HELLENIC OPEN UNIVERSITY

**MASTER'S DEGREE PROGRAMME IN SUPPLY CHAIN MANAGEMENT**

Postgraduate Dissertation:

# Blockchain technologies as a 4th Industrial Revolution facilitator in Logistics

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# Abstract

As Blockchain is all the more approached as a prominent facilitator for adopting 4th Industrial Revolution ideas across various industries, it is evident that Logistics is one of the sectors of the economy that is presented as the best candidates for such implementations. In this study, we explore both how academia and the business world approach this potential, the implementation of Blockchain technologies in Logistics as part of the whole 4th Industrial Revolution platform. After the necessary introductory chapter, where scope, purpose, methodologies etc. are discussed, in the second chapter we lay down the basic theory behind the three key concepts explored in this study. In chapters three and four, then, we conduct the actual research, first in the available scientific literature, through an SLR and a classical literature review, and then in terms of case studies from the real world. In the fifth and final chapter we discuss the extend at which the potential of Blockchain technologies implemented in Logistics has been tried out and how future research can further the subject.

Keywords: Blockchain, Logistics, 4th Industrial Revolution, Smart Contracts, Transparency

# Chapter 1. Introduction

## 1.1 Scope and Purpose of the Study

The world got introduced to the Blockchain technology back in 2008 and the introduction of the Bitcoin cryptocurrency. It was the year that the global financial crisis would shake the foundations of the world economy, especially the banking and finance systems, leading to a multitude of transformations in many industries, Logistics being among them, as an answer to the new challenges. Some years later, in the wake of the economic crisis, the $4^{th}$ Industrial Revolution and its ideas would rise as a prominent new platform to solve problems of the past and face challenges of the future, through its proposed tools and technologies. In the meanwhile, cryptocurrencies brought forth the promises of this new Blockchain technology, Climate Change has become a priority for most nations, and the COVI-19 pandemic posed new challenges.

All of the above have culminated in a “brave new world”, in which Logistics play an important role as a facilitator for both solutions (economic sustainability) and challenges (environmental sustainability), and in which new technological propositions have arisen, through the new era that the $4^{th}$ Industrial Revolution has ushered. These new technological tools, with Blockchain being a part of a greater new technological approach platform, have been over the few years the main research subject of many academics and companies alike.

Based on the above, this study begun its scope as an effort to identify and report how academia and the world of business has approached those new technologies, and especially Blockchain, as a means to improve how Logistics operate within the broader global setting of supply chains and under the pretext of the new challenges that have risen over the past few years, from climate change and environmental sustainability, to income inequality and socioeconomic justice.

As the scope of the study was forming, it became clear that its purpose would account to fulfilling the need to understand how Blockchain technologies and the possibilities they carry could be implemented in today's Logistics, efficiently and sustainably, within the general context of the paradigm shift that the $4^{th}$ Industrial Revolution brings to the global economy, including the supply chains around the planet.

This purpose can be fulfilled with a "two-prong" approach, which means by studying both the available research literature on the subject and studying real life cases of Blockchain implementation, so as to be able to identify trends in both the world of academia and the world of business, regarding the connection between the Blockchain technology, the $4^{th}$ Industrial Revolution, and the Logistics sector, within the context of bringing forth a new standard for the better operation of global supply chains.

## 1.2 Research Questions

Based on the above explained scope and purpose of this study, the research questions that will guide the research work necessary for achieving this study's goal and help form the end findings are the following:

1. What is the level of interest in the global literature regarding Blockchain technologies used in Logistics within the context of the $4^{th}$ Industrial revolution?
2. What are the main trends explored in research literature regarding the thematic explained in the previous question?
3. Are there real-life examples of Blockchain technologies implementation in Logistics, within the context of the $4^{th}$ Industrial revolution?
4. Based on the above, how good does the prospective of Blockchain technologies implementation in Logistics, within the context of the $4^{th}$ Industrial revolution in the future looks?

The above research questions comprise the core of how this study is structured and in general approached, they formulate how the research is going to be carried out, with which methods and tools, and they, essentially, dictate how the findings of this study will be presented.

## 1.3 Research Methodology

The scope and purpose of this study suggests, within the framework of modern-day academic research, to take into consideration mostly online resources. Conducting the necessary research for this study means that information acquisition methods had to be taken under serious consideration, especially in regards to variety and reliability of information.

Nowadays, researchers in need of acquiring material such as papers and other peer-reviewed pieces of research can make use of a series of established and reliable sources, such as publishers, online libraries, and academic repositories, like Elsevier's ScienceDirect or SAGE's SAGE Journals. These online scientific resources aggregators can give access to a multitude of journals, books, papers etc. and on a multitude of subjects. Nonetheless, even within these vast knowledge bases, one has to identify the materials that are most relevant and useful to their research, and to do that, a series of reviewing methodologies exist.

Within the scope of the present study, the method that will be used is the Systematic Literature Review method. According to Dewey & Drahota (2016), one *"identifies, selects and critically appraises research in order to answer a clearly formulated question"* within the parameters of using SLR. By employing this methodology, a clearly defined and specifically designed protocol must be followed in order to study a series of clearly stated and defined criteria. Furthermore, in order to achieve the required levels of comprehension and transparency within its scope, an SLR needs to utilize research materials of multiple databases that are openly accessed to (at least) other researchers. Finally, conducting a Systematic Literature Review includes stating key characteristics of the study, such as the time boundaries, the search terms, and the specific databases used, among others.

Pittway's (2008) seven principles suggest a framework for a successful and meaningful conduct of an SLR. These seven principles one must adhere to are the following:

I. *“Transparency*
II. *Clarity*
III. *Integration*
IV. *Focus*
V. *Equality*
VI. *Accessibility*
VII. *Coverage”*

In order to more clearly understand the process of an SLR, the guidelines proposed by the Charles Sturt University are a useful tool. Within those guidelines, a systematic literature review is recognized as a demanding process that needs multiple researchers investing prolonged periods of time for a successful and thoroughly implemented SLR. According to those guidelines, the optimal process for an SLR is explained through the following steps:

- *“Identifying the answerable research question.*
- *Developing the protocol.*
- *Conducting systematic searches (including search strategy, text mining, choosing databases, documenting, and reviewing).*
- *Selecting studies for inclusion.*
- *Critically appraising included articles.*
- *Extracting and synthesizing data.*
- *Writing and publishing the review.”*

In order to understand the specifics of the systematic literature review methodology, we must note that its origins are traced, basically, in the field of medicine and, in general, it is linked to practices that are evidence-based. As Grant & Booth (2009) suggest, "the expansion in evidence-based practice has led to an increasing variety of review types". In their research, a comparison of 14 review types, listing strengths and weaknesses of each one, among others, entails an appraisal of the exhaustive nature of the systematic literature review methodology, as it revolves around achieving conclusions by exploring the links and the results between the exclusion and or the inclusion of search terms, along multiple search queries.

Regarding the current study and its scope, it can be understood that a Systematic Literature Review cannot be implemented in the fullest of its potential and using the whole offering it has in tools, as the needed manpower and time frame is beyond the resources available for the present study. Thusly, the Systematic Literature Review conducted in the context of this study will utilize a basic toolset and a choice of characteristics, so as to give the ability to deduct sufficient findings in regards to the discussed subject.

## 1.4 Findings and Limitations

The results of the study are more in depth explained in the conclusions chapter, but, overall, they can be summarized in the general conclusion that there is both an academic interest in and real-life applications of Blockchain technologies implementation in Logistics, especially within the context of the 4$^{th}$ Industrial Revolution.

There are, though some important limitations regarding the conduct of the research needed to achieve the aims of this study, as Blockchain technology is still a rather novel technology, so, on one hand, academic research is not adequately focused on certain aspects of the whole concept that this study discusses, and, on the other hand, study cases don't have enough time depth to offer the abundance of information needed to extract precise and deliberate conclusions.

## 1.5 Study Structure

The study is structured is such a way that its main purpose is achieved through a step-by-step deepening of the understanding of the key concepts discussed and the connections between them, both on a theoretical and on a practical basis.

After the current introductory chapter, the second chapter revolves around setting a theoretical foundation for the three key concepts that are discussed. Therefore, a presentation and explanation of key characteristics and aspects of the Blockchain technology, the Logistics sector and the premise of the 4$^{th}$ Industrial Revolution is conducted in the second chapter.

The third chapter hosts the literature review part of the study. In particular, the protocol and the results of a Systematic Literature Review on the available international research and regarding the key concepts of the study are presented, before extending the review to a series of actual papers from amongst the ones studied in the SLR, which have been found particularly interesting within the scope of the study.

The fourth chapter, on the other hand, serves to present real life practical implementation cases of the Blockchain technologies in the Logistics sector and especially within the premise of the 4$^{th}$ Industrial Revolution. These cases range from minor examples with references not overly deep, up to the case of COVID-19, which is analyzed and shown from a multifaceted aspect.

Finally, the fifth chapter concludes the study with a discussion of the finds from the three previous chapters, from the theoretical basis to the academic research review, and then to the real-life case studies, in order to aggregate and specify the results of the study. The fifth chapter ends with a set of proposals for further, in depth and in width, research on the general subject of this study.

# Chapter 2. Theoretical Foundation

## 2.1 Introduction

The scope of this study revolves around three distinct concepts. The technological breakthrough of Blockchains, the reality of the 4$^{th}$ Industrial Revolution as we already experience it, and the sector of Logistics, one of the most prominent economic sectors globally for the past few decades. In order for the purpose of this study to be fulfilled as it has been stated in the previous chapter, a theoretical foundation needs to be laid for each one of these three concepts. Therefore, in this second chapter, a presentation and explanation of the core characteristics of these three key concepts will be attempted, so as for the reader to be able to understand the extent and importance of each of those characteristics within the interactions and relations between the three key concepts.

## 2.2 Blockchain Technology

Blockchain technology is an emerging disruptive force regarding various industries, as it offers potential solutions to a variety of challenges faced by traditional systems in the context of the upcoming 4$^{th}$ Industrial Evolution era. It is essentially an electronic ledger technology, from which a host of other solutions has emerged, from cryptocurrency to ownership verification technologies, and beyond.

Following, the study will provide a theoretical foundation for understanding Blockchain technology, its history, applications, shortcomings, and benefits. By exploring these aspects, one can comprehend how Blockchain facilitates the implementation of 4th industrial revolution values within the logistics sector.

### *2.2.1 History of Blockchain Technology*

Blockchain technology originated with the introduction of Bitcoin in 2008 by an individual or group using the pseudonym Satoshi Nakamoto. Bitcoin's underlying Blockchain architecture revolutionized the way transactions were recorded, introducing a decentralized, transparent, and immutable ledger. Since then, Blockchain technology has evolved, and numerous alternative platforms and applications have been developed.

It was cryptographer David Chaum who first proposed a Blockchain-like protocol in the dissertation *"Computer Systems Established, Maintained, and Trusted by Mutually Suspicious Groups"* (1982), while it was Stuart Haber and W. Scott Stornetta (1991) who in their work introduced the concept of a "*cryptographically secured chain of blocks"*, in an attempt to achieve the implementation of a system within which timestamps that could not be tampered with could be attached to documentation. Further on, Haber, Stornetta, and Dave Bayer (1992) used the methodology of Merkle trees, incorporating it into their system design and, thusly, improving its efficiency though certificate collection from multiple documents within one singular block.

Regarding the modern iteration of the Blockchain technology, it was the "anonymous" person or group of people under the moniker of Satoshi Nakamoto that introduced the first concept of a decentralized Blockchain (2008). Nakamoto essentially worked upon improving the initial concepts behind the idea of a block of data containing tamper-proof certificates of documents, and they managed this by implementing techniques allowing for timestamping to not require signing by a trusted party, including the concept of a difficulty parameter as a stabilization parameter for the rate at which blocks can be added to the chain, effectively creating a decentralized, peer-to-peer system that didn't rely upon individual parties or authorities, but rather on multiple nodes within a distributed system (Narayanan et al., 2016). Of course, this was at first only a design concept, but within one year Nakamoto used the proposed technological solution of the Blockchain as the core component of the bitcoin cryptocurrency bitcoin, serving as a public, distributed ledger for the totality of the cryptocurrency's network transactions (The Economist, 2015).

Closing this brief historical reference to the emergence of the concept of the Blockchain, it is important for research purposes to note that the term Blockchain was not initially used as one word, but rather the separate words block and chain were used by Satoshi Nakamoto in the original paper, the complete term eventually being popularized later on, by 2016 (Johnsen, 2020).

Furthermore, an important indicator of how the Blockchain technology can potentially grow is the size of the historical bitcoin Blockchain file size, the file that actually contains the record of all the occurred transactions of the bitcoin network. In the beginning of 2015, the size of the file was already at around 30 GB, while in the beginning of the subsequent years was 50 GB and 100 GB. In December of 2023, the file size has already reached a size of 500 GB.

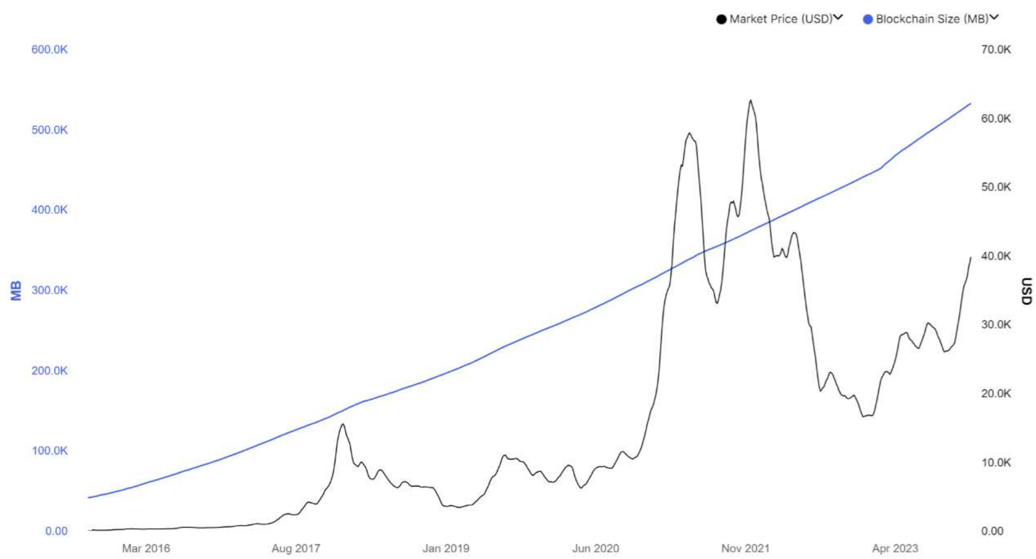


*Figure 1. Bitcoin network file size (Source: https://www.Blockchain.com/explorer/charts/blocks-size)*

## *2.2.2 How Blockchain Technology works*

### 2.2.2.1 Structure and Components

As previously explained, a Blockchain is effectively a distributed ledger that consists of blocks of data, each containing a list of transactions. These blocks are linked together in a chronological order, forming a chain. Apart from the basic component of the Blockchain, the block itself, and along with the concept of decentralization, the key components of a Blockchain include the consensus mechanisms, cryptographic hashing, and its distributed network nodes.

#### 2.2.2.2 The Concept of Decentralization

Decentralization is a fundamental aspect of Blockchain technology, eliminating the need for a central authority by distributing control across a network of participants. Effectively, data storage across an established peer-to-peer network helps the elimination of various risks posed when data is centrally stored.

The basic trait of a decentralized network is that each node in the decentralized system carries a copy of the whole Blockchain. The quality of the data file is maintained through this massive replication of the database itself, accompanied by mechanisms regarding computational trust (Raval, 2016). The lack of a centralized copy that exists as a unique official and authorized version, along with the fact that no user is considered more trusted amongst the other, are the effective tools that characterize decentralization and its usefulness.

#### 2.2.2.3 Consensus Mechanisms

Consensus mechanisms, such as Proof of Work (PoW) or Proof of Stake (PoS), ensure agreement on the validity of transactions, preventing malicious activities and promoting trust.

Proof of work (PoW) is a method of proving in cryptography, where the prover is expected to prove to the verifiers the fact that a specific amount of computational effort is expended. It’s a concept invented by Moni Naor and Cynthia Dwork in 1993 (Dwork & Naor, 1993) as a method to deter service abuses, such as DOS attacks or spam, by requiring the expenditure of computational work on behalf of the party that requests a service. In effect, this method provides when used in Blockchains an increasing degree of difficulty in verifying transactions, which in turn secures the validity of those transactions. This is also its biggest disadvantage, as the growing number of transactions and subsequently needs for computational power means that wide adoption of such Blockchains, such as the bitcoin, lead to huge amounts of energy consumption.

Proof of Stake (PoS), on the other hand, is a proving method that relies on selecting the needed validators by comparing the quantity of holdings they have in the associated Blockchain, a method that avoids the massive computational cost of PoW systems (Saleh, 2021). Of course, this comes along with its own disadvantages, as it is considered less secure than the PoW method, while it is also believed to be more centralization prone, because is effectively favors owners of larger amounts of stake in a Blockchain (Chandler, 2022).

### *2.2.3 Applications of Blockchain in Logistics*

#### 2.2.3.1 Supply Chain Management

Blockchain technology can enhance supply chain management by providing transparency, traceability, and accountability. Through an immutable ledger, stakeholders can track the movement of goods, verify authenticity, and ensure compliance with regulations. Smart contracts can automate and streamline processes, reducing intermediaries and increasing efficiency.

#### 2.2.3.2 Invoicing and Payments

When it comes to challenges in logistics, the development of efficient and secure systems for the purposes of invoicing and payments is a prominent one. As Blockchain technologies have already proved the benefits they provide in handling transactions effectively and securely with the introduction of cryptocurrencies and NFT’s, they are a prominent candidate for the solution to handling invoicing and payments in the logistics sector. The implementation of Blockchain technologies in this field can simplify payments across international borders, all the while ensuring the security and transparency of the transactions, preventing frauds and minimizing errors (Honrubia, 2023).

#### 2.2.3.3 Track and Trace

Blockchain-based track and trace systems enable real-time monitoring of goods throughout the supply chain. By recording each transaction on the Blockchain, stakeholders can easily verify the provenance, quality, and condition of products, reducing counterfeiting and enhancing consumer trust.

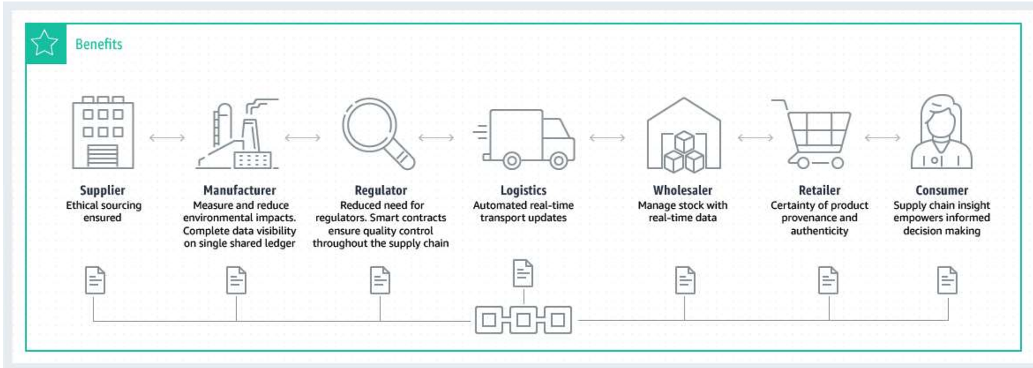


*Image 1. Amazon Web Services illustration on the benefits of using Blockchain technologies in logistics (Source: https://aws.amazon.com/Blockchain/Blockchain-for-supply-chain-track-and-trace/)*

#### 2.2.3.4 Smart Contracts and Automation

Smart contracts are self-executing agreements coded on the Blockchain. Within logistics, smart contracts enable automated processes, such as payment settlements, cargo insurance, and customs documentation. By eliminating manual intervention and intermediaries, smart contracts improve efficiency and reduce costs. (Governatori et al., 2018)

### *2.2.4 Shortcomings and challenges of Blockchain Technology*

#### 2.2.4.1 Scalability and Performance

One of the significant challenges Blockchain faces is scalability, as the technology's decentralized nature requires consensus from multiple nodes. The transaction processing speed and the size of the Blockchain can impact performance, limiting its applicability to high-volume logistics operations.

#### 2.2.4.2 Data Privacy and Security

While Blockchain offers enhanced security through cryptographic techniques, the immutability of data presents challenges related to privacy regulations, such as the General Data Protection Regulation (GDPR). Striking a balance between transparency and data privacy remains a critical consideration for Blockchain adoption.

### *2.2.5 Benefits of Blockchain in Logistics*

#### 2.2.5.1 Enhanced Transparency and Trust

Blockchain's immutable and transparent nature fosters trust among stakeholders by providing a single source of truth. Participants can verify the integrity and authenticity of data, reducing the reliance on intermediaries and improving overall transparency.

#### 2.2.5.2 Improved Efficiency and Cost Reduction:

By automating processes, eliminating paperwork, and reducing the need for intermediaries, Blockchain technology streamlines logistics operations. This leads to increased efficiency, reduced delays, and lower operational costs.

#### 2.2.5.3 Strengthened Security:

Blockchain's cryptographic techniques protect data integrity and prevent unauthorized access or tampering. This heightened security helps mitigate fraud, counterfeiting, and cyber threats within the logistics sector.

### *2.2.6 Conclusion*

Blockchain technology offers significant potential for revolutionizing the logistics sector by facilitating the implementation of 4th industrial revolution values. By enabling transparency, traceability, and automation, Blockchain enhances supply chain management, while its decentralized nature promotes trust and reduces reliance on intermediaries. Despite challenges related to scalability and data privacy, the benefits of Blockchain make it a promising solution for the logistics industry.

## 2.3 4$^{th}$ Industrial Revolution

The 4th Industrial Revolution represents a transformative phase in which emerging technologies are reshaping industries and societies. This section establishes a theoretical foundation for understanding the 4th Industrial Revolution, including its history, key technologies, potential applications, shortcomings, benefits, and initiatives taken by countries to embrace this revolution. By exploring these aspects, we can comprehend how Blockchain technologies can facilitate the implementation of 4th Industrial Revolution values within the logistics sector.

### *2.3.1 History and Evolution of the Industrial Revolutions*

The First Industrial Revolution, initiated in the late 18th century, witnessed the mechanization of production processes through the introduction of water and steam power, leading to the birth of factories and mass production.

The Second Industrial Revolution, in the late 19th and early 20th centuries, saw the advent of electrification, assembly lines, and the introduction of mass production techniques, transforming industries and enabling the rise of the consumer society.

The Third Industrial Revolution, starting in the late 20th century, brought about the digital revolution, characterized by the widespread adoption of computers, the internet, and automation. This phase revolutionized communication, information access, and global connectivity.

The 4th Industrial Revolution represents the integration of digital technologies with physical systems, blurring the lines between the physical, digital, and biological worlds. It is characterized by the convergence of various emerging technologies that include artificial intelligence (AI), robotics, Internet of Things (IoT), big data analytics, and Blockchain, among others. (Philbeck & Davis, 2018)

### *2.3.2 Key technologies of the 4th Industrial Revolution*

#### 2.3.2.1 Artificial Intelligence (AI)

AI involves the development of intelligent systems that can simulate human intelligence, enabling tasks such as natural language processing, machine learning, and computer vision. AI has the potential to revolutionize decision-making, predictive analytics, and automation within the logistics sector.

#### 2.3.2.2 Robotics and Automation

Advancements in robotics have led to the development of autonomous systems that can perform tasks traditionally carried out by humans. In logistics, robotics and automation enhance operational efficiency, reduce labor costs, and enable autonomous vehicles for transportation and warehousing.

#### 2.3.2.3 Internet of Things (IoT)

IoT connects physical objects and devices to the internet, enabling seamless data exchange. In logistics, IoT devices, such as sensors and RFID tags, provide real-time visibility, tracking, and monitoring of goods, optimizing supply chain processes and enhancing inventory management.

#### 2.2.2.4 Big Data Analytics

The enormous amount of data generated in the digital age can be harnessed through big data analytics. By analyzing vast datasets, logistics companies can gain valuable insights, optimize routes, predict demand, and improve overall operational efficiency.

### *2.3.3 Potential Applications of the 4th Industrial Revolution in Logistics*

#### 2.3.3.1 Smart Warehousing and Inventory Management

The integration of technologies such as IoT, robotics, and AI enables intelligent warehousing systems that optimize inventory management, automate picking and packing processes, and enhance overall supply chain efficiency.

#### 2.3.3.2 Predictive Analytics and Demand Forecasting

By leveraging big data analytics and AI, logistics companies can predict demand patterns, optimize routing, reduce lead times, and improve resource allocation, resulting in cost savings and improved customer satisfaction.

#### 2.3.3.3 Autonomous Transportation

Autonomous vehicles, enabled by robotics and AI, have the potential to transform transportation within the logistics sector. Self-driving trucks, drones, and delivery robots can increase delivery speed, reduce costs, and minimize human errors.

#### *2.3.4 Shortcomings and Challenges of the 4th Industrial Revolution*

##### 2.3.4.1 Workforce Displacement and Skills Gap

The widespread adoption of automation and AI technologies may lead to workforce displacement, requiring a reevaluation of job roles and skill sets. The need for upskilling and reskilling programs becomes crucial to ensure a smooth transition.

##### 2.3.4.2 Data Privacy and Security Concerns

As more data is generated and shared within interconnected systems, ensuring data privacy and security becomes a critical challenge. Robust cybersecurity measures and regulations are necessary to protect sensitive information.

#### *2.3.5 Benefits of the 4th Industrial Revolution in Logistics*

##### 2.3.5.1 Increased Efficiency and Cost Reduction

The integration of emerging technologies leads to streamlined processes, reduced human error, optimized resource allocation, and improved operational efficiency, resulting in cost savings for logistics companies.

##### 2.3.5.2 Enhanced Customer Experience

By leveraging advanced technologies, logistics companies can provide real-time tracking, improved delivery speed, and personalized services, enhancing the overall customer experience.

#### *2.3.6 Initiatives to Embrace the 4th Industrial Revolution*

##### 2.3.6.1 Germany's Industry 4.0

Germany has launched the Industry 4.0 initiative, focusing on the digitization of manufacturing and logistics processes. The initiative aims to enhance productivity, sustainability, and competitiveness through the adoption of emerging technologies.

2.3.6.2 China's Made in China 2025

China's Made in China 2025 plan emphasizes the integration of advanced technologies, such as AI, robotics, and IoT, to transform industries, including logistics. The goal is to transition from a manufacturing-based economy to an innovation-driven one.

#### *2.3.7 Conclusion*

The 4th Industrial Revolution represents a transformative era driven by the convergence of emerging technologies. By embracing technologies such as AI, robotics, IoT, and Blockchain, the logistics sector can unlock new opportunities for efficiency, transparency, and customer-centricity. However, challenges related to workforce displacement, data privacy, and security must be addressed to fully realize the potential of the 4th Industrial Revolution within logistics.

## 2.4 The Logistics Sector

The logistics sector plays a crucial role in facilitating the movement of goods, services, and information across the global economy. This section provides a theoretical foundation for understanding the logistics sector, including its history, subsectors, economic significance, incorporation of various technologies, and challenges faced in recent times. By exploring these aspects, we can comprehend the context in which Blockchain technologies can facilitate the implementation of 4th industrial revolution values within the logistics sector.

#### *2.4.1 History of the Logistics Sector*

The history of logistics can be traced back to ancient civilizations where efficient transportation and supply chain management were essential for economic and military operations. Over time, logistics has evolved from simple barter trade to complex global networks, driven by technological advancements and changing trade patterns.

### *2.4.2 Subsectors of the Logistics Sector*

The logistics sector encompasses various subsectors, including transportation, warehousing, inventory management, packaging, and information management. Each subsector plays a critical role in ensuring the efficient movement and storage of goods throughout the supply chain.

### *2.4.3 Economic Significance of the Logistics Sector*

The logistics sector has a significant impact on the global economy. According to World Bank data, global logistics costs accounted for approximately 7.7% of the world's GDP in 2019, highlighting its economic significance. The sector provides employment opportunities and contributes to trade facilitation, economic growth, and competitiveness.

### *2.4.4 Incorporation of Technologies in the Logistics Sector*

#### 2.4.4.1 Information and Communication Technologies (ICT)

ICT has transformed the logistics sector by enabling real-time tracking and monitoring, optimizing route planning, enhancing supply chain visibility, and improving coordination among stakeholders. Technologies such as IoT, big data analytics, cloud computing, and data-sharing platforms have revolutionized logistics operations.

#### 2.4.4.2 Automation and Robotics

Automation and robotics have revolutionized logistics operations by streamlining warehouse processes, optimizing material handling, and improving order fulfillment. Technologies such as autonomous vehicles, drones, and robotic systems enhance efficiency, reduce costs, and improve safety within the logistics sector.

#### 2.4.4.3 Blockchain Technology

Blockchain technology offers potential solutions to challenges in the logistics sector, such as supply chain transparency, traceability, and trust. Through its decentralized and immutable nature, Blockchain can enhance visibility, improve provenance verification, enable secure transactions, and streamline processes, contributing to the overall efficiency of the logistics sector.

### *2.4.5 Challenges Faced by the Logistics Sector*

#### 2.4.5.1 Climate Change and Sustainability

The logistics sector faces the challenge of reducing its environmental impact, given its significant contribution to greenhouse gas emissions, energy consumption, and waste generation. Efforts are underway to implement sustainable practices, promote alternative fuels, and optimize supply chain operations to mitigate the sector's environmental footprint.

#### 2.4.5.2 Pandemics and Disruptions

The COVID-19 pandemic highlighted the vulnerability of global supply chains to disruptions. Lockdowns, border closures, and reduced transportation capacities impacted logistics operations. The sector must develop resilience, contingency plans, and digital capabilities to navigate future crises effectively. Further elaboration on the subject will be presented in the next chapter, through a more in-depth look on the COVID-19 case, regarding its effect on global supply chains.

#### 2.4.5.3 Geopolitical Conflicts and Trade Wars

Geopolitical conflicts, trade wars, and protectionist policies create uncertainties and disruptions in global trade flows. The logistics sector must adapt to changing regulations, tariff barriers, and geopolitical dynamics to ensure the smooth movement of goods and services across borders.

### *2.4.6 Conclusion*

The logistics sector, with its historical evolution and diverse subsectors, plays a crucial role in global trade and economic development. By incorporating various technologies, such as ICT, automation, robotics, and Blockchain, the logistics sector can enhance efficiency, visibility, and sustainability. However, challenges such as climate change, pandemics, and geopolitical conflicts require proactive measures and innovative solutions to ensure the sector's resilience and adaptability.

# Chapter 3. Literature Review

## 3.1 Introduction

In order to better understand the current academic and research take on the subject of this study, a systematic literature review has been conducted, so as to identify the presence of the discussed concepts within the overall academic research reality. In this chapter, the systematic literature review protocol and results will be presented, alongside a more in-depth review of specific articles that can give better insight regarding the connection between the three key concepts of this study.

## 3.2 Systematic Literature Review Protocol

As mentioned, achieving the goals this study has set, including answering the research questions that have been posed, involves a systematic literature review (SLR), which will be conducted according to methodologies published in research papers and other credible sources (Shaffril et al, 2021; Ortiz et al, 2021; Mariano et al, 2017) and within the context presented in the first chapter.

The basis for an SLR to be conducted is, first of all, to establish the basic question pertaining to the scope of the particular review. In the case of this study, the question would be “is there interest in the global research community regarding the connection between Blockchain technologies and the Logistics sector, especially within the context of the 4$^{th}$ Industrial revolution?”.

With the main question in mind, the main objective of this SLR is to perform a systematic review on the available literature on the connection between Blockchain technologies and the Logistics sector, and more specifically to see if this connection is referencing the premise of the 4$^{th}$ Industrial Revolution. By doing this review, the study will help in the identification of possible gaps in international literature in regards to the subject discussed, the integration of Blockchain technologies in the Logistics sector as part of a transformation process within the scope of the 4$^{th}$ Industrial Revolution.

In order to accumulate the proper sample of articles, a series of inclusion and exclusion criteria must be set, a process that is very important in conducting a Systematic Literature Review. These criteria determine whether a paper will be included in the analysis or be excluded from it. These criteria, essentially serve as indicators of most of the main characteristics of the analysis, which are the time period from which research is selectable, keywords used when searching for papers, the sources / depositories that will be used, amongst other.

For the purposes of the current study the criteria are the following:

Inclusion criteria

- Study contains the keyword “Blockchain”.
- Study contains the keyword “Logistics”.
- Study contains the key phrase “4$^{th}$ Industrial Revolution”.
- Study has been conducted from 2018 onwards.
- Study is open access.
- Study is in the form of published scientific paper.

Exclusion criteria

- Study not in a published paper form.
- Study not in English.
- Study not validated.
- Publication data of the study not available.
- Either of the keywords is only referenced and not used within the main context of the study.

From the criteria presented here, it is clear that research will be conducted in the sense of identifying papers published between 2018 and 2023 in two of the most prestigious research paper depositories, i.e., SAGE and ScienceDirect, in the English language, and mentioning at least the terms Blockchain, Logistics, and 4$^{th}$ Industrial Revolution, all while not satisfying any of the the exclusivity criteria, which include a better analysis of how the key terms are used within the papers.

So as to be able to further and narrow down the selection process of the articles closer to the purpose of this study, the following two questions must be positively answered for a paper to be accepted:

- Is the study referring primarily and in depth to the connection between Blockchain and Logistics?
- Is the study connecting the two main concepts to the premise of the $4^{th}$ Industrial Revolution, even by simple reference?

These two questions pose as the second stage of screening the searched papers, after the inclusion and exclusion criteria. The papers that pass the two phases are then counted within the scope of the Systematic Literature Review and are further analyzed in whether they are useful enough to be referred to the next stage of this study, the basic literature review stage.

## 3.3 Systematic Literature Review Results

The two main depositories used, SAGE Journals and ScienceDirect by Elsevier have their own search schemes, therefore each one of the two search processes should be tweaked accordingly.

Particularly, in the case of SAGE, the term $4^{th}$ Industrial Revolution was excluded, as it gave back zero (0) results, while in the case of ScienceDirect the term was included in the search in order to narrow down the results. Thusly, as one can see in the screenshots from the search queues, there were eventually a total of 280 results, 93 from SAGE Journals and 187 from ScienceDirect.

This first batch of papers was then analyzed as to both the inclusion and exclusion criteria (most of which were integrated in the search process itself) and the second phase questions. As a result, a total of 29 articles were found to adhere to the rules of both phases of the selection process. The list of the papers that made it to the end of the review process is presented in the Appendix of the study. The ones used for the further literature review section can also be found in the References of the study.

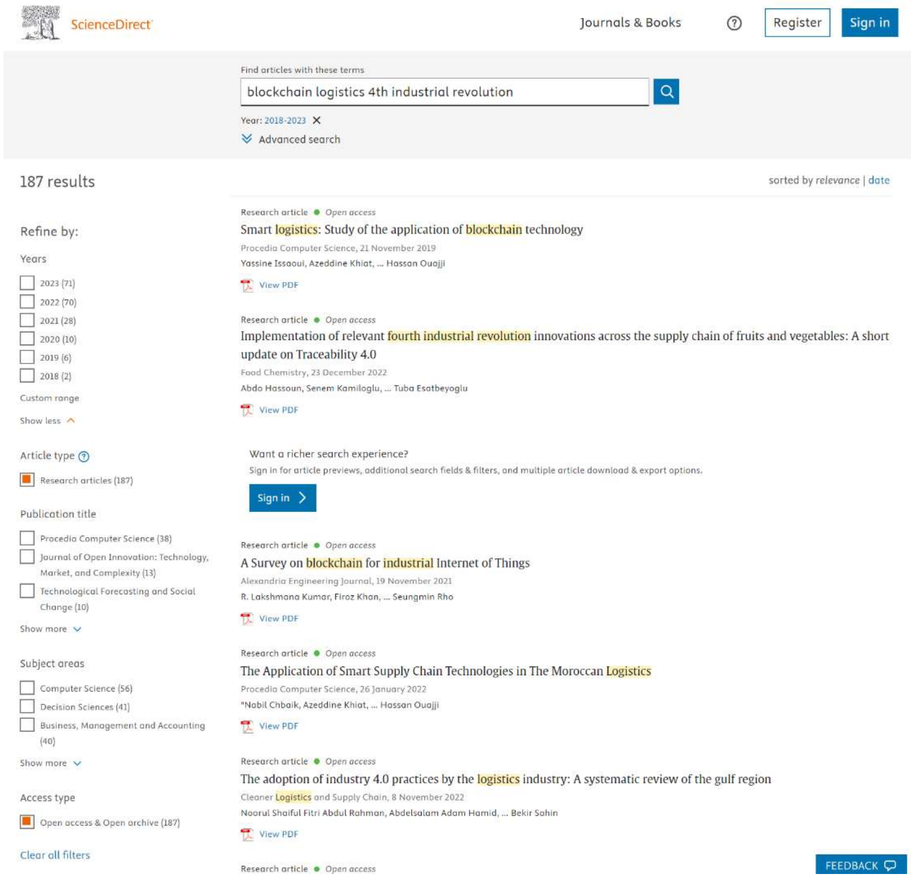


*Image 2. Search Results on ScienceDirect (Source: www.sciencedirect.com)*

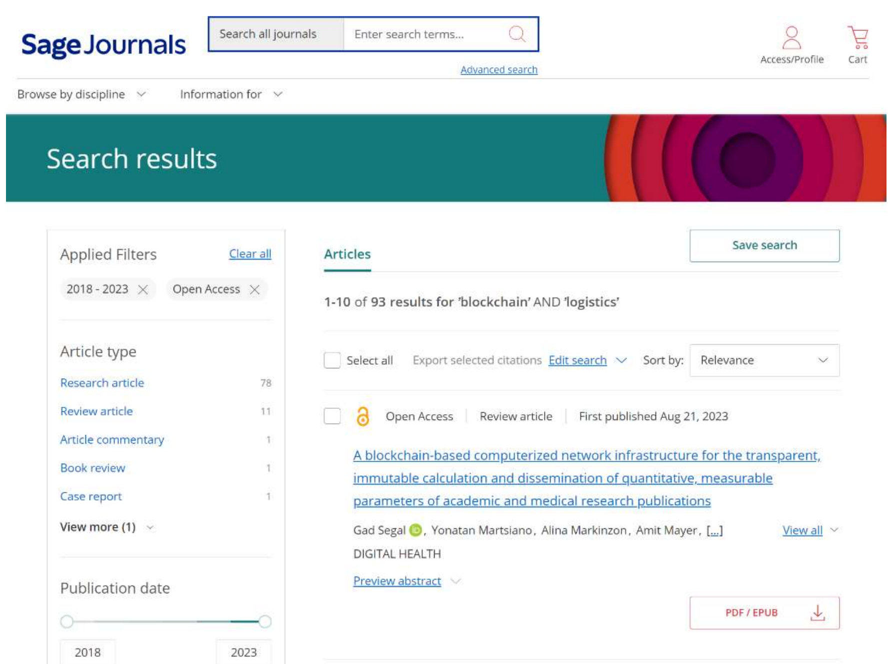


*Image 3. Search results on SAGE Journals (Source: journals.sagepub.com)*

What that means for the overall discussion regarding the purpose of this Systematic Literature Review is that, although Blockchain technologies as an implementable concept, especially within the framework of the Logistics sector, is a fairly novel concept, academic interest is present.

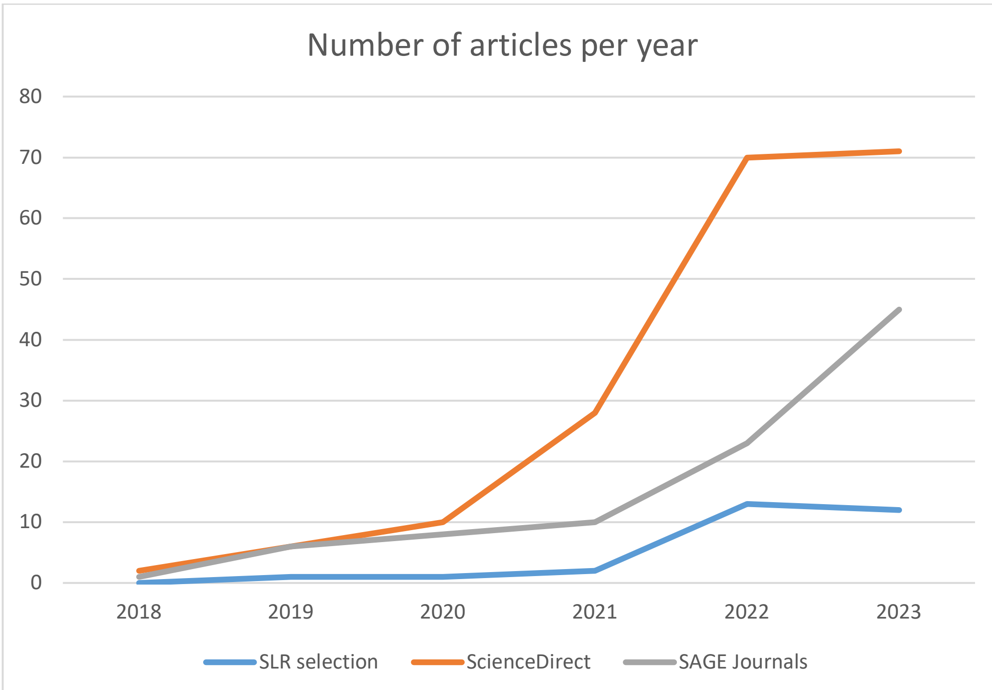


*Figure 2. Number of articles per year - By source and passing the SLR conditions*

Nonetheless, there is still room for further specification of the research as to connecting the three main concepts of this study, which means to not only study the implementation of Blockchain technologies in the Logistics sector, but also studying the synergies that can come from this connection within the scope and purpose of the 4th Industrial Revolution.

Overall, the main finding of this review is that the scientific world is at the beginning of the research on the implications that Blockchain technologies can have on the Logistics sector and the global economy itself, in the dawn of the 4th Industrial Revolution.

Regarding the main trends that have been identified in the selected articles, the following graph showcases the most prominent ones. It should be noted that certain trends are found within the same article.

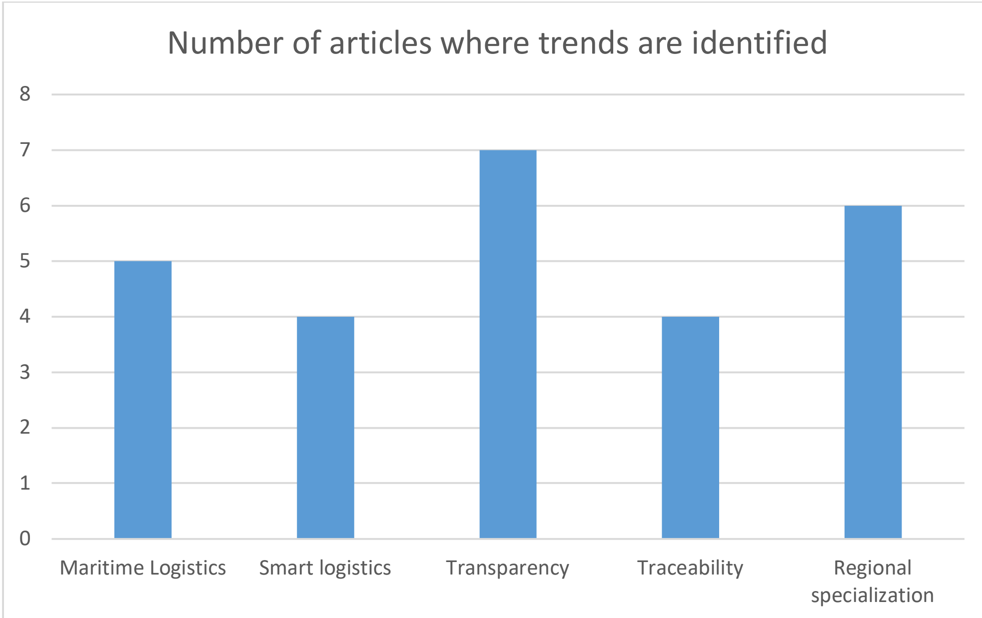


*Figure 3. Number of articles where trends are identified*

## 3.4 Literature Review

In this section of the literature review part of this study, a series of subjects will be discussed as found within the context of the SLR performed and the relevant scientific articles selected through it. Each subject will cover one or more articles and will showcase research and practical implementations of blockchain technologies in logistics, especially under the overall theme of the 4th Industrial Revolution.

Two sidenotes are important. First, not all the articles identified in the SLR are used in this section, due to varying degrees of interest of their content in comparison to the scope of this study. Although all 29 articles are satisfying the conditions placed in the SLR above, not all of them serve the purpose of this subsection, in presenting key trends found within the literature. Therefore, although all 29 articles are listed in the Appendix, they are not all referenced in the study's bibliography.

Second, although the SLR is conducted within the time restriction of articles published from 2018 onwards, within the identified and used here articles there are sources and references that precede this date. As it was selected to present the original sources of further material found within the reviewed articles, rather than attributing everything in them to the article's writers, there can be found references in this review predating 2018.

### *3.4.1 Transparency in Logistics*

Within the framework of research on Blockchain technologies implementation in Logistics, certain aspects of the core of this technology have gained more track. For example, the trait of transparency is among the most sought-after traits of the technology, as it is a key component of the freedom it offers its stakeholders from traditional institutions and authorities. Therefore, it is expected that research has gone into this aspect as well.

For example, Iranmanesh et al (2023) have investigated how much businesses along the path of extended supply chains are intended to adopt Blockchain technologies and what contributes most in their decision to do so. In order to proceed with their investigation, they conducted a field study, which aimed to measure the extent that parameters of Blockchain technology contribute to influencing supply chain stakeholders to adopt said technology among. The target group of the study were mainly SMEs and in particular the necessary data was acquired from inquiring the managers of 204 manufacturing SMEs in Malaysia. The main outcome from this survey was that managers seemed to have greater intentions of adopting Blockchain by certain contributions they believed it would have towards the operation of their supply chains. Particularly, transparency and agility, as well as alignment and adaptability, all interrelated attributes of a supply chain, were the main contributing factors that the inquired managers suggested as the most significant. In general, modern-day Logistics have grown in scope and complexity, meaning that there are even greater margins for both error and fraud, therefore transparency, especially for smaller actors with limited resources, within an extended Blockchain network that supports information dispersion and process automation, means that they can have access to decision making important data in a fast and reliable way, ensuring their businesses' sustainability.

How important of an aspect transparency is when considering Blockchain technologies implementation in Logistics is evident when investigating how it can affect finance in the industry. Guo et al (2022) have studied such implications on what they call Supply Chain Finance (SCF), a concept of designing and operating financial service where banks trust a series of core enterprises up and down the supply chain to manage capital flows and operations of logistics. Utilizing the SCF concept means that a *“self-testing and closed-loop credit model to control funds and risks”* is adopted, with the core element of a successfully implemented SCF system being the deployment of an efficient and sufficient information systems which can enable enterprises and organizations along the supply chain to partner up efficiently and accelerate processes that affect cash flows upstream and downstream. As Blockchain technology features a host of traits, such as decentralization, tamper-proofing, and traceability, all the while it facilitates “smart” technologies, like Internet of Things (IoT), to accumulate data in almost real time in real-world situations, it has been widely accepted as a remarkable solution in Logistics finances for the creation of efficient and innovative collaborations between supply chain stakeholders.

### *3.4.2 Traceability in Logistics*

Another core element of Blockchain technologies that has been researched in the context of real-world Logistics implementation, especially within the scope of 4$^{th}$ Industrial Revolution ideas and concepts, is traceability, the capacity to reliably know and understand the path a product, a process, a cash flow, information etc. have taken up and down a supply chain. Industries that deal with especially sensitive products, like foods and pharmaceuticals, as well as dangerous ones, can benefit in terms of protecting the end users and their sustainability by implementing Blockchain technologies in their Logistics.

For example, Hassoun et al (2023) are suggesting the concept of Food Traceability 4.0, i.e. applying 4th Industrial Revolution technologies, tools and concepts in ensuring the authenticity, safety, and high quality of food products. As interest in traceability for the food industry has grown the past decades, a wide range of specialized methods (chemical, biomolecular, spectroscopic, isotopic, and chromatographic) have been developed in order to achieve the best possible level of food traceability, all with performance and success rate that widely vary. Hassoun et al reviewed how applying the concept of Food Traceability 4.0 in the sectors of fruits and vegetables is benefiting the supply chains, especially focusing in Blockchain enabled tools form the 4$^{th}$ Industrial Revolution toolset, like Internet of Things and Big Data. According to their study, Food Traceability 4.0 is a platform with significant potential in improving the quality and safety of products in the fruits and vegetables sector, by enhancing transparency, reducing costs regarding food recalls, and decreasing the produced waste. As Blockchain technologies advance such tools will be able to better be implemented along supply chains, expanding the benefits to greater networks.

Apart from food, pharmaceuticals also is a field that can benefit from the advanced traceability that the implementation of Blockchain technologies, within the scope of 4$^{th}$ Industrial Revolution as a technological platform can offer to supply chain stakeholders, as Mueen et al (2021) show in their study. On pharmaceutical supply chains (PSC). These consist of a multitude of stakeholders that includes raw material suppliers, manufacturers, distributors, regulators, pharmacies, hospitals, and patients. As products and transactions flows display a high level of complexity within a PSC, a more effective traceability system is needed for the determination of the ownership history of a product. Furthermore, with the digitization of tracking and tracing of pharmaceuticals, significant benefits can arise regarding regulatory oversight and, effectively, product safety. Therefore, a Blockchain-based method of tracing drugs could provide a potential viable solution in the creation of a distributed and shared platform for data, characterized by immutability, trustworthiness, accountability, and transparency. Mueen et al present in their study an overview of the issues that PSC’s face regarding product traceability, like counterfeit medicine, and offer an insight on how blockchain technology could effectively provide solutions to those issues, displaying how research can help the implementation of Blockchain technologies in various Logistics subsectors, especially with the help of tools provided by the 4$^{th}$ Industrial Revolution platform.

### *3.4.3 Regional and localized research*

A trend that was identified in the SLR conducted regarding the implementation of Blockchain technologies in the Logistics sector, within the scope of the 4$^{th}$ Industrial Revolution, is that research can focus or regional and localized cases, exploring the depth of adoption of the technologies studied in the present study, possibly suggesting more customized solutions, in regards to the needs and challenges of distinct areas of the planet.

For example, Rahman et al (2022) have studied how Logistics in the Gulf region can be affected by digitalization approaches stemming from the 4$^{th}$ Industrial Revolution platform in sectors like manufacturing, retailing, warehousing, and transportation. In the so-called Gulf Cooperation Council (GCC) region is, according to Rahman et al, the adoption of 4$^{th}$ Industrial Revolution technologies by the Logistics sector is *“still at the nascent stage*”. Such studies are useful in identifying gaps within the global supply chain that generalized research could possibly miss. Knowing where the adoption of a new technology is lacking, is a great way to improve the ways it is approached and implemented.

Another example comes from Chbaik et al (2022) and their study on Moroccan supply chains. In this study, the researchers discuss how smart supply chain technologies, with Blockchain technologies being prominent amongst them, are implemented in the Moroccan industry, by segmenting their study in three parts: first, they present how Moroccan industries are classified on a global scale, according to their Gross Domestic Product, second, they calculate and display what percentage of this GDP is represented by Logistics processes within each industry, and, third, they conduct a survey regarding the application of smart technologies in the Moroccan industry. Thusly, they have designed a system that can help better understand the adoption of innovative technologies in industries, normalized according to their relation to the Logistics sector.

Lastly, as per the scope of this review, there is a study by Nadir Munir et al (2023) that focuses on Pakistani logistics. The researchers have conducted a survey with a cross-sectional design, collected data from 475 SME managers from Pakistan. Their study offers finding that accent the significance of

Blockchain technologies adoption by SMEs, in facilitating them to achieve a supply chain wide integration of data sharing. Closing this section, it should be mentioned that similar research was further identified, all articles suggesting how Blockchain has gained fame as a potentially powerful tool in modern Logistics, across various regions on the planet.

#### *3.4.4 "Smartification" of Logistics*

As it has been previously mentioned in this study, the integration of so called "smart" technologies, i.e. technologies that adhere to some of the 4$^{th}$ Industrial Revolution core ideas, like automation, web access, AI etc., in Logistics, has been a proponent of growth of the sector in recent years. Thus, research into the still fairly complex concept of Smart Logistics is on the rise.

Smart Logistics is a multifaceted tool; they can be used to accommodate functions within geographically dispersed areas, to acquire raw materials of the highest possible quality while maintaining costs that are low enough to be considered sustainable, as well as to facilitate the marketing of new products reaching larger numbers of consumers. The 4$^{th}$ Industrial Revolution tools that Smart logistics incorporate vary from IoT devices to 5G enabled interconnectivity, and from high end sensors and actuators to RFID cards. All these components, through their interoperability, can amass, consequently, exorbitant amounts of data, the generation of which leads to the emergence of new challenges (Rafik et al, 2019). Therefore, issues arise in the sense of confidence, true interoperability, security, reliability, transparency etc., posing major challenges in the implementation of wider infrastructures under the framework of Smart Logistics. Problems like fraud or theft, like loss or damage of data, even diversification needs within the parameters of marketing policies, as well as the variability and amount of expenses accompanying the innumerable financial transactions that are needed for the management of goods around the globe, are intensified by the data generated, the same data that can actually boost the efficiency and results of Logistics. (Issaoui et al, 2019)

Among the challenges mentioned above, transparency within the supply chain remains utterly important and in the core of most of the problems regarding the most difficult to manage areas of logistics and supply chain management (Abeyratne & Monfared, 2016). This means that if the industry could achieve a simple, secure, and fast method of sharing information (as well as products, funds, and processes) the needs of the vast majority of the sector's companies would be met. This is the void that Blockchain technologies, as a new paradigm for both computer science in science and data flows in particular, have been screened as a possible solution, through their broad variety of potential implications regarding how supply chain management and logistics could develop in the future. This is mostly due to how Blockchain technologies have the capacity to ensure higher levels of data security, along with reliability, traceability, and authenticity, resulting in increasing the trust that occurs between actors within the supply chain and the end consumer, by means of providing highly reliable information through the use of a publicly accessed Blockchain network (Tian, 2017).

Based on the above, Issaoui et al (2019) conducted research on the basis that examining *"the scope of Blockchain technology in the field of smart logistics"* was a research field that needed immediate attention. For this purpose, their study was segmented into four distinguished thematics around the implementation of Blockchain technologies to a general Smart Logistics framework. These are a) Information, b) Transport, c) Finance, and d) Management. These are considered by Issaoui et al as the most important categories of Blockchain implementation in Logistics as part of the Smart Logistics philosophy. As Smart Logistics is mostly defined by implementing 4th Industrial Revolution staple technologies, like AI, IoT, Cloud etc., all the while being characterized by its capacity to facilitate *"transfer of autonomy, intelligence, and autonomous decision-making machines*", the emergence of Blockchain technologies has revolutionized the possibilities that the four distinct fields mentioned above in terms of data acquisition, handling, analyzing, and, finally, utilizing, within the framework of more secure, more reliable, and more transparent communication along the supply chain's whole length. It is this ability the Blockchain has to boost the characteristics of traceability and authenticity of information within a context of intelligently contractualized relationships within an environment that can be effectively trustless, that has sparked the interest of companies and researchers regarding its implementation in Smart Logistics (Saberi et al, 2018). Regarding, now, the four fields Issaoui et al focused their research on, they have concluded the following.

a) Information

Communications and flow of information are highly prioritized in the Logistics sector, with supply chains relying on data for a variety of reasons, like being able to ensure internal and external communications with stakeholders along the supply chain, utilizing data in order to facilitate control and decision making, enabling the collection of forecasting data etc. As this information is apparently of high value for the organizations and companies, they are induced to utilize methods that can lead to upgraded security and reliability within the management scope of the supply chain entities. At the moment, Blockchain technologies are the ones that allow this so needed more secure tracking for the information flows of supply chains, especially within the context of Smart Logistics, where $4^{th}$ Industrial Revolution tools offer vastly broader data variety and quantity. Applying Blockchains in the context of information means that each asset needs to be registered in the blockchain as it passes through supply chain nodes. These assets can be order tracking data, receipts and invoices, payment information, licenses and certifications, warranties, serial numbers and barcodes, and various other official documents and digital assets (Tijan et al, 2019).

Issaoui et al refer a number of examples on this benefit in their research. Amongst those, there is a mutual project brought forth by the companies Microsoft and Mojix, with the intention to achieve a minimization on how databases generated within supply chains, by different stakeholders, can differ. Achieving that, would make supply chains even more agile, as new information could be more quickly and more effectively be accounted for in decision making, as it would be more compatible with one’s systems (del Castillo, 2017). Furthermore, Issaoui et al refer the consortium of companies BASF (a chemical industry actor), Quantoz (a fintech start-up), and the Ahrma group. The purpose of this partnership is the collection and sharing of data within their supply chain, nearly in real time, based on a system incorporating sensors-equipped palettes that are capable of writing data straight to a blockchain that the partners have access to (Lace, 2017). Apart from the quick and effective collecting and sharing of data within the supply chain, the ability to monitor, report, and effectively track information along a supply chain, offering data traceability capacities to both end-users and stakeholders is an important aspect of Blockchain technologies implemented within the scope of smart Logistics. As Blockchain observes a decentralized model, where public access and authentication are key traits, Blockchain technologies can offer a lot of advantages in this field of informatics. Issaoui et al have two implementation examples to refer, regarding data traceability in a Smart Logistics environment. The first is in regards to the partnership between the grain exporting company CBH and an Australian start-up company in the agricultural field, AgriDigital, a partnership that has as a core aim to help the CBH group gain competitive advantage in the Asias markets by means of proving the oats they provide are sourced from Australia, therefore of higher quality (Zhao, 2017). The second refers to the creation of an application that can facilitate the traceability of geological samples produced by a prominent mining company, BHP Billiton. The way the application helps is by immutably recording data to a public channel on the Ethereum Blockchain regarding original sampling locations, as well as handling processes data (Rizzo, 2016).

b) Transport

Applying Blockchain technologies in the transportation field can vary and offer diverse solutions. For example, Walmart, one of the greatest retailers worldwide in the supermarkets field has pursued and granted a patent regarding the improvement of last-mile logistics via the connection of delivery drones to a blockchain network (Hackett, 2017). Innovation in this field has the capacity to get generalized across every agent and operator, operation or equipment included in every segment of the supply chain. Furthermore, to integrate blockchain technologies into maritime logistics can lead to the increase of sustainability and problem identification speed, as well as the reduction of fraud, delays, waste, and red tape. According to research, such implementations could lead to the increase of world GDP by ~5% and volume of trade by ~15% (WEFR, 2018). Additionally, according to data DHL (2019) has officially published, information wrong enough to rise litigation claims can be found in up to 10% of all bills of lading worldwide, a problem that blockchain technologies could quite possibly play an important role reducing, while also improving logistics processes in general. All these implementations and integrations are part of a broader approach of “smartification” of transports, within the broader Logistics field.

c) Finance

As has been mentioned previously in this study, essentially the Blockchain technologies, as they are today, were first introduced as the basis for the first cryptocurrency, Bitcoin. By making use of a P2P architecture and through operating without the need for an authority, like a bank, a centralized national or multinational agency, a notary etc., Bitcoin, and cryptocurrency in general, strives for a payment finalization process where intermediate actors are absent, meaning that both such intermediary costs and delays are also reduced, close to zero(), as well as the minimization see the absence of the charges of movement of the funds. If one combines the above traits of cryptocurrencies, therefore Blockchain technologies, with the “smartification” of Logistics, a series financial services, like remittances or online payments can be facilitated. Such services greatly affect efficiency within supply chain processes and the end result of financial transactions long the supply network (Hofmann et al, 2018). Just the simplification of the processes regarding the acquisition of products and services, all done through basic concepts like overcoming currency constraints and minimizing transfer charges, can improve the business aspect of Logistics.

d) Management

Another aspect that Blockchain technologies integration in the “smartification” process of Logistics could have a drastically positive effect is management in general. As Smart Logistics is attributed the ability to improve processes within the supply chain, management can benefit from the added agility and transparency within the improved supply chains. As data acquisition and communication can now become nearly in real-time, managers can have a clearer picture on the operating status along even the entirety of a supply chain, acquiring, thus, the capacity to make decisions in time and reliably. As is referred in Issaoui et al's research, there are various examples regarding this benefit and suggests further research, as in Kshetri (2019), where multiple case studies are referenced, or Saberi et al (2019), where the most significant obstacles regarding the adoption of blockchains within the context of Smart Logistics are explored. Within the more distinct management aspect, smart contracts are recognized as the Smart Logistics tools backed Blockchain technology that most positively influences sharing of data between supply chain participants and, effectively, the continuous improvement of processes within it (Saberi et al, 2018), through the provision of a better interconnection between transactions involving various currencies and from a multitude of sources globally, that offers advanced security and speed of completion (Eyal, 2017).

### *3.4.5 Blockchain in Maritime Logistics*

The usage of Blockchain technologies as a means to facilitate the introduction of 4th Industrial Revolution concepts and tools in arguably one of the most significant sectors of Logistics, Maritime Logistics, is present in research literature. Ichimura et al (2022) are studying how major maritime actors plan out their future strategies in regards to the digitization of Maritime Logistics, beginning with recognizing the importance of the 4th Industrial Revolution as a platform providing an array of cutting-edge technologies, such as Artificial Intelligence, Big Data Analytics, Cloud Computing, and Internet of Things. These technologies, as Ichimura et al note, already influence the field. Such examples can be found even in advanced projects like the construction of autonomous ships, with projects like the Yara Birkeland or the Autonomous Spaceport Drone Ship (ASDS). The operational paradigm of maritime transports has already transitioned in a digitalization era, with shipping companies promoting this process as the future of maritime logistics, focusing their efforts on setting up relevant strategies and already executing transitional programs. Among those efforts, Blockchain technologies play an important role as a key component of many of the projects, tools, and paradigms applied to maritime operations, in order to further progress the digitization of the industry.

Another interesting idea on the utilization of Blockchain technologies within the context of Maritime Logistics and the utilization of 4$^{th}$ Industrial Revolution tools and methods is explored by Behzad (2023), in their study on the Port 4.0 concept. As port and terminal operators come to face even greater challenges regarding how complex and demanding the Logistics field is growing, there has risen a need for the complete port ecosystem, including not only seaports, but also the intermodal terminals that support the supply chains inland, to alleviate this modernization pressure, by implementing new tools, methods, and concepts. Such a concept is presented by Behzad in Port 4.0: a philosophy in designing and managing a port such that leveraging advanced technologies in order to achieve the digital transformation of core business processes, improvements to security, better operational efficiency, and greater levels of sustainability, is made possible. Behzad offered a conceptual framework for Port 4.0, as seen in the following image.

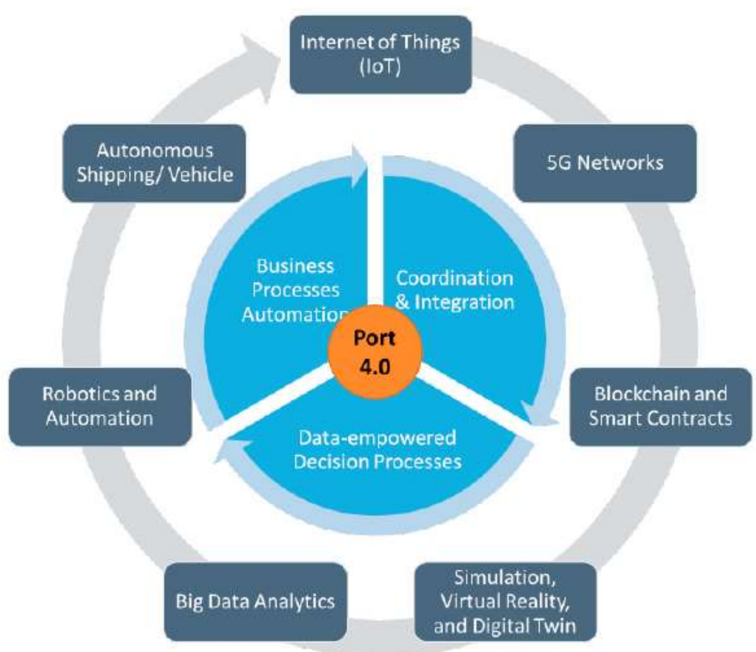


*Image 4. Port 4.0 concept framework (Source: Behzad, 2023)*

In this conceptual framework, a number of key principles that enable the digitalization of key port services and processes is presented. Blockchain technologies are at the core of this effort, as the decentralized digital ledger philosophy that essentially describes the Blockchain, is the key to all actors along the supply chain being able to verify transactions, as soon as they occur, hence allowing for the near total omittance of faking, hacking, or disrupting crucial data in the network. Further deeper in Blockchain implementation, the tool of smart contracts, as an essentially self-executing form of contract, is a great asset for the digitization of maritime logistics, giving stakeholders the capacity to store predetermined terms and conditions for the transactions between buyers and sellers in a blockchain and have them automatically carry out a contract if the given conditions are met (Sangeerth & Lakshmy, 2021). By using these smart contracts in the process of automating workflows and communications, stakeholders enable the better use of IoT devices and applications, promoting automation in ports (Ahmad et al., 2021).

# Chapter 4. Case Studies

## 4.1 Introduction

As Blockchain technologies are already being implemented in a variety of real-life scenarios, it is important to study such cases so as to understand the potential synergies between the Logistics sector and the 4$^{th}$ Industrial Revolution proposed solutions, within the framework of the revolution the Blockchain technologies themselves can bring to the more efficient and more secure operation of Logistics on a worldwide scale.

In this chapter, a variety of cases will be explored, from the overall situation the COVID-19 pandemic brought the world economy into, to more specific implementations and applications of Blockchain based solutions in the broader Logistics sector.

## 4.2 The COVID-19 case

The logistics sector has faced unprecedented challenges during the COVID-19 pandemic, leading to significant disruptions in global supply chains. This section explores the specific impacts of the pandemic on the logistics sector, including the bullwhip effects and price elevation observed in sectors such as automobiles. The analysis is supported by references from reputable news outlets.

### *4.2.1 Impact of the COVID-19 Pandemic on the Logistics Sector:*

a. Reduced Transportation Capacity

The COVID-19 pandemic resulted in a sharp decline in global air cargo capacity as airlines grounded flights and imposed travel restrictions. According to the International Air Transport Association (IATA), global air cargo capacity in April 2020 was down 35% compared to the same period in 2019 (Mouawad, 2020). The reduced air cargo capacity disrupted the flow of goods and caused delays in logistics operations.

b. Supply Chain Disruptions

The pandemic exposed vulnerabilities in global supply chains, with disruptions in manufacturing, closure of factories, and shortages of raw materials. The closure of factories in China, a major manufacturing hub, had a cascading effect on global supply chains. The Wall Street Journal reported that the shutdown of Chinese factories disrupted the supply of critical components and materials, affecting industries worldwide (Zumbrun et al., 2020).

c. Increased Demand Variability

The COVID-19 pandemic resulted in significant shifts in consumer behavior and demand patterns. Panic buying and stockpiling of essential goods, as well as increased demand for e-commerce deliveries, created fluctuations in demand. The abrupt changes in demand posed challenges for supply chain management and inventory planning. For instance, the surge in demand for medical supplies, such as personal protective equipment (PPE), strained global supply chains and led to shortages (Wallis, 2020).

d. Bullwhip Effects and Price Elevation: The automotive sector case

The automotive sector experienced substantial disruptions due to the COVID-19 pandemic. Lockdown measures, factory closures, and reduced consumer demand resulted in a decline in vehicle sales. However, the sector also faced challenges related to the bullwhip effect caused by disrupted supply chains.

The bullwhip effect in the automotive sector was observed through amplified fluctuations in inventory levels and distorted demand signals along the supply chain. The disruption in the supply of critical components, such as semiconductors, led to reduced vehicle production and elevated prices. The New York Times reported that the semiconductor shortage caused by the pandemic disrupted automotive supply chains, resulting in production cuts and price increases for new vehicles (Ewing, 2021).

#### *4.2.2 Recovery and Adaptation in the Logistics Sector*

a. Digital Transformation

The COVID-19 pandemic accelerated the adoption of digital technologies in the logistics sector. Remote work, digital communication tools, and the use of technologies like IoT and AI enabled logistics operations to continue amidst lockdowns and travel restrictions. These digital transformations enhanced supply chain visibility and resilience (McGregor, 2020).

b. Supply Chain Redesign

Companies have reevaluated their supply chain strategies to build more resilient and adaptable systems. This includes diversifying suppliers, implementing nearshoring or onshoring strategies, and adopting agile inventory management practices (Ward, 2020).

c. Collaboration and Risk Management

The pandemic highlighted the importance of collaboration and risk management in the logistics sector. Close collaboration with suppliers, customers, and partners allowed for better communication, coordination, and contingency planning to mitigate disruptions (Saenz, 2020).

#### *4.2.3 Recovery from the COVID-19 Pandemic – The role of 4th Industrial Revolution Technologies and Blockchain in the Logistics Sector*

In recovering from the significant challenges during the COVID-19 pandemic the logistics sector has faced, the adoption of 4th Industrial Revolution (4IR) technologies, including Blockchain, has played a crucial role, as the new standards that this historically unique event brought forth demanded for a swift paradigm change away from traditional solutions that could no longer suffice for the challenges that supply chains around the world were now facing. This section explores how these technologies have helped or could help the logistics sector navigate the challenges posed by the pandemic, through the basic principles of Blockchain technologies, such as decentralization, visibility and collaboration.

#### 4.2.3.1 Enhanced Supply Chain Visibility and Resilience

a. Blockchain for Supply Chain Transparency

Blockchain technology offers immutable and transparent records, which can help enhance supply chain visibility and transparency. By leveraging Blockchain, stakeholders can track and trace goods, verify product authenticity, and ensure compliance with regulations. Blockchain-enabled supply chain platforms have the potential to minimize fraud, counterfeiting, and supply chain disruptions (Christidis & Devetsikiotis, 2016).

b. Smart Contracts and Automation

Smart contracts, powered by Blockchain technology, can automate and streamline various logistics processes. These self-executing contracts enable real-time monitoring of contract terms, automate payment settlements, and facilitate secure data exchange among supply chain participants. Smart contracts can help reduce manual intervention, enhance efficiency, and mitigate potential risks during the pandemic (Huckle et al., 2016).

#### 4.2.3.2 Mitigating Supply Chain Disruptions

a. Decentralization and Resilience

The decentralized nature of Blockchain technology can contribute to supply chain resilience. By eliminating single points of failure and distributing data across a network of nodes, Blockchain can enhance the reliability and robustness of supply chain operations. This can help mitigate disruptions caused by lockdowns, factory closures, and transportation restrictions (Iansiti & Lakhani, 2017).

b. Improved Inventory Management

Blockchain's real-time visibility and data sharing capabilities can facilitate more accurate demand forecasting and inventory management. By providing a shared ledger accessible to all supply chain stakeholders, Blockchain can help optimize inventory levels, reduce excess stock, and minimize shortages, thereby enabling more efficient logistics operations during unpredictable times (Dimitrov et al., 2020).

4.2.3.3 Trust and Collaboration

a. Trustless Interactions

Blockchain technology eliminates the need for intermediaries and enables direct peer-to-peer interactions. This can foster trust among supply chain partners, especially in times of uncertainty. Smart contracts and cryptographic algorithms ensure the integrity and authenticity of transactions, facilitating secure and transparent collaboration among logistics stakeholders (Brito & Castillo, 2016).

b. Collaborative Networks

Blockchain-based platforms can facilitate collaborative networks among logistics participants, enabling real-time information sharing, coordination, and decision-making. This collaborative approach can enhance agility and responsiveness in managing supply chain disruptions, enabling faster recovery and adaptive planning (Nikou et al., 2021).

## 4.3 Blockchain applications in Logistics

In this section, a series of applications of Blockchain technologies by real life companies and organizations within the broader sense of Logistics and the scope of the 4th Industrial Revolution will be presented. As Blockchain technologies are still a novelty in many ways, distinct case studies with a sufficient amount of data to evaluate their overall result in comparison to the vision behind them are difficult to be identified and presented, so the following cases are presented mostly as a matter of identifying and listing potential solutions that worldwide companies are still experimenting with, within the context of exploring the possibilities of Blockchain technologies bringing forth a new era in Logistics, through their close relation to the 4th Industrial Revolution ideas and especially the Logistics digitalization process.

*4.3.1 Inventory Tracking*

As seen in the literature review presented in Chapter 3, one of the possible outcomes of Blockchain technology adoption is the capacity for companies and organizations to track down products and trace their path along their supply chain, an ability all the more important when dealing with sensitive, dangerous, or overall critical for public health materials and products. The possible real-life benefits for such capabilities are very important, not only in regards to supply chains efficiency and their stakeholders' financial sustainability, but for public health as well. Almost a decade ago, a serious E. coli outbreak occurred in the U.S., because of a batch of infected spinach spread the disease. Should something similar occurred today, it would be easier to identify infected batches and the entirety of their path within the supply chain, up to the end user. Therefore, apart from the financial benefit of not having to destroy the whole stock, managing this incident fast and reliably would lead to a smaller risk for damages to the consumers' health. (Honrubia, 2023)

A prime example of a case where Blockchain, utilizing tools suggested in the 4$^{th}$ Industrial Revolution platform, is used in order to create a system for tracking products in the food industry is the recent partnership between IBM and a series of corporations active in the food retailing sector, such as Walmart, Nestle, and Unilever. The technology developed by IBM will facilitate the backtracking individual food items even as long back as to the farms they are sourced from. The main aim behind this endeavor is to minimize food contamination and public health hazards, as IBM's blockchain specialists claim that this blockchain network can evolve into an expanding ecosystem and, eventually, into an effective solution to food distribution challenges and risks, through the transparency and traceability across the whole food supply chain. (Browne, 2017)

According to IBM (2023), "*52% of consumers say that knowing where food comes from is very-to-somewhat important, 63% of Americans surveyed said they would pay up to a third more for products that are responsibly made and transparently sourced, and 94% of consumers surveyed said they would be more loyal to a brand that offers complete transparency*". Walmart had already successfully implemented Blockchain technologies in their supply chain twice, as they had been able to track pork in China and mangoes in Mexico, as far as back to their place of production. As pointed in Walmart's official website (Sristy, 2021), in 2016 it took their team, after a manager's request, to trace a package of sliced mangoes back to its origin point a staggering time of 6 days, 18 hours, and 26 minutes, despite all the necessary data residing in their information system. Their partnership with IBM and the subsequent Blockchain based system they developed, Walmart managed to trace the same product that was stored in a US store, back to its origin in Mexico, in a mere 2.2 seconds.

### *4.3.2 Shipping*

Maritime logistics is one of the most important subsectors of Logistics globally, facing unique challenges, especially in an all the more environmentally conscious world, meaning that their operations need to follow a paradigm shift in many aspects. To this end, Blockchain technologies have been tested in a series of applications, especially regarding bills of lading, as digitization of such documents could mean an environmental benefit of huge proportions even just from the courier services that are needed to accommodate distributing the paperwork among different points within the supply chain. Unfortunately, the greatest case study for such implementations is that of an essentially failed system, TradeLens by IBM and Maersk.

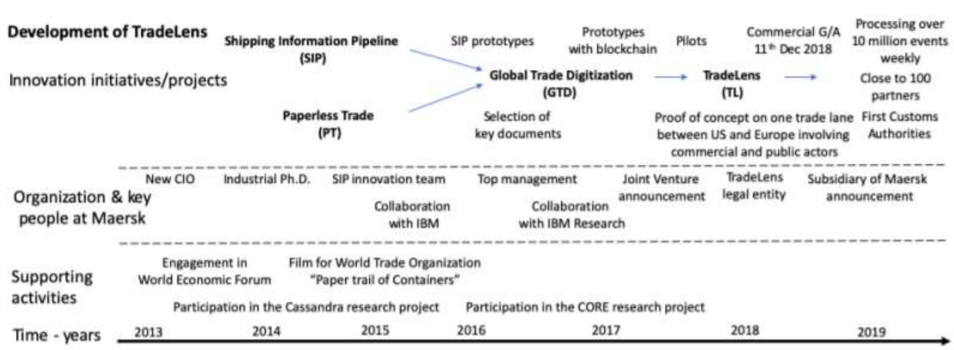


*Image 5. Digitalization efforts by Maersk timeline (Source: Jensen et al)*

The ambitious project taken upon the two colossal in their respective sectors companies originated in the early 2010's and the earlier efforts that Maersk made in order to decrease costs through digitization (Jensen et al, 2019). The history of TradeLens itself starts essentially in 2018 and the THINK '18 convention in San Fransisco, where IBM and Maersk announced a collaboration with the aim to build a digital platform that would serve the shipping industry. The TradeLens Platform was launched August 2018, and by December of the same year the shipping events published per day to the platform reached one million.

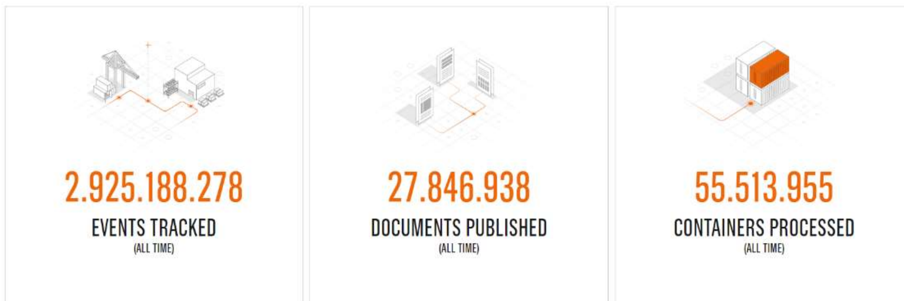


*Image 6. TradeLens activity up to February 2022 (Source: Melissanidis, 2022)*

Despite the technological success of the project and the fact that it showed the capabilities of a digitized global supply chain, it failed to reach adoption levels by the global industry that would make it financially viable. Therefore, Maersk decided to stop the project and gradually remove its offerings within 2023 (Maersk, 2022). Although the project was essentially a commercial failure, it is far from condemning Blockchain usage in shipping. On the contrary, as an endeavor it offered unique insight on what is the potential for such implementations, as well as what challenges are to expected and what levels of scalability are needed for such projects to be more successful in the future. (Lorenz-Meyer & Santos, 2023)

### *4.3.3 Invoicing and Payments*

As Blockchain technology was introduced though a financial tool, the Bitcoin cryptocurrency, it is apparent that financial services and products are one of the fields that blockchain is more prominent as a possible solution to a series of safety, security, transparency, and authenticity issues. Especially in logistics, where the burden that invoicing processes has in time and money costs within a supply chain is not negligible, Blockchain solutions, partnered with automations stemming from the 4$^{th}$ Industrial Revolution toolset, can offer great benefits. The usage of a blockchain-based invoicing system can enable payments with higher degrees of freedom, all while maintaining transactions safety. (Sontakke et al, 2023)

There is a number of enterprises trying to achieve a viable model for offering invoicing and payments through the use of Blockchain-based systems, and one of the seemingly more successful until now is the case of Request Network. According to their website, their mission is *“to enable the growth of a financial ecosystem built on open-source, decentralized blockchain infrastructure”*, while their vision entails “*an inclusive and decentralized financial future where people own their data and automation effortlessly streamlines financial services”*. Also, they claim that they have processed $500 million, over a monthly average of 13.000 transaction, while offering invoicing infrastructure for over 2.000 companies. (Request Network, 2024)

Essentially, Request Network acts as a protocol for storing payment requests, with its main aim to solve the problem where, effectively, blockchain transactions lack useful context information on why a transaction occurred. By storing information needed by businesses’ financial processes on the blockchain, allows said businesses to take advantage of opportunities on financial services such as loans, insurance, or fundraising, while also enabling automatic auditing and tax reporting, as well as triple-entry accounting.

### *4.3.4 Authenticity and Transparency*

A prominent trait that companies take advantage from Blockchain technologies is that when used within a supply chain, all the nodes on it, be it companies, organizations, authorities, agencies, even end users and customers can benefit from the transparency that a Blockchain offers and the absolute levels of data, therefore product, authenticity, regarding the flows up and down the stream of said chain. This means that implementations of Blockchain in Logistics can aim for that particular trait, allowing all participants in the network to feel confident about the authenticity of their intakes, therefore facilitating a more agile and risk-free trading environment.

An application of the sorts that proves advantageous for end consumers is the Everledger Platform. The Blockchain based authentication platform supports producers and retailers who want to trade assets in a range of industries, by offering services that verify the authenticity of the asset and elevate the customer experience for end consumers of highly valuable and unique products. The company offers services for the following industries (Everledger, 2024):

- Art
- Batteries
- Critical Minerals
- Diamonds
- Fashion
- Gemstones
- Insurance
- Luxury Goods
- Wines & Spirits

Another application of Blockchain technologies in Logistics can be showcased with the Provenance Blockchain, a public, open-source blockchain, created in 2018 with the purpose to enable financial institutions (over 70 at the time of writing this study), like fintechs, DeFi brands, banks, and credit unions, to manage assets in real world, in real time, and with advanced levels of transparency and authenticity. According to Provenance's website (2024), by the end of 2023 there have been transactions regarding financial assets of over $16B supported and processed through the Provenance Blockchain. In order to support the Provenance Blockchain, the Provenance Blockchain Foundation was founded in 2021, with the aim to help in the development and growth of the open source blockchain. Among the services that the Provenance Blockchain supports, there is issuing and managing investment funds, lending, banking, payments, tokenized deposits, and ownership of digital assets.

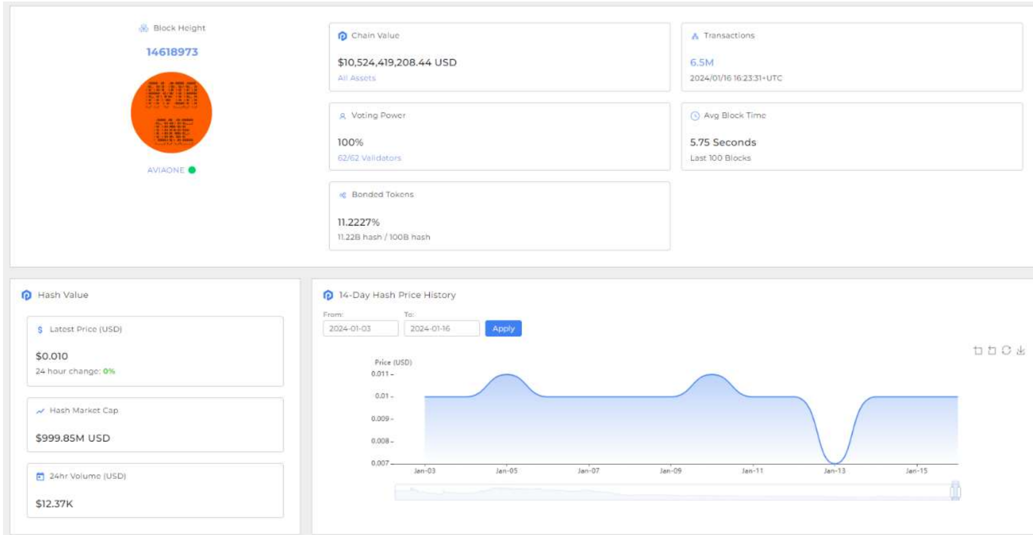


*Image 7. Provenance Blockchain openly offers real time data on various of its characteristics for transparency purposes (Source: Provenance Blockchain official website)*

### *4.3.5 Dispute Resolution*

Closing this series of case studies, the last aspect of Logistics that will be explored is the one of the greatest challenges in freight management and transports, and that is dispute resolution in cases of delayed or misplaced cargo. In this context, FedEx, one of the biggest courier services worldwide, employed tools based on Blockchain technologies in order to accommodate the resolution of disputes arising from their provided services. FedEx is actually a member of BiTA or the Blockchain In Transport Alliance, which was founded in 2017 and has now grown into the biggest commercial blockchain network globally, counting around 500 members, mostly in the Logistics sector and especially in the business of freight and transportation, generating more than $1 trillion revenue per year collectively. Within the context of this collaboration, FedEx has launched an initiative to develop relevant tools for dispute resolution, through automation and transparency offered with the implementation of Blockchain technologies, an interest endeavor for future research.

# Chapter 5. Conclusions

## 5.1 Discussion on results

In order to discuss the findings of the research conducted in this study and draw the necessary conclusions, the research questions posed in the first chapter will be effectively answered here.

Regarding the first research question and what is the level of interest in the global literature regarding Blockchain technologies used in Logistics within the context of the 4$^{th}$ Industrial revolution, the literature review has shown that although there is evident interest in academia regarding the subject, there is a lack of recognizing how close Blockchain technology is to the overall 4$^{th}$ Industrial Revolution platform and, therefore, they should be discussed more in parallel.

As for the question about what the main trends are explored in research literature regarding the thematic explained in the previous question, as seen in the classic literature review part of the study, traits inherent in Blockchain networks, such as transparency, traceability and authenticity are explored, while maritime and smart logistics are also a proponent item of discussion in academia.

Regarding the question of whether there real-life examples of Blockchain technologies implementation in Logistics, especially within the context of the 4$^{th}$ Industrial revolution, research has shown that from as back as at least 2018 there is a plethora of efforts to implement Blockchain technologies in Logistics, especially in tandem with tools and concepts from the 4$^{th}$ Industrial Revolution platform, others starting ambitiously and ending negatively, as the effectively failed commercially TradeLens conjoined program by Maersk and IBM, others starting with careful small steps in distinct cases and gradually expanding to a company wide adoption, like Walmart and its collaboration with IBM to develop traceability tools.

After examining the real-life examples and answering the previous question, when it comes to how good the prospective of Blockchain technologies implementation in Logistics, within the context of the 4$^{th}$ Industrial revolution in the future looks, the answer can lean towards a positive outlook. As Blockchain should still be considered a novel concept, the number of projects and ideas tested in the business world, regardless of the fact that some of them at the are deemed not sustainable, show that companies do believe that Blockchain can bring forth viable solutions regarding the future of Logistics within the context of the 4$^{th}$ Industrial Revolution and the modern day challenges the world faces.

## 5.2 Further research proposals

The research conducted has uncovered some limitations in identifying and collecting data and information regarding the scope of this study, that being the implementation of Blockchain technologies in Logistics, especially under the pretext of the 4$^{th}$ Industrial Revolution, that could be overcome by future research.

These limitations refer to the fact that as Blockchain is still a novel technology, both academic resources and data regarding real-life case studies are limited. Therefore, future research could be based on monitoring how this data is enriched over the time, essentially studying how the implementation of Blockchain in Logistics goes as a concept and whether the outcomes lean towards a positively contributing process.

Future research could focus more on distinct trends, as identified in both the third and fourth chapters, be it traits like traceability or transparency, concepts like Smart Logistics, or whole subsectors like Maritime Logistics, in an effort to further specialize research, as more and more real-life case studies are available and academia in general has gradually delved deeper into the subject.

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# Appendix

## A. List of articles selected in the SLR process

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