of blockchain in the airline industry on a scale from 1-10?

- 6 out of 10
- Despite the huge potential, the technology is still very uncertain and not much has been proven yet

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Expert 8: Pedro Arnaud Andersson

Company	Winding Tree Foundation	**Knowledge Blockchain**	7/10
Title	Founder and COO	**Knowledge Airline Industry**	6/10
Background	Co-founded the non-for profit blockchain start up Winding Tree in 2017; Winding Tree is a completely decentralized network on public blockchain with smart contracts to connect travel providers with sellers of travel. Using a simple API a hotel or airline can connect to thousands of points of sale eliminating months of negotiations and integrations with archaic, rent extracting intermediaries		

General insights

- Currently no knowledge of fully implemented blockchain use cases; firms mostly use it as marketing tool and merely announce PoCs
- If the world really wants to benefit from the blockchain, is has to be a public, fully decentralized blockchain environment; if it is a private blockchain you could most likely also use a database
- GDS with their oligopoly power as intermediaries in the travel industry claim large amounts of value without contributing much to the industry; their systems are based on very old technology and they are still riding a wave of past success; travel suppliers do not have direct relationships with the demand side and thus everything goes through the GDss allowing them to act as gatekeepers of innovation and sustaining their position
- Winding Tree initially created a version of their product that was completely on blockchain, but given the limitations in transactions, this was not suitable for the industry; It was then discussed how traditional technology can be used in combination with blockchain and decided that only the trust part (i.e. vetting for businesses) will have to take place on blockchain technology
- Winding Trees solution is ready, it works and is soon to be implemented; they have already 15 partner airlines on board; however, the current Covid-19 situation has delayed the announcements of new solutions which would complete the offered environment

RQ 1

Use Case 1: Connecting OTAs and Travel suppliers

- The goal of this solution is to create a decentralized marketplace without middlemen extracting fees
- GDSs nowadays provide aggregation in that you have most of the airlines and hotels in one place and they provide trust in that every business that is accessing your inventory has the right to do so, because the GDS has vetted them and given them access; but how can trust and aggregation be provided in a decentralized way?
- Blockchain comes into play not to handle the actual transactions, but rather the vetting of the business partners and thereby establishes trust in these businesses, which usually was done by intermediaries like Sabre, Amadeus or Travelport
- Businesses can prove their legitimacy and verify themselves creating a digital passport using verifiable claims (e.g. providing certifications or verified social media accounts, placing deposits, etc.); this vetting is done automatically using smart contracts, with the code providing the verification
- Once business have set up their digital passport and verified themselves, there can be a two-sided marketplace and businesses can start interacting with each other; e.g. Lufthansa can make their API available (not via blockchain, but traditional technology interfaces) to travel agencies and put in place thresholds for what kind of business they provide access to their API (e.g. only business that have met X criteria, only businesses that deposited $X worth of cryptocurrency, etc.) and have a direct connection with the businesses they want to cooperate with only
- In that way companies like Lufthansa can open their APIs to a travel agency without having to go through the traditional paperwork and long and lengthy negotiation process to figure out whether a start up is worthy to collaborate with
- Next to the OTAs, this environment also allows large corporations to engage with and connect to the APIs of airlines directly; e.g. Deloitte pays around a billion in travel per year and of this sum approx. 30% is paid in fees to the intermediaries; Contrarily, if they would approach airlines directly in the current setting, large corporations would need to approach and negotiate with every airline individually and integrate with its respective API, which is not a scalable process

Use Case 2: Settlement between airlines

- There are attempts between some airlines that are investigating possibilities of blockchain in the settlement area
- It is a good use case, but most likely the airlines are approaching it wrong as they consider permissioned blockchains only
- The airlines are under NDA and thus no further information could be provided

Use Case 3: Digital Traveler IDs

- Levels of security requirements are ever increasing, however innovations in this area are lacking far behind and thus leave the identification process oftentimes to be very inefficient
- A global public blockchain identity project would be incredible for travel and provide huge advantages regarding the flow of passengers between countries and any touchpoint the customer may have during his journey
- It is a very futuristic idea which would require collaboration and coordination across global governments

Use Case 4: Supply chain management/ parts

- Not discussed and only mentioned briefly

RQ 2

Enablers for successful Implementation:

- It is a human challenge rather than a technological one as the underlying technology is available and ready *(Note: referring to the Winding Tree solution)* and highly depending on how the decision makers prioritize and also react to unexpected situations; e.g. during the Covid-19 outbreak, one partner airline was completely halting integration due to employee cuts, whereas another provided more resources, as employees were grounded and thus available to focus on the integration)

Roadblocks for implementation:

- Finding the right blockchain use case and the right people to execute it appropriately can be difficult
- The transition from existing technologies towards blockchain featured and decentralized solutions are hard, but nonetheless the right thing to do to be prepared for the future

Additional information

Personal opinion towards blockchain

- Blockchain is something that is going to help the industry as a whole; it is kind of like sustainable energy vs coal; if you are running on coal right now, it is hard to make the shift, but definitely the right decision long-term

Potential of blockchain in the airline industry on a scale from 1-10?

- 9 out of 10

***Expert 9*:** Matthias Krohnen

Company	Miles & More GmbH (Lufthansa Group)	**Knowledge Blockchain**	7/10
Title	Manager IT	**Knowledge Airline Industry**	6/10
Background	Leads exploration of emerging technologies as head of internal innovation lab at Miles & More; Investigation of blockchain applications during several projects; Jury member of the 2018 Lufthansa Aviation Blockchain Challenge		

General insights

- Merely taking existing business models and transfer it to blockchain technology does not bring many advantages except for the technological benefits of blockchain and customers do not care which underlying technology is used in the end, if they do not feel a benefit; He does not believe that any airline in the world will say we have to go to blockchain with our existing business model
- This was a problem of many solutions proposed in the Aviation Blockchain; no new business models were developed, and processes were rather transferred to blockchain environments
- The hype around blockchain from 2017/2018 came to an end and despite having developed some PoCs no solution actually went into production and was implemented on a larger scale
- Companies are not interested in running the same business model on a new technology stack just for the sake of using a new technology, if they have existing solutions in place that work
- The right approach towards blockchain is to first look into new potential business models and then see what the appropriate technology for this is – if blockchain is a good fit,

perfect, if not, be open for other solutions; do not focus on one technology just for the sake of implementing this technology

RQ 1

Use Case 1: Frequent flyer program

- The initial idea was to transfer the existing frequent flyer program to a private blockchain environment without drastically changing its business model; A PoC based on a private blockchain environment was created as they did not want to give away all their control and rather use blockchain as a technology and exploit the associated benefits like the complete and transparent chain of transactions or the inability to manipulate transactions
- The main benefits associated were that it was quite cheap to implement, as you merely need to define the business rules and set up the smart contracts within the blockchain; the PoC with all basic frequent flyer program functionalities was built in collaboration with a partner within 2 months only; blockchain technology comes along with many required functions due to its technological structure and thus you do not need to worry about how to do reliable transactions from the customer to partner A to partner B for example
- Customers could spend their earned miles, which would be transformed into crypto-frequent flyer coins then, immediately at partners
- It was concluded that only using blockchain as a technology stack would not enable a business model transformation and a such it would be just a new technology with some more benefits compared to existing systems, making internal processes more efficient but not having a direct impact on the customer; Therefore it became a technology cost case, raising the question whether an existing solution that is up and running and works, even though some things may be a little complicated, should be replaced with a new system; the question was whether a budget would be spend on a new technology underlying the existing frequent flyer solution, or rather invested into something with a real customer impact
- It was concluded that the budget would rather be spent on another project with a higher direct customer impact and the blockchain use case was stopped

Use Case 2: GDS system on a blockchain

- Running a GDS like system on a blockchain; disintermediate the existing players by buying and selling tickets via a public blockchain and reduce dependencies from the three main GDS systems *(Note: presumably he talked about Winding Tree)*
- This would definitely save some costs as high fees are paid to GDSs for their service
- He does not know whether the project is still running

Use Case 3: Pilot flight logs stored on a blockchain

- Pilots need to make sure that they have x flight hours per year/months to maintain their flight license
- The idea was to create a decentralized solution that stores this information on a blockchain and thereby provide a transparent, trustful and not manipulatable source of flight logs across airlines
- Currently, every airline individually handles the flight logs of their pilots in a centralized way using different standards and formats, which makes it hard to pilots to migrate from one airline to another

Use Case 4: passport data stored on a blockchain

- Not discussed in detail

Use Case 5: Flight schedules on blockchain

- Not discussed in detail

RQ 2

Roadblocks for implementation:

- There must be the right use case for the application, ideally involving a real business model change with an impact for the customer, instead of only transferring an existing business model to a blockchain environment

Additional information

Personal opinion towards blockchain

- Not an enthusiast of blockchain anymore, the hype from 2018 is gone and the investigated PoCs have not proven to be valuable enough to be implemented

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Expert 10: Kaj Burchardi

Company	BCG Platinion	**Knowledge Blockchain**	9/10
Title	Managing Director – Head of Platinion Netherlands	**Knowledge Airline Industry**	6/10
Background	18 years of experience at BCG Platinion; Heading multi-disciplinary blockchain team across BCG and BCG Platinion since 2015; delivered 30+ projects in a blockchain contexts across different industries, including the airline industry		

General insights

- BCG uses a framework to assess use case for blockchain; most prominent features are that there is a minimum amount of two parties involved, the trust level is not very high, transaction volumes are substantial and costs for transactions in the current process are high
- Development of a "quick and dirty" blockchain PoC can nowadays already be below $ 500k; for a production ready product around $1mio can be expected
- A big challenge currently is to find the "holy grail" of which use case in combination with which platform is currently the right time to go for production; for that you need to understand the use case but also the capabilities and industry-readiness for any platform that might be relevant for the use case
- The starting point for most companies will be permissioned blockchain environments, because it is much closer to how they think, work, act, and behave; more innovative companies will always put a possibility to go public at a later point in time into their platform
- Overall, there may be other industries, where blockchain will have a stronger impact, but still there are some interesting and good use cases were blockchain can have a real impact in the airline industry

RQ 1

Use Case 1: Loyalty points

- Especially allocation and reconciliation of loyalty points between airlines within the same group or with code share agreements can benefit greatly from blockchain technology
- Reconciliation and netting between the airlines is a super cumbersome, partially even manual process and each year several hundred thousands of dollars are going down the drain just by executing this process; the airlines know that this process is never really accurate

- With a consortium blockchain solution this could be automated pretty heavily, and provide airlines with a clear understanding that the data they transfer and reconcile is correct; In this environment, there is a bit of trust between the airlines, but airlines within an alliance are still competitors so overall trust levels are not very high; furthermore, there is a substantial amount of money involved that may be saved and resultingly, the value from a more efficient process on the alliance level may be up to a million dollars per year
- Additional benefits are that airlines have less faulty transactions and delays in mileage transfer for the customer; today quite a number of times if you buy with one airline and fly with another, it takes ages before the mileage is transferred to the customer's account; with blockchain however, as soon as the carrier closes the doors, mileage can be directly transferred to the customer's account; this real-time transfer of mileage would then again enable the customer to directly spend the mileage on the flight which would definitely increase the benefits for the customer
- The biggest limitation for this solution is that one of the airlines (a large player within an alliance for example) must do the first step and champion the technology, create partnerships, establish guidelines and eventually invest in it; given the circumstances, this is obviously not easy these days; typical chicken and egg problem that needs to be resolved first (typically, you would need two airlines that build the system on a PoC level approach that shows the value and then you move ahead and directly build it in a very general way that other airlines from the alliance for example can join it)
- At least one alliance he knows of has not resolved this problem yet and spends hundreds of thousands of dollars per year for reconciliation
- Most promising use case that was discussed with many airlines as it really enables airlines to generate high cost-savings

Use Case 2: Luggage tracking

- The three involved parties here are basically the airline, the airport and the customer and as of today the luggage tracking process involves different data bases owned by the involved players, that are hardly connected
- By tagging and scanning the luggage throughout different checkpoints in the departure airport, the aircraft and the arrival airport and storing this information in a blockchain environment, there would be a single source of truth available to all parties, which would be able to provide a transparent history of where the luggage was during the journey and thereby show the exact location of the luggage at any time; this would make it very easy to inquire when and where pieces of luggage got lost
- This solution could be done similarly to the R3 Corda way and only create point-to-point connection between the parties *(note: i.e. between the airline, the airport and the customer*), without making all information available to all other nodes
- This would be really big from a network effect basis, however, the value behind it is very hard to quantify

Use Case 3: Engine service agreements

- Engines are currently used more as a service; Airlines don't buy the engines but rather purchase service agreements about power hours or servicing hours; there might be opportunities for blockchain technology in this area to create new business models/ change existing processes
- Not discussed in detail

Use Case 4: Maintenance parts

- Promising use case; parts could be traced back to birth
- Not further discussed due to time limitations of interviewee

RQ 2

Enablers for successful Implementation:

- Essentially, there are three main enablers: the existence of a real business problem, a certain level of trust, and a certain level of innovation capability
- The fundamental baseline for any blockchain project is that there is a real business problem that can be solved using blockchain technology, and it must be relevant for all partners
- Then, there needs to be a certain amount of trust between the partners; having such a starting point to kick-off the discussions from helps tremendously, especially when considering that airlines are still competitors, even though they are in the same alliance; within alliances, typically some of the airlines trust and respect each other more than others
- Eventually, there needs to be a certain degree of innovation willingness or curiosity for all partners involved; having these capabilities and the right mindset to assess where blockchain makes sense and where it doesn't helps tremendously; the Lufthansa Innovation Hub is a great example to build/provide those capabilities, but unfortunately many airlines do not have those structures and thus lack innovation capabilities

Roadblocks for implementation:

- Too often, people want to do blockchain projects for the purpose of better understanding the technology, which typically does not fulfill a business purpose and thus does not provide any benefits like reducing costs or providing additional revenues etc.; Such projects are shut down at the moment someone from finance/ controlling looks at them as they do not bring benefits; often this creates internal organizational hurdles for potential future blockchain projects

Roadmap towards implementation:

- Similar to a typical roadmap towards innovations
- First, run an innovation sprint to better understand key business problem in regard to potentially required efficiency increases and/or new revenue generation points
- Validate whether the use of blockchain in this particular use case is a superior solution compared to anything else in terms of its technological capabilities
- If a use case was found and the associated benefits are high enough while the implementation risk is low (it is straightforward how to put it on a blockchain), create a PoC, validate the value and go for MVP and production; after each step you have a milestone validating if what you are trying to solve really adds value
- Standard approach towards innovative technologies

Additional information

Reasons that slow down adoption of blockchain in the airline industry

- Not each platform is in general ready for production on an enterprise level and not each platform is valid for each use case
- The right combination between which platform to use with which use case can be very hard to assess/find

Potential of blockchain in the airline industry on a scale from 1-10?

- 7 out of 10