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Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry

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ABSTRACT

This paper investigates the major implications of blockchain technology for operations management (OM) with a focus on the decision-making processes in supply chain management (SCM) from the perspective of sustainable performance. The links between blockchain technology, OM, and sustainability issues within SCM are analysed. This two-step research study includes a broad review of the main contributions in the literature that have focused on blockchain technology and OM in SCM. It covers the airport industry from the perspective of sustainable performance and data analysis by reading and processing financial statements, non-financial reports, and the website of one strategic airport infrastructure in southern Italy. The Italian airport infrastructure investigated successfully adopted the Airport Collaborative Decision Making (A-CDM) platform. This is one of the main blockchain technology applications in the airport industry. It promotes cooperation between the main players in the aviation industry and the air traffic controllers (ATCs) to reduce fragmentation, inefficiency, and uncoordinated operations. It also allows information and data sharing, but it is still not possible to observe a high level of sustainable performance.

Although the adoption of blockchain technology presents numerous benefits, especially in improving OM, these new technological solutions do not guarantee the achievement of the best performance in terms of effectiveness, efficiency, and sustainability issues. Managers and policy makers need to work together to create a real forum within their collaborative network in which there is a common culture and mutual trust. This article adds an interesting reading of blockchain technology to the existing research with concerns about OM and sustainability issues within the airport setting in Italy.

1. Introduction

Blockchain technology is able to transform significantly many activities and operations in the supply chain that require increasing attention from scholars and practitioners (Kshetri, 2018). Indeed, the growing use of new technologies, such as the Internet of Things (IoT) and artificial intelligence (AI) applications, will affect supply chain management (SCM) (Apte and Petrovsky, 2016; Kshetri, 2018; Saberi, Cruz, Sarkis, & Nagurney, 2018). For instance, blockchain technology enables one to enhance and track goods and passengers in real time from their origins through the overall SCM. In the supply chain, blockchain technology enables all of the actors to know who is performing which actions by defining and evidencing the time and location of the actions. One of the most direct relevant benefits of blockchain technology is the provision of possible solutions for identity management (Alam, 2016). Blockchain technology implies positive and negative effects on the overall business world (Aste, Tasca, & Di Matteo, 2017; Giungato, Rana, Tarabella, & Tricase, 2017; Kewell, Adams, & Parry, 2017; Kshetri, 2018; Lu & Xu, 2017; Vranken, 2017). Specifically, disruptive technologies have been making crucial transformations and changing all the end-to-end production and business models in the major economic sectors. Because of blockchain technology, global SCM is being rethought, redesigned, and reshaped. The adoption of these new technological solutions is revolutionising the processes that have traditionally been used for creating value. The advent of blockchain technology provides greater spatial and temporal flexibility. New technology is bringing operations, production, and sales closer together, and it is promoting significant changes by rethinking, redesigning, and reshaping the operations management (OM) of supply chains.

The existing contributions in the literature still do not provide significant knowledge about the implications of blockchain technology for

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future industries, especially regarding its practical application and the main effects on OM in SCM (Beck & Müller-Bloch, 2017; Büyüközkan & Göçer, 2018; Fosso Wamba, Kamdjoug, Robert, Bawack, & G Keogh, 2018; Tian, 2016).

Numerous studies have reported significant benefits of blockchain technology in logistics and the supply chain (Hughes et al., 2019; Kamble, Gunasekaran, & Arha, 2019; Kamble, Gunasekaran, & Sharma, 2019; Morkunas, Paschen, & Boon, 2019; Queiroz & Fosso Wamba, 2019; Shuetz & Venkatesh, 2019; Tönnissen & Teuteberg, 2019; Wang, Singgih, Wang, & Rit, 2019; Wang, Han, & Beynon-Davies, 2019; Ying, Jia, & Du, 2018). These benefits include improved cybersecurity and protection (Kshetri, 2017), transparency and accountability (Kshetri, 2018; Zou et al., 2018), traceability and fraud prevention (Biswas, Muthukkumarasamy, & Tan, 2018; Chen, 2018; Lu & Xu, 2017), and so forth. Blockchain technology is able to redefine, redesign, and remodel the characteristics of the relationships between all the players in the supply chain (Queiroz & Fosso Wamba, 2019).

Adopting blockchain technology in SCM makes OM safer, more transparent, traceable, and efficient (Aste et al., 2017; Kshetri, 2018). Furthermore, blockchain technology is able to increase the cooperation between the members of SCM (Aste et al., 2017), with indirect positive effects on cost and efficiency in the supply chain. Blockchain technology can also enhance customers' trust, thanks to the traceability of goods during their entire journey across the supply chain (Biswas et al., 2017). Furthermore, it supports the prevention of product fraud and fakes across the supply chains (Chen, 2018), which has a positive impact in terms of cost reduction and efficiency.

Otherwise, blockchain technology applied to SCM is still in its infancy (Queiroz & Fosso Wamba, 2019), because firms tend to pay too much attention to the adoption phase and neglect other features, such as the organisational and managerial strategies and policies needed for successful blockchain technology and the link to the three components of sustainability (environmental, social, and economic sustainability) (Elkington, 1997; Kajikawa, 2008; Schoolman, Guest, Bush, & Bell, 2012).

Drawing from past research, this paper aims to investigate the main implications derived from blockchain technology for OM and focuses the attention on the decision-making processes related to operations in the supply chain. It adopts the perspective of sustainable performance with a focus on the airport industry.

Specifically, sustainable performance, related to the concept of sustainability, can balance the three sets of criteria that are related to the environmental, social, and economic components of sustainability (Elkington, 1997; Kajikawa, 2008; Schoolman et al., 2012). Thus, firms that perform in a sustainable manner are able to provide their products with respect to these criteria. However, most literature on this topic has pointed out that the balance is not easy to achieve. Therefore, economic, financial, social, and environmental components are sometimes in conflict from the sustainable performance perspective (Boons & Wagner, 2009; Boons, Montalvo, Quist, & Wagner, 2013; Pullman, Maloni, & Carter, 2009; Spreitzer & Porath, 2012). For this reason, scholars and practitioners have investigated the organisational, accounting, and reporting practices or policies that enable firms to achieve sustainable performance and create the right equilibrium between the three mentioned components. They have also proposed several measures to promote environmental, social, and economic sustainability (Hoejmose & Adrien-Kirby, 2012; Seuring & Müller, 2008).

Thus, we analyse the link between blockchain technology, operations management, and sustainability issues within SCM. In this case, considering the link between blockchain technology and sustainability within SCM, we focus mainly on so-called sustainable supply chain management (SSCM). By adopting a sustainable supply chain perspective, firms tend to focus much more on searching for clear, transparent, and effective sustainable practices, thus considering blockchain technology and its social, environmental, and economic impact (Saberi, Kouhizadeh, Sarkis, & Shen, 2019; Steiner & Baker, 2015). Although scholars have paid attention to blockchain technology, OM, and SCM from the perspective of sustainability, defining SSCM, the contributions regarding this issue are still scarce. This is especially true for the possible negative effects of blockchain technology on OM within SCM for sustainable performance and for the identification, development, and implementation of effective organisational and managerial practices that are able to increase the positive impact of blockchain technology in the direction of SSCM.

Consequently, our research questions are the following: "What are the major effects of blockchain technology on operations management for achieving sustainable performance in SCM, making the idea of SSCM possible?" and "What are the main managerial and technological solutions for preventing and managing blockchain disruptions in the airport industry?"

To achieve this research goal, an exploratory study was conducted and articulated in two different steps. Thus, this paper consists of a theoretical and a practical study. At the beginning, we analyse the major contributions in the literature on the phenomenon investigated to point out the research gap that still exists and the primary directions to follow for the subsequent practical analysis. The first part provides a broad review of the literature. Second, we adopted a case study methodology, through secondary data analysis, to investigate the implications of blockchain technology for operations management and the involvement of the players within the supply chain related to the airport industry to achieve high sustainable performance.

The airport sector was chosen as the research context for three main reasons. First, the airport industry plays a relevant role in SCM. Indeed, airports constitute critical nodes in the air transport system and consequently in territory connectivity. They are also part of the aviation sector. Second, the airport industry has experienced important changes resulting from blockchain technology through the adoption of new and technologically advanced applications. Finally, the airport sector has an increasingly recognised environmental, social, and economic impact, which requires considerable attention in the search for technical and managerial solutions to achieve sustainable performance while overcoming the negative effects of technological disruptions. Our emphasis is on an Italian airport infrastructure with a strategic role and core position within the Trans-European Transport Network (TEN-T) and a significant impact on the local community.

The primary findings show the need to investigate the airport industry and to pay most attention to the main effects of blockchain technology on OM from the perspective of sustainability. The Italian airport infrastructure investigated has successfully adopted the platform Airport Collaborative Decision Making (A-CDM). This is one of the most relevant blockchain technology applications in the airport industry. It promotes cooperation between the main players in the aviation industry and the air traffic controllers (ATCs) to reduce inefficiency, fragmentation, and uncoordinated operations and to stimulate and manage information and data sharing. However, it is still not possible to observe high sustainable performance. A-CDM consists of a technologically advanced platform that is able to reduce airport mistakes and incidents and en route delays significantly and to optimise airport operations. It enables the improvement of efficient turnaround processes, gate management, point congestion, and flight predictability through real-time data exchange for air navigation services. A-CDM permits accurate and timely information sharing among airport partners and the implementation of operational procedures and automated processes that benefit all of the operations at the airport. Thus, A-CDM makes more efficient use of the existing capacity and resources. It also provides resilience and potentially better recovery from disrupted days. Furthermore, it can significantly reduce the operating costs for fuel burn, which can have an impact on environmental targets (Corrigan et al., 2015; IATA Report A-CDM, 2018).

Thus, the main contribution of this study consists of analysing together topics that are usually considered separately, especially the connection between sustainable performance and operations management through the adoption of blockchain technology. In more detail, this study can represent a useful guideline for investigating the managerial solutions needed for effectively and successfully adopting blockchain technology from the sustainable performance perspective within the airport industry, which is one of the most significant industries in SCM. Hence, our theoretical and empirical study provides suggestions about how to collect, elaborate, and read useful information and data from documentation (financial and non-financial reports, websites, etc.) to understand the positive and negative effects of blockchain technology on sustainable performance.

This paper is structured as follows. Section 2 describes the methodology adopted in the study, which consists of a two-step research approach that employs a broad review and case study methodology. Sections 3.1, and 3.2 provide a review of the main concepts for the research, such as the major issues related to blockchain technology, OM, and sustainability as applied to the airport industry. In Section 4 the case study is described, and in Section 5 the main results are outlined and discussed. Section 6 provides management implications. Finally, Section 7 describes the conclusions and limitations of the study and makes suggestions for future research.

2. Methodology

This theoretical and practical study followed a two-step research process. First, we conducted a broad review of the main contributions in the literature regarding blockchain technology. We took into account especially the relationship between technology, operations, sustainability, and SCM. Moreover, we investigated these topics and their combination in the airport industry, which is continuously and significantly characterised by deep changes in terms of technological innovations but still under-researched. We followed the typical stages for conducting a broad review of the literature (Booth, Sutton, & Papaioannou, 2016; Dickersin, Scherer, & Lefebvre, 1994; Moher et al., 2008; Randolph, 2009).

In the primary step of the study, the online search adopted and combined specific key words, specifically “blockchain”, “technology”, “blockchain technology”, “operation management”, “supply chain”, “sustainable operations”, “technological applications”, “sustainable performance”, “technology and airport”, “disruption management and airline industry”, “aviation industry”, and “managerial solutions for blockchain technology”. These keywords needed to appear in the title, abstract, or keywords of the papers in our research. This search was performed in two freely accessible web search engines that specialise in academic contributions, that is, the ISI Web of Science (WoS) and Google Scholar (GS). The search identified 68 research papers, distinguishing three main research issues and areas investigated, namely blockchain technology (39), sustainability (15), and the airport industry (14).

Second, we considered only papers in academic journals published during the last decade, 2008–2018, including the first 6 months of 2019. We started our research in 2008 because blockchain technology began to receive attention from scholars and become an interesting research topic only recently. Third, the papers had to have been published in English and to contain at least one of the selected words and terms in the title, abstract, and keywords. The papers had to have dealt with research issues and the keywords blockchain technology, technological applications, operations management, SCM, sustainability, technology, and airports. Fourth, all of the identified studies were analysed using spreadsheet software to identify the relationships between the issues investigated (Fig. 1).

The literature review outlined two main elements. The phenomenon investigated is still underrepresented in the research. Above all, the major primary directions and features were identified to take into account in the subsequent practical analysis. We conducted this qualitative research study to verify the adoption of blockchain technologies in the Italian airport infrastructure. We found evidence of the benefits, but we mainly identified the main practices developed in the blockchain technology frame.

In the second step of our study, we developed an empirical analysis using case study methodology. Specifically, we used the insights gathered from our literature review as a guide for the design and execution of our qualitative research. Until now, research has been unable to provide suggestions for specific managerial solutions that could be adopted to implement blockchain technology effectively and successfully, especially concerning sustainable performance within SCM and in the direction of SSCM.

An archival data analysis through reading and processing financial statements and non-financial reports (sustainability and social reporting) and a thorough reading of the website of a strategic airport infrastructure in southern Italy (Napoli-Capodichino airport) was performed. With reference to this last point, we checked the last update of the websites and investigated the non-financial documents provided by websites using the keywords “sustainable performance”, “blockchain”, “technology”, “blockchain technology”, “operation management”, “technology investments”, and “technology strategies”.

The following phases characterised the empirical analysis conducted on the selected Italian airport. First, we analysed the website of the airport system for evidence of the type of content and information provided in terms of the technologies used (blockchain technology), sustainable performance, and the mission and vision of the organisation. Second, we collected and examined reports and official documents (financial statements and non-financial reports were taken into account) related to sustainability, finance, and governance. The official financial and non-financial documents and the reports and manuals of the selected airport were collected through an Internet search. The websites and all of the available published documentation (reports, documents, archival data, and so forth) were read and investigated. Then, they were analysed using spreadsheet software regarding the identified relationships concerned with our research objectives. This allowed us to identify the major tools (advanced technologies) used within the airport system to perform its processes and manage its operations.

The academic literature has recognised and clearly identified the case study approach as a useful method that is able to investigate phenomena that are as yet unexplored (Eisenhardt, 1989; Gibbert, Ruigrok, & Wicki, 2008; Scapens, 2004). Case studies allow us to examine phenomena separately from their context and to consider specific variables (2013, Yin, 1994). Through reading and processing financial statements, non-financial reports, and the website of the Napoli-Capodichino airport, we investigated the case of this airport and collected related information and data concerning blockchain technology (specifically the A-CDM application), OM, SSC, and sustainable performance. The Napoli-Capodichino airport was chosen for several reasons. First, this airport is the most representative of airports in Italy, especially in the south. It is considered by the Italian regulation (see D.P.R. 17 September 2015, no. 201) as strategic due to its location, size, and traffic volume (passengers and goods) and its core position in the Trans-European Transport Network in Europe, that is, the infrastructure – TEN-T – connecting Europe; thus, it is one part of the Network Manager of EUROCONTROL. Second, this airport presents a strategic position along important traffic routes that cross the Mediterranean region. Third, it has recorded a large increase in the volume of cargo and passenger traffic. For instance, in 2018, the airport served around 10 million passengers, and this record is a significant increase from 2000 (+15.8%) (Statistiche Assaeroporti, 2019). Additionally, in June 2017, the airport was awarded the “Aci Europe Award” as the best in Europe in the 5–10 m category of passengers. It was especially recognised for the services provided, which were characterised by a high degree of innovativeness, and the substantial attention paid to customers. In addition, in 2018, the airport was the first in its category to win the “Fast and Furious” title. This award is presented to the airport that

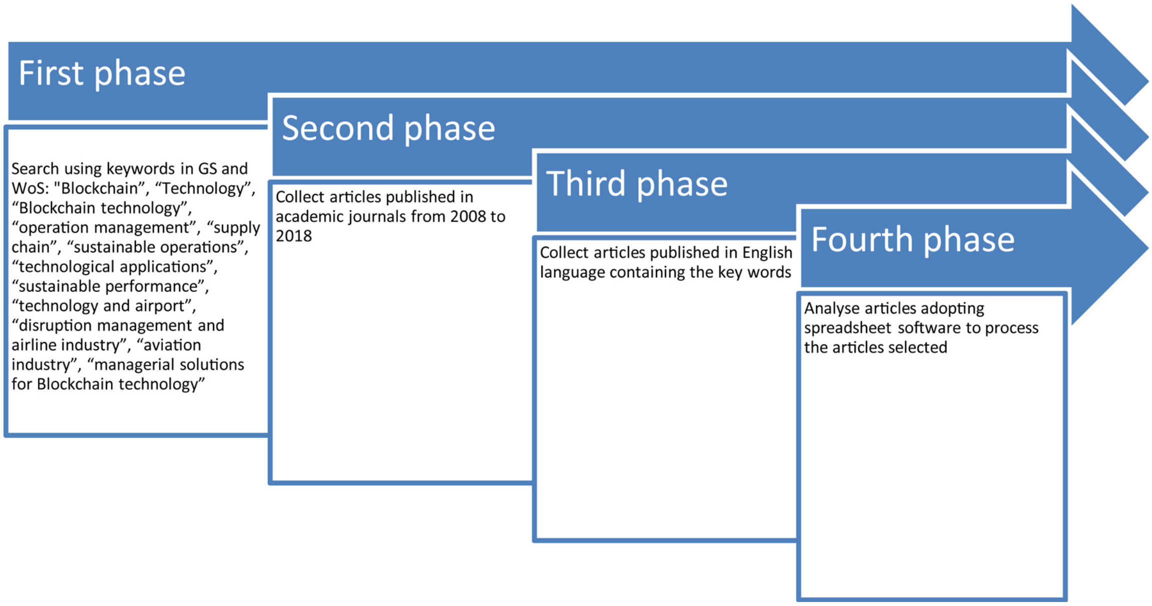

Fig. 1. Phases of the research process.
Source: Authors' processing.

has achieved the greatest growth in Europe, and the airport increased its number of passengers by about 15.8% from 6,775,988 passengers in 2016 to 8,577,507 passengers in 2017 (Statistiche Assaeroporti, 2019).

This airport has also been paying increasing attention to the three features of sustainability (environmental, social, and economic dimensions) as well as to innovation management and technology innovation related to blockchain technology. Indeed, this international airport is the first airport in Italy to use electric buses, starting in the winter of 2018, thanks to a partnership between two companies (Gesac and Handler). Finally, this airport is located in a city. This means that the airport's activities and operations for passengers and cargo can have a relevant and direct impact on the overall community and territory (e.g., air and noise emissions and waste management).

3. Literature review: Blockchain technology and operations management in SCM

The results of our review allowed us to collect some interesting data and make some considerations. The research papers that our search identified were published in many top-tier journals, mainly the *International Journal of Information Management* (11), *Journal of Cleaner Production* (6), *Sustainability* (4), *International Journal of Production Economics* (2), and *Production and Operations Management* (2). Most papers concerning the issues investigated were published in specialised and contextualised journals, such as the *Journal of Air Transport Management*, or in conference proceedings and working paper books. We specifically did not consider conference proceedings and working paper books in our review, but we consulted them to improve our knowledge of the phenomenon investigated. The presence of papers on the three research areas, also in combination, has recorded significant growth in the last five years (2014–2019), showing that this phenomenon is becoming very important and is receiving more attention from scholars and operators, also in the airport industry. The sample includes papers and journals mostly related to the management field in general and to the airport industry, according to the criteria adopted in the web search. The search outlined significant elements that have received increasing attention from scholars on the phenomenon and, more specifically, on the link between "blockchain technology" and the "airport industry", which has become stronger over the years with the concern about sustainability issues. Regarding the "blockchain technology" research area, most publications are available in the *Journal of Information Management*.

As shown by the results of the review, scholars have mainly focused on investigating the major positive and negative effects of blockchain technology on firm performance, paying attention mostly to processes and operations management within supply chains. Then, the main studies on sustainability issues in the airport industry linked to blockchain technology and, in general, technology have focused on subtopics such as "environmental sustainability" and "green airport development" (Table 1).

Blockchain technology started to be considered only recently, "becoming one of the mostly promising technologies of the new economy" (Kamble, Gunasekaran, Arha et al., 2019; 2019b, p. 2). Indeed, it appeared for the first time in 2008, and it was implemented in 2009 (Nakamoto, 2008), but its identity was not clarified and formalised then. Most of the attention in the practice of blockchain technology has been paid to its applications concerning the cryptocurrency bitcoin (Nakamoto, 2008; Zheng, Xie, Dai, Chen, & Wang, 2018).

According to Beck and Müller-Bloch (2017) blockchain technology consists of distributed ledger technology (DLT), that is, a distributed transactional database, in which the security and trust for collecting and sharing data are guaranteed by cryptography through a consensus mechanism. Thus, "Blockchain could be regarded as a public ledger in which all committed transactions are stored in a chain of blocks which continuously grows when new blocks are appended to it" (Zheng et al., 2018, p. 354). The key characteristics of blockchain technology, recognised as the main benefits, are decentralisation, persistency, anonymity, and auditability. Thanks to blockchain technology, any transaction can be performed in a decentralised fashion. Consequently, the cost can be greatly reduced and the efficiency improved (Zheng et al., 2018). Indeed, blockchain technology, conceived as a new type of disruptive internet technology, is broadly used for technologically supporting enterprises in improving their production processes and reducing their costs (Pan, Pan, Song, Ai, & Ming, 2019).

Blockchain technology allows users to record digital facts, but it cannot be considered simply as "a record", because it takes into account many other features, such as smart contracts for preventing and responding to technological disruptions, like fraud (Buterin, 2014). Blockchain is mainly associated with the technology that enables cryptocurrencies, such as bitcoin, but, by defining the concept of

Table 1
Literature Review web search 2008–2019 (*first six months*).
Source: Authors' processing.

#Tot	Research Area	Major Papers	Subtopic	Methodology
39	Blockchain technology	Hughes et al., 2019; Schuetz & Venkatesh, 2019; Kamble, Gunasekaran, Arha et al., 2019, 2019b; Behnke & Janssen, 2019; Thakur et al., 2019; Pan et al., 2019; Wong et al., 2019; Tönnissen & Teuteberg, 2019; Büyüközkan & Göçer, 2018; Mallick, Manna, & Mondal, 2018; Fettermann et al., 2018; Fosso Wamba et al., 2018; Casado-Vara, Prieto, De la Prieta, & Corchado, 2018; Kshetri, 2018; Hawlitschek et al., 2018; Zheng et al., 2018; Groenfeldt, 2017	Positive and negative effects of BT, Firm performance, Supply Chain Management, Operations Management	Conceptual study (Systematic review), Qualitative study, Quantitative study (ISM-DEMATEL methodology; Technology Acceptance Technology Model, etc.)
15	Sustainability	Giungato et al., 2017; Vranken, 2017; Bocken et al., 2014; Boons et al., 2013; Schoolman et al., 2012; Glavič & Lukman, 2007; Bowen et al., 2001; Spreitzer & Porath, 2012	Sustainable Management, Sustainable Performance, Green Supply Chain,	Conceptual study, Qualitative methodology
14	Airport industry	Vojtek & Smudja, 2019; Behnke & Janssen, 2019; Santonino et al., 2018; Robinson, 2017; Adams, Parry, Godsiff, & Ward, 2017; Chang & Yeh, 2016; Apte & Petrovsky, 2016; Blome et al., 2014; Akins et al., 2013; Bottasso & Conti, 2012; Castro & Oliveira, 2010; Gillen & Lall, 2002; Bettis & Mahajan, 1985.	Technology and Airport performance, Environmental Sustainability, Airline industry, Environmental Management, Green airport development	Qualitative study (Case study methodology)

blockchain technology with its other applications, it can also be linked to significant economic and social transactions (Beck et al., 2017; Lindman, Tuunainen, & Rossi, 2017). As already outlined, one of the most promising technologies for the next generation of internet interaction systems is blockchain technology, with its many applications, such as in public services, smart contracts, IoT, reputation systems, and security services (Akins, Chapman, & Gordon, 2013; Kosba, Miller, Shi, Wen, & Papamanthou, 2016; Noyes, 2016; Sharples & Domingue, 2016; Zhang & Wen, 2015). Otherwise, as numerous applications of blockchain technology have been identified, an increasing number of studies have been conducted from various sources and with different viewpoints, like blogs, wikis, forum posts, codes, conference proceedings, and journal papers (NRI, 2015; Tschorsch & Scheuermann, 2016; Zheng, Xie, Dai, Chen, & Wang, 2017, 2018).

The inter-individual and inter-organisational relationships can be developed and managed significantly thanks to a distributed record system characterised by a high level of reliability, authentication, and trust (Beck et al., 2017;Mainelli & Smith, 2015; Ølnes, Ubacht, & Janssen, 2017; Palfreyman, 2015; Swan, 2015; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016; Zyskind & Nathan, 2015). "Wherever people, processes, businesses, governments, or the social good requires proof of identity, ownership, transactions, or commitments, Blockchain technologies promise to meet those needs with a degree of trust and integrity never before possible" (Jack Shaw, Executive Director American Blockchain Council). Thus, blockchain technology can successfully meet the relevant needs of the actors in any economic and social setting in terms of trust, integrity, and efficiency.

To make blockchain technology, and consequently the overall economic system, work successfully, it is necessary to develop the conditions in which individuals and organisations can trust other parties in creating, storing, and distributing fundamental records. For instance, in many service industries, like healthcare, banking, financing, transport, and education, organisations construct and maintain records through third parties. For this reason, it is very important to prevent corruption or human mistakes in record repositories by using blockchain-based digital systems (Nærland, Müller-Bloch, Beck, & Palmund, 2017). Nevertheless, especially for producing and delivering services, blockchain technology can play a crucial role within supply chains (Kamble, Gunasekaran, Arha et al., 2019, 2019b; Wong, Leong, Hew, Tan, & Ooi, 2019), which entail interconnected activities that involve coordination, planning, and controlling products and services between suppliers and customers. These actors within the supply chains need to coordinate and collaborate. Because of the technological developments, especially regarding information collecting, processing, and sharing, the adoption of blockchain technology is relevant to address the supply chain operations better and to meet the real needs of all the actors (Büyüközkan & Göçer, 2018).

Most studies on blockchain technology have investigated its positive effects in terms of transparency, accountability, coherent data sets, cost reduction, and effective production processes in different contexts, such as manufacturing, and mostly in supply chains, like agriculture, food, and transport supply chains (Behnke & Janssen, 2019; Kamble, Gunasekaran, Arha et al., 2019, 2019b; Pan et al., 2019; Thakur, Doja, Dwivedi, Ahmad, & Khadanga, 2019; Wong et al., 2019). Blockchain technology plays a relevant role especially within supply chains. It has been conceived as a "concatenation of data combined into individual blocks and stored on all of the users' computers" (Tönnissen & Teuteberg, 2019, p. 2). These specific data in blocks acquire the form of chains thanks to their sequences as transactions. To include new records, the passage of a consensus mechanism (e.g. proof of work whereby the computer executes a mathematical algorithm) is required to obtain agreement among all of the partners in the supply chain (Beck et al., 2017; Risius & Spohrer, 2017). In this way, the data will certainly be the same in all nodes in the network (Swan, 2015).

Otherwise, SCM is an integrative approach to deal with the planning and control of materials, operations, and information from suppliers to end customers. Using blockchain technology to coordinate all the elements of the supply chain, from parts suppliers to retailers, achieves a level of integration that represents a competitive advantage that is not available in traditional logistics systems (Blome, Schoenherr, & Eckstein, 2014).

In this context, SCM design performs and manages the operations of resource flows (movements of products, people, information, and finance). In so doing, it facilitates the integration of various resources across multiple organisations. Therefore, products, people, information, and finances are resources that are integrated with other resources as firms build and sell their offerings (Mallick et al., 2018). By connecting all of these resources, SCM is always about servicing resource integration by managing flows on both the demand and the supply side. Research on logistics service quality has underlined that customers care about issues like product availability and condition, timeliness, the quality of order-related information, interpersonal communication, and the discrepancy-handling process. In this way, retailers or end-user consumers are concerned about these elements, because having the right products available when needed not only satisfies their own needs but also is a precondition for servicing their customers further downstream. Hence, blockchain technology has been widely applied in several supply chains related to finance, transport, power, and food/agriculture (Groenfeldt, 2017; Kshetri, 2018; O'Marah, 2017). These applications have been successful in terms of ROI (Bünger, 2017), especially considering the relevant transformations derived from blockchain technology for supply chains. Indeed, the use of the IoT, radio frequency identification (RFID) tags, sensors, barcodes, or GPS tags and chips significantly affects SCM, such as in all activities related to locating products and tracking packages and shipping containers (Kshetri, 2018). Thanks to blockchain technology, it is now possible to identify management (Alam, 2016), and all of the actors in the supply chain are able to know which actions are being performed and who is performing them by defining and recording the time and location of these actions. Among the several benefits recognised for blockchain technology, we can mention that it provides possible solutions for identity management (Alam, 2016) and facilitates valid and effective measurement of the outcomes and performance of key SCM processes (Koetsier, 2017; Kshetri, 2018).

Scholars have investigated the impact of blockchain technology on SCM in terms of strategic goals (Kshetri, 2018) or considered the acceptance of blockchain technology considering country differences (Queiroz & Fosso Wamba, 2019). They have also demonstrated that the trust between members in SCM means that institutional intermediaries do not need to be involved (Ying et al., 2018). Only a few scholars have also investigated the link between blockchain technology and sustainable development goals (SDGs) and looked for evidence regarding how blockchain technology could present significant benefits in meeting the UN SDGs (Hughes et al., 2019). Furthermore, scholars have explored how blockchain technology can significantly transform supply chains, because the secure exchange of data in a distributed manner can affect the structure and governance of supply chains as well as the configurations of relationships and information sharing between actors in the chains (Wang, Singgih et al., 2019).

However, blockchain technology has positive and negative effects on the overall business world (Aste et al., 2017; Giungato et al., 2017; Kewell et al., 2017; Kshetri, 2018; Lu & Xu, 2017; Vranken, 2017). Thanks to blockchain technology, it should be possible to achieve the traditional objectives of the supply chain, which are to improve the cost, quality, speed, dependability, risk reduction, sustainability, and flexibility (Baird & Thomas, 1991; Bettis & Mahajan, 1985; Bowen, Cousins, Lamming, & Faruk, 2001; Goldbach, Seuring, & Back, 2003; Kovács, 2004; Meyer & Hohmann, 2000; Rao & Holt, 2005; White, 1996). Indeed, in supply chains, logistics services are often crucial for enabling firms to deliver customer value (Mentzer, Flint, & Hult, 2001). Otherwise, the main goal to achieve within SCM consists of delivering products and services in the right condition, in a timely manner, and with the lowest possible costs while reducing the risks (Flint, 2004; Kshetri, 2018). Blockchain technology can allow a great advancement in the authentication and validation of supply chains, although traditional quality and auditing processes are needed at each step to creating a transactional record. Thus, blockchain technology provides major and significant advances for effective supply chains, but there is still a need for quality audits (Apte and Petrovsky, 2016). With blockchain technology, the process is faster and the transactional records become more robust and reliable (Apte and Petrovsky, 2016; Kshetri, 2018).

In summary, blockchain technology can add significant value to supply chains (Wang, Singgih et al., 2019). Academic contributions to the link between blockchain technology and supply chains are still scarce, since they only started in 2015. Blockchain technology can enable transactions offering transparency, authenticity, visibility, trust, and security to all the participants in a supply chain. For instance, due to real-time tracking, it is possible to know exactly where a product is and when it can be delivered, and all the firms within a supply chain can have and share the same data and information (Kim & Laskowski, 2016; Loop, 2017; MH&L, 2016). In addition, blockchain technology has made it possible to improve efficiency in supply chains (Bedell, 2016; MH&L, 2016) as well as to reduce waste, costs, and the time that the products are in the transit process (Barnard, 2017; Kharif, 2016; Loop, 2017). Indeed, blockchain technology speeds up the transfer of data. This allows the participating firms to be informed in real time and products to spend less time in transit. This provides opportunities to improve inventory management and to reduce the related costs and waste.

3.1. *Blockchain technology applications in the airport industry: the A-CDM*

One of the numerous supply chains involved in the positive effects of blockchain technology applications is represented by the transport industry, especially the airport industry (Akmeemana, 2017; Álvarez-Díaz, Herrera-Joancomartí, & Caballero-Gil, 2017).

During the last two decades, the airport sector has been experiencing relevant changes as it has been significantly affected by the advent of blockchain technology, taking into account the main implications derived from establishing the operational standards of service performance in the airport industry, in which a very broad revolution is taking place due to the development and adoption of new technologies. Otherwise, blockchain technology within the airport setting, as well as in other crucial service contexts, significantly affects the overall services provided by making them more satisfying and highly standardised according to the main mission and vision of the airport industry, which provides high-standard operational services that respond strictly to passengers' collective attitudes and needs. Since the 1980s, most airports have aimed to maximise user satisfaction by providing higher service levels (Bottasso & Conti, 2012; Caplice & Sheffi, 1995; Park & Park, 1994). The critical performance indicators for airport planning, design, and management concern the service levels and operational standards that are specifically based on the queuing time, service processing time, space requirement per passenger, and so forth (Park, 1989).

With the advent and spread of blockchain technology, increasing attention has been paid to the concepts of the service level and operational standards in the airport industry. The main factors considered have been the temporal and spatial conditions. This is in line with the dominant service logic, which requires specific interventions in terms of design or physical standards and operational standards that are able to affect passenger perceptions. Hence, most airports should update their operational standards based on passenger perceptions and needs to provide more satisfying services (Bottasso & Conti, 2012; Caplice & Sheffi, 1995; Park & Park, 1994). Airports have been conceived as multi-product firms that are able to supply the market through a broad package of services (Bottasso & Conti, 2012; Office of Fair Trading (OFT), 2006).

In this scenario, especially by implementing blockchain technology applications, airports are changing the ways in which they perform by taking into account some different issues, such as sustainability, especially environmental and economic sustainability, always in relation to the service pattern. The recent advances in technology, regarding communications, navigation, and surveillance, have created the conditions for an architecture in which all of the players that are directly and indirectly involved in the airport industry and in SCM have responsibilities and perform their specific operations through the A-CDM system (Ball, Chen, Hoffman, & Vossen, 2001). Among the numerous blockchain technology applications within the airport supply chain (maintenance, passenger and crew identity management, ticketing, loyalty, security, ancillary revenue and in-flight entertainment, luggage chain of custody, air cargo, customs clearing, flight planning, smart contracts, and compensation), A-CDM plays a crucial role and significantly influences the effectiveness and efficiency of SCM.

A-CDM based on AI represents a joint government industry initiative that addresses the improvement of the traffic flow management aspect of air traffic management through an increase in information exchange and an improvement in decision support tools (Chang et al., 2001; Groppe, Pagliari, & Harris, 2009; Hoffman, 2001). A-CDM was created and developed in 1991, when the Federal Aviation Administration's (FAA's) Air Traffic Management office required an investigation to measure the effects of the airlines' flight substitution process on the efficacy of ground delay programmes (GDPs). These experiments showed that enabling airlines to submit real-time operational information to the Air Traffic Management Office could improve air traffic management decision making.

The main problem for the airline companies is represented by operations management in the relation between flight arrival delays (FADs) and flight departure delays (FDDs). Considering that the flights are carried out by aircraft that have already been used in previous flights, an arrival delay and the aircraft turnaround time at the airport are not enough to represent a great issue for the airline companies. Therefore, the companies entrust the disruption management process to the Airline Operations Control Centre (AOCC). Castro and Oliveira (2010) identified the main causes of disruption. Some are due to air navigation (e.g., en-route air traffic, en-route weather, en-route aircraft malfunction, and flight diversion). Others are due to the OM by the airport operators (e.g., crew delays, cargo/baggage loading delays and passenger delays, crew members who do not report for duty, air traffic control reasons, air craft malfunctions, and weather conditions on departure or arrival). From the airport perspective, to manage some of the causes of disruption ascribed to the airport operations, A-CDM represents a significant system for improving air traffic management through information exchange, procedural improvements, tool development, and common situational awareness. Thanks to A-CDM, the traffic flows and the associated resource allocation decisions are managed and recognised as a great responsibility of the AOCC. This system works through two main principles: information and data sharing and distributed decision making. With the adoption of new business models and especially innovative technologies, A-CDM aims to achieve the following goals: to generate better information, due to the merger between flight data and information on airspace users; to create major and common awareness through information sharing for both traffic managers and airspace users; and to create tools and procedures that are able to respond quickly and efficiently to possible capacity/demand imbalances.[1]

According to most operators, the *A-CDM implementation manual* was designed and introduced to facilitate the harmonised implementation of A-CDM at European airports. In 2017, the *Implementation manual* was introduced as guideline for all users. It explained all of the steps required for successful implementation and operation. For instance, details were provided regarding the timing schedules for management decisions in organising an A-CDM project. The *A-CDM implementation manual* represents a very relevant tool for all of the players, aircraft operators, air traffic services, airport operations, ground handlers, service providers, and any other partners. It provides important information for decision makers as well as technical and operational experts. The *A-CDM implementation manual*, in its structure and content, considers all of the partners and addresses the common goals of globally improving the air transport infrastructure and achieving the greatest possible efficiency of the air SSSM. To achieve these goals, specific information and data are required with respect to the needs of all the partners and the final customers (passengers). A-CDM is embedded in the air traffic management (ATM) operational concept. Thus, its implementation requires the adoption of technologies and new managerial solutions for improving operational efficiency, predictability, and punctuality by the ATM network and airport stakeholders. A-CDM has a significant impact on the operating efficiency of airport partners and should contribute to reducing the buffer times for resource planning and flight times due to enhanced predictability. The implementation of A-CDM can lead to numerous changes in communication policies and procedures as well as the overall operations management in SSCM. Scholars and practitioners have usually described A-CDM as something that is easily related to better information sharing. It can be viewed as one revolutionary system for making the SSCM in the airport industry more efficient thanks to the adoption of new technologies and with respect to the standards of sustainable performance (Okwir & Correas, 2014).

The new technologies in blockchain applications as well as A-CDM enable airports to automate as much as possible to increase the information flow and create digitised service. Many effective and efficient solutions can be adopted by airports to make their performance more sustainable. For instance, easier delivery of information to passengers, airlines, personnel, and other users by having more information on the airport system will add value, and the passengers and other partners can provide the airport with more information. As already outlined, most airports and airport authorities should update their operational standards by taking into account the passengers' perceptions and thus by providing more comprehensive service levels to maximise their satisfaction (Chang et al., 2001; Groppe et al., 2009; Hoffman, 2001).

3.2. Effects and sustainability

Blockchain technology, which is the base for a distributed and democratically sustained public ledger of transactions, could foster new and challenging opportunities. Especially, blockchain technology solutions can be effective tools for achieving the sustainable development goals (SDGs) agenda introduced by the United Nations (UN) in 2015 in any country worldwide and in any economic setting, especially within supply chains (Giungato et al., 2017; Hughes et al., 2019; Kewell et al., 2017; Saberi et al., 2018, 2019; Vranken, 2017). Otherwise, Kranzberg argued that "technology is neither good nor bad; nor is it neutral" (Kranzberg, 1986, p. 545), reminding us of the moral and ethical features related to innovations. Research has mostly focused its attention on the technical characteristics, efficiency gains, and profits linked to blockchain technology projects, experimental distributed ledger technologies (DLTs) (Kewell et al., 2017; McWaters, Galaski, & Chaterjee, 2016; Ng, 2013; Potts, Davidson, & De Filippi, 2016; Swan, 2015; Walport, 2016), as well as the commercial and consumer benefits drawn from blockchain innovation. Meanwhile, less attention has been paid to social and environmental effects and other implications of blockchain technology applications (CPTM, 2016; Kewell et al., 2017). Blockchain technology has been recognised as a promising catalyst to meet the SDG targets (Babcock, 2015; Giungato et al., 2017; Kewell

[1] This section regarding A-CDM for the airports has been freely taken from the reports and manuals on the topic, specifically the *Airport CDM implementation manual* (2017). Retrieved from https://www.eurocontrol.int/publications/airport-cdm-implementation-manual.

et al., 2017; Xia, Zhou, & Peng, 2017; Yan & Zhang, 2016). For instance, thanks to blockchain technology, it should be possible to build a smart city by developing shared economic services (Yan & Zhang, 2016) or to improve the quality of life (QoL) as well as the quality of services (QoS) by making cities smarter and by creating a smart environment in which, by collecting a large amount of data from several sources, the social and environmental aspects of citizens' needs can be satisfied (Pieroni, Scarpato, Di Nunzio, Fallucchi, & Raso, 2018). Indeed, some features related to security, like confidentiality, availability, and integrity, are necessary for implementing trust-free sharing services in a smart city, and we can find these elements as fundamentals in blockchain-based technology. Blockchain technology, as already outlined, represents a decentralised protocol whereby all information is completely confidential and third parties cannot access the data. Moreover, Faber and Hadders (2016) demonstrated that blockchain technology potentially creates an infrastructure to implement "new social contracts for sustainability", promoting the transition to sustainable development without requiring centralised functions for connections and relationships between individuals. Hence, blockchain technology extends beyond the current business model, which is mainly managed by old mainstream bureaucratic and power institutions (political parties, banks, local governments, etc.), and it can be applied in the decentralisation of the entire system.

It is possible to identify three main elements of blockchain technology performance in economic systems: horizontal integration in value creation networks; vertical and network integration of manufacturing systems; and end-to-end engineering during product life cycles.

Blockchain technology provides companies with a new way of designing their SCM, which can allow them to satisfy new customer requirements and face challenges on the supply side and fulfil other expectations in efficiency improvement (Pfohl, Yahsi, & Kurnaz, 2015). This new supply chain has the potential to be faster, more accurate, more granular, and more efficient. As a matter of fact, the delivery time can be reduced by up to a few hours, and real-time, end-to-end transparency is provided throughout the supply chain. Mass customisation may be realised thanks to the management of customers in granular groups. This allows suppliers to offer more appropriate products; the automation of both physical tasks and planning increases efficiency.

To bridge the gap in the implementation of blockchain technologies within supply chains (Giungato et al., 2017; Kewell et al., 2017; Tjahjono et al., 2017), the areas that are the most affected by the introduction of blockchain technology are the fulfilment of orders and the logistics of transport. Nevertheless, some technologies can translate into both threats and opportunities. The reason for this is that all of the different areas are interrelated, without clear boundaries between them, and, depending on where the analysis occurs, this could have negative or positive implications. The new technologies are able to introduce organisational and technical improvements and advantages. Moreover, the same technologies are able to contribute in several ways to the performance of production processes (Lee, Kao, & Yang, 2014). The difficulties that present obstacles to the implementation of blockchain technology solutions are the lack of highly skilled labour that is capable of developing algorithms (enabling self-learning intelligence) and the high cost of implementing of these technologies (Tortorella & Fettermann, 2017).

The advent and spread of blockchain technology is leading to new levels of demand from customers. This is increasing the need for productive systems to provide adept responses. In the future, blockchain technology will also play a crucial role by contributing significantly to the development of the business world and the global community towards more "sustainable" industrial value creation (Giungato et al., 2017; Hughes et al., 2019; Kamble, Gunasekaran, & Arha, 2018; Kewell et al., 2017; Saberi et al., 2018, 2019; Stock & Seliger, 2016). In the existing research and practice, sustainability has been characterised by three principal components, specifically social, economic, and environmental dimensions (Glavič & Lukman, 2007; Quak & De Koster, 2007). These are named the "triple bottom line" for sustainability development, which emerged in the early 1980s (Bebbington & Unerman, 2018; Elkington, 1994). The social dimension concerns the need for a reduction of any negative impacts from industrial activities. The economic dimension focuses on the efficiency of business operations, creating a balance between the use of resources for manufacturing products and the offering of services to people. The environmental dimension pays attention to future generations through the preservation and protection of natural resources. In the existing literature on blockchain technology, the economic and environmental dimensions represent the major dimensions of sustainability considered (Kamble et al., 2018; Saberi et al., 2018). Therefore, another challenge for blockchain technology is to respect environmental sustainability (Bonilla, Silva, Terra da Silva, Franco Gonçalves, & Sacomano, 2018). In particular, the requirement of adopting renewable energy systems must be met.

Environmental sustainability frames production within specific limits. Exploitation should not exceed regeneration, waste generation should not exceed the assimilation allowed by the biosphere, and depleted non-renewable resources should be replaced by substitutes (Fettermann, Sá Cavalcante, de Almeida, & Tortorella, 2018). The satisfaction of these requirements by blockchain technology is necessary to achieve sustainability.

According to the literature, sustainable development could be expected through new business models and new processes (Tsvetkova, 2017). In general, digital technologies could integrate renewable energy sources. However, factors such as the quantity of materials used, primary energy consumption, and working conditions will affect this development negatively. Furthermore, the ways of collecting and sharing information and data will play a key role. If companies manage and improve their social, economic, and environmental performance in the supply chain, they can avoid waste, optimise processes, discover new product innovations, reduce costs, and increase productivity.

In addition, blockchain technologies could increase inequality and further exclude the disenfranchised. The contribution of policy makers will be decisive. They have to be aware of the changes resulting from the implementation of digital technologies and thus act accordingly to avoid infringing on social and economic rights (Bocken, Short, Rana, & Evans, 2014). The powerful analytical capabilities of digital technologies can be an asset for policy makers in this regard and can help in the prioritisation of sustainable development goals in the new scenario created by blockchain technology.

Although numerous studies have provided a clear reading of the blockchain technology era, demonstrating its main characteristics, functions, and implications, its practical application through a specific procedure is still unclear and underdeveloped (Fettermann et al., 2018), especially concerning how the overall blockchain technology can affect operations management (OM) (Almada-Lobo, 2016) and particularly considering some specific organisational settings, like the airport industry.

Blockchain technology requires the operations to be redesigned and reorganised by adapting the technology and management to a different level of operating systems and tools that are able to create the potential value for the activities (Saucedo-Martìnez, Pèrez-Lara, Marmolejo-Saucedo, Salais-Fierro, & Vasant, 2017). In this direction, organisational change is necessary and involves all of the resources within firms (human, financial, and technical resources) by applying new techniques that are able to generate value by providing market stability. For instance, the integration of business operations represents an important practice that allows business activities to improve along the entire value chain (Neeraja, Mehta, & Chandani, 2004).

Although research on the link between OM and sustainable performance has recognised the relevant role of blockchain technology in affecting OM for sustainable performance, these studies are still scarce, especially within SCM from the perspective of SSCM and most especially in the airport industry.

4. Case study

In the Italian airport industry, a different organisational model has recently been adopted (D.P.R. n. 201/2015), which consists of a new frame for redesigning the overall airport system. Strategic airports, as compared with airports with national interest, have been identified and categorised while taking into account specific roles and functions in terms of their performance standards and their presence in the European core network.[2] According to the transport regulations in Italy (Codice della Navigazione, 2018, art. 698 – Code of Navigation in Italy), it is possible to distinguish and identify airports and airport systems of national interest. These are recognised as essential nodes for enabling the Italian State to exercise exclusive powers. They are identified by looking at the size and the type of traffic, the territorial location, and the strategic role of these airports as well as the standards reported by the European TEN projects. In accordance with the regulations within the European Union (EU) regarding the Trans-European Transport Network (TEN-T network, Regulations No. 1315 and 1316/2013), the Italian rule system recognises the special relevance of airports that are "core nodes" of the TEN-T network.

Starting from this brief description of Italian airports' organisational set-up, the case of the Naples airport system has been deeply investigated and has provided useful information through a case study description of how blockchain technology can significantly affect SCM, focusing the attention on the operations management.

The airport of Naples, called Napoli-Capodichino, is an infrastructure managed by GE.S.A.C. S.p.A. (Gestione Servizi Aeroporti Campani). This is a concessionaire established in 1980 with a shareholding that is mainly composed of private operators: Aeroporti SPA (private shareholder) owns 87% of the shares, Città Metropolitana di Napoli (public shareholder) owns 12.5% of the shares, and finally the Municipality of Naples (public shareholder) owns 0.5% of the shares. According to the last statistical report published by ASSAEROPORTI, which is the Italian airport association, in 2018, Napoli-Capodichino managed about 9,932,029 passengers, ranking among the main Italian and European airports (retrieved on 15 January 2019 from https://www.assaeroporti.com/statistiche_201812/).

The services provided by Napoli-Capodichino are not limited to ensuring assistance services for the embarkation, disembarkation, and transit of passengers and their luggage but also guarantee the security and safety services and all the other services that are useful for passengers in each step of their trip. These steps include the services in the area outside the airport infrastructure (e.g., parking, taxis, shuttles, and so forth); services within the airport infrastructure but outside the check area (e.g., duty free, restaurants, coffee point, toilets, shops, customer services, check-in desk, information point, emergency room, digital arrival and departure time schedule, and so on); and services in the infrastructure between the check area and the embarkation area (e.g., duty free, restaurants, typical local cuisine, street art tour, WiFi Express, restricted areas, BenBo to sleep in the airport, FastTrack, gifts, shops, e-shops, and so forth). All the services provided are organised into activities including more and more operations that involve numerous players.

According to the regulations and the legal procedures, especially the legislative decree no. 151/2006, there are strict rules that apply to the roles and responsibilities among the public and private players in the operations that characterise the SCM in the airport. Indeed, following the legislative decree, the airport concessionaire is responsible for the safety and security of airport functions and operations and, above all, its functions and powers of coordination for the whole system. Specifically, the concessionaire is charged with the technical and operative coordination and control of all the private players operating in the infrastructure.

Principally, it is necessary to ensure the time coincidence between two or more flights in the international spaces, because Napoli-Capodichino airport is the fifth player of EUROCONTROL, as the Network Manager, that is, the airport network nominated by the European Commission from July 2011 until 31 December 2019. Its mission is to contribute to the delivery of air traffic management (ATM) performance in the pan-European network in the areas of safety, capacity, environmental and flight efficiency, and cost-effectiveness. Thus, the Network Manager's priority in the European ATM network is to forge operational partnerships and to foster cooperative decision making. Both of these are needed to achieve the performance targets in a transparent and impartial way. Indeed, the effectiveness and efficiency of the operations management represent a critical factor of the airport services bundle (Tsiotsou & Wirtz, 2015).

In this direction, Napoli-Capodichino has implemented A-CDM to reduce the main inefficiencies in the airport's management as well as to optimise the airport infrastructure using all the available data. The lack of a full picture of the processes and operations related to flights that involve more airports influences the planning and, consequently, the performance in terms of sustainability.

The A-CDM project represents a transition in the "turnaround" management operational methodology from "first come, first served" to "first ready, first served". It is an integrated platform that transfers information on the status of all departing flights in real time to the EUROCONTROL Management Operations Centre, which, in turn, transmits this information to other partner airports. In this manner, it is possible to optimise the air traffic flow, the airport capacity management, and the use of airport infrastructure and human resources in addition to increasing flight punctuality, reducing fuel consumption and its related environmental impact, and improving airport efficiency, punctuality, and the predictability of events. The digitalisation of operations is standardised along with communication among the players involved to reduce any possible error source. In this programme, based on an information exchange platform, all flight phases, from departure to landing, are considered as a "single process", which ensures the optimisation of air traffic management and ground handling operations.

The advantages of A-CDM, due to sharing and predicting the aircraft readiness time, allow the airport to plan earlier departure sequences, to manage runways and taxiways better, and to reduce the fuel usage because of aircraft holding on standby. The airports also have more time to resolve gate conflicts and thus improve the passenger experience. Finally, the ground handlers are able to deploy their resources more efficiently.

The current situation at airports shows that numerous separated and untrusting parties still exist that are not able to come together to achieve the common goals of ensuring that the aircraft are landed, turned around, and airborne again within the constraints of realistic turnaround times, weather events, and above all safety. Because of the involvement of many different organisations and systems, the main topic is to break down silos and share information. This would establish perfect grounds for a consortium blockchain, whereby each party would participate in the chain and each party would be able to see a real picture of what is happening in nearly real time at another airport. Consequently, the decision-making process would not happen in isolation. This would result in fewer delays and potentially highlight areas that regularly cause delays (retrieved on 25 March 2019 from https://medium.com/@akme_c/blockchain-platform-ideas-that-will-enable-the-airline-industry-80b1eaeb9b56). In this way, decisions and actions could be adopted to solve the business issues for operations management linked to flight delays.

To plan pre-departure sequences, one of ACDM's primary

[2] The Italian airport infrastructures, although they present a public nature, are managed through the concessionaire agreement; that is, specific organisations, named concessionaires, which are usually private, plan and manage the airport infrastructures.

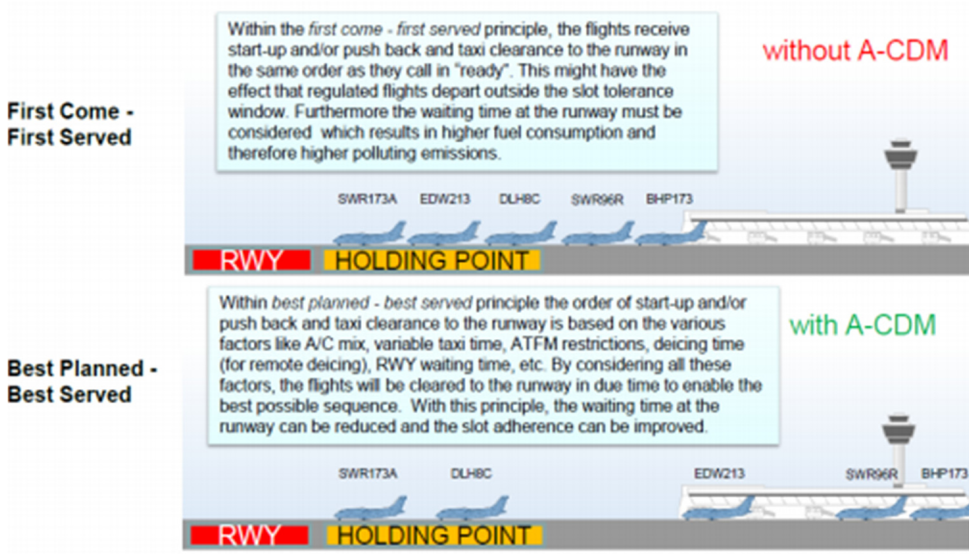

Fig. 2. A-CDM – Turnaround management.
Source: Available at http://centropuliziesiena.it/download/documenti/cliente%203/R1.1.1%20-%20Pitagora%20-%20Stato%20dell_arte%20delle%20tecnologie%20adottate%20in%20ambito%20aeroportuale.pdf.

requirements is to define the "target take-off time" (TTOT) in the most accurate possible manner to improve the "en route" and "sector" planning on the part of the European ATM. This objective may be obtained by implementing a series of DPI (departure planning information) messages and "FUMs" (flight update messages), which are then sent to the NMOC (network manager operations centre).

In other words, A-CDM represents a change of operating methodology in the management of the "turnaround" from "first come, first served" to "first ready, first served". One of the main objectives of A-CDM is to evaluate the target take-off time (TTOT) in the most accurate way as well as to know in real time the traffic for the "en route" and "sector" European management (ATM). This objective is attainable through the implementation of a series of "DPI" (departure planning information) messages and "FUMs" (flight update messages) sent to the central flow management unit (CFMU). The CDM airport can be considered to be the basis for the connection of the single airport to the ATM system (Fig. 2).

In this manner, airport CDM procedures may be considered to be a basis for linking the airport and the ATM system. The A-CDM procedure was implemented through the introduction of processes based on the following five elements: the milestones approach (turnaround process), variable taxi time (VTT), collaborative pre-departure sequence, CDM in adverse weather conditions, and collaborative management of flight updates. A-CDM procedures begin with the transmission of ATC flight plans three hours prior to the EOBT (estimated off block time) and continue through sixteen milestones that describe the flight status in all of its phases prior to take-off (ATOT – actual take-off time).

There is much emphasis on the application of algorithms. These are a series of instructions, like a flowchart, which can be followed to solve a specific problem. Although not a "technology" per se, they can be found in activities such as the scheduling of departing aircraft to avoid heavy aircraft jet engine thrust adversely affecting smaller aircraft behind them (algorithms are particularly appropriate for that sort of activity) and baggage handling.

This condition is relevant to tackle airport congestion both on the runway and at the gate to respond to the passengers' needs. Therefore, the A-CDM programme for the control of arrival and departure waves at major hub airports is an obvious application.

Blockchain technology is particularly adept at the integration of information between different players in providing passengers with a seamless journey through an airport. This process involves the airport, airline, ground handling company, and one or more IT supplier services, so, if something goes wrong involving one or more of those players, the passengers can be apprised of the situation and of their alternatives immediately (as long as they have the right tools). At the same time, it is ensured that all of those players are updated simultaneously. All of this process still conforms perfectly to what A-CDM hopes to achieve for the players and ultimately the customers. Blockchain technology allows airports to promote and realise the integration of information and data (retrieved on 24 March 2019 from https://centreforaviation.com/analysis/airline-leader/airport-technology–what-passengers-want-greater-personal-control-of-the-airport-process-395194).

5. Findings and discussion

A-CDM promotes the cooperation between the main players of the aviation industry, such as airlines, airport operations (airport operators and ground handlers), and air traffic controllers (ATCs) to reduce fragmentation, inefficiency, and uncoordinated operations (Fig. 3).

The platform allows the Napoli-Capodichino airport to connect with the ENAV, that is, the Italian air navigation service provider, and exchange all of the information related to the flights. In this way, it is possible to send the information in real time to the network manager operations centre through EUROCONTROL. The adoption of the digital integrated system also increases flights' punctuality, thereby reducing their fuel consumption and negative environmental effects. Thanks to A-CDM, all the phases of a flight, from the flight plan to the airport operation and from take-off to the flight route until the next landing, are considered to be a "single process" that connects the flights, starting with the incoming one. It allows for the optimisation of air traffic management (ATM) and all the assistance operations through the constant exchange of information, updated in real time, among the operators involved. In terms of airport operations, the platform optimises the use of the infrastructure thanks to all the information being available in real time. It also reduces congestion as well as concerns about ground handling. The platform promotes the reduction of movement costs and optimises the use of ground handling resources. Regarding air traffic control (ATC), the platform allows flexible pre-departure planning, reduces slot wastage, and thus reduces taxiway congestion. With regard to the central flow management unit (CFMU), it improves the predictability related to the process and provides real-

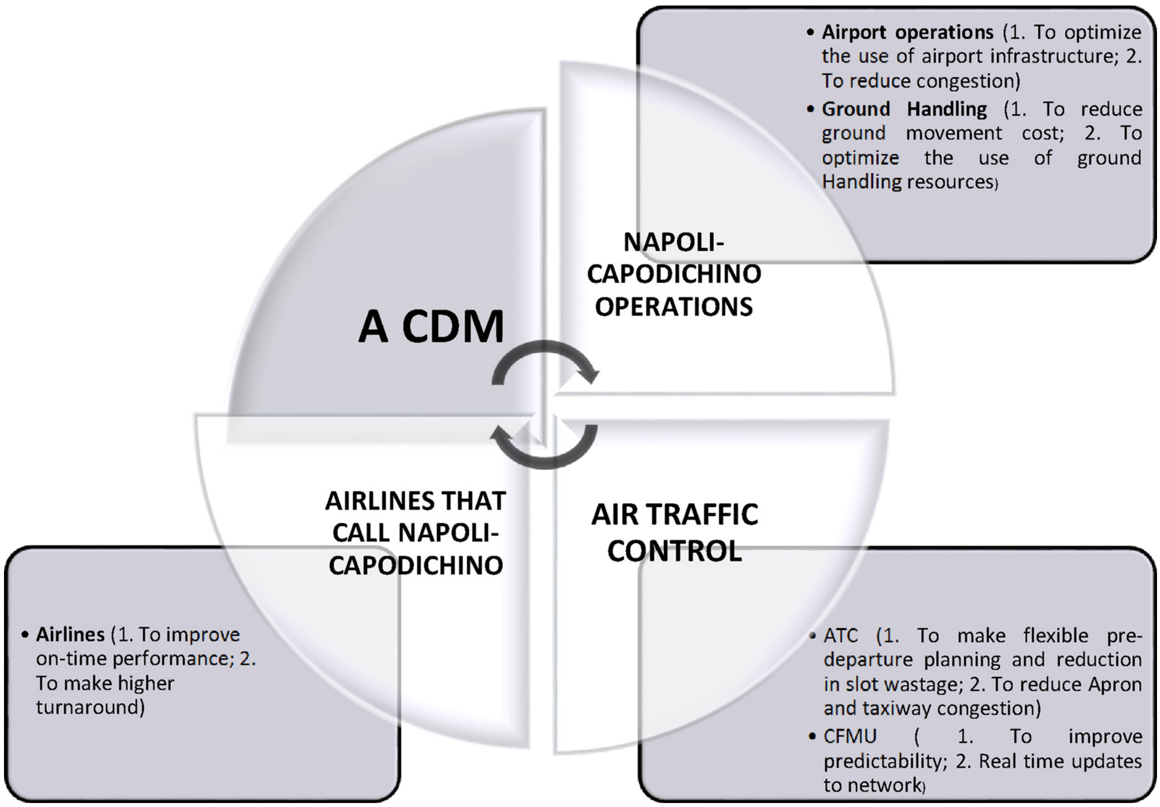

Fig. 3. A-CDM in Napoli-Capodichino Airport.
Source: Adapted by Collaborative Decision Making in Aviation (Available at https://www.capgemini.com/gb-en/).

time updates to the network. Finally, concerning the effects for the airlines, the platform allows the improvement of on-time performance to obtain faster turnaround.

A-CDM allows the management of the information flow among more partners, focusing on and linking three big activities of the process: inbound (arrival), turnaround, and outbound (departure).

In these three phases, information about the "taxi times" needs to be included to obtain an accurate block prediction to start the turnaround process and a take-off prediction for the network. Considering that the default taxi times can often be inaccurate, the airport partners have to be involved. However, the adoption of A-CDM by Napoli-Capodichino does not seem to be the right solution in adverse conditions. Indeed, the disruption in adverse conditions consists mainly of a major reduction in capacity and slow recovery due to missing information, communication, and prioritisation.

This problem could be due to the characteristics of blockchain technology, which requires operators to rethink, redesign, and remodel all the operations to be able to manage the different levels of the operating systems (Saucedo-Martínez, Pérez-Lara, Marmolejo-Saucedo, Salais-Fierro, & Vasant, 2018). Indeed, improving the management of disruptions is always not easy, because it also requires the standardisation of the disruption management process (Kleindorfer & Saad, 2005).

Although previous studies on the adoption of blockchain technology have highlighted its benefits in overcoming trust-related issues (Glaser, 2017), on the other side, it does not seem to eliminate the need for trust between partners in sharing data and information (Hawlitschek, Notheisen, & Teubner, 2018). Besides, the usefulness of A-CDM has been read as a response to the need for sustainability performance for an airport, as highlighted by the non-financial disclosure.

For instance, in 2017, the Naples airport non-financial report stated that, since 2016, A-CDM had been introduced as an integrated platform with the specific function to collect, manage, and share information in real time by connecting all the airports (for more details, see the Appendix).

Both sentences allow us to see that the airport of Naples shows a collaborative orientation with the overall airport networks and the local territory, in which the adoption of a specific integrated platform and of a proactive strategy that is also focused on the local economy is able to achieve two objectives through reporting practices. The first objective is to help all of the airports to share crucial information about the flights and use the infrastructures with relevant positive effects in terms of sustainability. The second is to create synergies with local institutions that make and adopt decisions that are strategically relevant to the development of the entire community and territory.

Thus, this airport tends to line up with other airports, such as Munich, Brussels, and Paris-Charles de Gaulle, which had already introduced A-CDM in 2011 to optimise the interactions between more organisations, leading to better punctuality for all flights (Graham, 2016).

In this case, the airport's sustainable performance has been achieved through collaboration and integration between all of the players by strengthening global partnerships in the direction of the 2030 Agenda. We can interpret this result in relation to the 17 SDGs and through an integrated strategy by promoting the territory as well as from the perspective of inclusive, safe, resilient, and sustainable cities and local communities, in which the 11 SDGs can be represented.

6. Theoretical and managerial implications

Adopting blockchain technology to improve the efficiency, effectiveness, and sustainability of processes requires the involvement of all stakeholders. Indeed, in some industries, as well as in the airport setting, technological disruptions require the planning and complete standardisation of the processes of technologies' crisis management. This means that the A-CDM partners and the A-CDM stakeholders (e.g.

aircraft operators, airport operators, etc.) should also implement the A-CDM culture in the network, because the platform is a tool that involves people as well as passengers.

These findings allow us mainly to confirm the few existing studies in the literature on blockchain technology applied in the airport industry with A-CDM within SCM (Corrigan et al., 2015; Katsaros & Psaraki-Kalouptsidi, 2011; Nadeem, 2018; Okwir & Correas, 2014; Robinson, 2017; Santonino, Koursaris, & Williams, 2018; Vojtek & Smudja, 2019). Specifically, most authors who have investigated A-CDM have found that there was a need to adopt a participative approach to make it more effective and successful and to prevent and manage the possible disruptive and transformative processes for OM. This was achieved through the involvement of all of the partners and the employees within SCM to increase their trust (Corrigan et al., 2015; Katsaros & Psaraki-Kalouptsidi, 2011; Okwir & Correas, 2014; Robinson, 2017). Some authors have already outlined the relevance of a trust climate within SCM for making blockchain technology effective and successful in any industry; indeed, because of the trust between players in SCM, the co-operation is supported by knowledge and information sharing (Pan et al., 2019).

A-CDM was analysed here as one useful blockchain technology application within the airport supply chain that significantly optimises the airport operational efficiency (Katsaros & Psaraki-Kalouptsidi, 2011). As already outlined, although studies have investigated A-CDM and in general the blockchain technology in the airport industry and pointed out the main advantages and negative effects, they have still not paid attention to the link between blockchain technology and OM within SCM from the perspective of sustainable performance.

Otherwise, the benefits of adopting blockchain technology have been observed. In the airport industry, thanks to A-CDM, airports are better able to address punctuality, but the current digital system does not include other processes and activities in which “internal” and “external” human resources are involved (e.g., airport equipment and passengers). Indeed, taking into account all of the human resources in the context of their active involvement and commitment can contribute to the effectiveness and efficiency of the services through the digital transformation process witnessed by A-CDM.

This study should be a useful guide for managers, especially supply chain managers within the airport industry, to rethink, redesign, and remodel the organisational process and to introduce and promote training and educational programmes for employees that are not simply focused on using A-CDM but that aim to develop and stimulate the cultural change in the digitalisation era. In this way, the disruptions from technology can be managed through the involvement of all individuals in the process. Besides, involving the passengers, thanks to direct interactions in the process, could support the knowledge and the management of A-CDM from the customer perspective.

The results of this case study contribute to the existing literature on blockchain technology in several ways. The study does not easily show evidence of the advantages and disadvantages of the innovation, but it highlights some issues that remain underinvestigated, such us the co-operation between players in a supply chain (e.g. airports) linked to blockchain technology, the disruption issues, the cultural approach, and the role of trust conveyed by the digital transformation of the operations. In general, as already outlined by previous studies, blockchain technology is automatically able to build a trust system for implementing value exchange and improving firms’ performance (Behnke & Janssen, 2019; Pan et al., 2019). Indeed, the implementation of blockchain technology can effectively manage and solve the information asymmetry among the partners in any supply chain (Pan et al., 2019).

Therefore, the aviation industry, especially airports, can be an empirical setting to investigate further while also considering the strong orientation towards sustainable development (SD), especially the sustainable development goals (SDGs) (Chang & Yeh, 2016). Thus, to make A-CDM among blockchain technology applications more effective for sustainable performance, the technology disruption management must be entrusted to the organisational dimension of the partners involved in A-CDM by sharing the information, the activities, and the operations of the disruption management processes. From this perspective, the main operators of the aviation industry discussed here should pay more attention to the needs not only of the operators involved in the business-to-business (B2B) supply chain but also of those in the business-to-consumer (B2C) segment in the SDGs’ logical theoretical framework.

In summary, from the case study presented above, it is possible to derive some interesting implications as described. Our study provides new insights into how blockchain technology can significantly and positively influence OM in SCM for sustainable performance through a different model to analyse these issues. Indeed, we examine these topics differently, and it is not easy to find evidence for the main benefits and challenges involved in adopting blockchain technology in SCM (Hughes et al., 2019; Kshetri, 2018; Queiroz & Fosso Wamba, 2019), but we propose different instruments, such as organisational, managerial, and reporting tools, for investigating blockchain technology for SSCM.

7. Conclusions

The aim of our research was to explore blockchain technology in the airport industry from the perspective of sustainable performance. The primary findings show that Napoli-Capodichino is significantly affected by new technologies, especially the adoption of the A-CDM system, which has been recognised as a relevant blockchain technology application. This platform, adopting AI in airports, allows, although partially, the management of disruptions that are due to external and internal causes and thereby improves the efficiency, effectiveness, and sustainable performance of the overall air transport process.

Although our research offers interesting insights, the nature of the study was explorative and suffered from a few limitations. We considered only one airport in our empirical analysis, and we focused only on the analysis of documents and other sources of information and data. Some scholars have recognised that blockchain technology allows users to overcome all of the problems related to disclosure and accountability (Casey & Wong, 2017), but today the impact that blockchain technology applications have on the business models in SCM is still unclear (Tönnissen & Teuteberg, 2019).

However, the findings of our study seem to show that there is not yet a procedure at this airport to manage the A-CDM disruptions, especially if the technological disruptions involve multiple airline companies and airports. Through a critical analysis of documents, each decision that concerns technological disruption management that has an impact on the operations must be included in a standardised process called “A-CDM disruption management”. Besides, the role of the human resources in the technological disruption management is not mentioned in any of the sources that we used to conduct this study from the perspective of the negative effects of blockchain technology on sustainable performance. These results highlight that strategic industries, such as airports, are still under-researched in terms of managing blockchain technology effectively, efficiently, socially, and environmentally (Queiroz & Fosso Wamba, 2019; Wang, Singgih et al., 2019). Therefore, on one side, all the advantages linked to blockchain technology applications can support the decision-making processes of all the players involved. On the other side, they can represent some threats with consequent financial losses and lacking sustainable performance in SCM.

These findings also allow us to think about further questions to investigate. Does the airport industry think about the positive effects of blockchain technology? Are airports and other players in the supply chain aware of the impact of blockchain technology and of the sustainability issue? What do airports offer to their passengers supported by blockchain technology? What is the opinion of supply chain managers, employees, and passengers in the airport industry about blockchain technology adoption?

However, the results provide an interesting contribution to the existing literature on the issues analysed and make some advancements in the current scientific research. Besides, they could contribute to supporting practitioners in developing managerial solutions to manage the A-CDM application and preventing and managing the potential difficulties and limitations.

In the future, our study can be improved by taking into account other airports in the Italian context and by making a comparison with the blockchain technologies adopted by other European and international airports. In this case, it should also be interesting to investigate whether and how cultural and social variables can affect the benefits of blockchain technology in SCM for sustainable performance. Furthermore, our research could benefit from the involvement of more diverse participants and include managers, passengers, and policy makers in SCM.

Appendix

Quotes from non-financial reports

The 2017 Naples airport non-financial report states:

> "*Since 2016 the Airport Collaborative Decision Making (A-CDM) system is an integrated platform that transmits real-time status information about all flights departing from EUROCONTROL (Network Management Operations Center) which in turn transfers them to other connected airports. Thus, it is possible to optimize the flow of air traffic, the airport management, the use of airport infrastructure and human resources, by increasing the flight punctuality and reducing fuel consumption and the negative environmental impact.*"

"There is a strong link between the Airport of Naples and the development of Neapolitan and Campania tourism: in 2017 both the Airport of Naples and the local institutions have confirmed the positive trend recorded in previous years, testifying how an integrated strategy to promote the destination and development of the airport connections network can represent a mutual advantage for developing the tourism economy and beyond.

Four years ago, GESAC defined the new strategy for developing the Airport of Naples, starting from the analysis of the main opportunities. … … … The Airport of Naples therefore set a specific goal consisting of actively contributing to enhance the Neapolitan tourism destination, promoting it, and achieving its enormous a leading tourist destination in Europe, in the case of Naples for the city break segment.

In continuity with its strategy undertaken, in 2017 GESAC has continued its efforts to strengthen the capacity of the territory to attract as a tourist destination:

- *Network and traffic development and marketing policies aimed at attracting new airlines and opening new links with the national and international market basins, which are more interesting both in terms of incoming and outgoing;… …*
- *Promotion of the destination and communication program aimed at promoting the uniqueness of the attractions of the Naples destination which, since 2017, has assumed a more markedly cultural declination with the objective of de-seasonalizing the tourist flows: Naples, a city for 'year!*

Networking as an active and innovative role for the tourist development of the Naples destination and, more generally, of the Campania Region through a synergistic collaboration model that involves the operators of the tourism industry, from public institutions to trade associations, from the directions of the museums poles and archaeological sites to local mobility workers."

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