PIERA BEATRIZ BESERRA

BLOCKCHAIN TECHNOLOGY TO IMPROVE SUPPLY CHAIN MANAGEMENT

A Systematic Literature Review

UNIVERSIDADE DO ALGARVE

FACULDADE DE ECONOMIA

2020

PIERA BEATRIZ BESERRA

BLOCKCHAIN TECHNOLOGY TO IMPROVE SUPPLY CHAIN MANAGEMENT

A Systematic Literature Review

Dissertação

Mestrado em Gestão Empresarial

Trabalho efetuado sob a orientação de:

Professor Doutor Sérgio Pereira dos Santos

Professora Doutora Carla Alexandra da E. F. Amado

UNIVERSIDADE DO ALGARVE

FACULDADE DE ECONOMIA

2020

BLOCKCHAIN TECHNOLOGY TO IMPROVE

SUPPLY CHAIN MANAGEMENT

A Systematic Literature Review

Declaração de Autoria do Trabalho

Declaro ser o(a) autor(a) deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Piera Beatriz Beserra

____

To my family and friends.

Thank you, PhD Sérgio Pereira dos Santos and PhD Carla Alexandra E. F. Amado for your guidance and for making this possible.
Thank you, Anderson Oliveira, for your companionship and support during this journey.

ABSTRACT

This study followed the systematic literature review approach to analyse how blockchain technology can improve supply chain management and to promote a future research agenda. The search was carried out at Web of Science Core Collection between September 2019 and February 2020 by using the keywords "blockchain" AND "supply chain" OR "blockchain" AND "logistics" in the title. In this review 127 studies were identified for screening and a final sample of 67 studies met the inclusion criteria and were analysed to answer the research questions. After examining the selected studies, our findings uncover a range of approaches showing how blockchain can enhance the supply chain management and point out which sectors are most likely to benefit from its implementation. This study contributes to the existing literature by systematising the most relevant information on blockchain implementation in supply chains. In addition, the findings of this study also provide managers and researchers with insights about the likely consequences of blockchain adoption in various sectors. Although there are already some literature reviews on blockchain technology in the supply chain management, this is one of the first studies that brings together the main issues focused on the consequences of blockchain adoption in the supply chain management.

Keywords: blockchain technology, supply chain management, systematic literature review, performance, benefits, sustainability

RESUMO

A gestão da cadeia de abastecimento está a passar por um processo de digitalização das suas operações justificada pela Quarta Revolução Industrial (Indústria 4.0) que prevê a adoção de novas tecnologias com o objetivo de reduzir custos operacionais, aumentar a eficiência da cadeia de abastecimento e agregar valor aos produtos e serviços. Ferramentas tecnológicas como a internet das coisas (*IoT*), identificação por radiofrequência (*RFID)* e *Big Data,* estão a ser utilizadas na melhoria dos controlos de produção, compra, procura, na tomadas de decisões dos gestores, entretanto, a recente tecnologia *blockchain* tem chamado atenção de pesquisadores e especialistas devido ao seu potencial transformador nos negócios e principalmente na gestão da cadeia de abastecimento. Por este motivo, este estudo propõe uma revisão sistemática de literatura com o objetivo de analisar como a tecnologia *blockchain* pode melhorar a gestão da cadeia de abastecimento e propor uma agenda de investigação para o futuro.

A pesquisa foi realizada na base de dados *Web of Science Core Collection* entre setembro de 2019 e fevereiro de 2020 usando as palavras-chave "*blockchain*" E "*supply chain*" OU "*blockchain*" E "*logistics*" no título. O critério de seleção dos artigos considerou apenas estudos revistos por pares, anais de conferência e livros nos idiomas inglês, espanhol, francês e português. A seleção dos estudos ocorreu em duas etapas. Na primeira etapa, foram analisados títulos e resumos. Na segunda etapa, foi realizada a leitura integral dos estudos que não foram excluídos na primeira fase. Os critérios de exclusão foram: artigos de revisão de literatura, relatórios, estudos focados em informações técnicas, estudos que enfatizaram outras tecnologias (*IoT*, *RFID*), gestão financeira da cadeia de abastecimento e/ou estudos relacionados com bitcoins. Os artigos que preencheram um desses critérios foram excluídos com justificativa. Embora tenhamos excluído artigos de revisão de literatura, esses documentos ainda foram utilizados para identificar estudos-chave que não haviam sido capturados da base de dados *Web of Science.* Por fim, nesta revisão foram identificados 127 estudos para triagem e uma amostra final de 67 estudos atendeu aos critérios de inclusão e foram analisados para responder às perguntas da pesquisa.

As perguntas a que a pesquisa teve por objetivo responder foram: quais os benefícios e riscos da tecnologia *blockchain*; quais os setores que já adotaram a tecnologia *blockchain* na gestão da cadeia de abastecimento e sua fase de implementação; quais as características das empresas

que utilizam a tecnologia; quais são os fatores facilitadores e barreiras para a adoção da tecnologia *blockchain* nas empresas; qual a influência da tecnologia *blockchain* na garantia da sustentabilidade da cadeia de abastecimento dentro da estratégia organizacional e dos níveis operacionais; como avaliar o desempenho da tecnologia *blockchain* na gestão da cadeia de abastecimento.

Os estudos selecionados apontam que a partir de 2017 houve um aumento expressivo de estudos relacionados ao uso da tecnologia *blockchain* na cadeia de abastecimento. Os Estados Unidos, China e Índia são os países com a maior percentagem de publicações sobre o tema e representam aproximadamente 44% do total. Os estudos foram publicados em jornais especializados em sistema de produção e processos, engenharia industrial, tecnologia, gestão, logística, cadeia de abastecimento e sustentabilidade. Quanto aos benefícios e riscos da adoção da tecnologia *blockchain*, os estudos indicam que a transparência dos dados, rastreabilidade e a redução dos custos operacionais são um dos maiores benefícios da adoção da tecnologia *blockchain* na cadeia de abastecimento, enquanto a escalabilidade e interoperabilidade foram identificados com os maiores riscos/limitações da implantação da tecnologia. No que tange aos fatores facilitadores da adoção da tecnologia *blockchain*, a gestão de topo apresenta-se como agente principal no incentivo à adoção do *blockchain* nas organizações, além disso, a perceção de utilização da tecnologia pelos funcionários também influencia o sucesso de implantação da tecnologia *blockchain*. Outras características que afetam a adoção da tecnologia são a infraestrutura das empresas, políticas governamentais e a cultura do país, entretanto esses fatores tendem a ter níveis diferentes de acordo com o país onde a empresa está instalada. No que diz respeito aos fatores que dificultam a implantação do *blockchain* nas organizações, são apontados a falta de conhecimento da tecnologia *blockchain* e dos seus potenciais benefícios, a existência de um número reduzido de aplicações do *blockchain* nas empresas, a coordenação e comprometimento dos parceiros de negócios na resolução de problemas e no tratamento de dados, fatores externos, como a legislação e incentivos governamentais.

Após examinar os estudos selecionados, a nossa análise revela uma série de abordagens que mostram como a *blockchain* pode melhorar a gestão da cadeia de abastecimento e identifica os setores mais propensos a retirar benefícios de sua implementação. A indústria de alimentos e a indústria farmacêutica são apontados como os setores com maior vantagem na adoção do *blockchain* devido a criticidade dos seus produtos, a procura crescente por informações referente a proveniência dos bens e seu alto valor agregado. O perfil das organizações que

adotaram a tecnologia blockchain são geralmente multinacionais de grande e médio porte, com capilaridade de parceiros de negócios, grande volume de produção e alto valor agregado aos seus bens. Quanto a sustentabilidade, a tecnologia *blockchain* pode influenciar, através da transparência e rastreabilidade dos produtos, na redução da produção de lixo e das emissões de carbono no meio ambiente, no controlo das leis e práticas laborais, evitando-se trabalho escravo e, relacionado com as questões económicas, redução dos custos com auditorias, controlo de pedidos de compra, produção e procura. Os indicadores de performance, de acordo com os estudos revistos, podem ser melhorados com a utilização da tecnologia *blockchain*, promovendo novas métricas sustentáveis baseadas na rastreabilidade e na transparência dos dados. Apesar da fase inicial da tecnologia *blockchain*, alguns estudos propõem indicadores que avaliam a eficiência da cadeia de abastecimento após a adoção do *blockchain*, como o tempo de processamento das transações, a utilização de recursos (água, energia elétrica) e níveis de emissão de carbono.

Embora já existam algumas revisões de literatura sobre a tecnologia *blockchain* na gestão da cadeia de abastecimento, este é um dos primeiros estudos que reúne questões importantes focadas nas consequências da adoção do *blockchain* na gestão. Além disso, os resultados deste estudo fornecem implicações para a gestão e para a teoria sobre as prováveis consequências da adoção de *blockchain* em vários setores da economia.

Palavras-chave: *blockchain*, gestão da cadeia de abastecimento, revisão sistemática de literatura, desempenho, benefícios, sustentabilidade

GENERAL INDEX Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BT	Blockchain technology
CVaR	Conditional value at risk
ERP	Enterprise source planning
ICT	Information and communication technology
IT	Information technology
IoT	Internet of things
KPI	Key performance indicator
MCDM	Multiple-criteria decision-making
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
QR Code	Quick response code
RFID	Radio-frequency identification
SC	Supply chain
SCM	Supply chain management
SLR	Systematic literature review
SME	Small and medium-sized enterprises
TAM	Technology acceptance model
TPB	Theory of planned behaviour
TRI	Technology Readiness Index
UK	United Kingdom
USA	United States of America
UTAUT	Unified theory of acceptance and use of technology
WoS	Web of Science

Chapter 1. INTRODUCTION AND MOTIVATION

Since the first study of blockchain technology (BT) by Nakamoto (2008), researchers and professionals have studied the potential of this technology on the economy. Blockchain is the technology behind the cryptocurrency. It was first applied in the finance sector (Francisco and Swanson, 2018) due to its capacity of validating double spend payments. However, over the years, BT has demonstrated potential to be implemented in other sectors, such as power, tourism and specially in supply chain management. A supply chain is, according to Schroeder, Goldstein and Rungtusanatham (2013:223), “the set of entities and relationships that cumulatively define the materials and information flows both downstream toward the customer and upstream toward the very first supplier”.

The supply chain (SC) is considered a strategic area of the organizations and it is identified by several experts, as the one with the greatest potential for the adoption of technologies that assist management due to the diversity of processes, the volume of documents and global partnerships (Kshetri, 2018). Under the influence of the fourth industrial revolution, companies began to use technology to improve processes and reduce costs with the aim to increase their local and global competitiveness. After the implementation of integrated systems, tools such as IOT (Internet of Things), Radio-Frequency Identification (RFID) and Big Data have been used in an attempt to eliminate bottlenecks and assist managers through predictive analytics to make decisions based on the data generated from their operations (Azzi, Chamoun and Sokhn, 2019).

Blockchain is considered one of the key tools of supply chain management in the digitalisation era (Queiroz and Wamba, 2019). BT is a distributed ledger that uses cryptography to process information (smart contracts) and to add this information to a data chain making the process visible point-to-point (Nakamoto, 2008). The main characteristics of blockchain like decentralization, intangibility, and transparency (Tapscott and Tapscott, 2016) have been attracting the attention of researchers, entrepreneurs, and governments interested in exploring the advantages that this technology can offer to many economic sectors. According to Kshetri (2018), blockchain has the potential to transform the way companies do business. Issues like inventory management, traceability and provenance of the products, logistics, process analysis, reduction of risks and sustainability are some of the areas where blockchain can assist decision makers (Cole, Stevenson and Aitken, 2019; Saberi, Kouhizadeh, Sarkis and Shen, 2019; Kshetri, 2018; Treiblmaier, 2018).

Currently, there are studies which analyse the use of blockchain technology in various fields in the supply chain. These studies focus mainly on developed frameworks and models to analyse the impacts of BT in SC. Despite the growing interest of researchers in assessing the impact of blockchain on the supply chain and despite pilot projects having been carried out in prestigious companies, the theme is still unknown to most professionals and in certain countries due to their technological level and their business network (small and medium-sized enterprises).

Although there are already some literature reviews of blockchain technology in the supply chain management, this is one of the first literature reviews that brings together the main issues on the consequences of the blockchain adoption in the supply chain management. The study will allow us to identify the sectors where this technology has been applied, the risks and benefits of its application, the success factors and barriers to its implementation, the performance indicators commonly used to assess its performance and its potential to ensure the sustainability of the supply chain. As there is no review providing this information, and it is considered useful for researchers and managers, this study provides a valuable contribution to knowledge.

This study aims to present the most up to date review on the use of blockchain in supply chain management, allowing us to further our understanding of how blockchain technology can enhance supply chain management.
To help meet this objective, we aim to provide an answer to the following research questions.

(1) What are the sectors where blockchain has been applied to assist the supply chain management and what is its degree of implementation?

(2) What are the characteristics of companies where blockchain technology has been applied to manage the supply chain?

(3) What are the benefits and the risks associated with the use of blockchain technology for supply chain management?

(4) What are the facilitating factors and barriers that exist in the implementation of blockchain technology?

(5) What is the influence of blockchain in ensuring the sustainability of the supply chain within organizational strategy and operational levels?

(6) How to evaluate the performance of the blockchain technology in supply chain management?

In addition, this study proposes to identify a future research agenda based on the adoption of blockchain in the supply chain management. By the end of this study, the reader will be able to know what has been published about blockchain in supply chain management until February 2020 and what future research avenues in this area need to be explored.

The remainder of this dissertation is organized as follows. Section 2 discusses what is blockchain and its role in the supply chain management. Section 3 presents the systematic literature review methodology. Then, in section 4, we present the findings and discussion, systematise the benefits and risks of blockchain, discuss the success and critical factors for adoption into companies, identify the sectors that have deployed the technology, present potential sustainable practices, and discuss how to measure the performance of blockchain implementation. In section 5, we suggest future research directions. Section 6 discusses the managerial and theoretical implications of this review. Finally, in section 7 the study concludes with a discussion of the limitations of the literature review.

Chapter 2. THEORETICAL BACKGROUND

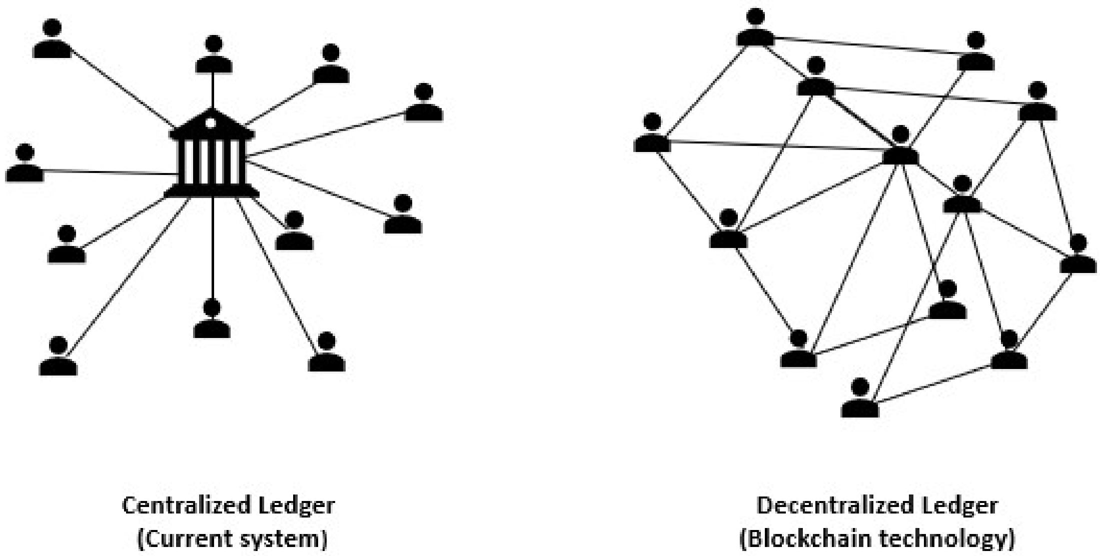
The aim of this study is to present an overview about the blockchain and its application in supply chain management. By systematizing the information about the applications of blockchain for supply chain management, this study discusses the usefulness of this technology in different sectors and identifies aspects that are important to take into account to maximize the potential contribution of this technology. Considering that there are several books and articles offering technical expositions about the blockchain technology, due to space limitation, we will not discuss these technical details here. The reader interested in the technical aspects of blockchain is referred to Kim and Laskowski (2018), Pilkington (2016) and Tapscott and Tapscott (2016). This section will discuss the application of blockchain in a managerial perspective. With this in mind, a comprehensive definition of blockchain and its role in the Supply Chain Management is presented.

2.1 What is blockchain

Blockchain is the technology behind the Bitcoin, the virtual coin used in financial transactions, presented by Nakamoto (2008) to solve the double-spending problem – when it is possible to use the same currency twice - in a digital network. Since then, the technology has been adopted by the financial world and in other fields, such as Medicine, Logistics, Food and Energy. Contrarily to the current (centralized) systems, the blockchain technology is a decentralized and distributed ledger that records all transactions in the network (Azzi et al., 2019; Liao and Wang, 2018; Perboli, Musso and Rosano, 2018; Pilkington, 2016).

In a centralized system (see Figure 2.1) there are several nodes which depend on third parties (e.g. governments, banks) to validate the transactions (e.g. payments). Besides this, centralized systems tend to be more vulnerable to collapse due to the dependency of each node (Perboli et al., 2018). In decentralized and distributed systems, the third-party approvals are not mandatory, because each node is responsible for the data validation. Additionally, the partners can be geographically separated as occurs in the global network. The decentralized and distributed ledger system can contribute to a greater transparency, enhancing trust between upstream and downstream partners (Azzi et al., 2019; Liao and Wang, 2018; Perboli et al., 2018).

Figure 2.1 Differences between centralized and decentralized ledger systems



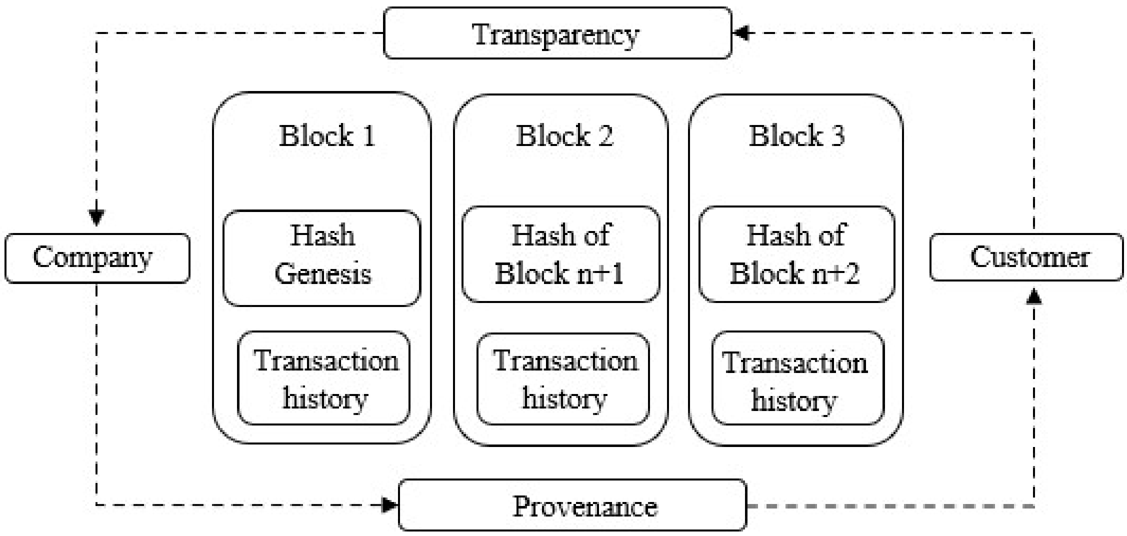
Source: Author

In the blockchain technology all data are organized into chronological blocks arranged in a chain. Each block is linked by a hash (Figure 2.2), the output of the original information (Pilkington, 2016), keeping the entire information and process in their chain and facilitating the traceability of transactions. In theory, blockchain allows anyone to include data into the chain. The information becomes visible to everyone after being validated by the participants (nodes in the system). Once approved, the data is updated in real time, increasing the visibility of the operations.

When applied to the Supply Chain Management (SCM), this mechanism allows managers to verify all the stages of the operation and review them at any time. According to Banerjee (2019) and Pervez and Haq (2019), blockchain technology has the potential to help managers in performing predictive analyses due to the transparency and traceability of the information.

The technology uses cryptography to process and verify every single transaction on the chain. The system is not controlled by a single entity as in centralized operations, but by a group of participants and each transaction is validated by their computers. If someone tries to enter false information or modify something in the blocks, the system does not process the data due to the previous hash, which contains the last processed information, and notifies the network. This process increases the security since the data is immutable and cannot be changed or deleted (Cole et al., 2019; Kshetri, 2018; Korpela, Hallikas and Dahlberg, 2017; Abeyratne and Monfared, 2016; Tian, 2016).

Figure 2.2 Blockchain environmental process



Source: Author

The blockchain configuration indicates the main characteristics of this technology. They are: Open distributed and real-time ledger, ensuring that complex areas, such as supply chain, healthcare and drugs management can be improved with information sharing and controlling processes in real time (Barghuthi, Mohamed and Said, 2018; Perboli et al., 2018). Smart contracts ensuring that a digital agreement is made between partners to facilitate, verify, or enforce terms of a contract. It can facilitate payments after the delivery of products. The contract code can identify irregular products or deals and refuse payments automatically (Chen, Shi, Ren, Yan, Shi and Zhang, 2017).

Peer-to-peer network, ensuring that every node (participant) validates the transactions during the operations. Then, each block is distributed and stored in the network for everyone to access (Hald and Kinra, 2019). Immutability of the data, guaranteeing that, after the blocks are validated, it is almost impossible to alter or delete some information into the chain (Cole et al., 2019; Scuderi, Foti and Timpanaro, 2019; Chen et al., 2017; Pilkington, 2016).

Besides these characteristics, there are three types of blockchain developed according to the requirements of the industry. Public (e.g. bitcoin), private (permissioned) and hybrid system (Azzi et al., 2019; Cole et al., 2019; Xu, Rahman, Shakya, Vassilev, Forte and Tehranipoor, 2019; Pilkington, 2016). The main difference between them is the permission to participate in the network and the knowledge regarding the identity of the participants as shown in Table 2.1.

Table 2.1 Types of blockchain

	Public	Private	Hybrid
Access	Open for anyone	Permissioned	Semi-open
Security	Low	High	High
Identity	Unidentified entities	Only preapproved entities	Preapproved entities

Source: Author

A public blockchain is a completely open and decentralized system (Azzi et al., 2019; Hald and Kinra, 2019; Xu et al., 2019) where anyone can add transactions into the system and visualize the entire chain (Azzi et al., 2019; Cole et al., 2019). However, it carries disadvantages due to the necessity of a huge amount of computer´s energy to validate all the previous transactions, and due to the low security related to the key information and the unidentified participants (Cole et al., 2019; Hald and Kinra, 2019).

In a private blockchain, the network is controlled by an organization, which is responsible for making decisions and validating the processes (Azzi et al., 2019; Pilkington, 2016). Only participants with an invitation and approved data are allowed into the system (Cole et al., 2019; Hald and Kinra, 2019) improving the security of transactions. In that case, only authorized companies can enter data and track the products in the chain. Moreover, the central organization can define the level of access provided to stakeholders (Hald and Kinra, 2019) which means that, depending on the stakeholders, they can only read or write at a particular stage of the operation. Most of the industries have strategic information, which cannot be accessed by competitors, thus this type of blockchain system tends to be a better option for companies (Cole et al., 2019).

Finally, the hybrid blockchain consists of a mix of the best parts of the public (decentralization) and private (efficiency/security) systems and is often called Consortium Blockchain. These blockchains are managed by a group of audited users as illustrated in the Table 2.1 above (Xu et al.,2019; Pilkington, 2016).

2.2 The blockchain in the supply chain management

According to Hackius and Petersen (2017), blockchain has potential to improve processes and enhance business models in supply chain management. As pointed out by Schroeder et al. (2013: 223): “Supply chain management is an essential aspect of business today” and for this reason, it attracts the attention of managers and researchers. Over the years, supply chain operations have taken place in a global market with many challenges and bottlenecks to solve along the entire process. Some of the main problems mentioned by researchers and specialists are the lack of transparency, grey traceability, and low trust between partners due to its international dimension, which makes it impossible to develop a more sustainable and reliable chain (Liu, Li and Qi, 2019; Saberi et al., 2019; Kshetri, 2018; Liao and Wang, 2018). According to Kshetri (2018), one of the major objectives of supply chain management is to reduce the risks, which lie in the product journey.

Blockchain technology was introduced in this area with the promise of solving the main problems of the supply chain due to its capacity of tracking the flow of goods in real-time and, enhancing the visibility and transparency of the operations (Azzi et al., 2019; Saberi et al., 2019; Kshetri, 2018). These benefits can improve the security of transactions (Liu et al., 2019; Liao and Wang, 2018) and trust among partners (Hald and Kinra, 2019), because as mentioned above, all transactions will be validated by a group of partners. Besides this, blockchain technology can reduce costs (Treiblmaier, 2018) and avoid risks related to the provenance and quality of products (Montecchi, Plangger and Etter, 2019; Kshetri, 2018).

The possibility of tracking the entire process and knowing the provenance of the materials not only enhances transparency and trust, but also promotes a quick response if something wrong happens during the operations (Cole et al., 2019). The decision-making process can become more assertive when it is based on real-time data provided by blockchain technology (Azzi et al., 2019). Areas such as inventory management, quality management, procurement, and logistics tend to reach a high level of efficiency due to greater operations visibility.

In real cases, blockchain technology has also demonstrated to reduce administrative costs with paperwork and to reduce delivery time in the international logistics (Kshetri, 2018).

Prior literature reviews indicate that blockchain technology provides better operational efficiency, adding value into the supply chain and increasing the trust among partners due to the transparency of transactions and security measures (Gurtu and Johny, 2019). Most of these conclusions have been drawn from studies carried out in developed countries such United Stated of America (USA), United Kingdom (UK) and Germany (Queiroz, Telles and Bonilla, 2019).

Due to the early stage of the blockchain technology implementation, there is a lack of empirical studies which analyse the impacts of the adoption of this technology in real multi-echelon supply chains. This suggests that, from a theoretical point of view, there are vast areas to develop and spread knowledge mostly related to business models, blockchain frameworks and theoretical analyses. Gurtu and Johny (2019) and Queiroz et al. (2019) proposed that future studies should aim to identify the benefits of implementing blockchain in the supply chain and investigate the capabilities required by organizations to implement the blockchain; and assess the possibility of blockchain utilization in the sustainable supply chain.

These research opportunities were one of the motivators to develop this study. Besides this, the implementation of technology not only influences the operations process, but also impacts stakeholders and their behaviours (Hald and Kinra, 2019). These changes can make the implementation of technology more complex because they are influenced by culture, government policies, infrastructure and so on (Hastig and Sodhi, 2020; Yadav and Singh, 2020; Gunasekaran and Arha, 2019; Queiroz and Wamba, 2019). It is, therefore, necessary to identify the main factors which help or hinder the adoption of technology for improving companies' performance and solve the main tasks in the area. The identification of these factors was another important motivator for this study.

Chapter 3. METHODOLOGY

The method chosen in this research is the Systematic Literature Review (SLR) following the PRISMA guidelines to construct a concise and replicable study to systematise the information available in published papers regarding the benefits, challenges, adoption, sustainability, and update areas of the blockchain technology (BT) for supply chain management.

The SLR enables to deduce conclusions based on data search about what is known and unknown regarding research questions (Briner and Denyer, 2012). The PRISMA method consists of a checklist of 27 items in order to support a literature review (Liberati, Altman, Tetzlaff, Mulrow, Gøtzsche, Ioannidis et al., 2009). It is one of the essential tools to reliably and accurately summarize evidence that fits the pre-specified conditions and eligibility criteria of the researcher to answer a specific research question (Liberati et al., 2009).

The SLR documented in this dissertation aims to find answers to the six questions pointed out previously, and in doing so identify in which sectors of the supply chain has blockchain been implemented and what is its degree of implementation; what are the characteristics of companies (sector, size, etc.) where blockchain technology has been applied to manage the supply chain; what are the benefits and risks associated with the use of blockchain technology for supply chain management; what are the facilitating factors and barriers that exist in the implementation of blockchain technology; what is the influence of blockchain on the sustainable supply chain within organizational strategy and operational levels and how to evaluate the performance of blockchain technology in supply chain management.

In order to find an answer to these research questions, this study selected papers published until February 2020. With the aim of analysing high-quality and relevant articles, a search on the Web of Science Core Collection (WoS) was conducted. This database has a careful publication system containing only peer-reviewed journals, book chapters and conference papers. The search was carried out between September 2019 and February 2020 by using the keywords "blockchain" AND "supply chain" OR "blockchain" AND "logistics" in the title. The use of this combination of keywords intended to identify studies related to the application of this technology to support supply chain management. Due to the development of the blockchain technology, an increase in published proceedings was observed. These documents were presented at international conferences, providing new insights and frameworks with relevant information about blockchain and supply chain. For this reason, in order to present the most recent updates in this area, the SLR included, in addition to publications in scientific journals, conference proceedings indexed in the Web of Science.

3.1 Study selection and exclusion criteria

The selection of the literature was made by the author and based on a set of predefined exclusion and inclusion criteria. The selection criteria considered only peer-reviewed research articles, conference proceeding papers and book chapters in English, Spanish, Portuguese, and French with the keywords "blockchain" AND "supply chain" OR "blockchain" AND "logistics" in the title. The selection of the articles occurred in two stages. In the first stage, titles and abstracts were analysed. In the second stage, full-text reading of studies which had not been excluded in the first stage took place.

The exclusion criteria were the following: Literature review papers, grey literature, reports, documents focused on technical information, studies which emphasized other technologies (Internet of things, Radio frequency identification, Big Data), financial supply chain or studies related to bitcoins. Articles meeting one of these criteria were excluded with a justification. Although we excluded literature review papers from the SLR analysis, these papers were still used in order to identify key studies which had not been captured from the Web of Science database.

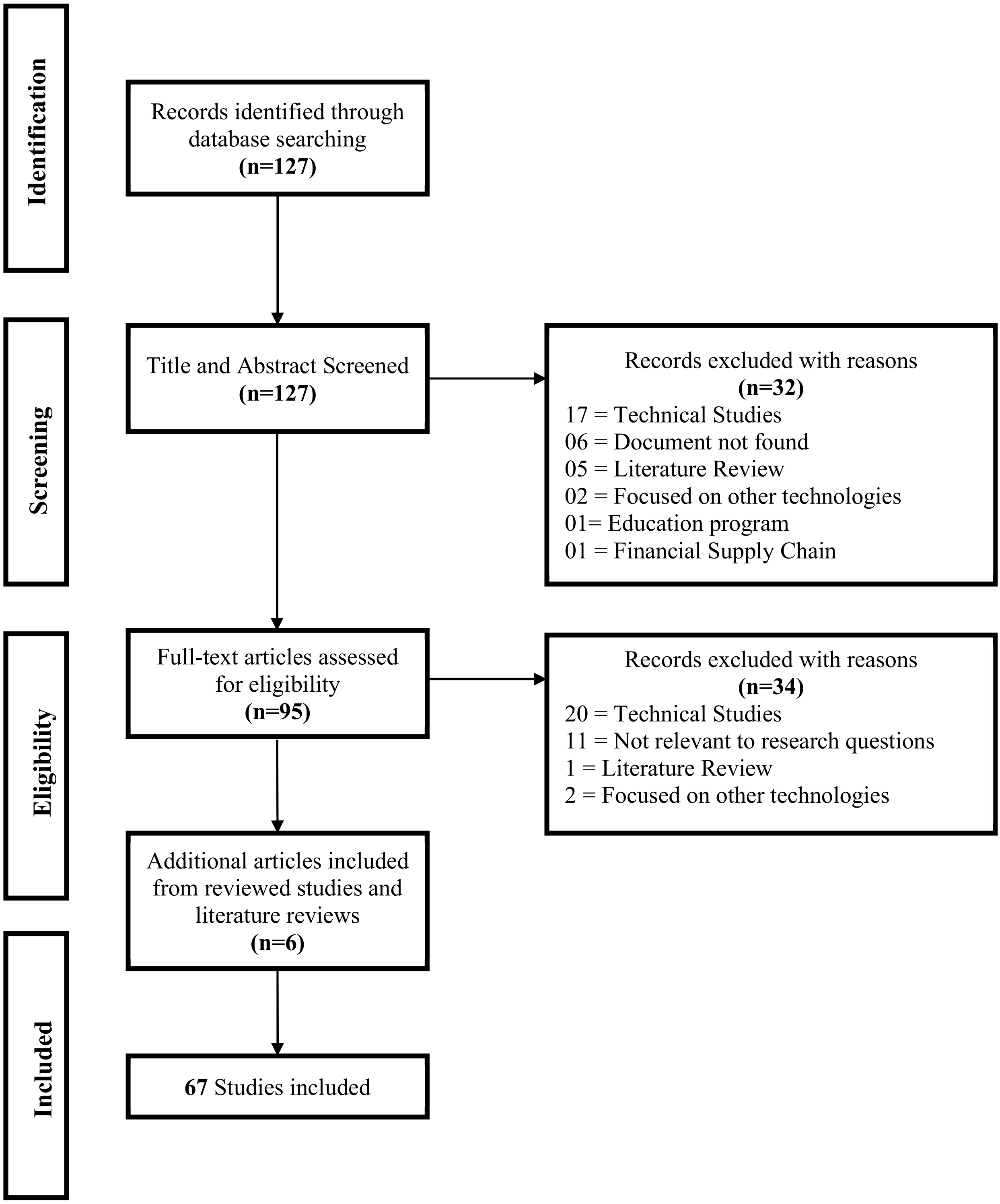
3.2 Title and abstract screening

The search based on the listed combination of keywords returned a sample of 127 papers, books chapters and conference proceedings. The title and abstract of each selected article were examined and the documents without a focus on managerial results and without a discussion on the potential of blockchain, were removed. In this stage, 32 papers were excluded with justification. Seventeen studies were excluded because they focused on technical information, 6 papers were excluded because the full text versions were not found, 5 documents were excluded because they were literature reviews, 2 studies were excluded because they focused on other technologies (IOT, RFID), one paper was excluded because it was about an education program and finally, one study was excluded because it was a financial study.

3.3 Full-text assessment and final selection

At the end of the previous stage, 95 articles remained in the sample. In the full text reading phase, the papers were excluded when they focused on technical information or on, business framework development, provided few managerial insights or were related to bitcoin, RFID, IoT or other support technologies. The number of articles excluded and the reasons for exclusion are indicated in Figure 3.1 After this stage, the sample reached 61 articles, included for complete data extraction and analysis. The full-text step identified, however, another six keys articles (from the references of the studies reviewed and from the references of other literature reviews) . These six studies were downloaded, read, and accepted, resulting in a total of 67 articles reviewed – the final sample (see Figure 3.1). In the next section, the findings of the review are presented and discussed.

Figure 3.1 Systematic literature review process



Source: Author

Chapter 4. FINDINGS AND DISCUSSION

In order to systematise the findings, this study opted for the content-analysis approach (Queiroz, Telles, and Bonilla, 2019; Seuring and Gold, 2012). By doing so, it was possible to clearly identify the evolution of the research about blockchain in the supply chain field. The first stage of the analysis is focused on three key-criteria: distribution of papers during 2016-2020, number of publications by countries, number of articles by journals and number of proceedings of conferences. The second stage of the analysis is focused on the research questions presented earlier.

A data extraction template was designed in Excel with the purpose of collecting the most relevant information capable to shed light on the research questions. The information extracted from the 67 papers was divided in two parts. The first part summarizes mostly bibliometric data like the name of the study; year and country of publication; journal; type of study (empirical and theoretical); sector of the industry; topic of study and suggestions for future research. The second part (see appendix A) is slightly more descriptive and summarizes data regarding the purpose of the study; characteristics of companies; benefits and risks of blockchain; facilitating factors and barriers to blockchain implementation; the potential of the technology for the sustainability of the supply chain; performance indicators used to assess the success of implementation.

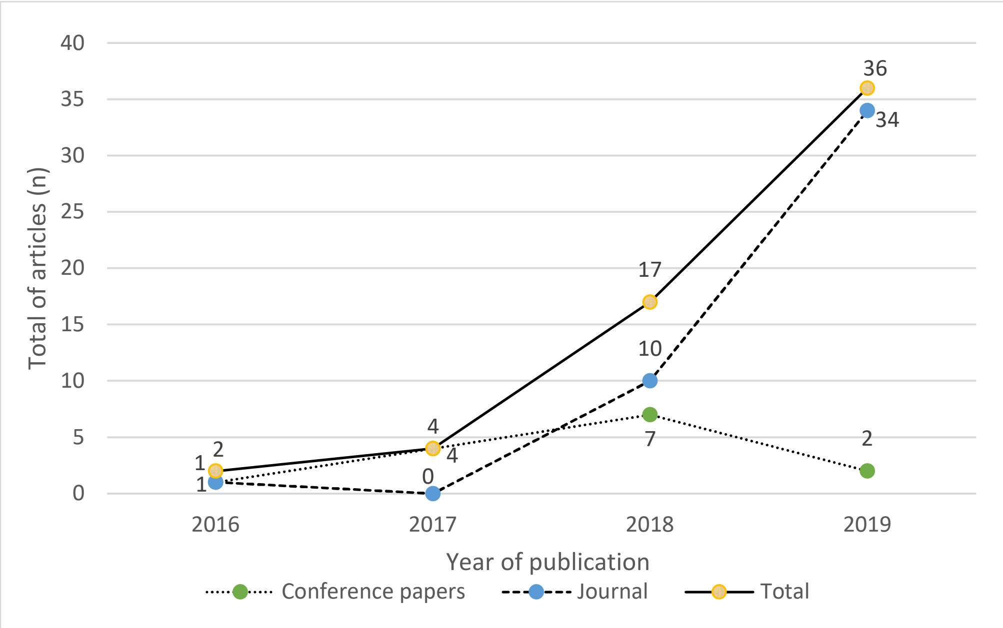
4.1 Distribution of papers published by year

The studies based on the application of the blockchain in the supply chain management are recent, however, it has been observed a gradual increase, in the number of publications which we consider to have been influenced by the digitalisation of the area, boosted by the Industrial Revolution 4.0 and the growing challenges in the global supply chain.

Figure 4.1 reports the number of papers published from 2016 to 2019. The blockchain technology (BT) exists since 2008, as it was first mentioned by Nakamoto (2008), nevertheless the first studies applicable in the supply chain management were published in 2016, related both to manufacturing and agriculture – other potential sectors of study for application of BT will be mentioned in section 4.6.

In 2017 only conference papers were published, different from what happened in the following year with an increase of journal publications, confirming greater interest by researchers and practitioners. In 2019, the total number of publications doubled, revealing an increasing interest in the development of this field. From January to February 2020 eight articles were published on this topic, however, they were not included in Figure 4.1 as they only represent the publications of two months.

Figure 4.1 Evolution of publication per type of study



Source: Author

4.2 Publications by country

Table 4.1 illustrates the number of publications by country from 2016 to 2020. The first papers were published by authors from England and Austria and focused on the use of the blockchain technology in the manufacturing and agro-industry, respectively. During the following years, it has been noticed an increase of studies published by authors from the USA and China followed by India, an important emergent market. These countries are responsible for 44% of the publications on blockchain applications in the supply chain management.

Analysing by Continent, Asia is responsible for 39% of the publications, Europe accounts for 36% of the studies (led by England), North America (USA and Canada) for 20%, Latin America 4% (Brazil and Colombia) and Oceania represents 1%. Based on the publications, it is possible to identify a global interest for the improvement of the Supply Chain through the use of blockchain technologies.

Table 4.1 Publications by authors' country affiliation

Country	2016	2017	2018	2019	2020(Feb)	Total (n)	Total* (%)
USA	0	0	6	7	2	15	19%
China	0	1	2	6	1	10	13%
India	0	0	2	4	3	9	12%
England	1	0	0	3	1	5	6%
United Arab Emirates	0	0	1	3	0	4	5%
Austria	1	1	1	0	0	3	4%
France	0	0	0	2	1	3	4%
Germany	0	1	2	0	0	3	4%
Italy	0	0	1	2	0	3	4%
Switzerland	0	0	0	2	1	3	4%
Brazil	0	0	0	2	0	2	3%
Finland	0	1	0	0	1	2	3%
Korea	0	0	0	2	0	2	3%
Australia	0	0	1	0	0	1	1%
Canada	0	0	1	0	0	1	1%
Colombia	0	0	1	0	0	1	1%
Denmark	0	0	0	1	0	1	1%
Greece	0	0	0	1	0	1	1%
Iran	0	0	0	0	1	1	1%
Lebanon	0	0	0	1	0	1	1%
Netherlands	0	0	0	1	0	1	1%
Norway	0	0	0	1	0	1	1%
Pakistan	0	0	0	1	0	1	1%
Russia	0	0	0	1	0	1	1%
Singapore	0	0	1	0	0	1	1%
Taiwan	0	0	0	1	0	1	1%
Turkey	0	0	0	0	1	1	1%

Source: Author
Note: When one paper included authors from more than one country, the respective paper was counted as a publication in each of the countries. This results in a total count of publications superior to 67.
* Values rounded to one decimal place

4.3 Classification of publications in scientific journals and conference proceedings

The aim of this analysis is to determine what journals and in which areas have the studies been published. This search identified 51 publications in 32 journals which correspond to 76% of the publications, followed by 14 conference proceedings (21%) and two book chapters (3%). Table 4.2 indicates the 9 journals which have the highest number of published papers, representing 42% of the studies.

Table 4.2 Publications by journals

Journals	Total (n)	Total (%)
International Journal of Production Research	5	7%
IEEE Access	4	6%
IFAC-PapersOnLine	4	6%
Computers & Industrial Engineering	3	4%
Sustainability	3	4%
Supply Chain Management - An International Journal	3	4%
Business Horizons	2	3%
International Journal of Information Management	2	3%
Transportation Research Part E: Logistics and Transportation Review	2	3%
International Journal of Operations & Production management	1	1%
Journal of Intelligent & Fuzzy Systems	1	1%
Journal of Research in Engineering and Technology	1	1%
Logistics	1	1%
ACM Transactions on Design Automation of Electronic Systems (TODAES)	1	1%
Cogent Economics & Finance	1	1%
Electronics	1	1%
Enterprise information Systems	1	1%
Informatics	1	1%
International Journal of Aviation, Aeronautics, and Aerospace	1	1%
International Journal of e-Collaboration	1	1%
International Journal of Environmental Research and Public Health	1	1%
International Journal of Healthcare Information Systems and Informatics	1	1%
International Journal of Physical Distribution & Logistics Management	1	1%
IT Professional	1	1%
IT Information Technology	1	1%
Journal of Purchasing and Supply Management	1	1%
Management Research Review	1	1%
Production and Operations Management	1	1%
Quality - Access to Success	1	1%
Resources, Conservation and Recycling	1	1%
Technological Forecasting and Social Change	1	1%
Worldwide Hospitality and Tourism Themes	1	1%

Source: Author

The journal with the highest number of publications is the International Journal of Production Research which focuses on the production economics, engineering, strategy, manufacturing and logistics. The content of the other journals focuses mostly on industrial engineering, electronics, technology, business, management, logistics, supply chain and sustainability. This table indicates that most of the studies published so far are still concerned with the technical developments, as well as the supply chain management. In recent years, the issue of sustainability seems to have also attracted an increasing interest. These areas are also important to help deploying an efficient supply chain management in the digitalisation era.

The majority of proceedings have been published in technology's conferences (see Table 4.3) due to the hype of the theme, however, they have also started to appear in logistics and management conferences with an opportunity to solve gaps in operations, like quality of transports and data accuracy.

Table 4.3 Publications by conference events

Conference Events	Total (n)	Total (%)
2018 IEEE Confs on Internet of Things, Green Computing and Communications, Cyber, Physical and Social Computing, Smart Data, Blockchain, Computer and Information Technology, Congress on Cybermatics	2	3%
2016 13th International Conference on Service Systems and Service Management (ICSSSM 2016)	1	2%
14th International Conference on Service Systems and Service Management (ICSSSM 2017)	1	2%
14th IEEE International Conference on E-Business Engineering: ICEBE 2017	1	2%
8th International Conference on Logistics, Informatics and Service Sciences	1	2%
2018 Fifth HCT Information Technology Trends	1	2%
2018 Resilient Week	1	2%
Computational Science and Its Applications – ICCSA 2018	1	2%
Proceedings of the 1st International Scientific Conference "Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth" (MTDE 2019)	1	2%
Proceedings of the 2018 International Conference on Blockchain Technology and Application	1	2%
2nd International Conference on Communication, Computing and Digital systems (C-CODE)	1	2%
Proceedings of the 50th Hawaii International Conference on System Sciences	1	2%
Proceedings of the Hamburg International Conference of Logistics (HICL)	1	2%

Source: Author

Albeit the book chapters (Table 4.4) represent only 3% of publications in this SLR, they emphasise an important issue in the decision-making process and during the blockchain implementation. In specific, these book chapters discuss how to combine the blockchain with other technologies (legacy systems, IoT), already installed in the company, to gain higher performance and efficiency.

Table 4.4 Publications in books

Books	Total (n)	Total (%)
Chapter 9 - Blockchain with IOT: Applications and use cases for a new paradigm of supply chain driving efficiency and cost. In Advances in Computers, 2019	1	1,5%
Chapter 3 - Blockchain Technology: Supply Chain Insights from ERP, In Advances in Computers, 2018	1	1,5%

4.4 Benefits and risks of blockchain deployment in the context of supply chain management

This systematic literature review gathered the main perceived benefits of the blockchain for enhancing the supply chain management. The main advantages indicated by representative empirical and theoretical studies are summarised in table 4.5. The purpose of this table is, based on the findings of some of the main authors, to identify studies that have already tested the technology and confirmed some of its likely strengths put forward in conceptual articles.

The benefits of blockchain technology, when combined, show great potential to enhance the efficiency and performance of supply chain management, due to their attributes capable of facing the challenges in this area. The system can track the flow of goods, provide transparent operations, reduce the risks of low quality and high costs of operations (paperwork and transactions), resulting in a reliable relationship between partners and customers', also contributing to address sustainability concerns.

According to Kshetri (2018), the system can manage actions on the supply chain in order to measure and increase its performance. The performance is usually based on quality, lead time, cost, and risk reductions. For better use and results in the supply chain management, blockchain tends to be combined with other technologies, such as Internet of the things, Big Data, QR Code and RFID, guaranteeing accurate data in real time. There are some studies that analyse the efficiency of two or more tools, for instance, blockchain and IoT, blockchain and Enterprise Resource Planning (ERP), as well as blockchain and Big Data.

The present study focuses specifically on the blockchain technology, nevertheless other authors indicate advantages of using these resources to achieve a great operational experience.

Banerjee (2018) supports the combination of blockchain and ERPs for a more transparent and interactive operation among partners. This combination complements the functions and benefits of both systems to improve the entire industry. Most of the information is kept on the ERP and the main data remains available in the blockchain for all relational partners in order to speed up orders, improve prices and discounts on the right items. The energy consumption, a great villain of blockchain, drops since only the necessary data is maintained in the blockchain network. Furthermore, the author also argues for the IoT combination to make analyses with real time data, because of the potential to allocate information in the system (Banerjee, 2019).

Lanko, Vatin and Kaklauskas (2018) focus on the combination of blockchain with RFID to significantly reduce losses caused by human errors and unethical information, besides enhancing trust between partners. Meanwhile, Santonino III, Koursaris and Williams (2018) claim that the combination of blockchain with RFID rises efficiency, reaches better performance, reduces costs, and promotes a greater experience to customers.

Tian (2016) also confirms that the quality and safety of agri-food products is greater when blockchain and RFID are combined in the industrial operations. All the mentioned tools provide precise data which aid managers to analyse each situation and make decisions related to their companies' goals. For enterprises that already have some of these technologies, it tends to be easier to adopt the blockchain to integrate all information and partners (Tian, 2016).

The SLR identified several benefits as seen in the table 4.5. The advantages mentioned most often are detailed below.

Traceability is one of the main characteristics and benefits of the blockchain. There are studies that focus on the traceability as a powerful competitive advantage (Tian, 2017; Tian, 2016). According to Kshetri (2018), the tracking and monitorisation of goods are the main reason for the implementation of blockchain in international companies. The author points out enterprises such as Walmart, Maersk and Gemalto as representative examples of organizations that use the technology for monitoring their supply chain.

Blockchain can track every product using RFID, QR Code or IoT beyond tiers and store the data in the network. According to Tian (2016), the blockchain can be an efficient and reliable system to agri-food supply chain management because it covers each participant in the sector, such as quality supervisors and government departments. In case a food accident happens, the companies could take emergency measures to prevent the spreading of the situation (Tian, 2016). The transparency and traceability of the blockchain will, in turn, help ensure the provenance and the trust into operations.

Table 4.5 The main benefits of blockchain

Benefits / Authors	Type of study	Azzi et al., 2019	Li et al., 2018	Queiroz and Wamba, 2019	Saberi et al., 2019	Kshetri, 2018	Hackius and Petersen, 2017	Bose et al., 2018	Tian, 2016	Treiblmaier, 2018	Jamil et al., 2019	Bettín-Díaz et al., 2018	Montecchi et al., 2019	Banerjee, 2018	Manupati et al., 2020	Nayak and Dhaigude, 2019	Choi and Luo, 2019	Total of study
Transparency	Empirical	✓	✓	✓							✓	✓				✓		13
	Theoretical				✓			✓	✓	✓			✓		✓		✓	
Traceability	Empirical	✓	✓	✓		✓	✓				✓	✓						13
	Theoretical				✓				✓	✓				✓	✓		✓	
Risk reduction	Empirical	✓		✓		✓					✓	✓						8
	Theoretical				✓				✓					✓				
Cost reduction	Empirical	✓	✓	✓		✓		✓				✓				✓		13
	Theoretical				✓			✓					✓	✓	✓		✓	
Real time tracking	Empirical	✓	✓	✓		✓	✓		✓		✓							12
	Theoretical				✓			✓		✓			✓	✓				
SC Performance	Empirical					✓					✓					✓		9
	Theoretical				✓			✓	✓					✓	✓		✓	
Trust	Empirical			✓		✓					✓	✓				✓		9
	Theoretical				✓				✓	✓				✓				
Security	Empirical			✓		✓					✓	✓						11
	Theoretical				✓			✓	✓	✓				✓	✓		✓	
Sustainability	Empirical					✓										✓		5
	Theoretical				✓				✓								✓	
Auditability	Empirical											✓			✓			4
	Theoretical								✓								✓	
Immutability of data	Empirical					✓					✓	✓			✓			6
	Theoretical									✓				✓				
Data quality	Empirical	✓	✓	✓		✓	✓				✓							10
	Theoretical				✓				✓				✓				✓	

In addition to the benefits pointed out previously, blockchain can aid in maintaining the information accurate (Kshetri, 2018), fight against counterfeit (Tian, 2016), increase security (Bettín-Díaz, Rojas and Moncayo, 2018), provide immutable data (Petersen, Hackius and von See, 2018) and facilitate audit trails (Hald and Kinra, 2019; Tian, 2016). The supply chain management efficiency will improve due to the real time information provided by Blockchain. Managers will have access to stock management information, purchase orders, goods received, shipping, invoices, and payments will be made according to smart contracts (Cole et al., 2019).

Transparency is another important benefit of the blockchain because it refers to information available to all companies involved in the supply operation (Francisco and Swanson, 2018). The possibility to gather all the crucial information about the flow of goods in a distributed ledger, permitting access of partners to immutable data, provides great transparency in the supply chain operations, thanks to the traceability mechanism.

Sectors such as the food industry (Tian 2017; Tian, 2016) and pharmaceuticals (Hastig and Sodhi, 2020; Azzi et al, 2019) are aware of the potential to track all the stages the goods go through in order to increase the provenance of products, avoiding spoiled food or counterfeit products, as well as controlling the temperature and quality of the raw materials. If something occurs during the tracking, it is possible to identify who is responsible for the issue and act promptly. The transparency of blockchain technology can reduce counterfeit products like medicines and luxury fashion products (Kshetri, 2018) due to the capacity to analyse the supplier's operations.

Furthermore, the transparency enhances the sustainability of the supply chain operations by providing information related to carbon emissions, waste management, human rights, labour practices, and cost reduction (Bai and Sarkis, 2020; Saberi et al., 2019; Kouhizadeh and Sarkis, 2018).

The transparency of the supply chain increases the visibility of the operations. Each participant can see the flow of goods in real time, verify the temperature of food and medicines, identify the exact location of products and access documents such as the bill of lading, thanks to the traceability and the connection with other gadgets (Hald and Kinra, 2019). The performance of the supply chain increases because the stakeholders can better plan the operations (Francisco and Swanson, 2018). Based on the blockchain data, managers can make decisions for increasing the efficiency of the company like demand forecast, order fulfilment and may influence inventory management positively. From a financial point of view, it reduces administrative costs, human errors, frauds and contributes to the environment by minimizing the waste (Treiblmaier, 2018).

Blockchain technology also reduces the necessity of third parties, without entity´s validation, the process becomes faster and, consequently, costs related to the partners´ validation, are reduced.

Another mechanism which helps to reduce costs is the use of smart contracts. Due to the capability to self-validate virtual agreements, smart contracts can be programmed to make automated payments according to the conditions, rights, and obligations previously accorded (Hald and Kinra, 2019). Thanks to the traceability and transparency, the improvement of warehouse management also can reduce costs with stocks, recalls and uncertain demand.

Risk management also has potential to be improved by blockchain. The blockchain technology contributes to reduce hidden and invisible risks that are hard to detect by a limited number of stakeholders (Min, 2019). The technology can reduce fraud, errors, and delays recurrent in the supply chain ecosystem (Azzi et al., 2019) since all transactions are validated and immutable, counterfeits can be easily identified (Jamil, Hang, Kim and Kim, 2019). The order fulfilment errors can be reduced, and order processes can be speeded up, due to the integrity of the transactions (Min, 2019).

The food, pharmaceutical and fashion industries are some of the sectors which deal with counterfeiting and sustainable problems in their operations. They are exposed by the global supply chain and it is difficult to control the upstream and downstream process.

According to Kshetri (2018), industries that suffer with counterfeit tend to adopt the blockchain to manage the risks better. The knowledge of the origin of the products can reduce the risk perceptions by customers and suppliers (Montecchi et al., 2019).

Furthermore, the blockchain will help to manage the challenges related to human rights and labour practices due to the capacity of evaluating the suppliers and their sustainability. It can also reduce the risk of information asymmetry (Fu and Zhu, 2019; Liu et al., 2019). The stakeholders will have access to the same data, sharing information in order to minimize the misunderstanding and errors in the operations (production, shipping, transportation). Finally, it allows minimising the risk of transactions. Only partners accepted in the network can make transactions, maintaining the trust and security (Kshetri, 2018).

The blockchain technology will guarantee the security of transactions (Liu et al., 2019; Zheng, Zhang, Chen and Wu, 2019) due to the cryptography system (Tian, 2016). As previously mentioned, all transactions are cryptographed and only permitted companies can have access to the data. This can ensure a higher security during the operations. Lockheed Martins is an example of a company which applies the blockchain to reduce cyber risks in its manufacturing operations. The manufacturer Moog launched a service called Veripart which tracks and traces the provenance of the products (Kshetri, 2018).

According to Francisco and Swanson (2018), trust is a key element of blockchain technology due to the information integrity in the blockchain. Trust is the result of a transparent process where every partner has the same immutable information in the blockchain and could track each part of the operations. In the private networks, only authorized companies are allowed to see and include data in the network, strengthening the security of transactions and payments. The stakeholders know exactly what they are buying, due to the provenance, tracking, and reduction of the transaction risks. According to Li, Qu, Tu, Fu, Guo and Zhu (2018) the trust provided by blockchain increases the reliability of philanthropic projects, enhances the honesty rate and the quality of materials (Li et al., 2018).

Another characteristic which assures the security of transactions is the immutability of data. No information can be deleted or modified in the network (Min, 2019) facilitating full audits (Mylrea and Gourisetti, 2018) because all the information can be easily tracked, by suppliers, customers and partners, providing even more security (Bettín-Díaz et al., 2018) in the operations. Smart contracts also play an important role, because according to Mylrea and Gourisetti (2018), it can automate the supply chain security, creating alerts and updates to help monitor the companies' criteria, increase the data management and security payments.

All the advantages listed above increase the efficiency in many areas of the supply chain management. The demand and forecast management could minimise the bullwhip effect. The inventory management can reduce costs of storage and waste produced thanks to the real time tracking (Kim and Shin, 2019; Sheel and Nath, 2019). Sustainability goals tend to improve due to the transparency in the operations. Despite being a recent and expensive technology, many studies and some real cases show evidence of the benefits of blockchain in rising supply chain efficiency. The system has the capacity to help in better and assertive decisions-making.

Furthermore, blockchain can be used to improve customer value and service through implementation of data analytics (Çolak, Kaya, Ozkan, Budak and Karasan, 2020; Banerjee, 2019).

4.4.1 Risks of blockchain technology in the context of supply chain management

As any system in its initial stage, blockchain has some challenges to overcome before being a successful technology system. Researchers and practitioners classified these limitations as risks of implementation. Risk, because although the industry agrees with its deployment, the technology requires more improvement. This is the reason why the information technology (IT) infrastructure is a major concern in this study field, justified by the level of development (Bettín-Díaz et al., 2018). Since the initial publication of Santoshi Nakamoto (2008) the technology has evolved and reached the third phase, the highest level so far, although it still needs some adjustments to become useful in the supply chain operations of both public and private networks.

As previously mentioned, each node carries the hash of the previous transactions to create the flow´s story. Each information added to the block makes it bigger and heavier, increasing the data validation and processing time. Besides that, the blocks need a great amount of energy to be executed (Mao, Wang, Hao and Li, 2018) which will force many companies to look for other sources of energy, such as renewables or increase their expenses due to the increase in energy consumption.

The scalability is, at the same time, a risk and a barrier of implementation into companies. Considered one of the main concerns of the researchers and practitioners, the scalability is the limit of the block size and the frequency of transactions in a period of time (Bettín-Díaz et al., 2018). In other words, the bigger a block is, the longer is time it takes to process and validate the information required. Blockchain technology also faces issues in terms of throughput, latency, and capacity when dealing with mass data in a real business environment. This situation became a primary and urgent issue to solve (Tian, 2017).

Currently, blockchain systems are unable to store a great amount of data and due to their limit, they are not prepared for massive use yet (Azzi et al., 2019). Moreover, according to Min (2019), the technology requires huge computing power and high bandwidth internet connection for processing and validating all the blocks. Companies need to invest in the infrastructure, besides blockchain developments, for running the information and improving their efficiency/market value. In order to solve these challenges, some authors suggest storing only the critical information in the blockchain, leaving the other in the companies´ legacy systems (Banerjee, 2018) to avoid overloading the blockchain.

Interoperability is, as well as scalability, considered a performance issue (Wang, 2019) before and after the blockchain implementation. Interoperability is the capacity of the blockchain to communicate transparently with other systems, such as SAP, Microsoft Azure, PHC Software and so on. This matter means that combining various legacy systems with the blockchain can be a hard task for companies (Min, 2019) because each one has personalized ERPs and the lack of blockchain standards tends to generate customized solutions, which may restrict the efficiency of blockchain and increase the resistance of new technologies acceptance (Min, 2019). The developers of this technology, assisted by managers, need to design solutions which suit all the stakeholder's legacy. In this way, the information could be easily integrated and accessible for all supply chain actors.

Banerjee (2018) argues that applying blockchain in an ERP system can reach a greater efficiency and cost benefit in the final delivery of goods, because ERP guarantees the efficiency in the internal operations and uses the technology as a centralized repository for multiple actors.

Nevertheless, Korpela et al. (2017) argue that high integration costs for mapping and integrating companies' systems tend to be a risk of investments. The authors analyse whether cloud integration could offer a cost-effective business model for interoperable digital supply chain. During their research, low levels of system interoperability were presented. Therefore, in this case, the company incurred in high financial investments, without potential benefits. The authors concluded that blockchain does not provide interoperability alone, being necessary another standard system to integrate the data. Van Hoek (2019b) confirms in his empirical study, that blockchain technology is a complement tool for enhancing companies' legacy systems.

Banerjee (2018) presents a successful case in the integration of systems. Renault is a French example that uses a blockchain solution based on Microsoft Azure to manage car ownership and maintenance details, moreover, the company tracks products in the market thanks to a project design which meets the French industry needs (Banerjee, 2018).

Another risk pointed out in the literature review is the energy consumption. As previously mentioned, the blockchain transactions spend a high volume of energy to validate the nodes, especially public blockchains which need to validate many algorithms (Kouhizadeh and Sarkis, 2018; Mylrea and Gourisetti, 2018). Thus, this limitation could compromise the sustainability goals of the company because of the great consumption of energy and other natural resources to produce more power (Kouhizadeh and Sarkis, 2018; Perboli et al., 2018). Despite that, Perboli et al. (2018) prove empirically that the cost of blockchain implementation shows to be highly sustainable when compared with the resulting benefits, such as the waste reduction, storage conditions and inbound efficiency.

Security and privacy in blockchain implementation are also of concern to researchers and practitioners. Unlike the security provided by transparency and traceability, in this case, the worries are related to hackers' attacks, the risk of losing all data stored in the system and to data security (Min, 2019; Saberi et al., 2019; Banerjee, 2018). An empirical study made by Hackius and Petersen (2017) pointed out that 41% of supply chain professionals interviewed considered security as an important risk/barrier for their companies. Data security is justified by the fear of sharing data outside the company's boundaries (Banerjee, 2018). In particular, there is a risk of exposing strategic information to competitors (Montecchi et al., 2019). Once again, this concern is linked to the lack of knowledge regarding the technology, the lack of real cases and to the fact that blockchain technology is still in the early stages of its development (Hackius and Petersen, 2017).

4.5 Success and critical factors of blockchain adoption in the context of supply chain management

For a successful blockchain implementation it is important to analyse the main factors which can boost or constrain the implementation. These factors can be different according to the sectors (Çolak et al., 2020), infrastructure, companies´ goals, government policies and so on (Kamble, Gunasekaran and Arha, 2019; Queiroz and Wamba, 2019; Van Hoek, 2019b). This is crucial for understanding the industries' limitations and for achieving great supply chain efficiency. The SLR points out the disadvantages and risks related with the application of the blockchain in the supply chain and operations management, however, most of them focus on the main factors that could help or hinder implementation.

According to Nayak and Dhaigude (2019), Queiroz and Wamba (2019), van Hoek (2019b) and Wamba and Queiroz (2019), the actors´ behaviour represents an important factor in the success of the blockchain deployment. Van Hoek (2019b) analyses three business cases in North America and Europe. In all of them, top managers had an important role in the implementation of the blockchain. Queiroz and Wamba (2019) as well as Wamba and Queiroz (2019) analysed which behaviours were observed in Americans, Indians, and Brazilian during a technology implementation. The authors concluded that the professionals´ behaviour is different in each country.

Other authors use some theories to identify and understand the steps of the blockchain adoption in the supply chain management. Abeyratne and Monfared (2016) focus on the green marketing, ecological modernization theory and social confirmation theory to understand which factors could boost or constrain blockchain implementation. Treiblmaier (2018) analyses the adoption by the perspective of transaction cost, principal agent, resource-based view, and network theory. The author analyses how these theories can aid industries in adopting blockchain and makes recommendations on how to integrate the technology based on these theories.

Kamble et al. (2019) propose a model using three theories to comprehend the user perceptions on BT adoption in Indian context. Technology acceptance model (TAM), technology readiness index (TRI) and the theory of planned behaviour (TPB). The study indicates, based on empirical analysis, that the factors like perceived usefulness, attitude and perceive behaviour control, influence positively the blockchain adoption in organizations.

All these theories have been extensively studied in prior studies where it was necessary to implement a new technology, like ERPs and even RFID. They can help understand and predict the actors´ behaviour involved in the implementation and design of a better network according to the companies´ needs.

The blockchain faces two dimensions of implementation barriers. Intra-organizational with behavioural and organisational challenges and inter-organizational which relates to customers, technological, and regulations issues (Manupati, Schoenherr, Ramkumar, Wagner, Pabba and Inder Raj Singh, 2020; Kamble et al., 2019; Saberi et al.,2019). Both success and critical factors depend on the environment where each company operates, government regulations, incentives to research and development (R&D), companies´ infrastructure and culture of the stakeholders.

4.5.1 Success factors

The success of a technology implementation starts with the knowledge of the company´s business. It is important to identify the main products, the challenges, and the objectives of the organization (Saberi et al., 2019). This knowledge will help managers to perceive whether the company needs the blockchain and which problems it can solve. Furthermore, the company has the possibility of increasing competitive advantage and add market value. The second step after the implementation decision, is to analyse which will be the functions of blockchain in their operations (Azzi et al.,2019).

Hald and Kinra (2019), argue that blockchain design can both facilitate and hinder its implementation in a company, because it depends on how the deployment affects the supply chain employees. To these authors, the ability to share information, explore the resources and competences in the supply chain operations, beyond routines and approaches, help workers and decision makers spread the technology into the company. The success of implementation depends on the supply chain actors understanding how the technology works and its potentials, otherwise the employees increase resistance and hinder the deployment of the system (Azzi et al. 2019; Fu and Zhu, 2019; Wang, 2019).

Prior studies argue that coordination and collaboration of the supply chain professionals is the main factor that contributes to blockchain adoption (Azzi et al., 2019; Malyavkina, Savina and Parshutina, 2019; Min, 2019; Montecchi, et al., 2019; Van Hoek, 2019b; Banerjee, 2018; Kshetri, 2018; Perboli, Musso and Rosano, 2018; Tian, 2016). This is the case because these professionals work together to construct collaborative network information, feel like a part of the process, and use their skills and intelligence as a source of implementation (Hald and Kinra, 2019).

Empirical studies conducted in USA and India prove that performance expectancy has a positive effect on the behavioural intention of adopting the technology (Kamble et al., 2019; Wamba and Queiroz, 2019). It means that when professionals understand what the blockchain is and how it will improve their performance, they become more susceptible to use the new technology and their attitude changes positively. However, there may be differences between countries, for instance, Brazilian professionals are more influenced by the social network than by the facility conditions provided by the companies (Queiroz and Wamba, 2019). This result confirms the Francisco and Swanson´s (2018) propositions that social influence positively affects behavioural intentions to use blockchain technology.

Francisco and Swanson (2018) also argue that technical resources and organizational support (facilitating conditions) positively impact the behavioural intention to use blockchain technology, which is confirmed by Queiroz and Wamba (2019) and Wamba and Queiroz (2019). Both studies applied surveys in the American, Indian, and Brazilian supply chain markets using the unified theory of acceptance and the use of technology (UTAUT) to identify which factors affect these populations. These studies conclude that the social influence (co-workers, friends, and relatives' opinions) has a great influence in India and Brazil, while in the United States the major factor relates to the facilitating conditions provided by companies. Wamba and Queiroz (2019) suggest that emerging markets do not have the same support and infrastructure conditions as developed markets such as the USA. These studies confirm that the success factors could change according to the country and their operational capabilities.

Another factor which helps the implementation of the blockchain is the experience of each professional in the supply chain. Employees more experienced have a better perception of the technology´s potential (Hald and Kinra, 2019); Meanwhile the concerns about the implementation are lower when they have blockchain knowledge (Petersen et al., 2018).

For the experienced group of professionals, the security and digital privacy are the main priorities and the smart contracts represent the most valuable functionality according to 88% of the interviewees (Korpela et al., 2017). The smart contract is one of the characteristics of the blockchain which, according to the company´s needs, can be programmed to reduce costs, make payments, make deals among partners and help to monitor sustainable indicators and practices.

In the last years, due to growing concerns of sustainable practices forced by government laws and conscious customers, many industries started to study ways to become more sustainable and to prove that they achieve this goal. Blockchain represents a potential tool to achieve sustainability due to the transparency, immutability, and tracking potential.

For this reason, some studies analyse the adoption factors in the sustainable supply chain management. Kouhizadeh and Sarkis (2018) argue that companies, industries, type of products and competitive environments influence the adoption of the technology, because these characteristics can improve the reputation of the company and maintain customers.

Nayak and Dhaigude (2019) study the adoption of blockchain in small and medium enterprises. Using the multiple-criteria decision-making (MCDM) methodology with practitioners and industrial experts, the authors identify the critical factors which influence the adoption of blockchain technology in sustainable supply chain management. The crucial factor pointed by Nayak and Dhaigude (2019) is the information technology boosted by the top management.

Top management is responsible for providing the guidelines to planning, execution and team support during the system adoption. This factor is also mentioned by Saberi et al. (2019) as a main indicator of successful implementation, nevertheless, the authors draw attention to the fact that many managers failed in long-term commitment, support, and pursuit of the sustainability values.

The importance of the top management is empirically confirmed by van Hoek (2019b) when the author analyses the logistics services (North America), retail (USA) and food & beverage products (Europe). Although they have different objectives, in all the cases the directors, managers and medium stakeholders have a crucial role in the blockchain pilot implementation.

Following the sustainable supply chain adoption, Yadav and Singh (2020) make an empirical analysis and identify 39 variables which affect the implementation of the blockchain. These variables were reduced to six factors, validated by supply chain experts, in order to develop a plan to support the implementation. The factors are data safety and decentralization, accessibility, laws and policy, documentation, data management and quality. The factors are related to the data quality and the level of accessibility to the data, which are especially important in the sustainable process. However, these factors are hard to tackle and it is difficult to measure the gains they generate. Differently to those identified by Wamba and Queiroz (2019), the factors here are inter-organizational because they focus on government regulations, the infrastructure and the quality of the data created by stakeholders that impact directly in the sustainability and on the supply chain´s efficiency.

For Kshetri (2018), competition could help spread the implementation of blockchain by companies, because the market makes pressure to stay competitive and if one industry demonstrates positive results it may influence other companies to do the same.

The major factor which promotes the adoption of blockchain, according to prior studies, is the awareness of the actors involved in the changes. This has been confirmed by van Hoek (2019a) however, as emphasized by this author, actors' behaviour can be affected by external issues, such as the social network, the facilities promoted by the enterprises, the level of technology and government regulations.

4.5.2 Critical factors

Blockchain was launched in 2008 by Santoshi Nakamoto and it was used mainly in the finance sector until it caught the attention of researchers and practitioners globally as a new tool for improving the supply chain management. Nevertheless, the technology still faces challenges and barriers to its spread in the industry. The critical factors are clustered in inter organisation, intra organisation, IT infrastructure and external barriers (Azzi et al, 2019; Montecchi, et al., 2019; Saberi et al.,2019).

Intra and interorganisational factors are the most critical barriers for blockchain's implementation. In the previous section one of the enabling factors was the perception of usefulness by the supply chain professionals. However, some studies identified that the employees and partners also have the potential to constrain the implementation. Lack of knowledge, lack of technical expertise and the reduce number of applications of blockchain in organizations are others barriers that has been pointed out in the literature (Longo, Nicoletti, Padovano, D'Atri and Forte, 2019; Saberi et al., 2019; Wang, 2019; Treiblmaier, 2018).

Longo et al. (2019) confirm that small and medium enterprises (SME) suffer with lack of knowledge about blockchain potentials and benefits. Meanwhile, Nayak and Dhaigude (2019) argue that SMEs face behavioural challenges such as the resistance to change. Before opting for the implementation, the managers must invest in professional training and analyse a way to improve the organisation´s culture with the aim of achieving a better commitment among employees.

Additionally, the partners and customers are also perceived as interorganisational barriers due to the lack of acceptance of the technology, coordination between companies and collaboration to address problems (Saberi et al., 2019; Petersen et al., 2018). Besides this, the lack of commitment among partners could affect the resources and financial decisions (Saberi et al., 2019).

In addition to the barriers related to the stakeholders, the infrastructure is pointed out as a technological barrier to blockchain implementation. The lack of standards make it difficult to develop a system that works in any company, moreover the risk of interoperability – the capacity to communicate with other programs – could limit and constrain the blockchain deployment due to the existence of various platforms (Min, 2019).

Banerjee (2018) defends the use of blockchain with ERPs to reach a better efficiency and performance in the supply chain management. The interoperability could be solved ensuring the connection with the legacy systems. Only the major information for partners would be available on the network.

The scalability is one of the drawbacks of the blockchain. Considered a risk for industries with huge volume of data, it is also a barrier for blockchain implementation. Scalability is the capacity of the system to process a great volume of data or to be prepared for it.

Studies point out that blockchain technology is not prepared to process massive amounts of data, as required (Casino, Kanakaris, Dasaklis, Moschuris and Rachaniotis, 2019; Hald and Kinra, 2019; Malyavkina et al., 2019; Min, 2019; Perboli et al., 2018). In 2017 the blockchain technology processed only 7 transactions per second while VISA can handle up to 47000 transactions per second (Tian, 2017). Apart from this, each block needs 10 minutes to confirm a transaction, as opposed to VISA that confirms in few seconds (Perboli et al., 2018). This latency and the size of the block concern professionals and practitioners because the amount of data foreseen to the global supply chain tends to grow exponentially. Another factor related to scalability is the energy efficiency. Each transaction spends a huge quantity of energy to be validated by nodes - computers networks (Cole et al., 2019; Jayaraman, Salah and King, 2019; Min, 2019; Wang, 2019; Keivanpour, Ramudhin and Kadi, 2018) which compromises sustainability objectives and increases the expenses in the company.

The privacy and security are two other factors referred by studies as barriers to the implementation of the blockchain for supply chain management (Hald and Kinra, 2019; Jayaraman et al., 2019; Nayak and Dhaigude, 2019; Kshetri, 2018; Petersen et al., 2018; Chen et al., 2017). Although the transparency is one of the main characteristics of blockchain, managers are afraid of their privacy (Hald and Kinra, 2019) because they understand that the intellectual properties and business strategies are at risk (Rahmanzadeh, Pishvaee and Rasouli, 2020; Montecchi et al., 2019).

Security issues are related to fake information input by professionals and potential attacks on the network to steal information. Moreover, professionals are worried about losing data due to failure of the system (Petersen et al., 2018; Hackius and Petersen, 2017).

Finally, the immaturity of the technology is mentioned as a concerning factor (Hastig and Sodhi, 2020; Baharmand and Comes, 2019; Kamble et al., 2019; Kim and Shin, 2019; Malyavkina et al., 2019; Schmidt and Wagner, 2019; Wang, 2019; Mao et al., 2018; Mylrea and Gourisetti, 2018; Petersen et al., 2018; Santonino III et al., 2018; Tian, 2016).

There are many benefits and challenges to be addressed in this area before spreading the blockchain system to all industries and continents. Some associations and countries have invested in studies to improve the technology and to develop projects, between 2016 and 2020 the number of studies and pilots has increased significantly, however the area continues to need more practical analyses.

The high costs of implementing and maintaining the blockchain network are mentioned as one of the major barriers to deploy the system (Manupati et al., 2020; Choi and Luo, 2019; Cole et al., 2019; Malyavkina et al., 2019; Min, 2019; Nayak and Dhaigude, 2019; Sheel and Nath, 2019; Wang, 2019; Banerjee, 2018; Perboli et al., 2018; Abeyratne and Monfared, 2016). The investments are associated with hiring technical professionals, training employees, changing the organisation culture' and improving the infrastructure. In addition, after the implementation, there is a cost of maintaining and monitoring the system (Baharmand and Comes, 2019).

The process of a technology implementation follows a pattern. First, it is necessary to analyse the best system based on the companies 'core business, hire skilled professionals to develop a project, identify the key actors and promote courses for them, prepare the stakeholders for the changing organisational process and, after going live, it is necessary to monitor the system and make periodic maintenance. However, in the blockchain field, there is a lack of case studies which prove the return of payment for the investment.

Maersk, Walmart, and Carrefour are the most famous companies that have already deployed the blockchain in their supply chain and logistics. The critical details of the implementation in these companies are still kept unknown. Maersk confirms that the blockchain implementation helped to reduce administrative costs and lead time in the logistics (Kshetri, 2018). The pilot case indicates a good result, necessary for further testing, but as mentioned above, more case studies are required to increase the trust from managers.

Choi and Luo (2019) argue that the blockchain implementation in the emergent sustainable fashion supply chain will increase the social welfare, however, due to the high costs of maintenance, tends to reduce companies´ profits. In order to support these costs and continue to reach the environmental indexes, the authors propose a government sponsorship to support technological development in emergent markets. This proposal can establish a “win-win” deal among industries and governments to continue improving the sustainable goals and at the same time to increase the companies’ efficiency and profits.

The government policies are considered an external barrier for the blockchain implementation (Hastig and Sodhi, 2020; Nayak and Dhaigude, 2020; Malyavkina et al., 2019; Min, 2019; Saberi et al.,2019; Sheel and Nath, 2019; Wang, 2019; Banerjee, 2018; Kshetri, 2018; Perboli et al., 2018). Each country has its own laws and regulations which make difficult a standard development of the technology and the deals among partners. According to Bettín-Díaz et al. (2018), this obstacle needs to be surpassed with governmental policies and education. Choi and Luo (2019) and Al Barghuthi, Mohamed and Said (2018) propose that governments may sponsor and organise technological support for the industries. In recent years, some countries have invested in studies for the development of new technologies in order to increase their global competitiveness. It is the case of European countries. These studies have been sponsored by Horizon 2020 – an EU Research and Innovation programme to develop breakthrough ideas for the European markets.

In 2016 a “five-year informatization plan” was launched in China to develop cutting-edge information technologies, including the blockchain (Fu and Zhu, 2019) and the Indian Government launched the project “Digital India Initiative” to increase digital development in the emergent market (Choi and Luo, 2019). It can be noticed that these countries have a considerable number of studies published regarding the referred blockchain technology and its application for supply chain management. These strategic markets have perceived the potential of the technology for trade and sustainable practices. At the same time, some governments constrain the development of regulations and policies such as Indonesia (Kshetri, 2018).

Other factors pointed out by Saberi et al. (2019) as external barriers are the lack of industry involvement due to the scepticism related to the real benefits of the blockchain technology; lack of ethical and safe practices in regions with corruption problems; demand uncertainty which affects the market competition and hampers integration of sustainability and blockchain technology.

Most of the critical factors mentioned above result from the lack of knowledge about the blockchain and its likely benefits. Possibly the barriers can be justified by the initial stage of the technology, which has raised more doubts than assurance. The rising interest in the technology and the dissemination of success cases will possibly help mitigate these barriers.

4.6 Sectors and fields where blockchain has been (or can be) applied in the context of supply chain management

Since the first application of the blockchain technology, practitioners and researchers have been studying new areas where blockchain can add value, reduce risks, and enhance competitive advantage. Supply chain management has proven to be one of the areas with the greatest potential for blockchain adoption (Kshetri, 2018).

There is a spread of theoretical and empirical studies dedicated to supply chain discussing blockchain technology implementation. Currently, most studies are theoretical, due to the early stage of blockchain, however, the number of empirical studies evaluating real implementation cases is increasing.

Strategic companies have started to adopt blockchain in their supply chain and, for this reason, this study identifies which enterprises are these, their characteristics, and the sectors where blockchain has already been deployed or studied. Thereby, the present study could provide insights for researchers and practitioners, as well as contribute to the development of a tool to analyse the possibility of deploying this recent technology in a specific sector or field.

In order to analyse which sectors and companies have already implemented the blockchain technology in the supply chain management, we clustered the studies analysed into empirical (Table 4.6) and theoretical (Table 4.7) studies. Studies based on case studies in real companies, interviews with supply chain professionals, and that tested a business model in the environment were considered empirical. All the other studies were considered theoretical or mixed.

Mixed studies are those that make contributions to theory but based on real world applications. In these cases, the studies were also classified as empirical, as they mention real cases. Finally, studies that contribute exclusively to the development of concepts, theories and business models were considered theoretical.

Table 4.6 presents empirical studies divided by company name, country of origin, sector, and topics where the blockchain was analysed. The topics are classified according to the purpose of the studies, keywords, and to their findings.

Some of the studies do not mention the companies´ names, but it is possible to identify in which sector the technology is applied. In other cases, the studies make enquiries with supply chain professionals to comprehend behavioural patterns and cover various industries.

Of the 67 studies reviewed, 33 were classified as empirical, which represents almost half of the literature review sample. Despite of the amount of publications, the companies indicated below were cited by more than one document and some of them analyse more than one topic of study.

Table 4.6 Blockchain implementation sectors in supply chain management

Study	Country	Company	Sector	Topic
Azzi et al. (2019)	Switzerland	Ambrosus Modum	Food Industry Pharmaceutical	Traceability
Li, Shen and Huang (2019)	China	Not mentioned	Real estate (EcLRE)	Warehouse Logistics
Rahmanzadeh et al. (2020)	Iran	Pars Khazar Company	Home appliance	Intellectual property
Queiroz and Wamba (2019)	Brazil France	Not mentioned	Not reported	Adoption
Jamil et al. (2019)	Korea	Smart Hospital	Pharmaceutical	Security
Scuderi et al. (2019)	Italy	Not mentioned	Food Industry	Traceability
Salah, Nizamuddin, Jayaraman and Omar (2019)	United Arab Emirates	Soybean company	Food Industry	Traceability
Kshetri and Loukoianova (2019)	Japanese USA China China USA	Toyota Provenance JD.com Alibaba Walmart	Automotive Food Industry	Adoption Risk Management
Fu and Zhu (2019)	China	Not mentioned	Pharmaceutical	Risk Management
Liao and Wang (2018)	USA	Not mentioned	ICE - Integrated casinos and entertainment	Logistics
Petersen, Hackius and von See (2018)	Germany	Not mentioned	Manufacturing Logistic services Retail	Adoption
Mao et al. (2018)	Switzerland USA	Nestle IBM &Walmart	Food Industry	Food safety

(Continued on next page)

Table 4.6 (continued)

Study	Country	Company	Sector	Topic
*Kshetri (2018)	Denmark UK China USA USA Switzerland UK USA Netherlands USA USA	Maersk Provenance Alibaba Lockheed Martin Chronicled Modum Everledger Walmart Gemalto Intel Bext360	International logistic Food Industry Aircraft Pharmaceutical	Traceability Adoption Food safety Sustainability Tracking Risk management
Westerkamp, Victor and Küpper (2018)	Germany	Not mentioned	Manufacturing	Quality Management Traceability
Li et al. (2018)	China	Not mentioned	Philanthropy	Sustainability Logistics Traceability
Bettín-Díaz et al. (2018)	Colombia	Colombian coffee traders	Food Industry	Traceability coffee
*Perboli et al. (2018)	Italy	Ecommerce food retailer	Food Industry	Operational costs
*Tian (2017)	Austria	Not mentioned	Food Industry	Traceability
*Chen et al. (2017)	China	Laptop company	Electronics SC	Quality management
Longo et al. (2019)	Italy	Not mentioned	Wholesalers and big-box retailers	Performance Information asymmetry
*Nayak and Dhaigude (2019)	India	SMEs	Not reported	Sustainability Performance Adoption
*Sheel and Nath (2019)	India	Not mentioned	Not reported	Performance
van Hoek (2019a)	USA Europe USA	Not mentioned	Logistics services Food Industry Retail	Implementation
van Hoek (2019b)	USA Europe USA	Not mentioned	Logistics services Food Industry Retail	Implementation

(Continued on next page)

Table 4.6 (continued)

Study	Country	Company	Sector	Topic
Kim and Shin (2019)	Korea	Various	Various	Performance
*Wang (2019)	UK	Panel Expert	Construction SC	Adoption
*Baharmand and Comes (2019)	USA USA	UNICEF WFP	Humanitarian supply chain	Adoption barriers Logistics
*Wamba and Queiroz (2019)	France Brazil	Not reported	Not reported	Adoption
*Casino et al. (2019)	Greece	Not reported	Agri-food	Traceability
Mann, Potdar, Gajavilli and Chandan (2018)	Canada Australia	Yamana Gold BHP	Mining Industry	Data provenance Transparency Traceability
Korpela et al. (2017)	Finland	Finnish Consortium	Retail Automotive Electronics Aviation Chemical	Digital SCM integration
*Kamble et al. (2019)	India	Not mentioned	Not reported	Adoption Procurement Manufacturing Logistics Distribution
Hackius and Petersen (2017)	Denmark UK USA	IBM &Maersk Everledger Walmart &IBM	International Logistics Pharmaceutical Food Industry	Logistics Traceability Adoption

Source: Author
(*) Theoretical studies with real world applications.

Based on the table 4.6, above, it is possible to identify that most companies that have already adopted the blockchain technology are American. Asia and Europe also have representative companies such as Alibaba and Maersk, respectively. Start-ups represent an interesting portion of the companies that developed projects based on the provenance of goods, especially in pharmaceutical and food industries. Table 4.6 indicates that most of the studies have been interested in analysing traceability issues, followed by adoption of the technology (i.e. implementation), risk management, operational costs, and logistics.

Moreover, the companies which have already deployed blockchain, or have interest to do so, tend to have similar characteristics. These enterprises are often international, with an infrastructure to support developments and investments. They are also companies with multi-echelon supply chain, high volume of production and delivery, which automatically imply higher risks for operations until the final customer. Van Hoek (2019b) points out, in his study, that all the three real cases already had other technological tools, as RFID or barcodes in their supply chain operations, and use the blockchain technology as a complement. This suggests that companies have already invested in other technologies to improve their operations.

This type of company has the capacity to invest in studies and technologies aiming at a better efficiency and competitive advantage in the market. In addition, these companies tend to invest in training for key actors and tend to have a team to monitor the system´s performance. That is one of the reasons why there are only a few real cases of application. However, a successful implementation is capable of spreading the knowledge and the necessity for innovation to medium and small business. It may be utopic to imagine the implementation of blockchain in small and medium-sized companies, nevertheless, there are several incentives from governments for studying and applying ICTs (information and communications technology) in this type of companies. The sooner companies get prepared, the more competitive advantage they will have in the future.

Table 4.7 provides information similar to the one displayed in Table 4.6 but focuses on theoretical studies. Some of them mention companies that have blockchain projects, as example, but do not analyse them. Other publications analyse various sectors as the studies by Hastig and Sodhi (2020), Banerjee (2019) and Montecchi et al. (2019), while others have more than one topic of study (Manupati et al., 2020; Banerjee. 2019; Liu et al., 2019; Saberi et al., 2019).

Among the studies analysed, fourteen did not report companies and study sectors, focusing only on theoretical and conceptual developments in the general supply chain management. Five of these studies have been published in the United States, focusing on sustainability, blockchain adoption barriers in the supply chain, risk management, and transaction security. The remaining studies were published in Asia (India, Taiwan and China, United Arab Emirates) with studies also focusing on sustainability, traceability, and international trade. Europe (Austria, Finland, Denmark and Switzerland) contributes with studies in the areas of sustainability and business strategies.

Table 4.7 Supply chain management theoretical studies based on blockchain technology

Authors	Country	Sector	Topic
Choi, Wen, Sun and Chung (2019)	China	Air Logistics	Risk management
Chang, Chen and Lu (2019)	Taiwan	Not reported	Tracking
Hald and Kinra, (2019)	Denmark	Not reported	Performance
Xu et al. (2019)	USA	Electronics SC	Data Management Information asymmetry
Liu et al. (2019)	China	Manufacturer Retailers	Adoption Risk management
Cole et al. (2019)	UK	Food Industry Transports Pharmaceutical International logistics Wholesalers	Operations Supply Chain
Montecchi et al. (2019)	UK	Fashion Luxury Pharmaceutical Food Industry	Risk Management Provenance Quality
Saberi et al. (2019)	USA	Not reported	Sustainability
Malyavkina et al. (2019)	Russia	Not reported	Implementation
Pervez and Haq (2019)	Pakistan	Logistics Transport	Key performance measures
Min (2019)	USA	Not reported	Risk Management and security
Bose, Raikwar, Mukhopadhyay, Chattopadhyay and Lam (2018)	Singapore	Electronics - Integrated Circuits	Traceability
Al Barghuthi et al. (2018)	United Arab Emirates	Not reported	SC Trade
Mylrea et al. (2018)	USA	Electric Power	Data management Risk Management Security
Banerjee (2018)	India	Distribution	Procurement Ordering Demand supply Manufacturing Logistics
Treiblmaier (2018)	Austria	Not reported	Business Strategy
Santonino III et al. (2018)	France	Aviation	Manufacturing maintenance management
Tian (2016)	Chinese	Food Industry	Traceability - Food safety

(Continued on the next page)

Table 4.7 (Continued)

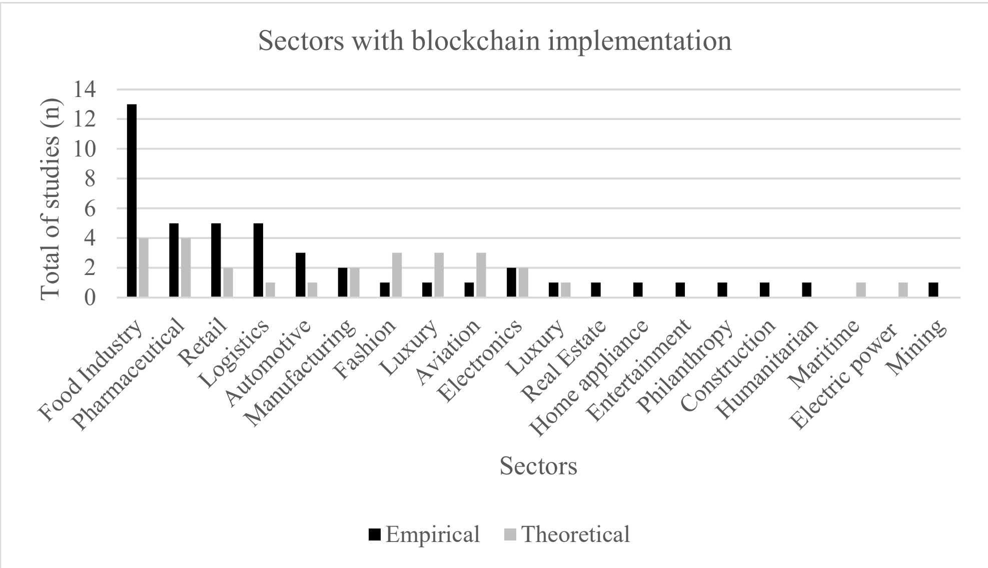
Authors	Country	Sector	Topic
Manupati et al. (2020)	USA Switzerland India	Fashion	Sustainable Performance Operational costs
Zheng et al. (2019)	USA	Aviation	Risk Management
Schmidt and Wagner (2019)	Switzerland	Not reported	Operational costs Governance decisions
Yadav and Singh (2020)	India	Not reported	Sustainability
Choi and Luo (2019)	China	Fashion	Sustainability Data Quality
Jayaraman et al. (2019)	United Arab Emirates	Healthcare	Traceability
Banerjee (2019)	India	Food Industry Automotive SC Digital home Manufacturing Distribution industry	Operational Costs
Lambourdiere and Corbin (2020)	France	Maritime SC	Performance
Khanna, Nand and Bali (2020)	India	Not reported	Tracking
Çolak et al. (2020)	Turkey	Food Industry Pharmaceutical Electric Power Jewerly	Adoption of BT in various sectors
Hastig and Sodhi (2020)	UK	Textile Cobalt Pharmaceutical	Traceability
Bai and Sarkis (2020)	Finland China USA	Not reported	Sustainable Performance
Juma, Shaalan and Kamel (2019)	United Arab Emirates	Not reported	International trade
Abeyratne and Monfared (2016)	UK	Manufacturing	Adoption
Kouhizadeh and Sarkis (2018)	USA	Not reported	Green SCM
Francisco and Swanson (2018)	USA	Not reported	Traceability Adoption

Source: Author

According to the literature review, the food and pharmaceutical industries are the main sectors where blockchain pilots have been tested. These results can be justified by the high value of the products in these sectors and the increasing demand for the provenance of goods by consumers (Francisco and Swanson, 2018). In addition, according to Çolak et al. (2020), pharmaceutical and food industries can explore much better the blockchain technology due to the perishable products contrarily to what happens with the jewellery market.

Figure 4.2 indicates the main sectors where blockchain technology has been deployed and researched over the years. Figure 4.3, in turn, summarises the topics of study related to supply chain management based on blockchain adoption. The implementation/adoption, traceability and logistics represent the major focus of the researchers and practitioners in empirical studies. While traceability, risk management and sustainability are the most studied topics in theoretical studies.

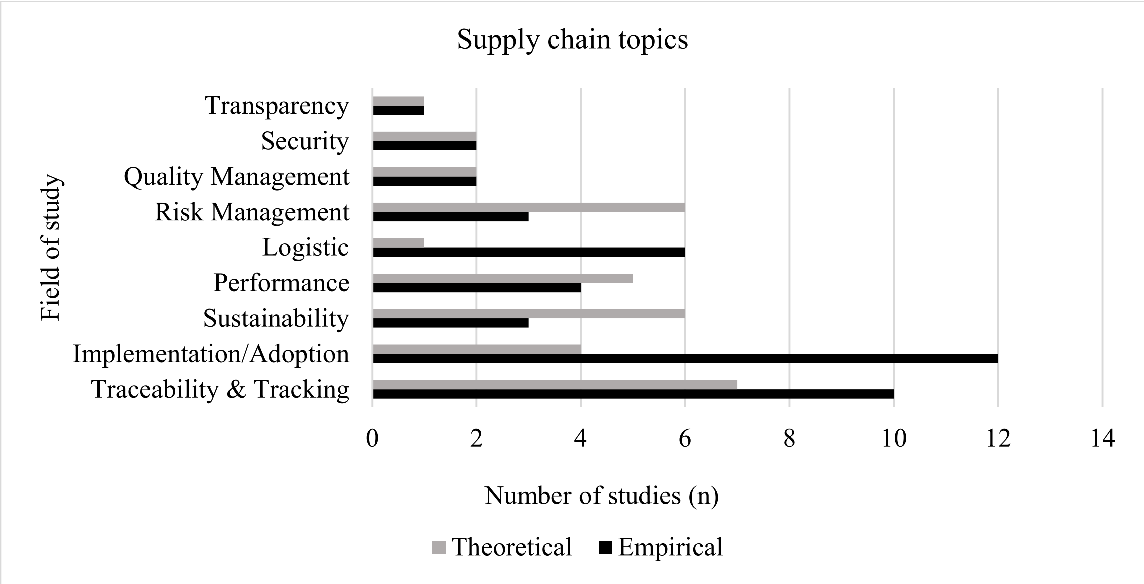
Figure 4.2 Blockchain implementation by sectors



Source: Author

Blockchain technology has been extensively studied in the food industry, as illustrated in Figure 4.2. This sector represents 39% of the empirical studies and accounts for 13 studies in total. It is considered one of the major sectors where blockchain can improve the supply chain management. The reasons behind this are related to food safety, fraud fight, levels of quality, information asymmetry, and the customer experience (Kshetri, 2018; Scuderi et al., 2019).

Figure 4.3 Topics of study of supply chain management based on blockchain adoption



Source: Author

Walmart is the best-known food company which, in 2016, made a project for monitoring mangoes in the United States and meat pork in China. All the sensitive information can be found in the blockchain, like farm details, factory data, temperature, and shipping. This control was only possible due to the combination of RFID tags, sensors, and the use of the blockchain technology to register the critical information. The result reported by Walmart in 2017 indicated that the technology reduces the lead time from days to minutes. Besides this, blockchain has a great capacity for cost-savings, in this sector, because it aids to identify tainted food and engage to remove the products rather than recall the whole production (Kshetri, 2018).

Intel also developed in 2017 a seafood traceability project in order to increase the accuracy of data after fishing. Using IoT, the pilot could gather telemetry information in the blockchain as control of temperature from the fisherman to the restaurant (Kshetri, 2018). Another enterprise involved in the food sector is IBM. They developed a blockchain platform called "Food Trust Chain" which is used by the main agri-food companies (Scuderi et al., 2019).

Scuderi et al. (2019) analyse the importance of blockchain in the "blood oranges" produced in small Italian farms in order to ensure the quality of the products and a fair relationship with big retailers. Tian (2016) and Tian (2017) analyse the importance of the food traceability to guarantee safety and quality products. All the cases above have commonalities. According to these studies, the main implementation reason is related to the food safety. Cases of contamination, frauds and quality control problems can be avoided by traceability. The reduction in the delivered time, paperwork and cost savings in recalls are examples of other benefits of the blockchain in the agri-food sector.

The pharmaceutical industry is the second sector where blockchain has been drawing attention, representing 15% of the empirical studies. The studies focus on the traceability, security, and risk management fields justified by the safety problems and counterfeit products faced by medicine companies (Azzi et al., 2019; Jamil et al., 2019).

The counterfeit of drugs is a huge problem faced by the industry. According to Jamil et al. (2019), almost 30% of the world medicine production is fake. In addition, there are other drugs which do not follow the government regulations making it more difficult to track the distribution, compromising the human health (Jamil et al., 2019).

In the current operations it is a hard to identify which products are fake or not because of the complexity of partners relationships (Jamil et al., 2019). For Hackius and Petersen (2017), blockchain technology has potential to improve patient safety through a transparent supply chain made by manufactures, wholesales and pharmacies. The technology can aid to enhance the traceability of drugs minimizing the health risks and improving the security. Prior studies analysed real cases and developed frameworks in order to increase the efficiency of the pharmaceutical industry.

The start-ups Modum and Ambrosus, two swiss start-ups were analysed by Azzi et al. (2019). Both are specialized in the pharmaceutical supply chain and developed a system which uses the IoT, RFID, blockchain and sensors to track and send information in real time about products in order to guarantee the visibility, quality assurance and safety of products. In the Modum´s system a quality manager can create a monitor criterion to alert the group to any problem. Meanwhile, Ambrosus is tracking components according to product type and clients´ needs (Azzi et al., 2019).

Jamil et al. (2019) developed a framework where doctors, nurses, pharmacists, and patients can manage, access, and share the personal medical data in order to become more transparent and secure. The tests show an increase in the performance of the system, however the system needs to be deployed in a real ambience to validate the results.

Hastig and Sodhi (2020) analyse which are the business requirements and the critical factors that influence a successful blockchain implementation focused on a traceability system in the pharmaceutical industry. The study demonstrates that each actor (suppliers, consumers, and regulators) has specific needs, requiring a system which curbs illegal practices, improves sustainability performance, increases operational efficiency and the supply chain coordination, and, finally, detects market trends. As mentioned in the previous section, the pharmaceutical critical factors confirmed the importance of companies' capabilities, stakeholder's cooperation, blockchain maturity level, leadership, and governance policies.

The pharmaceutical and healthcare industry were also analysed from a theoretical point of view. As in empirical studies, traceability and risk management are also the main topics of the studies. To minimize risks with falsifications and enhance quality of information, the authors propose structures that can guarantee safety and risk reduction (Jayaraman et al., 2019; Montecchi et al., 2019). In addition, Hastig and Sodhi (2020) identified the critical factors for a successful implementation in the pharmaceutical area. The points raised by the authors were previously discussed in section 4.5.

Logistics sector appears in the third position, they are companies that provide various modes of goods transportation, such as freight rail, maritime, air and road.

The giant Danish company called Maersk has been the object of study by several authors (Hackius and Petersen, 2017; Kshetri, 2018) due to the success of the project implemented in 2017. A part of supply chain, this sector is crucial for the competitive market and customer experience, because it integrates several partners and connects to customers. Nowadays, due to the increase of demand for personalized products, the logistics became more complex and uncovers the necessity of transparency and controls for the delivery of goods in the right time and place (Liao and Wang, 2018). International logistics suffers with amounts of paperwork, usually tampered with or copied, robberies of goods and counterfeit products, which impacts in billions of dollars in maritime sector every year (Kshetri, 2018).

Maersk was one of the first companies to adopt blockchain in the international logistics in order to reduce paperwork and to improve the traceability of the goods. The company, responsible for 20% of the market, is a high-profile example of a blockchain pilot successfully implemented in international logistics, which has tracked flowers, fruits, and electric components between ports all around the world (Kshetri, 2018).

Because of Maersk, empirical studies have focused on traceability, implementation/adoption aspects of blockchain technology and operational costs, such as those related with paperwork and shipping time for Maersk's containers.

Retail is another sector that has provided empirical studies. Unlike the other sectors already mentioned, the names of the companies analysed were not disclosed, thus hampering further analysis. The studies are concentrated in the USA and Europe. In Finland, there is a consortium of companies that aim to achieve a disruptive transformation in digital supply chain integrating blockchain technology to their operations. The companies operate in various industrial sectors and they are working together to develop a standard blockchain network integration and collaboration process (Korpela et al., 2017). The main topics of study are blockchain implementation, its integration in the supply chain and performance based on information asymmetry.

Finally, some empirical articles do not mention company names. They analysed not just one sector, but several professionals from various sectors in India, USA, and Brazil in order to identify behavioural factors that could comprehend the adoption of blockchain in the supply chains. These findings were also discussed in section 4.5.

Beyond the huge industries, there are further sectors which apply and analyse the potential of blockchain. Examples of such sectors include the automotive industry, home appliance, electronics, construction, fashion, luxury, philanthropy, humanitarian, and aviation.

Although tourism (entertainment) has rarely been mentioned, with the exception of Liao and Wang (2018), this area could be positively affected by the blockchain technology. There are projects related with car and bike sharing which have removed third parties, as well as examples of tracking and inventory management in hotel services (Cole et al. 2019) which are potentially relevant to this sector.

Further to the above sectors, the fashion industry appears in the theoretical studies as a potential sector to deploy blockchain technology based on sustainable supply chain management. Considered one of the most polluting sectors (Choi and Luo, 2019), the companies are usually located in emerging countries (India, China, Brazil) where the infrastructure and government policies could hinder the sustainable supply chain development.

The authors that have studied this sector have proposed theoretical models that can monitor the performance of the fashion industry (carbon emissions, operations costs), and analyse how data quality can enhance the sustainability of supply chains by improving the traceability and provenance of production (Manupati et al., 2020; Choi and Luo, 2019; Montecchi et al., 2019).

The areas of manufacturing, retail and logistics sought to understand, through the theory of conditional value at risk (Mean-CVaR), the level of risk aversion behaviour in manufacturing and retail decision-making (Liu et al., 2019). Bose et al. (2018) analyse the requirements and challenges of the adoption of blockchain technology. While Pervez and Haq (2019) propose performance indicators in the logistics area.

The other studies, not discussed above, propose other sectors where blockchain technology also has potential to be useful. These sectors include the electric power industry, the maritime logistics, distribution, electronic, cobalt and luxury markets (diamonds, wines). Although the economic sectors are varied, traceability remains one of the main topics of study related to the blockchain implementation in the supply chain.

4.7 Sustainable supply chain and the blockchain capabilities – triple bottom line

Sustainability is getting the attention of governments, industries, and customers concerned with the socio-environmental consequences of the rise of production, like pollution, increase of waste, diseases, and deteriorating work conditions. These issues have been hard to manage and control because of the complexity of the supply chain relationships and operations. Furthermore, measuring and analysing the indicators of sustainability are real challenges for the companies interested.

There are many studies which focus on the sustainability of the supply chain, green products and reverse logistics (Yadav and Singh, 2020; Choi and Luo, 2019; Nayak and Dhaigude, 2019; Saberi et al, 2019; Kouhizadeh and Sarkis, 2018; Kshetri, 2018). In these studies, quality of products, unethical attitudes, counterfeit, and carbon emissions are some of the problems faced by the global supply chain. Due to the quantity of upstream and downstream partners, it is almost impossible to ensure that every partner is committed to the human rights, the quality of goods, and sustainable resources.

Some companies like Apple (Yadav and Singh, 2020) and Chipotle Mexican Grill (Saberi et al., 2019) had problems with work conditions and spoiled food, respectively. Each company faced legal problems. In Chipotle´s case, many people got sick. If one of these companies already had a transparent system capable of managing the quality of the products, transportation, suppliers, and, at the same time, measuring the use of natural resources, some problems could have been avoided.

Blockchain has drawn the attention of experts and researchers because of its potential to improve the sustainability of supply chains (Saberi et al., 2019; Kshetri, 2018). Sustainability is defined by the triple-bottom-line concept which comprises the social, environmental, and financial goals of a company (Saberi et al., 2019).

The traceability is the principal feature which makes blockchain the key to solve sustainability challenges. The possibility to track the flow of goods provides a transparent and trustworthy system for identifying the provenance of materials. Another attribute of the blockchain is the use of smart contracts. It has a significant role in the sustainable indicators because it can be programmed to monitor carbon emissions, to deal with suppliers, to reduce costs, and to enhance trust among partners (Bai and Sarkis, 2020).

Cole et al. (2019) and Kshetri (2018) argue that sustainability is the central reason behind the blockchain implementation. There are already companies committed to making their supply chain more transparent, ethical, and sustainable in partnership with start-ups, like the company Provenance, which provides technology and infrastructure to achieve these objectives.

Nevertheless, the studies published relating blockchain and sustainable supply chain are mostly theoretical, based on the characteristics of the technology, these studies analyse the benefits and draw frameworks for applying this technology. Thus, there is a lack of empirical studies which prove the potential of blockchain to contribute to the sustainability of companies. Fortunately, an expressive number of companies and start-ups have already applied this technology in their operations and presented the results (see Table 4.8).

The studies point out three main sectors in which the technology can help the sustainability of supply chains. Pharmaceuticals (Jamil et al.,2019), Agro-Industry (Kshetri, 2018; Tian 2017; Tian, 2016) and Fashion and Luxury Retail (Manupati et al., 2020; Choi and Luo, 2019; Kshetri, 2018). Pharmaceuticals face a lot of problems with counterfeits drugs (Hastig and Sodhi, 2020), handling sensitive logistics because each medicine needs a specific temperature, time, and way of transportation. Every year the companies suffer important economic losses, furthermore, there is a health problem in case someone is treated with fake or damaged drug.

Table 4.8 Business cases of blockchain application in the supply chain operations

Company	Sector	Case
Provenance Kshetri, 2018	Agro-Industry	A project to enable traceability in the fish industry using mobile phones during 6 months in 2016, Indonesia.
Walmart Kshetri, 2018; Bai and Sarkis, 2020; Liu et al., 2019		A pilot to track the origin of pork in China and its production in the United States.
Hyperledger Sawtooth Banerjee, 2018		A framework where consumers can see all the tracking seafood information on their mobile phone. An IoT sensor monitors the location, temperature, humidity, motion, and shock, among others.
Alibaba Kshetri and Loukoianova, 2019		Development of a blockchain-based Food trust framework to track and monitor food products in order to fight against frauds.
Everledger Kshetri, 2018; Banerjee, 2018.	Luxury	A solution to track diamonds and eliminate the flow of diamonds mined in conflict zones, in Sierra Leone.
Luxchain Montecchi et al., 2019		The start-up offers the option to assure luxury products based on blockchain and artificial intelligence. The solution is based on digital assets with products´ brand, collection, material, ownership records and flow of goods.
Bordeaux Wine Bank ; Catina Volpone Vineyard Montecchi et al., 2019		Bordeaux Wine Bank developed a quality label system which guarantees the quality of the wine. The label contains information about the original wooden case; chateau documentation; professional storage; the total control and monitorization of temperature and humidity; annual certification.
Novartis Montecchi et al., 2019	Pharmaceutical	Identify counterfeit drugs and track temperature in real-time tracking system, providing the integrity of drugs during the operations.
BitGive Foundantion Jamil et al., 2019	Philanthropy	A Non-profit organization that uses distributed ledger to track and make sure the money destination is for the right causes.
IBM & Energy Blockchain Labs Inc Saberi et al., 2019	Environmental Sustainability	Pilot in order to help organizations to track and measure carbon footprint.
Martine Jarlgaard Montecchi et al., 2019	Sustainable Fashion Industry	Project which offers to customers a fully traceable garment using blockchain technology by Provenance app. Sustainable alpaca fleece from United Kingdom (UK) can be tracked and assured the product origin.

Source: Author

The agro-industry is one of the first sectors where the blockchain was explored due to the possibility to track the continental operations and improve the quality of goods. Large companies like Walmart have a pilot to track the Chinese pork to the United States and the start-up Hyperledger made a pilot to track fish using mobile phones, both aiming to reduce time, costs with paperwork and to increase the quality of the products management at all the stages of the operations. If something happens with a batch, it is possible to identify the problem and call those responsible for it.

The fashion industry is one of the most polluting sectors in the world characterized by uncertainty in demand and production of pollutants (Choi and Luo, 2019). Besides this, the sector also faces problems with human rights and safe work practices in the emergent markets. The technology has a great potential to transform the supply chain with the provenance of goods, avoiding partners that use forbidden chemicals in the production or violate human rights. According to Banerjee (2018), companies must trace their materials to protect their reputation, ensure quality and provide information to their customers.

In addition, governments started to impose environmental taxes in order to control pollutants use (Choi and Luo, 2019) and customers force more transparent information about the origin of materials and work practices. In the United Kingdom, there are fashion companies already working with solutions to achieve more transparent operations (Choi et al., 2019).

The traceability can guarantee the quality of raw materials, ethical ways of production, avoid slavery practices and improve the work conditions, choosing materials and partners committed with their sustainable company goals. This is the case for example of the company Everledger that made a project to track diamonds to ensure the origin and to eliminate goods mined in Sierra Leone, known by its conflicts.

4.7.1 Social impact

Blockchain can improve the social performance of companies with projects oriented to social sustainability claims (Kshetri, 2018). The technology may contribute to social supply chain sustainability due to the immutable information recorded in the nodes (Saberi et al., 2019).

Blockchain technology can be programmed to track raw materials with ecological and ethical standards (Westerkamp et al., 2018) enhancing the relationship only with responsible suppliers in an environmental and social framework (Liao and Wang, 2018). The technology can help to identify unethical companies (Cole et al., 2019; Nayak and Dhaigude, 2019; Saberi et al., 2019) and counterfeit products (Hastig and Sodhi, 2020; Manupati et al., 2020; Cole et al., 2019; Jamil et al., 2019; Saberi et al., 2019) since all the information can only be recorded by authorised partners (Saberi et al.,2019).

According to Saberi et al. (2019), despite of the importance of social performance, it is less developed than environmental metrics because it is difficult to measure and depends on the company's cultural context, involving many subjectivities. For this reason, some companies can hide or not share critical and personal information, compromising the transparency of the operations. Despite of that, there are companies which tested the use of blockchain in the charity logistics and fashion supply chain and both have proved to be a way to enhance the efficiency and the benefits in the social welfare (Choi and Luo, 2019; Li et al., 2018).

Charity companies suffer with a lack of information about their charitable proposals and the destination of the money. Blockchain can provide transparency linking the projects with their outcomes (Cole et al., 2019). BitGive Foundation is a blockchain charity firm that provides secure and transparent information for donors (Jamil et al., 2019). Tracking all the stages, the donations are followed and guaranteed to go to the right destination, enhancing the credibility of the operations and trust among charities and donors.

The fashion industry suffers with social challenges too. According to Choi and Luo (2019), the quality of data is one of the problems that impacts the social welfare. The blockchain can store critical information raising the quality of the data and helping managers to make decisions, like forecasting demand, setting the level of production and so on (Choi and Luo, 2019).

4.7.2 Environmental impact

For most people, the sustainability word immediately refers to the environmental impact. That is, the impact that a massive production and consumption can have on the environment and on the natural resources. Saberi et al. (2019) argue that blockchain has more potential to improve environmental issues than social ones because the environmental performance can be measured and monitored in the system. Over the years, metrics have been proposed by researchers and practitioners in order to measure the efficiency of the companies and to monitor the sustainable performance. Water and energy consumption, carbon emissions, waste management and the use of dangerous substances are examples of indicators (Saberi et al., 2019).

Blockchain can guarantee which products are really eco-friendly (Saberi et al., 2019) because the transparency of the information provides the ability to check the provenance of products (Schmidt and Wagner, 2019; Banerjee, 2018; Kshetri, 2018) and track goods (Westerkamp et al., 2018) with ecological and ethical standards. One example is the endorsement of the forestry certification programme which traces the provenance of certified forests all over the world using blockchain (Saberi et al., 2019).

The carbon emission tracking is another potential of the blockchain (Hastig and Sodhi, 2020; Manupati et al., 2020; Nayak and Dhaigude, 2019; Saberi et al.,2019; Kouhizadeh and Sarkis, 2018). Manupati et al. (2020) propose the use of blockchain for monitoring supply chain performance and the partners' level of carbon emission in order to reach sustainable operations minimizing the transaction costs and the emissions.

The supply chain managers can monitor the carbon emissions by smart contracts pre-programmed to track all data. According to the company policies and external regulations, the contract can trigger a monitorization of carbon emissions, when the level of emissions achieves the acceptable levels. The managers can decide to minimise and optimise the operations based on this data (Manupati et al., 2020). IBM, in partnership with Energy Blockchain Labs Inc., made a pilot in China by which companies can track and measure their carbon footprint. The companies can develop and trade carbon quotas selling or buying credits from companies with low emissions level (Saberi et al., 2019).

The Reverse Logistic (Reuse, Recycling) is another environmental example which can be aided by the blockchain (Bai and Sarkis, 2020; Nayak and Dhaigude, 2019; Saberi et al., 2019; Kouhizadeh and Sarkis, 2018). There are programmes which stimulate people to recycle based on financial returns, such as in Northern Europe. Social Plastic and RecycleToCoin are examples of projects based on blockchain technology which track plastic in order to reduce waste and turn it into money for people who recycle (Saberi et al., 2019).

Finally, the blockchain can improve the waste management (Bai and Sarkis, 2020; Nayak and Dhaigude, 2019; Saberi, et al.,2019; Kouhizadeh and Sarkis, 2018). The quality of data increases the decision making based on demand and purchase information avoiding stock waste (Longo et al., 2019) and leftovers, like in the fashion industry. In the Food industry, it is possible to reduce the rework and recall of the goods dropping the consumption and greenhouse gas emissions (Saberi et al., 2019).

4.7.3 Economic impact

One of the problems faced by the pharmaceutical industry, as previously mentioned, is the counterfeit of drugs (Hastig and Sodhi, 2020). This challenge affects the social and economic dimensions of the sector. The blockchain has been used to enhance the traceability in order to avoid frauds controlling and monitoring the medicine operations (Schmidt and Wagner, 2019).

The financial investments in blockchain is a daily concern of the managers and companies interested in the implementation. Due to the initial stage of the technology there are no real cases indicating the time of the return of investments. This concern is also visible in the sustainable practices because of the difficulty in measuring the investments in green practices and their returns.

Perboli et al. (2018) prove, by undertaking empirical analysis, that the costs of implementing blockchain are very sustainable compared to the benefits presented after its deployment. These benefits include inbound efficiency, reduction of waste of products and reduction of the costs with recalls. The authors also suggest that the savings reached by the implementation can be used to pay a contribution to the employees to maintain them committed. Another advantage to the sustainable finances is the improvement of data quality which affects the orders, procurement and distribution, reducing costs with stocks and avoiding waste produced by spoiled goods (Bai and Sarkis, 2020; Longo et al., 2019).

A different result was presented by Choi and Luo (2019) related to sustainability in the fashion supply chain. In emergent markets such as India, China and Brazil, the adoption of blockchain technology increases the quality of data and the social welfare, however, due to the operational costs to implement and maintain the system, the supply chain profits can reduce. To solve this issue, the authors propose that governments become a technology sponsor to help companies improve their infrastructure and the creation of an environmental tax waiving scheme to increase sustainability and, at the same time, to increase the profits in emergent markets.

Manupati et al. (2020) developed a blockchain framework to minimise operational costs and carbon emissions in a multi-echelon including suppliers, manufacturers, and distributors. The approach includes lead time restrictions, carbon footprint matters and considers raw materials and intermediate products in the final product emission. The tests show that the blockchain framework enables environmentally conscious decisions because it allows analysing the operational expenses and carbon emissions, balancing economic and environmental settings (Manupati et al., 2020).

The Blockchain has potential to address the major concerns related to the triple bottom-line. The companies will have the opportunity to choose upstream and downstream partners according to their sustainable policies and protect themselves against counterfeit and help to maintain the quality of products and labour practices. Despite the fact that the environmental element draws more attention for the society and is the most developed of the three, the social and financial elements deal with other critical measures in the global supply chain. The researchers and practitioners will continue to develop ways of using blockchain for improving the sustainability and decision makers must analyse what are the companies´ needs.

4.8 Supply chain performance – the measures

Key Performance Indicators (KPIs) are a well-known instrument to analyse areas in the companies in order to improve the competitive advantages, reduce operation costs, improve customers´ experience and so on. The indicators in the supply chain area have become one of the major tools for companies to analyse their performance and each company has its own indicators based on their business activities and operations.

The blockchain technology enables an effective measurement of results and performance of key supply chain processes (Kshetri, 2018). Auditable, it can promote new sustainable metrics based on the traceability and transparency (Bai and Sarkis, 2020). Although, technology helps evaluate the performance, Lambourdiere and Corbin (2020) argue that the technology does not work by itself, all actors need to be committed with the right information-sharing, coordination, and visibility of the supply chain. These activities are the real reason why efficiency rises.

The SLR highlights some studies which address the value of KPIs in the supply chain (Bai and Sarkis, 2020; Lambourdiere and Corbin, 2020; Manupati et al., 2020; Jamil et al.,2019; Kim and Shin, 2019; Sheel and Nath, 2019; Kouhizadeh and Sarkis, 2018; Kshetri, 2018) after the blockchain implementation. These studies point out different indicators based on the business sectors and the aims of a company. According to Kshetri (2018), the measurement of Supply Chain Management performance is often addressed by objectives such as quality, speed, dependability, cost, flexibility, and sustainability. Thus, the company needs to analyse the blockchain benefits in their operations and, to develop indicators which provide information for comparing the previous and actual performances.

Nevertheless, the early stage of the blockchain development makes it difficult to propose performance indicators, as there are few case studies and companies that have already implemented the technology (e.g. Walmart, Maersk). Most of the evaluations mentioned in the studies focus in the financial and operational performance due to the difficulty to predict objectives before the implementation (Bai and Sarkis, 2020).

Bai and Sarkis (2020) argue that to apply the usual methods to evaluate the technology could be inappropriate due to the amount of data provided by multiple stakeholders, the lack of knowledge about transparency and traceability processes, barriers and benefit analysis made by the company. In addition, there are no developed tools for blockchain selection, evaluation, and quantification in practice and academia, which can compromise the supply chain decisions and corroborate for uncertainties (Bai and Sarkis, 2020).

Perboli et al. (2018) emphasise the need to develop a strategic level plan for blockchain implementation in order to create a high longevity project, because only 8% of projects seem to succeed while the other 92% fail due to lack of solutions at strategic level. The authors argue that the business process model and the technology design process ought to be preceded by a definition of the company´s strategy such that the employees, financial and operational objectives could be defined by KPIs. Afterwards, the indicators are related to the aims of the company and following the implementation, the improvements are measured.

The indicators could depend on the sectors under analysis and their goals. For instance, for measuring supply chain performance after the blockchain, an appraisal performance model was proposed by Bai and Sarkis (2020) in order to reduce sustainability risks and build competitiveness in the global supply chain.

Bai and Sarkis (2020) discuss that transparency is a critical characteristic to reach a sustainable supply chain management. Therefore, to evaluate the level of transparency and sustainability three indicators were proposed. First, the range of transparency. This indicator measures the level of partner participation, scope of the operations, social and environmental information during the operations. Secondly, product transparency. The tracking of raw materials can provide sustainable information such as recycling and carbon emissions. Third, participant transparency. All the partners can be analysed based on their operations and sustainable practices (Bai and Sarkis, 2020).

Table 4.9 indicates some KPIs suggested by authors to use after the blockchain implementation. They are metrics to use in addition to the indicators already known as inventory costs (Longo et al., 2019; Manupati et al., 2019), orders fill rate (Kim and Shin, 2019; Longo et al., 2019), growth in sales (Kim and Shin, 2019) and so on.

Table 4.9 Blockchain-based supply chain indicators

Indicator	Definition	Measure	Study
Transaction response time	The period of time a transaction takes to request and respond from a blockchain platform.	The time of process transactions.	Jamil et al., 2019
Transaction Throughput	The speed of the system	The rate of speed by transaction per second	Jamil et al., 2019; Bai and Sarkis, 2020
Transaction Latency	Time taken for a transaction to be used in the network	The total time spend in the submission and the available results in the network	Jamil et al., 2019
Resource Utilization	The process of utilization of resources while processing transactions´ request and response.	Check the resources utilized by computers, memory, energy in a defined time of period.	Jamil et al., 2019
Cost	Reduction of operational costs	Reduction of paperwork, compliance costs, constrains low quality and counterfeit products	Kshetri, 2018; Li el al., 2018; Barghuthi, et al., 2018; Longo et al., 2019; Kim and Shin, 2019
Operational speed	Speed of the operations such as order, transportation	Reduction of interactions and communications.	Kshetri, 2018; Li el al., 2018; Barghuthi et al., 2018; Sheel and Nath, 2019; Kim and Shin, 2019
Sustainability	Sustainable practices in the supply chain operations	Carbon emissions levels, reduction of waste and amount of recycling.	Barghuthi, et al., 2018; Manupati et al.,2020;

Source: Author

Kouhizadeh and Sarkis (2018) propose a vendor environmental performance for measuring green values. The same occurred with supplier indicators avoiding critical partners. Some companies such as Dell, IBM and PepsiCo have training programs which increase the quality of suppliers and the possibility to measure their development after the trainings.

In the medical sector, Jamil et al. (2019) propose a drug supply chain management in a smart hospital. They undertook a proof of concept (practical model that can prove a concept) to analyse the ability of blockchain to increase performance and test situations to measure performance. The framework with 500 queries, at the same time, proves that blockchain enhances performance in terms of throughput and minimises latency with less resources.

In the retail, Longo et al. (2019) made an experimental study with wholesalers and big-box retailers to explore the potential of the blockchain implementation in this area. For analysing the supply chain performance, the authors applied the following KPIs: "orders´ fill rate, the on-hand inventory, the total inventory costs and the average inventory cost per day and per single item, revenues, costs and net profit" (Longo et al., 2019: 61). Over the tests, the experimental model identified that all the indicators improved with the use of blockchain technology, nevertheless, due to the high costs in implementing and maintaining the blockchain technology, the average profit margin did not present a considerable variation. Even with low variance in the profits, Longo et al. (2019) prove that companies with blockchain can perform better and increase the trust among partners.

Ultimately, in the food supply chain, Casino et al. (2019) propose a model based on traceability and smart contracts using as performance metrics the financial and operational efficiency, the responsiveness (measured by customer complaints and response time), food quality (measured by process and product quality), trust according to the accountability, immutability, and verifiability of information, the level of data transparency, security, privacy and resiliency (measured by the amount of business and continuity).

Chapter 5. FUTURE RESEARCH DIRECTIONS

The SLR pointed out gaps into the practical and real benefits of blockchain and in discussing how it can be applied in multiple sectors of the economy. Based on these gaps and suggestions identified in the literature, this thesis proposes some paths for future studies, divided by the themes discussed throughout this document. It was observed that empirical blockchain technology studies based on supply chain management are still insufficient and this directly affects the adoption of blockchain in this area. In order to promote new studies and stimulate practitioners, a table with gaps and opportunities was developed (Table 5.1).

Table 5.1 Agenda for future research

Theme	Research Gap	Future research
Adoption	Behaviour of the stakeholders	To analyse which factors most influence the supply chain actors in different countries in order to understand the internal and external effects in their behaviour.
	IT Infrastructure	To analyse the level of IT infrastructure of the country and the local industry. How does it affect the actors perceived use?
	SMEs	To analyse the benefits and challenges of blockchain adoption in SMEs. How can SMEs make the implementation feasible and how will they be impacted by large industries?
	Implementation	To evaluate a longitudinal study in a real case to identify the successful and failed paths in the industries adoption.
Sustainability	Triple bottom line relationship	To analyse the relationship between the environmental, social, and financial pillars using the blockchain technology.
	Social sustainability	How can blockchain trace the social sustainability and guarantee the partners ´contributions, especially in critical areas?
	SMEs sustainability	What is the sustainable impact of the blockchain in the SMEs companies? To examine the role of governments, the community, and the capacity of the adoption of this technology in small and medium enterprises.
Implementation	Supply chain integration	How can it be possible to connect downstream and upstream partners, overcome their differences in order to reach a full potential blockchain technology system?
	Blockchain Design	To understand the global supply chain principal needs for developing an international standard of the system to connect legacy ledgers with the blockchain.

Source: Author

Besides all the studies based on blockchain architecture, developments and, IT improvements it is important to understand which factors may influence the supply chain actors globally. Due to the differences in culture and government policies, it is necessary to analyse more than one nation to understand how the adoption can be easily accepted, the technical and behavioural challenges according to the nation and the type of industry. For instance, no study mentioned the factors which influence the Asian and the European market. European countries, although belonging to the Europe Zone, have different levels of infrastructure and technologies. The same occurs with the incentives of the government.

The analysis of common factors among these countries, of what industries need, of what motivates the stakeholders and the public investments may shed light on the adoption challenges and will help to develop a standard system to enhance the European competitive advantage over other markets. However, one of the biggest challenges to integrate the blockchain amidst partners is the stakeholder's contribution. As mentioned in this study, the reason lies in the lack of trust and commitment among actors. It is important to analyse how this challenge can be overcome and what are the benefits after that. To integrate and provide the same information for all participants it is necessary to use a common language to connect the partners.

Finally, the sustainability of the supply chain has become an issue of great interest nowadays. Nevertheless, Saberi et al. (2019) says that the social indicator is the least studied and evaluated measure in the sustainable supply chain. There are no academia and practitioners' cases with deep analysis of this topic, thus it is another future opportunity to understand what are the challenges, constrains and benefits for this control to the society and how the blockchain can guarantee that critical companies insert the real information and practice what they publish in the network.

Chapter 6. IMPLICATIONS

6.1 Managerial implications

This study represents an opportunity to promote understanding about the blockchain technology and its impacts on the supply chain management. It sheds light on some issues mentioned by managers as limitations to the adoption of blockchain in the supply chain management, on the benefits and risks of adoption, on the factors that restrict its implementation and on the different ways blockchain can improve a company's sustainability. Moreover, it identified the food and pharmaceutical industry as the largest sectors with the potential to adopt the blockchain technology. In this way, managers can, from the knowledge acquired, analyse whether their company has the support and structure necessary to adopt the blockchain and whether this technology will be able to solve problems in their operations, as well as add value to their products.

6.2 Theoretical implications

Based on future research, academicians will be able to deepen research regarding the adoption of blockchain in the supply chain.

Researchers have a great field to develop business models and theories that help reduce the lack of knowledge of professionals. Furthermore, this theme still needs empirical studies investigating if blockchain has an important role in improving supply chain management and its performance. Researchers can monitor the development and implementation of a blockchain pilot for a specific sector in order to identify which factors are successful and critical during implementation.

Despite the initial stage of applications, academia still lacks studies which evaluate blockchain after its adoption on supply chain management. This study identifies that large companies are the biggest investors in blockchain technology, however, it will not be long before small and medium companies are encouraged to adopt the technology. Researchers should pay particular attention in the near future at blockchain adoption from the perspective of the small and medium-sized companies.

Chapter 7. CONCLUSIONS AND LIMITATIONS

This study aimed to analyse how blockchain can enhance the supply chain management. For this purpose, a systematic literature review approach was adopted using only peer-reviewed journals, conference papers and book chapters extracted from the Web of Science Core Collection.

Only papers published until February 2020 and that identified the main benefits and risks of blockchain implementation into supply chain, the factors that help or hinder the technology´s adoption were analysed. Furthermore, this study sought to identify which main sectors have already adopted or are considering implementing blockchain in their supply chains, its potential for sustainability and which performance indicators have been most commonly used to evaluate the performance of the supply chain after the blockchain technology adoption. Finally, the authors made suggestions for future research based on what is known about the blockchain implementation into supply chain management.

The review returned 127 articles, of which 67 were classified as relevant to answer the research questions. The study indicates an increase in the number of publications between 2016 and

2020 being the USA, China, and India the countries with the most published studies related to blockchain technology in the supply chain. Based on the research questions, this study identified that the traceability and transparency are the main benefits of the blockchain technology in the supply chain management. In turn, the risks of blockchain implementation relate with the scalability and the interoperability of the system.

The factors which help and hinder the blockchain adoption are the perception of usefulness of actors and the role of the top management. Nevertheless, the adoption behaviours will depend on the culture, infrastructure, facilitation conditions and country´s government policies.

Our findings also indicate that, despite the initial stage of the blockchain technology, there are highly representative companies in the global market that have adopted the blockchain technology (pilots) in their supply chain in order to track their operations, monitor the quality of products, improve data transparency and enhance sustainability of the supply chain. These are mostly American, Chinese and European companies in the food and pharmaceutical sector that have value-added and highly perishable products that need to better control the multi-echelon network in order to reduce risks of production and delivery of goods. Besides the above sectors, the fashion industry emerges as a sector where blockchain can improve the triple bottom line, monitoring carbon emissions, avoiding slavery practices and guaranteeing good conditions of labour.

Blockchain has proved to be a potential technological tool for improving transparency and for enhancing supply chain performance. Although the majority of blockchain pilots are in large companies in the food, pharmaceutical and logistics sectors, it will not be long before small and medium-sized enterprises are affected, mainly in the agricultural sector and related to coffee and soybean production. This review suggests that companies that start preparing the implementation of the blockchain technology now will be better prepared to address huge increases in demand and become more competitive.

Despite this study being one of the first to gather key information about blockchain technology with focus on supply chain management, it also has its limitations. This study did not consider information on technical reports, newspapers, or websites. The systematic literature review used a single multidisciplinary database, meaning that, possibly, relevant articles may not have been considered. Another limitation is the use of few keywords. It is possible that specific papers were missed because they did not contain the keywords “blockchain” and “supply chain” or “logistics” in the title.

Chapter 8. REFERENCES

Abeyratne, S.A. & Monfared, R. P. (2016). Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger. *International Journal of Research in Engineering and Technology*, *05*(09), 1–10.

Al Barghuthi, N. B., Mohamed, H. J., & Said, H. E. (2018). Blockchain in Supply Chain Trading. In *2018 Fifth HCT Information Technology Trends (ITT)*, IEEE, 336-341.

Azzi, R., Chamoun, R. K., & Sokhn, M. (2019). The power of a blockchain-based supply chain. *Computers & industrial engineering*, *135*, 582-592.

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research*, *58*(7), 2142-2162.

Baharmand, H., & Comes, T. (2019). Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-based Smart Contracts. *IFAC-PapersOnLine*, *52*(13), 12-17.

Banerjee, A. (2018). Blockchain technology: supply chain insights from ERP. In Raj, P. & Deka, G.C. (eds.), *Advances in computers*, Vol. 111, Elsevier, 69-98.

Banerjee, A. (2019). Blockchain with IOT: Applications and use cases for a new paradigm of supply chain driving efficiency and cost. In Kim, S., Deka, G.C. & Zhang, P. (eds.), *Advances in Computers*, Vol. 115, Elsevier, 259-292.

Bettín-Díaz, R., Rojas, A. E., & Mejía-Moncayo, C. (2018). Methodological approach to the definition of a blockchain system for the food industry supply chain traceability. In *International Conference on Computational Science and Its Applications*, Melbourne, Australia, July 2-5, 2018, Springer, 19-33.

Bose, S., Raikwar, M., Mukhopadhyay, D., Chattopadhyay, A., & Lam, K. Y. (2018). Blic: A blockchain protocol for manufacturing and supply chain management of ics. In *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, Canada, July, IEEE, 1326-1335.

Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. *Handbook of evidence-based management: Companies, classrooms and research*, 112-129.

Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., & Rachaniotis, N. P. (2019). Modeling food supply chain traceability based on blockchain technology. *IFAC-PapersOnLine*, *52*(13), 2728-2733. Available at: www.sciencedirect.com/science/article/pii/S2405896319316088 (accessed on: 30.09.2019).

Chang, S. E., Chen, Y. C., & Lu, M. F. (2019). Supply chain re-engineering using blockchain technology: A case of smart contract-based tracking process. *Technological Forecasting and Social Change*, *144*, 1-11.

Chen, S., Shi, R., Ren, Z., Yan, J., Shi, Y., & Zhang, J. (2017). A blockchain-based supply chain quality management framework. In *2017 IEEE 14th International Conference on e-Business Engineering (ICEBE)*, Shanghai, November, IEEE, 172-176.

Choi, T. M., & Luo, S. (2019). Data quality challenges for sustainable fashion supply chain operations in emerging markets: Roles of blockchain, government sponsors and environment taxes. *Transportation Research Part E: Logistics and Transportation Review*, *131*, 139-152.

Choi, T. M., Wen, X., Sun, X., & Chung, S. H. (2019). The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era. *Transportation Research Part E: Logistics and Transportation Review*, *127*, 178-191.

Çolak, M., Kaya, İ., Özkan, B., Budak, A., & Karaşan, A. (2020). A multi-criteria evaluation model based on hesitant fuzzy sets for blockchain technology in supply chain management. *Journal of Intelligent & Fuzzy Systems*, *38*(1), 935-946.

Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: implications for operations and supply chain management. *Supply Chain Management: An International Journal*, *24*(4), 469-483.

Francisco, K., & Swanson, D. (2018). The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. *Logistics*, *2*(1), 2. Available at: www.mdpi.com/2305-6290/2/1/2 (accessed on: 30.09.2019).

Fu, Y., & Zhu, J. (2019). Big production enterprise supply chain endogenous risk management based on blockchain. *IEEE Access*, *7*, 15310-15319. Available at: https://ieeexplore.ieee.org/abstract/document/8626088 (accessed on 30.09.2019).

Gurtu, A., & Johny, J. (2019). Potential of blockchain technology in supply chain management: a literature review. *International Journal of Physical Distribution & Logistics Management*. 49(9), 881-900

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),* Berlin, October, 3-18.

Hald, K.S. and Kinra, A. (2019). How the blockchain enables and constrains supply chain performance. *International Journal of Physical Distribution & Logistics Management*, 49(4), 376-397.

Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. *Production and Operations Management*, *29*(4), 935-954.

Jamil, F., Hang, L., Kim, K., & Kim, D. (2019). A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital. *Electronics*, *8*(5), 505. Available at: www.mdpi.com/2079-9292/8/5/505 (accessed on: 30.09.2019).

Jayaraman, R., Salah, K., & King, N. (2019). Improving Opportunities in healthcare supply chain processes via the Internet of Things and Blockchain Technology. *International Journal of Healthcare Information Systems and Informatics (IJHISI)*, *14*(2), 49-65.

Juma, H., Shaalan, K., & Kamel, I. (2019). A survey on using blockchain in trade supply chain solutions. *IEEE Access*, *7*, 184115-184132. Available at: https://ieeexplore.ieee.org/abstract/document/8936386 (accessed on: 30.09.2019).

Kamble, S., Gunasekaran, A., & Arha, H. (2019). Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009-2033.

Keivanpour, S., Ramudhin, A., & Kadi, D. A. (2018). Towards the Blockchain-Enabled Offshore Wind Energy Supply Chain. In *Proceedings of the Future Technologies Conference*, Canada, November, Springer, Cham, 904-913.

Khanna, T., Nand, P., & Bali, V. (2020). Permissioned Blockchain Model for End-to-End Trackability in Supply Chain Management. *International Journal of e-Collaboration (IJeC)*, *16*(1), 45-58.

Kim, H. M., & Laskowski, M. (2018). Toward an ontology-driven blockchain design for supply-chain provenance. *Intelligent Systems in Accounting, Finance and Management*, *25*(1), 18-27.

Kim, J. S., & Shin, N. (2019). The impact of blockchain technology application on supply chain partnership and performance. *Sustainability*, *11*(21), 6181. Available at: www.mdpi.com/2071-1050/11/21/6181 (accessed on: 06.01.2020).

Korpela, K., Hallikas, J., & Dahlberg, T. (2017). Digital Supply Chain Transformation toward Blockchain Integration. In *Proceedings of the 50th Hawaii International Conference on System Sciences (2017)*, Hawaii, January, 4182–4191.

Kouhizadeh, M., & Sarkis, J. (2018). Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability*, *10*(10), 3652. Available at: https://www.mdpi.com/2071-1050/10/10/3652 (accessed on: 26.02.2020).

Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, *39*, 80–89.

Kshetri, N., & Loukoianova, E. (2019). Blockchain adoption in supply chain networks in Asia. *IT Professional*, *21*(1), 11-15.

Lambourdiere, E., & Corbin, E. (2020). Blockchain and maritime supply-chain performance: dynamic capabilities perspective. *Worldwide Hospitality and Tourism Themes*, 12(1), 24-34.

Lanko, A., Vatin, N., & Kaklauskas, A. (2018). Application of RFID combined with blockchain technology in logistics of construction materials. *In Matec Web of conferences*, EDP Sciences., 170, p. 03032.

Liao, D., & Wang, X. (2018). Applications of Blockchain Technology to Logistics Management in Integrated Casinos and Entertainment. *Informatics*, *5*(4), 44. Available at: www.mdpi.com/2227-9709/5/4/44 (accessed on: 30.09.2019).

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*, *62*(10), e1-e34.

Li, J., Qu, F., Tu, X., Fu, T., Guo, J., & Zhu, J. (2018). Public philanthropy logistics platform based on blockchain technology for social welfare maximization. In *2018 8th International Conference on Logistics, Informatics and Service Sciences (LISS)*, Toronto, August, IEEE, 1-9.

Li, M., Shen, L., & Huang, G. Q. (2019). Blockchain-enabled workflow operating system for logistics resources sharing in E-commerce logistics real estate service. *Computers & Industrial Engineering*, *135*, 950-969.

Liu, L., Li, F., & Qi, E. (2019). Research on risk avoidance and coordination of supply chain subject based on blockchain technology. *Sustainability*, *11*(7), 2182. Available at: www.mdpi.com/2071-1050/11/7/2182 (accessed on: 30.09.2019).

Longo, F., Nicoletti, L., Padovano, A., d'Atri, G., & Forte, M. (2019). Blockchain-enabled supply chain: An experimental study. *Computers & Industrial Engineering*, *136*, 57-69.

Malyavkina, L. I., Savina, A. G., & Parshutina, I. G. (2019). Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges. In *1st International Scientific Conference "Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth"(MTDE 2019)*, Russia, May, Atlantis Press, 10-15.

Mann, S., Potdar, V., Gajavilli, R. S., & Chandan, A. (2018). Blockchain technology for supply chain traceability, transparency and data provenance. *In Proceedings of the 2018 International Conference on Blockchain Technology and Application*, Xi'an China, December, Association for Computing Machinery, New York, United States, 22-26.

Manupati, V. K., Schoenherr, T., Ramkumar, M., Wagner, S. M., Pabba, S. K., & Inder Raj Singh, R. (2020). A blockchain-based approach for a multi-echelon sustainable supply chain. *International Journal of Production Research*, *58*(7), 2222-2241.

Mao, D., Wang, F., Hao, Z., & Li, H. (2018). Credit evaluation system based on blockchain for multiple stakeholders in the food supply chain. *International journal of environmental research and public health*, *15*(8), 1627. Available at: www.mdpi.com/1660-4601/15/8/1627 (accessed on: 30.09.2019)

Mylrea, M., & Gourisetti, S. N. G. (2018). Blockchain for supply chain cybersecurity, optimization and compliance. In *2018 Resilience Week (RWS),* Dever, August, IEEE, 70-76.

Min, H. (2019). Blockchain technology for enhancing supply chain resilience. *Business Horizons*, *62*(1), 35-45.

Montecchi, M., Plangger, K., & Etter, M. (2019). It’s real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons*, *62*(3), 283-293.

Nakamoto, S., & Bitcoin, A. (2008). Bitcoin: A peer-to-peer electronic cash system. Accessible at: https://bitcoin.org/bitcoin.pdf, (accessed on: 30.09.2019)

Nayak, G., & Dhaigude, A. S. (2019). A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology. *Cogent Economics & Finance*, *7*(1), 1667184.

Perboli, G., Musso, S., & Rosano, M. (2018). Blockchain in logistics and supply chain: A lean approach for designing real-world use cases. *IEEE Access*, *6*, 62018-62028.

Pervez, H., & Haq, I. U. (2019). Blockchain and IoT Based Disruption in Logistics. In *2019 2nd International Conference on Communication, Computing and Digital systems (C-CODE)*, Islamabad, March, IEEE, 276-281.

Petersen, M., Hackius, N., & von See, B. (2018). Mapping the sea of opportunities: Blockchain in supply chain and logistics. *it-Information Technology*, *60*(5-6), 263-271.

Pilkington, M. (2016). Blockchain technology: principles and applications. In Olleros, F.X. &Zhegu, M. (eds.), *Research Handbook on Digital Transformations*, Canada, Edward Elgar Publishing, 225–253.

Queiroz, M. M., Telles, R., & Bonilla, S. H. (2019). Blockchain and supply chain management integration: a systematic review of the literature. *Supply Chain Management: An International Journal*, 25(2), 241-254.

Queiroz, M. M., & Wamba, S. F. (2019). Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management*, *46*, 70-82.

Rahmanzadeh, S., Pishvaee, M. S., & Rasouli, M. R. (2020). Integrated innovative product design and supply chain tactical planning within a blockchain platform. *International Journal of Production Research*, *58*(7), 2242-2262.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135.

Salah, K., Nizamuddin, N., Jayaraman, R., & Omar, M. (2019). Blockchain-based soybean traceability in agricultural supply chain. *IEEE Access*, *7*, 73295-73305.

SANTONINO III, M. D., Koursaris, C. M., & Williams, M. J. (2018). Modernizing the supply chain of airbus by integrating RFID and blockchain processes. *International Journal of Aviation, Aeronautics, and Aerospace*, 5(4), 4.

Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management*, *25*(4), 100552.

Schroeder, R.G., Goldstein, S.M. & Rungtusanatham, M.J. (2013). *Operations Management in the Supply Chain - Decisions and Cases*. 6ª Edition. McGraw-Hill Irwin.

Scuderi, A., Foti, V., & Timpanaro, G. (2019). The Supply Chain Value of POD and PGI products through the application of blockchain. Calitatea, 20(S2), 580-587. Available at: www.researchgate.net/profile/Alessandro_Scuderi/publication/332980759 (accessed on: 30.09.2019).

Seuring, S., & Gold, S. (2012). Conducting content-analysis based literature reviews in supply chain management. *Supply Chain Management*, *17*(5), 544–555.

Sheel, A., & Nath, V. (2019). Effect of blockchain technology adoption on supply chain adaptability, agility, alignment and performance. *Management Research Review*, 42(12), 1353-1374.

Tapscott, Don; Tapscott, A. (2016). Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World. Portfolio,Penguin.

Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In *2016 13th international conference on service systems and service management (ICSSSM),* China, June, IEEE,1-6.

Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In *2017 International conference on service systems and service management,* Dalian, China, September, IEEE,1-6.

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management*, 23(6), 545–559.

van Hoek, R. (2019a). Developing a framework for considering blockchain pilots in the supply chain–lessons from early industry adopters. *Supply Chain Management: An International Journal*, 25(1), 115-121.

van Hoek, R. (2019b). Exploring blockchain implementation in the supply chain: Learning from pioneers and RFID research, *International Journal of Operations & Production Management*, 39(6/7/8), 829-859.

Xu, X., Rahman, F., Shakya, B., Vassilev, A., Forte, D., & Tehranipoor, M. (2019). Electronics Supply Chain Integrity Enabled by Blockchain. *ACM Transactions on Design Automation of Electronic Systems*, *24*(3), 1–25.

Wang, Y. (2019). Designing a Blockchain Enabled Supply Chain. *IFAC-PapersOnLine*, *52*(13), 6-11.

Wamba, S. F., & Queiroz, M. M. (2019). The Role of Social Influence in Blockchain Adoption: The Brazilian Supply Chain Case. *IFAC-PapersOnLine*, *52*(13), 1715-1720.

Westerkamp, M., Victor, F., & Küpper, A. (2018). Blockchain-based supply chain traceability: Token recipes model manufacturing processes. In *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData),*Canada, July-August, IEEE,1595-1602.

Yadav, S., & Singh, S. P. (2020). Blockchain critical success factors for sustainable supply chain. *Resources, Conservation and Recycling*, *152*, 104505.

Zheng, K., Zhang, Z., Chen, Y., & Wu, J. (2019). Blockchain adoption for information sharing: risk decision-making in spacecraft supply chain. *Enterprise Information Systems*, 1-22

APPENDIX A

Manuscript title: Blockchain technology to improve supply chain management – A systematic literature review

Table 1. Studies overview. (These sections are taken from the reviewed papers)

References and key information	Country	Type of study	Sector
1. Azzi, R., Chamoun, R. K., & Sokhn, M. (2019). The power of a blockchain-based supply chain. *Computers & Industrial Engineering*, *135*, 582–592. https://doi.org/10.1016/j.cie.2019.06.042			
Characteristics of companies: Ambrosus and Modum are both swiss Start-ups, that developed a system with IoT, blockchain technology and real-time sensors to trace products in food and pharmaceutical supply chains to guarantee the quality and the safety of the consumption enhancing the supply chain management. **Benefits:** Trust, food safety assurance, information credibility, ensure availability, accuracy, accessibility of data for all supply chain sectors, transparency, traceability, reduce counterfeit. **Risks:** Scalability. Success factor**s:** Comprehend the company tracking system and the blockchain´s role in their platform architecture. **Critical factors:** Properties and capabilities knowledge about blockchain. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Switzerland; Lebanon;	Empirical	Food Industry; Pharmaceutical;

2. Li, M., Shen, L., & Huang, G. Q. (2019). Blockchain-enabled workflow operating system for logistics resources sharing in E-commerce logistics real estate service. *Computers & Industrial Engineering*, *135*, 950-969. https://doi.org/10.1016/j.cie.2019.07.003			
Characteristics of companies: A Chinese E-commerce logistics real estate service which combines professional e-commerce logistics service and real estate service focused on warehouse services. **Benefits:** Decentralized, reliable data, privacy, transparency. **Risks:** - **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	China	Empirical	Warehouse Logistics
3. Rahmanzadeh, S., Pishvaee, M. S., & Rasouli, M. R. (2019). Integrated innovative product design and supply chain tactical planning within a blockchain platform. *International Journal of Production Research*, 58(7), 2242-2262. https://doi.org/10.1080/00207543.2019.1651947			
Characteristics of companies: Pars Khazar Company is an Iranian home appliance manufacture. The company is a well-known label in Iran with more than $115.1 million market capitalisation in 2018. The company has an extended supplying and distributing network with 10 subsidiaries, more than 150 suppliers, 44 services centres, and 11 distribution centres. Pars Khazar produces 38 groups of products in 209 models sold in the internal and external market. **Benefits:** Improve security, privacy, transparency, data integrity, traceability.	Iran	Empirical	Home Appliance

Risks: Technical limitations, such as block capacity restrictions and attacks, difficulty of data transactions between nodes. **Success factors:** Data accessibility. **Critical factors:** Intellectual property issues and protecting the rights of innovators. **Impact on the sustainability of the supply chain:** Blockchain technology can aid create a new business environment, develop innovative products and improve the sustainability. **Indicators of performance:** -			
4. Choi, T. M., Wen, X., Sun, X., & Chung, S. H. (2019). The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era. *Transportation Research Part E: Logistics and Transportation Review*, *127*, 178-191. https://doi.org/10.1016/j.tre.2019.05.007			
Characteristics of companies: Shipchain – American logistics start-up using smart contracts for logistics operations; Everledger – start-up focused on transparency of the flow of goods; Bosh – German international engineering and electronics company; Walmart – American international department store. **Benefits:** Examine previous decision data and transactions, help with estimation of the profit distribution, facilitate the use of information, and help with demand information updating and supply information updating. Enhance transparency and traceability. **Risks:** - **Success factors:** -	China	Theoretical	Air transport

Critical factors: - **Impact on the sustainability of the supply chain:** Ethical sourcing and transparency of the production flow. Blockchain allow companies to keep track of each step and stage of the SC. In the UK, Fashion companies are working with blockchain solutions providers to make the fashion SC more transparent, which facilitates ethical sourcing. **Indicators of performance:** -			
5. Chang, S. E., Chen, Y. C., & Lu, M. F. (2019). Supply chain re-engineering using blockchain technology: A case of smart contract-based tracking process. *Technological Forecasting and Social Change*, *144*, 1-11. https://doi.org/10.1016/j.techfore.2019.03.015			
Characteristics of companies: - **Benefits:** Better performance, enhance efficiency, enable the real-time tracking of business, reduce the expenses, solve vulnerability, enhance trust among partners. Improve transparency, information sharing, better utilization of business resources. **Risks:** Block size, efficiency (transaction throughput and latency), scalability, security, privacy, lack of legal issues, lack of standard protocols. **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Taiwan	Theoretical	Not reported

6. Hald, K.S. and Kinra, A. (2019), How the blockchain enables and constrains supply chain performance. *International Journal of Physical Distribution & Logistics Management*, 49(4), 376-397. https://doi.org/10.1108/IJPDLM-02-2019-0063			
Characteristics of companies: - **Benefits:** Immutability of the transactions, visibility and traceability, real-time tracking, enhance managerial ability, improve system efficiency, reduction of potential errors, potential to eliminate third parties, reducing costs with labour expenses, legal fees, tax advisors, increase trust and lower transaction costs. **Risks:** - **Success factors:** Blockchain design seen supply chain actors as sources of skills and intelligence to be supported. **Critical factors:** Lack of technology and infrastructure, blockchain design could affect supply chain actor's commitment, transparency could compromise data privacy, inflexibility of smart contracts, computer power, time, and memory, blockchain can reduce workforce and deskiller specialists' workers. **Impact on the sustainability of the supply chain:** Transparency and traceability enable to follow all information and increase knowledge about the origin of the products, making better decisions regarding sustainability. Another social and environmental impact is the possibility to chance the pattern and sourcing materials more sustainable. **Indicators of performance:** -	Denmark	Theoretical	Not reported

7. Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: implications for operations and supply chain management. *Supply Chain Management: An International Journal*, 24(4), 469-483. https://doi.org/10.1108/SCM-09-2018-0309			
Characteristics of companies: - **Benefits:** Greater visibility of the activities, transparency, efficiency, trust in information sharing, immutability of data, real-time data origins of material, purchase orders, inventory levels, good received, shipping manifests and invoices. High security, immutable data, improve quality data. **Risks:** Computational power necessary to maintain a large-scale distributed ledger, the cost of implementation, environmental impact due to the computational energy. **Success factors:** - **Critical factors:** Scepticism about blockchain investments, lack of standard, network speed, the adoption of the technology may not pay off. **Impact on the sustainability of the supply chain:** Improve the transparency of the suppliers ‘ behaviour can help to build a more sustainable business relationship. Trace the origin of the product, reduce counterfeit, make product recalls, monitor labour-intensive avoiding modern slavery. **Indicators of performance:** -	United Kingdom	Theoretical	Food Transports Pharmaceutical International logistics Wholesalers
8. Xu, X., Rahman, F., Shakya, B., Vassilev, A., Forte, D., & Tehranipoor, M. (2019). Electronics Supply Chain Integrity Enabled by Blockchain. *ACM Transactions on Design Automation of Electronic Systems*, *24*(3), 1–25. https://doi.org/10.1145/3315571			
Characteristics of companies: - **Benefits:** Improve efficiency, enhance supply chain integrity, security, convenience.	United States	Theoretical	Electronics

Risks: - **Success factors:** - **Critical factors:** Unique characteristics of each company. Not easy to identify counterfeit or real pieces only with shipping. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -			
9. Queiroz, M. M., & Wamba, S. F. (2019). Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management*, *46*, 70-82. https://doi.org/10.1016/j.ijinfomgt.2018.11.021			
Characteristics of companies: Indian and American supply chain professionals were interviewed in different sectors. The main industry, which responded the research in India is the manufacturing, meanwhile in the United States transportation, manufacturing and construction industries are the dominant. **Benefits:** In blockchain network all transactions are safer, more transparent, traceable, and efficient, enhance the supply chain actors' cooperation, cost reduction, monitor frauds and counterfeits, enhance trust between customers. **Risks:** - **Success factors:** Performance expectancy, social influence, facilitating conditions, blockchain transparency, trust among supply chain stakeholders. **Critical factors:** Facilitating conditions (India), social influence (United States).	Brazil France	Empirical	Not reported

Impact on the sustainability of the supply chain: - **Indicators of performance:** -			
10. Jamil, F., Hang, L., Kim, K., & Kim, D. (2019). A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital. *Electronics*, *8*(5), 505. https://doi.org/10.3390/electronics8050505			
Characteristics of companies: Not reported. **Benefits:** Enable provenance, safety, and transparency records, reduce times operations, monitor cost, labour, tracking the origin of products. **Risks:** Integrity of system, privacy data related to patient information. **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** Monitor and reduce the counterfeit drugs which affects the human health. **Indicators of performance:** The performance used to analyse the proposed system were in terms of transaction response time, throughput, latency, and recourse utilization.	Korea	Empirical	Pharmaceutical

11. Montecchi, M., Plangger, K., & Etter, M. (2019). It's real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons*, *62*(3), 283-293. https://doi.org/10.1016/j.bushor.2019.01.008			
Characteristics of companies: - **Benefits:** Increase the provenance of products, reduce risk perceptions, reduce transaction costs, increase transparency, assure the origin of the product, visibility of the operations. **Risks:** Exposure the company to competitors, intellectual property, trade secrets and supply chain details. . **Success factors:** Appropriate for products that customers carefully consider before purchasing. All partners in the supply chain need to agree on the blockchain solution and collaborate to implement it together. Financial investments. **Critical factors:** The transparency could exposure the company strategy like trade and intellectual property for competitors. The stakeholder's reactions of the blockchain implementation. **Impact on the sustainability of the supply chain:** Traceability and provenance can enhance the sustainability of the fashion sector, tracking the materials and the origin of products. **Indicators of performance:** -	United Kingdom	Theoretical	Fashion Luxury Pharmaceutical Food Industry

12. Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117-2135. https://doi.org/10.1080/00207543.2018.1533261			
Characteristics of companies: - **Benefits:** Transparency, security, durability, process integrity, traceability, trust supported by data collection, cost reduction, less waste, reduce human errors, deploy of the process and products faster, ensure safety, data, reduction of reliability, increase of customers trust. Potential to eliminate the third party. **Risks:** - **Success factors:** - **Critical factors:** Lack of commitment and support, financial decisions, lack of knowledge and expertise, lack of blockchain implementation, lack of customers conscious and tendency about sustainability and blockchain, communication and coordination in supply chain, law issues, lack of governmental policies, market competition and uncertainty, lack of external stakeholders involvement, lack of industry involvement in ethical and safe practices, lack of rewards and encouragement programs. **Impact on the sustainability of the supply chain:** Blockchain can influence the environmental, economic, and social issues due to its capacity of transparency, immutability and trustworthy database. Assurance human rights and fair work practices, detect unethical suppliers and counterfeit products, contribute to social supply chain sustainability, monitor the carbon tax, recycling. Reduce waste. **Indicators of performance:** -	United States	Theoretical	Not Reported

13. Liu, L., Li, F., & Qi, E. (2019). Research on risk avoidance and coordination of supply chain subject based on blockchain technology. *Sustainability*, *11*(7), 2182. https://doi.org/10.3390/su11072182			
Characteristics of companies: - **Benefits:** Transaction security, information asymmetry, reduces transactions risk, process deals with smart contracts, cost reduction, improve sustainability. **Risks:** - **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	China	Theoretical	Manufacturer Retailers
14. Scuderi, A., Foti, V., & Timpanaro, G. (2019). The Supply Chain Value of POD and PGI products through the application of blockchain. *Calitatea*, 20(S2), 580-587. Available at: www.researchgate.net/profile/Alessandro_Scuderi/publication/332980759 (accessed on: 30.09.2019).			
Characteristics of companies: Not reported. **Benefits:** Reduce frauds and counterfeit, transparency, traceability of products, trustworthy operations, immutable data, cost reduction. **Risks:** - **Success factors:** Necessity to provide food security, enhance the value of the product.	Italy	Empirical	Food Industry

Critical factors: - **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -			
15. Malyavkina, L. I., Savina, A. G., & Parshutina, I. G. (2019). Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges. In *1st International Scientific Conference" Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth"(MTDE 2019)*, Russia, May, Atlantis Press, 10-15. https://doi.org/10.2991/mtde-19.2019.3			
Characteristics of companies: - **Benefits:** Transparency, trust, cost reduction, security, improvement of the warehouse management, real time data, improvement of the forecast of consumer and demand. **Risks:** - **Success factors:** Commitment of the supply chain actors to make interactions, interested parties with developers of multifunction blockchain platforms. **Critical factors:** Interoperability, scalability, speed of transactions, capacity of processing, high cost of implementation, coordination with the main actors, lack of legal framework, immaturity of the blockchain technology, scepticism about its potential, company´s infrastructure. **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -	Russia	Theoretical	Not Reported

16. Salah, K., Nizamuddin, N., Jayaraman, R., & Omar, M. (2019). Blockchain-based soybean traceability in agricultural supply chain. *IEEE Access*, *7*, 73295-73305. https://doi.org/10.1109/ACCESS.2019.2918000			
Characteristics of companies: Soybean supply chain – No company´s name was reported. **Benefits:** Transparency, immutability of transactions, enhance trust among stakeholders, provenance. **Risks:** Scalability. **Success factors:** - **Critical factors:** Scalability, governance, identity registration, privacy, lack of a standard and regulations. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	United Arab Emirates	Empirical	Food Industry
17. Pervez, H., & Haq, I. U. (2019). Blockchain and IoT Based Disruption in Logistics. In *2019 2nd International Conference on Communication, Computing and Digital systems (C-CODE)*, Islamabad, March, IEEE, 276-281. https://doi.org/10.1109/C-CODE.2019.8680971			
Characteristics of companies: - **Benefits:** Real-time monitoring of flow and resources, stakeholder visibility and privacy, predictive analytics, accountability and non-repudiation, smart contracts, transparency, provenance, cost reduction (storage, labour cost, transportation). **Risks:** - **Success factors:** -	Pakistan	Theoretical	Logistic Transport

Critical factors: - **Impact on the sustainability of the supply chain:** Provenance of the goods and raw materials. **Indicators of performance:** Delivered (product has been delivered) DOT - Delivered on Time within the agreed period) DIF - Delivered in Full (delivery was in full, no ordered products missing) AI - Accurately Invoiced (Invoice is identical to product list and quantity) DOTIF - Delivered on Time in Full DIFOTAI - DIFOTAI is extension of OTIF. DIFOTAI is the Supply Chain term that describes the logistic service level. The DIFOTAI is fulfilled if the product is delivered to the customer according the DIFOTAI principles.			
18. Kshetri, N., & Loukoianova, E. (2019). Blockchain adoption in supply chain networks in Asia. *IT Professional*, *21*(1), 11-15. https://doi.org/10.1109/MITP.2018.2881307			
Characteristics of companies: Provenance is a British start-up which has a pilot project in Indonesia to track the fishing industry by mobile phones, blockchain and smart contracts. Toyota is a Japanese automotive company which tracks the car parts in various countries, factories and suppliers sharing real-time information among manufacturers, finance companies, ensures, customers and others. Alibaba and JD.com are Chinese companies based on e-commerce. Both explore the blockchain technology in the fight against food fraud. **Benefits:** Tracking all records by stakeholders, immutable data, trust, improve security, provenance of raw materials, cost reduction. Increase efficiency and transparency, improve financial liquidity by including not only manufacturers, distributors, and buyers but financing parties as well. **Risks:** -	United States	Empirical	Automotive Food Industry

Success factors: - **Critical factors:** Currently the implementation is justified in high value products than in cheaper one. **Impact on the sustainability of the supply chain:** Provenance of goods. Blockchain can help consumers, regulators, and other actors to track the source of their food and take relevant actions. The technology can reduce unethical and illegal practices in the industry including slavery. **Indicators of performance:** -			
19. Fu, Y., & Zhu, J. (2019). Big production enterprise supply chain endogenous risk management based on blockchain. *IEEE Access*, *7*, 15310-15319. https://doi.org/10.1109/ACCESS.2019.2895327			
Characteristics of companies: Pharmaceutical factory characterized as a big production enterprise which includes upstream suppliers, production enterprises, downstream distributors, retailers and customers. **Benefits:** Information asymmetry, operation efficiency, response speed, supply accuracy, integrity of cooperation, cost reduction, improve transparency, supply quality. **Risks:** - **Success factors:** Government investments. **Critical factors:** Acceptance process of blockchain implementation. **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -	China	Empirical	Pharmaceutical

20. Min, H. (2019). Blockchain technology for enhancing supply chain resilience. *Business Horizons*, *62*(1), 35-45. https://doi.org/10.1016/j.bushor.2018.08.012			
Characteristics of companies: - **Benefits:** Higher security, reduction of transaction costs, visibility of operations, auditable and immutable data, reduction of risks, reduction of order fulfilment errors and speed up the orders. **Risks:** - **Success factors:** Collaborative supply chain partnership, investments in information technology, risk mitigation. **Critical factors:** Lack of technical expertise, infrastructure, scalability, financial resources for blockchain investments, interoperability. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** A system for controlling and monitoring risk mitigation efforts, for checking if the plan is on schedule or reach the designated for continuous progress.	United States	Theoretical	Not reported
21. Liao, D., & Wang, X. (2018). Applications of Blockchain Technology to Logistics Management in Integrated Casinos and Entertainment. *Informatics*, *5*(4), 44. https://doi.org/10.3390/informatics5040044			
Characteristics of companies: Not reported **Benefits:** Reduction of transaction costs, immutable data, reduction of risks, information accuracy, security, operation efficiency, auditable. **Risks:** -	United States	Empirical	ICE (Integrated casinos and entertainment)

Success factors: - **Critical factors:** - **Impact on the sustainability of the supply chain:** The ICE Logistics could use blockchain for proving and track ownership goods and buy/certify if the materials come from areas with environmental social responsibility. **Indicators of performance:** -			
22. Petersen, M., Hackius, N., & von See, B. (2018). Mapping the sea of opportunities: Blockchain in supply chain and logistics. *it-Information Technology*, *60*(5-6), 263-271. https://doi.org/10.1515/itit-2017-0031			
Characteristics of companies: Supply chain actors were interviewed. Most the stakeholders work in retails and manufacturing small and medium-sized companies around 250 actors and an annual turnover of less than $50m. More than a half of the interviewees are from Germany, United States, Switzerland and France. **Benefits:** Real-time tracking, traceability, immutable data. **Risks:** - **Success factors:** - **Critical factors:** Interoperability, lack of blockchain maturity, lack of technology and the acceptance of the industry, regulations, data security, lack of knowledge of blockchain benefits and applications. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Germany	Empirical	Manufacturing Logistic services Retail

<table>
<tr><td colspan="4">23. Mao, D., Wang, F., Hao, Z., & Li, H. (2018). Credit evaluation system based on blockchain for multiple stakeholders in the food supply chain. International journal of environmental research and public health, 15(8), 1627. https://doi.org/10.3390/ijerph15081627</td></tr>
<tr><td>Characteristics of companies:
Nestle and IBM & Walmart guide a blockchain study in order to increase the supply chain efficiency, identify and mitigate food safety problems. Both companies are global food giants, from Switzerland and United States respectively.

Benefits:
Transparency, tamper-resistance, accountability, privacy, authorization, and permission of inserting data, smart contracts, trust, enhance the effectiveness of the regulation on the supply chain.

Risks:
Block size due to the storage of the entire history of the blockchain and the growing blockchain size.

Success factors:
-
Critical factors:
Early stage of blockchain, focused mainly on traceability of food rather than supervision and management traders.

Impact on the sustainability of the supply chain:
-
Indicators of performance:
-</td><td>China</td><td>Empirical</td><td>Food Industry</td></tr>
<tr><td colspan="4">24. Kshetri, N. (2018). 1 Blockchain’s roles in meeting key supply chain management objectives. International Journal of Information Management, 39, 80–89. https://doi.org/10.1016/J.IJINFOMGT.2017.12.005</td></tr>
<tr><td>Characteristics of companies:
Maersk is a Danish company and the world´s largest container carrier, representing almost 20% of the market. It is considered a high-profile example of blockchain implementation successful.
Provenance is a British start-up which developed a project to track fish in Indonesia.
Alibaba is a Chinese company based on e-commerce, which join up with other companies to explore the blockchain technology in the fight against food fraud.</td><td>United States</td><td>Empirical*</td><td>International logistic
Food Industry
Fashion
Aviation
Pharmaceutical
Luxury</td></tr>
</table>

Lockheed Martin is the world´s largest defense contracting firm. Chronicled is an American start-up focused on business solutions in life science. They made a pilot to track and trace products in the pharmaceutical industry. Modum is a Swiss start-up which use blockchain technology to guarantee the safe delivery of pharmaceutical drugs. Everledger is a British start-up which provide solutions to check the provenance of the goods. Walmart is a global food company which teamed up with IBM to develop a network to monitor food in the United States, China, Latin America. Gemalto is an international security company which works with the pharmaceutical industry. Intel is a technology giant company and Bext360 is an American start-up focused on traceability and transparency of the data. **Benefits:** Facilitate the validation and effective measurement of outcomes and performance, trust among partners, traceability, enhance quality products, high security, auditable, improve sustainability in food products. **Risks:** - **Success factors:** Supply chain actors´ capabilities, interesting and cooperation among partners. **Critical factors:** Regulations, commercial codes, laws, cooperation and integration among partners, potential for fraudulent and manipulative activities, attack, vulnerability, necessity of high degree of information technology. **Impact on the sustainability of the supply chain:** Help to end unethical and illegal practices due to the traceability and provenance of the raw materials and goods. Blockchain may also have important social and economic impacts. **Indicators of performance:** Indicators with quality, speed, dependability, cost, flexibility and sustainable, influenced about consumers. Indicators related to sustainability.			

25. Bose, S., Raikwar, M., Mukhopadhyay, D., Chattopadhyay, A., & Lam, K. Y. (2018). Blic: A blockchain protocol for manufacturing and supply chain management of ics. In *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, Canada, July, IEEE, 1326-1335. https://doi.org/10.1109/Cybermatics_2018.2018.00229			
Characteristics of companies: - **Benefits:** Tamper-proof system, trust, immutable data, security, transparency, operation efficiency. **Risks:** Computational power, storage, and bandwidth to process and validate each node in blockchain. **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Singapore	Theoretical	Electronics Integrated Circuits
26. Westerkamp, M., Victor, F., & Küpper, A. (2018). Blockchain-based supply chain traceability: Token recipes model manufacturing processes. In *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*,Canada, July-August, IEEE,1595-1602.https://doi.org/10.1109/Cybermatics_2018.2018.00267			
Characteristics of companies: Not mentioned. **Benefits:** Traceability, authenticity. **Risks:** --	Germany	Empirical	Manufacturing

Success factors: - **Critical factors:** SCM is operating systems isolated from other partners hindering the provenance among them and trust relations. **Impact on the sustainability of the supply chain:** The traceability has potential to track raw materials until retailers with ecological and ethical standards. **Indicators of performance:** -			
27. Li, J., Qu, F., Tu, X., Fu, T., Guo, J., & Zhu, J. (2018). Public philanthropy logistics platform based on blockchain technology for social welfare maximization. In *2018 8th International Conference on Logistics, Informatics and Service Sciences (LISS)*, Toronto, August, IEEE, 1-9. https://doi.org/10.1109/LISS.2018.8593217			
Characteristics of companies: Not reported. **Benefits:** Transparency, openness system, traceability, irrevocability, auditable, trustful. **Risks:** - **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** Utility, Fluency Analysis, Economic Cost Analysis, Social welfare maximization.	China	Empirical	Philanthropy

28. Al Barghuthi, N. B., Mohamed, H. J., & Said, H. E. (2018). Blockchain in Supply Chain Trading. In *2018 Fifth HCT Information Technology Trends (ITT)*, IEEE, 336-341. https://doi.org/10.1109/CTIT.2018.8649523			
Characteristics of companies: - **Benefits:** Security, trustful, exchange data and documents, trade integrity, visibility, cost reduction, reduction of paperwork and counterfeit, in meeting regulatory requirements, strengthens law enforcement capacity. **Risks:** Blockchain early stage, not matured to be used by governments, not suitable for large-scale deployment. Throughput, scalability, identity management, cross-chain consensus, security. **Success factors:** Clarity of roles, organization intent, proper governance, effective monitoring of implementation and objectives. Successful implementation requires public/private blockchain supporters. **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** Efficiency of trade procedures refers to the speed and ease with which cross-border business transactions are conducted with a high degree of quality, level of resource waste and decrease of costs.	United Arab Emirates	Theoretical	Not reported
29. Mylrea, M., & Gourisetti, S. N. G. (2018). Blockchain for supply chain cybersecurity, optimization and compliance. In *2018 Resilience Week (RWS)*, Dever, August, IEEE, 70-76. https://doi.org/10.1109/RWEEK.2018.8473517			
Characteristics of companies: - **Benefits:** Reduce cost and increase of effectiveness of grid cybersecurity, regulators monitor, security, improve compliance, increase transparency, immutable data, traceability.	United States	Theoretical	Electric Power

Risks: Lack of functionality, high costs, security, energy efficiency, interoperability. **Success factors:** Scalability, speed, costs, and cyber resilience. **Critical factors:** Blockchain early stage, lack of regulations, standard application. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -			
30. Bettín-Díaz, R., Rojas, A. E., & Mejía-Moncayo, C. ((2018). Methodological approach to the definition of a blockchain system for the food industry supply chain traceability. In *International Conference on Computational Science and Its Applications*, Melbourne, Australia, July 2-5, 2018, Springer, 19-33. https://doi.org/10.1007/978-3-319-95165-2_2			
Characteristics of companies: Organic coffee industry in the Colombia market. **Benefits:** Transparency, no intermediaries, low possibility of hacking or loss data, trust, security by traceability, accessible, no need for significant investments, not complex infrastructure, cost reduction, transaction speed, auditable, immutable data that could overcome the counterfeit. **Risks:** Lack of security, possibility to lose all data and need to repeat the process, scalability, interoperability. **Success factors:** Knowledge of the company´s operations, the actors involved in the implementation, the definition or characterization of the process to produce the product, according to the early steps of definition. **Critical factors:** Information technology infrastructure.	Colombia	Empirical	Food Industry

Impact on the sustainability of the supply chain: - **Indicators of performance:** -			
31. Banerjee, A. (2018). Blockchain technology: supply chain insights from ERP. In Raj, P. & Deka, G.C. (eds.), *Advances in computers*, Vol. 111, Elsevier, 69-98.			
Characteristics of companies: - **Benefits:** Improve trust, transparency, solve gaps in technology, could integrate between ERP systems. Improve supplier relations, customer management, cost reduction and add value. Improve the procurement, providing digital and automated data with a status of sold and delivered goods. Improve the order and demand management, enhance the visibility and reduce counterfeiting by provenance, improve sourcing, security and data quality, visibility. **Risks:** Interoperability. **Success factors:** Blockchain can bridge gaps in technology, transparency, and concurrency among various ERP systems integrating effective for reducing the interoperability. **Critical factors:** Infrastructure and network, interoperability, costs of onboarding and maintenance, data storage of blockchain, data validation latency, payload size restriction, (Global) regulatory and legal acceptance. Most of these challenges revolve around cost, network infrastructure and legal aspects. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** Product provenance is a huge potential for the 3 bottoms. Blockchain could track the origin of the product and trace the life cycle, identify manufacturers who abuse human rights.	India	Theoretical	Distribution

32. Treiblmaier, H. (2018), The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management*, 23(6), 545–559. https://doi.org/10.1108/SCM-01-2018-0029			
Characteristics of companies: - **Benefits:** Improve demand forecasting with visibility and a positive effect on inventory management. Reduce fraud and errors, reduce transit and shipping costs as well as waste. Speed, provenance of data, trust, privacy, security. **Risks:** **-** **Success factors:** - **Critical factors:** Lack of blockchain knowledge. **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -	Austria	Theoretical	Not reported
33. SANTONINO III, M. D., Koursaris, C. M., & Williams, M. J. (2018). Modernizing the supply chain of airbus by integrating RFID and blockchain processes. *International Journal of Aviation, Aeronautics, and Aerospace*, 5(4), 4. https://doi.org/10.15394/ijaaa.2018.1265			
Characteristics of companies: - **Benefits:** Maximize operational efficiency, improve performance, reduce errors and costs. Better satisfaction experience for customers, improve inventory control and maintenance. **Risks:** Handover of physical to digital assets and vice versa.	United States	Theoretical	Aviation

Success factors: Faster processing speeds and lower costs are factors to consider when optimizing operational efficiencies. **Critical factors:** **-** **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -			
34. Perboli, G., Musso, S., & Rosano, M. (2018). Blockchain in logistics and supply chain: A lean approach for designing real-world use cases. *IEEE Access*, *6*, 62018-62028. https://doi.org/10.1109/ACCESS.2018.2875782			
Characteristics of companies: E-commerce food retailer located in Europe - 10 warehouses and 3 distribution centres with suppliers situated worldwide. **Benefits:** Increase the efficiency, reliability, transparency of the overall supply chain, optimize the inbound processes, improve customer trust, reduction of frauds and counterfeit, reduction of expired items and waste of products. Improve accuracy in the tracking goods. **Risks:** **-** **Success factors:** Define the strategy for blockchain implementation. Identify each actor, the gains, the pains, the company´s goal. **Critical factors:** Blockchain early stage, scalability, blockchain costs, unclear real benefits and costs, supply chain actors´ cooperation. **Impact on the sustainability of the supply chain:** Costs of implementing Blockchain are highly sustainable when compared with the resulting benefits.	Canada Italy	Empirical*	Food Industry

Indicators of performance: Forecast accuracy, Inbound lead time (producer & warehouse manager).			
35. Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In *2017 International conference on service systems and service management,* Dalian, China, September, IEEE,1-6. https://doi.org/10.1109/ICSSSM.2017.7996119			
Characteristics of companies: Not reported. **Benefits:** Openness network, transparency, neutrality, reliability, security, information asymmetry. **Risks:** Scalability in terms of throughput, latency, and capacity when face mass data in a real business environment. **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Austria	Theoretical	Food Industry
36. Chen, S., Shi, R., Ren, Z., Yan, J., Shi, Y., & Zhang, J. (2017). A blockchain-based supply chain quality management framework. In *2017 IEEE 14th International Conference on e-Business Engineering (ICEBE)*, Shanghai, November, IEEE, 172-176.https://doi.org/10.1109/ICEBE.2017.34			
Characteristics of companies: Not reported. **Benefits:** Security network, real-time tracking, improving decision making, enhance quality management.	China	Empirical*	Electronics

Risks: - **Success factors:** - **Critical factors:** Privacy issues related to confidential company information. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -			
37. Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In *2016 13th international conference on service systems and service management (ICSSSM)*, China, June, IEEE,1-6. https://doi.org/10.1109/ICSSSM.2016.7538424			
Characteristics of companies: Not reported. **Benefits:** Improve the efficiency and reliability of agri-food supply chain management and significantly strengthen the quality and safety of agri-food products. Security, improvement of warehouse management, quality, and safety of the food. Auditable network. **Risks:** Blockchain early stage, scalability. **Success factors:** - **Critical factors:** Blockchain early stage, high cost of implementation and maintenance, lack of regulations. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	Austria	Theoretical	Food Industry

38. Longo, F., Nicoletti, L., Padovano, A., d'Atri, G., & Forte, M. (2019). Blockchain-enabled supply chain: An experimental study. *Computers & Industrial Engineering*, *136*, 57-69. https://doi.org/10.1016/j.cie.2019.07.026			
Characteristics of companies: The study recreates a network of suppliers, carriers, wholesalers, retailers and customers. No specific company was mentioned. **Benefits:** Improve trust among stakeholders, information asymmetry, paperwork efficiency, reduction of counterfeit, traceability. **Risks:** - **Success factors:** The improvement of trust among partners provide by information sharing. **Critical factors:** Lack of knowledge about blockchain in small and medium enterprises, trust depend on trust in partner companies, interoperability. **Impact on the sustainability of the supply chain:** Improve data quality the demand and purchasing could be more accurate and avoid waste, stock. **Indicators of performance:** Orders' fill rate, the on-hand inventory, the total inventory costs, the average inventory cost per day and per single item, revenues, costs, and net profit.	Italy	Empirical	Wholesalers Big-box retailer

39. Manupati, V. K., Schoenherr, T., Ramkumar, M., Wagner, S. M., Pabba, S. K., & Inder Raj Singh, R. (2020). A blockchain-based approach for a multi-echelon sustainable supply chain. *International Journal of Production Research*, *58*(7), 2222-2241. https://doi.org/10.1080/00207543.2019.1683248			
Characteristics of companies: - **Benefits:** Visibility and control of multi-echelon supply chain, reduction of cost and time, enhance operations efficiency of the entire system, real-time data help in decision makings. Improve traceability, auditability, and verifiability of each stage in the production. **Risks:** - **Success factors:** - **Critical factors:** Behavioural, organisational, technological, or policy-oriented barriers. **Impact on the sustainability of the supply chain:** Blockchain minimises both total cost and carbon emissions, tracking the carbon emissions. **Indicators of performance:** Data quality related carbon emissions and lead time in the integration of a carbon taxation policy into the supply chain network with an automated monitoring and data handling mechanism.	United States Switzerland India	Theoretical	Fashion
40. Nayak, G., & Dhaigude, A. S. (2019). A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology. *Cogent Economics & Finance*, 7(1), 1667184. https://doi.org/10.1080/23322039.2019.1667184			
Characteristics of companies: Small and medium-sized enterprises. **Benefits:** Tracing social and ecological conditions that might pose safety, health or environmental apprehensions for achieving the triple bottom line targets in sustainability.	India	Empirical*	Not reported

Risks: - **Success factors:** Top management, competition, culture, financial constraints are the drivers for sustainable supply chain management using blockchain technology. **Critical factors**: In small and medium enterprises faces technological, behavioural, policy-oriented and organizational challenges to implement blockchain technology. Lack of regulations, loss of privacy data, data storage, software costs and resistance to change. **Impact on the sustainability of the supply chain:** Blockchain ensure compliance with human rights, and fair, safe work practices by curbing malpractices. In terms of environmental concerns it can bring down product recall and manage it, help reduce greenhouse gas emissions, the authentication of environmental will give buyers more confidence to the product, recycling initiatives, emission trades, governance, carbon tax trading all to help achieve environmental performance. **Indicators of performance:** -			
41. Zheng, K., Zhang, Z., Chen, Y., & Wu, J. (2019). Blockchain adoption for information sharing: risk decision-making in spacecraft supply chain. *Enterprise Information Systems*, 1-22. https://doi.org/10.1080/17517575.2019.1669831			
Characteristics of companies: - **Benefits:** Reduction of transaction costs and risks, information asymmetry, improving the overall profit, guarantee the security, traceability, improve the safety and efficiency of the supply chain. **Risks:** - **Success factors:** - **Critical factors:** -	United States	Theoretical	Aviation

Impact on the sustainability of the supply chain: The transparency provides by blockchain can monitor the human rights. **Indicators of performance:** -			
42. Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management*, *25*(4), 100552. https://doi.org/10.1016/j.pursup.2019.100552			
Characteristics of companies: - **Benefits:** Transparency, immutability, trustful, reduction of transaction costs, enable more market-oriented governance structures for buyer-supplier transactions, limit opportunistic behaviour, environmental and behaviour uncertainty. **Risks:** Transfer real-world data as a security challenge. **Success factors:** - **Critical factors:** Privacy, data quality, blockchain early stage, lack of standard. **Impact on the sustainability of the supply chain:** Transparent product provenance can prevent fraud and counterfeit and thus save costs related to controlling and monitoring current and potential suppliers and ensuring product or service quality. **Indicators of performance:** -	Switzerland	Theoretical	Not reported

43. Sheel, A., & Nath, V. (2019). Effect of blockchain technology adoption on supply chain adaptability, agility, alignment and performance. *Management Research Review*, 42(12), 1353-1374. https://doi.org/10.1108/MRR-12-2018-0490			
Characteristics of companies: Not reported. **Benefits:** Transparency, more accurate demand forecast and improve inventory management, traceability of inventory, reduce or eliminate payments gaps, enable to trace the origin of products, improve decision making. **Risks:** - **Success factors:** Enhance the supply chain efficiency due the benefits of blockchain, improve the competitive advantage. **Critical factors:** Blockchain early stage, lack of organized ecosystem, governance, privacy, trained employees, high costs of implementation, lack of knowledge about blockchain benefits. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** Transaction costs, supply chain operational speed, value creation in the supply chain, level of services provided to the customer.	India	Empirical*	Not reported
44. van Hoek, R. (2019b). Exploring blockchain implementation in the supply chain: Learning from pioneers and RFID research, International Journal of Operations & Production Management, 39(6-7-8), 829-859. https://doi.org/10.1108/IJOPM-01-2019-0022			
Characteristics of companies: Case 1 is a logistic service provider located in North America with a blockchain pilot in an international shipping lane Case 2 is a food and beverage company located in Europa. Case 3 is a retail in the United States. All the mentioned company use data feeds from existing technology like RFID in case 1 and the other ones use barcodes.	United States	Empirical	Logistics services Food Industry Retail

Benefits: Enhance the sustainability, product quality, speed up international shipping, enhance visibility. **Risks:** - **Success factors:** Executive and key stakeholders' engagement, top management commitment, keep a team and the scope small to a faster start. **Critical factors:** - **Impact on the sustainability of the supply chain:** Consumers can access environmental footprints about products, making decisions based on the sustainability. **Indicators of performance:** -			
45. Yadav, S., & Singh, S. P. (2020). Blockchain critical success factors for sustainable supply chain. *Resources, Conservation and Recycling*, *152*, 104505. https://doi.org/10.1016/j.resconrec.2019.104505			
Characteristics of companies: - **Benefits:** Transparency, security, traceability, auditable, enhance quality, cost reduction, cost effective, high performance. **Risks:** - **Success factors:** Data safety and decentralization, accessibility, laws and policy, documentation, data management, quality. **Critical factors:** Government regulation or customer value demand.	India	Theoretical	Not reported

Impact on the sustainability of the supply chain: Improve the efficiency and effective use of resources. Blockchain can aid to provide sustainability standards for organic food and food life cycle. **Indicators of performance:** -			
46. Choi, T. M., & Luo, S. (2019). Data quality challenges for sustainable fashion supply chain operations in emerging markets: Roles of blockchain, government sponsors and environment taxes. *Transportation Research Part E: Logistics and Transportation Review*, *131*, 139-152. https://doi.org/10.1016/j.tre.2019.09.019			
Characteristics of companies: - **Benefits:** Improve data quality, social welfare. **Risks:** - **Success factors:** - **Critical factors:** High costs of blockchain implementation, environmental costs associated with product leftover. **Impact on the sustainability of the supply chain:** Blockchain help enhance social welfare reducing poor data quality. **Indicators of performance:** -	China	Theoretical	Fashion

47. Kim, J. S., & Shin, N. (2019). The impact of blockchain technology application on supply chain partnership and performance. *Sustainability*, *11*(21), 6181. https://doi.org/10.3390/su11216181			
Characteristics of companies: Not reported **Benefits:** Enhance product safety and security, quality management, illegal counterfeiting reduction, supply chain sustainability, inventory management, new product design and development, cost reduction, information transparency reducing bullwhip effect, immutability, reliability, partnership efficiency. **Risks:** **-** **Success factors:** Information transparency and immutability provides a business value to the supply chain network partners. **Critical factors:** Partnership efficiency has a negative impact on Supply Chain performance when blockchain is applied. Blockchain technology needs to be supplemented with more detailed functions or processes to help improve the supply chain performance. **Impact on the sustainability of the supply chain:** Blockchain is considered a next generation of information technology tool for sustainable growth. **Indicators of performance:** For improving bullwhip effect measures such as revenues, fill rates, inventory levels, information transparency.	Korea	Empirical	Various

48. Jayaraman, R., Salah, K., & King, N. (2019). Improving Opportunities in healthcare supply chain processes via the Internet of Things and Blockchain Technology. *International Journal of Healthcare Information Systems and Informatics (IJHISI)*, *14*(2), 49-65. https://doi.org/10.4018/IJHISI.2019040104			
Characteristics of companies: - **Benefits:** Secure data management and secure access to the stakeholders, auditable information, real-time validation, visibility of data, integrity, accuracy, fidelity, reduction of counterfeit, reduction of recalls and costs, efficient platform. **Risks:** - **Success factors:** - **Critical factors:** Blockchain early adoption, data privacy, energy efficiency. Compliance and security of IoT. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	United Arab Emirates	Theoretical	Healthcare
49. Banerjee, A. (2019). Blockchain with IOT: Applications and use cases for a new paradigm of supply chain driving efficiency and cost. In Kim, S., Deka, G.C. & Zhang, P. (eds.), *Advances in Computers*, Vol. 115, Elsevier, 259-292. https://doi.org/10.1016/bs.adcom.2019.07.007			
Characteristics of companies: - **Benefits:** Combined with IoT provide real-time analytics, security share data with partners, scalability, reliability, security, cost effectivity, cost of ownership, transparency, accessibility, improve operational efficiency, reduce rejections, and accelerate cash flow, cost reduction. **Risks:** -	India	Theoretical	Food Industry Automotive

Success factors: Add value to the product due to the real-time security information. **Critical factors:** Lack infrastructure and motivation to adopt blockchain technology by farmers. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -			
50. Lambourdiere, E., & Corbin, E. (2020). Blockchain and maritime supply-chain performance: dynamic capabilities perspective. *Worldwide Hospitality and Tourism Themes*, 12(1), 24-34. https://doi.org/10.1108/WHATT-10-2019-0069			
Characteristics of companies: - **Benefits:** Provide security and flexibility, reduction of transaction costs, enhance operational performance, increase transparency, accountability and visibility, improve customer service and transportation systems. **Risks:** **-** **Success factors:** Reduce human errors, improving data integrity. **Critical factors:** **-** **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -	France	Theoretical	Not reported

51. Khanna, T., Nand, P., & Bali, V. (2020). Permissioned Blockchain Model for End-to-End Trackability in Supply Chain Management. *International Journal of e-Collaboration (IJeC)*, *16*(1), 45-58. https://doi.org/10.4018/IJeC.2020010104			
Characteristics of companies: - **Benefits:** Transparency, visibility of flow of goods, traceability which represents the increase of trust among partnerships, real time data, immutability. **Risks:** - **Success factors:** - **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	India	Theoretical	Not reported
52. van Hoek, R. (2019a). Developing a framework for considering blockchain pilots in the supply chain–lessons from early industry adopters. *Supply Chain Management: An International Journal*, 25(1), 115-121. https://doi.org/10.1108/SCM-05-2019-0206			
Characteristics of companies: Case 1 is a logistic service provider located in North America with a blockchain pilot in an international shipping lane Case 2 is a food and beverage company located in Europa. Case 3 is a retail in the United States. All the mentioned company use data feeds from existing technology like RFID in case 1 and the other ones use barcodes. **Benefits:** Speed up shipments (case 1). New levels of visibility in the energy and water consumption (case 2). Improve tracking and communication throughout the supply chain. Cost reduction, more productivity and inventory management. **Risks:** -	United States	Empirical	Logistics Food Industry Retail

Success factors: Leadership commitment and stakeholders ‘engagement. Improve data and product security, improve visibility of internal processes, visibility of the inventory, accurate information, improve asset management and tracking, cost reduction, improve efficiency. **Critical factors:** Blockchain maturity, unknowledge of potential benefits, cost and return of the investment, technical limitations, costs of blockchain implementation, privacy issues, interoperability, data integrity concerns, scalability, lack of standards, training needs. **Impact on the sustainability of the supply chain:** Due to the levels of visibility, consumers can access environmental footprints about products, making decisions based on the sustainability. **Indicators of performance:** -			
53. Çolak, M., Kaya, İ., Özkan, B., Budak, A., & Karaşan, A. (2020). A multi-criteria evaluation model based on hesitant fuzzy sets for blockchain technology in supply chain management. *Journal of Intelligent & Fuzzy Systems*, *38*(1), 935-946. https://doi.org/10.3233/JIFS-179460			
Characteristics of companies: - **Benefits:** Reduction of time and costs operations provide transparency to create value for the customers, real-time tracking, improve inventory management, minimise shipping costs, reduce delays and identify problems faster. **Risks:** There is no standard system. **Success factors:** Work process become safer, more transparent, more manageable, traceable, and efficient increasing trust among partners. **Critical factors:** -	Turkey	Theoretical	Agri-food Pharmaceutical Electric Power Jewellery Textile

Impact on the sustainability of the supply chain: - **Indicators of performance:** -			
54. Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. *Production and Operations Management*, *29*(4), 935-954. https://doi.org/10.1111/poms.13147			
Characteristics of companies: - **Benefits:** Improve sustainability performance, operational efficiency, enhance coordination and sense of market trends. **Risks:** - **Success factors:** Pharmaceutical sectors see blockchain as a security solution for curbing unlawful practices, achieve sustainability and enhance the operational efficiency. **Critical factors:** Company´s infrastructure, collaboration, blockchain maturity, leadership, governance of the traceability efforts to lead to corruption as Chinese buyers. **Impact on the sustainability of the supply chain:** Traceability can improve sustainability performance, in social, environmental issues, avoiding forced child and slave labour, leader to counterfeit, incentive sustainable practices. **Indicators of performance:** -	United Kingdom	Theoretical	Cobalt Pharmaceutical

55. Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. International Journal of Production Research, 58(7), 2142-2162. https://doi.org/10.1080/00207543.2019.1708989			
Characteristics of companies: - **Benefits:** High potential to improve supply chain transparency and sustainability. **Risks:** - **Success factors:** Blockchain should be deployed as an opportunity to reduce risks. **Critical factors:** The psychological characteristics of decision makers, their different opinions, and the lack of blockchain knowledge. **Impact on the sustainability of the supply chain:** Blockchain can integrate the supply chain operations, real-time information, environmental and human rights into the network. **Indicators of performance:** Transparency performance metric as the level of supply chain partner information participation degree, scope of the operations, environmental and social information, product transparency, tracking product sustainable information (recycling, carbon emissions); participant transparency.	Finland China United States	Theoretical	Not Reported
56. Wang, Y. (2019). Designing a Blockchain Enabled Supply Chain. *IFAC-PapersOnLine*, *52*(13), 6-11. https://doi.org/10.1016/j.ifacol.2019.11.082			
Characteristics of companies: Consortium in the United Kingdom´s construction sector. A sector with 300.000 companies and 3 million employees. The public sector spending around GBP 50bn each year on construction and related activities. The researcher is a panel expert.	United Kingdom	Empirical*	Construction

Benefits: Transparency, security, provenance, traceability. **Risks:** - **Success factors:** Perception of usefulness – understand how the blockchain technology works and its potentials. **Critical factors:** Lack of knowledge and expertise, financial constraints, collaborative and information sharing issues. Regulatory uncertainties, energy consumption, unethical behaviours, interoperability, lack of large-scale blockchain deployment. **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -			
57. Baharmand, H., & Comes, T. (2019). Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-based Smart Contracts. *IFAC-PapersOnLine*, *52*(13), 12-17. https://doi.org/10.1016/j.ifacol.2019.11.084			
Characteristics of companies: UNICEF (United Nations Children's Fund) and WFP (World Food Programme) are worldwide humanitarian companies which have the aim to defend the children´s rights and provides food to people in 80 countries. **Benefits:** Efficiency, transparency, and accountability. **Risks:** - **Success factors:** Centralization on decision-making and interpersonal networks within an organization.	Netherlands Norway	Empirical*	Humanitarian Supply Chain

Critical factors: Investments in the supply chain actors, training, implementation, and monitoring. Technology immature, complexity, infrastructure and immutability, different strategic objectives, and culture between partners, top management support. **Impact on the sustainability of the supply chain:** Improve the transparency between humanitarian supply chain and logistic service providers. **Indicators of performance:** -			
58. Wamba, S. F., & Queiroz, M. M. (2019). The Role of Social Influence in Blockchain Adoption: The Brazilian Supply Chain Case. *IFAC-PapersOnLine*, *52*(13), 1715-1720. https://doi.org/10.1016/j.ifacol.2019.11.448			
Characteristics of companies: It was made a questionnaire survey in a Brazilian supply chain. There is no specific company reported. **Benefits:** Significant cost reduction, immutable data, trust, security, transparency, trust, more cooperation between partners. **Risks:** - **Success factors:** In Brazilian actors, social influence has a strong effect in facilitating conditions, performance expectancy and effort expectancy. **Critical factors:** **-** **Impact on the sustainability of the supply chain:** **-** **Indicators of performance:** -	France Brazil	Empirical	Not Reported

59. Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., & Rachaniotis, N. P. (2019). Modeling food supply chain traceability based on blockchain technology. *IFAC-PapersOnLine*, 52(13), 2728-2733. https://doi.org/10.1016/j.ifacol.2019.11.620			
Characteristics of companies: Not reported. **Benefits:** Transparency, secure, auditable transaction, traceability, provide to customers the product information, immutability, provide trust, cost reduction, integrity, and authenticity. **Risks:** - **Success factors:** - **Critical factors:** Scalability and storage of huge amount of data. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** Efficiency (cost, automation), responsiveness (customer complaints, response time), required trust assumptions, context requirements, required consensus mechanisms and food quality (process and product quality).	Greece	Empirical*	Food Industry
60. Mann, S., Potdar, V., Gajavilli, R. S., & Chandan, A. (2018). Blockchain technology for supply chain traceability, transparency and data provenance. In Proceedings of the 2018 International Conference on Blockchain Technology and Application, Xi'an China, December, Association for Computing Machinery, New York, United States, 22-26. https://doi.org/10.1145/3301403.3301408			
Characteristics of companies: Yamana Gold is a Canadian mining company interest in track gold from mines to refineries. BHP is an Australia´s largest mining organization. They are interest in work closely with their partners to enhance their supply chain process.	Australia India	Empirical	Mining Industry

Benefits: Data provenance, transparency, traceability, safety, information accuracy, cost reduction, counterfeit reduction. **Risks**: Interoperability, lack of legal regulations, lack of standard technology. **Success factors:** - **Critical factors:** Lack of legal regulations, limited information technology infrastructure, systems' performance. **Impact on the sustainability of the supply chain:** Blockchain can help with sustainable practices in social and ecological business, ensure ethical business practices, child labour reduction, waste reduction. **Indicators of performance:** -			
61. Juma, H., Shaalan, K., & Kamel, I. (2019). A Survey on Using Blockchain in Trade Supply Chain Solutions. *IEEE Access*, 7, 184115-184132. https://doi.org/10.1109/ACCESS.2019.2960542			
Characteristics of companies: - **Benefits:** Data and information integrity, traceability, monitor the transportation environment and optimise the processing model of customs authority due to the information exchange. **Risks:** - **Success factors:** The adoption of the blockchain technology in the trading domain is influenced by the scalability the willingness of the participants, and the cost. **Critical factors:** Scalability, the supply chain actors 'cooperation, the costs of implementation.	United Arab Emirates	Theoretical	Not reported

Impact on the sustainability of the supply chain: **-** **Indicators of performance:** -			
62. Abeyratne, S.A. and Monfared, R. P. (2016). Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger. *International Journal of Research in Engineering and Technology*, *05*(09), 1–10. https://doi.org/10.15623/ijret.2016.0509001			
Characteristics of companies: - **Benefits:** Enhance transparency, traceability, trust, durability, transparency, immutability and process integrity. **Risks:** - **Success factors:** **-** **Critical factors:** Information technology Infrastructure, performance capability, constant data update. **Impact on the sustainability of the supply chain:** Blockchain transparency can aid to track the environmental damage, end of the life waste, unethical labour, counterfeit products. **Indicators of performance:** -	United Kingdom	Theoretical	Manufacturing
63. Kouhizadeh, M., & Sarkis, J. (2018). Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability*, *10*(10), 3652. https://doi.org/10.3390/su10103652			
Characteristics of companies: - **Benefits:** Security, information transparency (auditability and traceability) - resulting in trust and reliability for SC partners. Immutable data, reduction of the risk in focal companies when they use blockchain for analyse vendor's performance.	United States	Theoretical	Manufacturing

Risks: - **Success factors:** Company, industry, product, and competitive environment characteristics may each influence the adoption of blockchain technology for sustainable supply chains. **Critical factors:** The lack of information related to supplier selection and evaluation. High costs of implementation. **Impact on the sustainability of the supply chain:** Enhance renewable energy, improve waste management, reverse logistics, traceability of green products, recycle of products, monitor the carbon emissions, auditable data. **Indicators of performance:** Vendors' environmental performance, performance measurement of supplier development programs, environmental performance measurement, waste reduction metrics.			
64. Korpela, K., Hallikas, J., & Dahlberg, T. (2017). Digital Supply Chain Transformation toward Blockchain Integration. In *Proceedings of the 50th Hawaii International Conference on System Sciences (2017)*, Hawaii, January, 4182–4191. https://doi.org/10.24251/hicss.2017.506			
Characteristics of companies: A Finnish business consortium of 30 companies operating in 36 countries. The executives, business managers and IT experts played an active role in global business networks. **Benefits:** Enhance Security and cost reduction in the Digital Supply Chain. **Risks:** Interoperability. **Success factors:** System security and privacy by digital signature, smart contracts. **Critical factors:** Interoperability, high cost of investments.	Finland	Empirical	Consortium with: retail automotive electronics aviation chemical

Impact on the sustainability of the supply chain: - **Indicators of performance** -			
65. Francisco, K., & Swanson, D. (2018). The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. *Logistics*, *2*(1), 2. https://doi.org/10.3390/logistics2010002			
Characteristics of companies: - **Benefits:** Trust, transparency of operations, traceability, mitigation of risks. **Risks:** **Success factors:** Social influence, facilitating conditions, inter-organizational trust, behavioural intention. **Critical factors:** - **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -	United States	Theoretical	Not reported
66. Kamble, S., Gunasekaran, A., & Arha, H. (2019). Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009-2033. https://doi.org/10.1080/00207543.2018.1518610			
Characteristics of companies: The study made an online survey with Indian supply chain professionals. No specific company was mentioned. **Benefits:** Speed up the supply chain processes, data more reliable, accurate demand forecast, manage resources, reduction of stocks and supply chain risks, visibility, transparency resulting in trust for the chain.	India	Empirical*	Not mentioned

Risks: - **Success factors:** Perceived usefulness, attitude, perceived behaviour control, subjective norms, perceived of ease of use. **Critical factors:** Technical knowledge, data governance, high costs of implementation, privacy issues. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** -			
67. 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), Berlin, October, 3-18*. https://doi.org/10.15480/882.1444			
Characteristics of companies: IBM & Maersk – Maersk is a Danish company and the world´s largest container carrier. The company joined forces with the American technology company giants IBM for digitalizing paper records and reduce the paperwork in shipping process. Everledger is start-up which developed a blockchain system which ensure the provenance of high value products, as diamonds. Walmart & IBM – IBM teamed up with Walmart an international food retail. In Maersk and Walmart case, blockchain technology is used to improve the existing legacy systems in the companies. **Benefits:** Trust between parties, eliminate the necessity of a third validation, cost reduction, identify counterfeit products, tracking the origin of the goods. **Risks:** - **Success factors:** -	Germany	Empirical	International Logistics Pharmaceutical Food Industry

Critical factors: Blockchain early stage, scalability, regulatory uncertainty, lack acceptance of the industry, data security, unclear blockchain benefits, dependence of blockchain operators. **Impact on the sustainability of the supply chain:** - **Indicators of performance:** **-**			