

Louvain School of Management

Analysis and recommendation for the improvement of retail supply chain traceability by using the blockchain.

How can blockchain improve traceability in the retail supply chain?

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Summary

In our ever-evolving world, marked by social, technological, and cultural advancements, it is only natural that we gravitate towards tools, processes, methods, and paradigms that enhance societal productivity at an ever-increasing pace. This progress comes from all kinds of technologies which tend to be increasingly interlinked, driven by emerging technological innovations such as blockchain, artificial intelligence, Internet of Things.

In this thesis, we'll look at how mankind has supplied itself over time to produce and improve its quality of life, leading to globalization. This has dispersed most of the production across the world, reducing visibility and control over product provenance, conformity, and ethics. This sometimes leads to scandals, wasted time, energy, and as consequence to additional costs due to errors in the supply chain, which must be traced, eliminated, or at least be monitored. Traceability is therefore becoming a major issue that many want to address, whether in economic, social, or political terms.

In this context, we wonder whether blockchain, a decentralized technology, could be a suitable solution to the problems related to exchanging goods and information. Is blockchain the ultimate solution to the problem of traceability? How can blockchain improve the supply chain?

Keywords: Blockchain, Traceability, Supply Chain, Globalization, Trust, Productivity, Efficiency, Distributed Technology, Decentralized Network, Cryptography, Smart Contracts, Interoperability, Food Safety, Technology Innovation, Corporate Social Responsibility, Shipment Tracking, Retail, Sustainability.

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Introduction

Before 2008 and hence before the creation of the blockchain concept, economic actors used to trust centralized entities to manage their money and transactions, deliver information on the status of their accounts or purchases, set up the necessary infrastructure to observe contracts, etc. Then came in 2008 the "subprime" crisis marked by a problem of liquidity of banks, pushing many actors to lose their trust in banks and more generally to centralized entities on which we have only limited visibility and control.

After that, a person or group of people with the pseudonym "Satoshi Nakamoto" published an online white paper¹ in 2008 that was the first to describe the idea of a blockchain. With no centralized organization or intermediary, the blockchain was developed to record transactions securely and openly on a distributed network. This technology distributes the responsibility and control of trust to all users of the same model, and not just to a handful of individuals. The first practical implementation of the blockchain was Bitcoin, which is a decentralized currency that records all transactions in each succeeding block. This allows to facilitate, secure and transparent transfer of ownership.

Following that, a series of new blockchain-based applications have emerged to address several types of problems often related to trust. By enabling safe and transparent transactions without middlemen, blockchain has the potential to disrupt numerous sectors. It has gained significant traction in the financial industry and is also being investigated for several additional applications, such as supply chain management, voting procedures, and identity verification.

Given that consumers are increasingly aware and attentive to the conditions of provenance of what they consume, and by the fact that history has been marked by numerous scandals in the supply chain such as the horsemeat in Findus lasagna cases, the working conditions at the Rana Plaza scandal, or the famous mystery of bat soup or pangolin consumption around covid-19 pandemic, blockchain is seen as a potential tool to offer visibility and trust on the supply chain.

¹ "A white paper is an informational document issued by a company or not-for-profit organization to promote or highlight the features of a solution, product, or service that it offers or plans to offer." (Hayes, 2023).

Indeed, the importance of traceability is gaining a lot of weight in the preference of consumption of the consumers. “52% of consumers say that knowing where food comes from is very-to-somewhat important. 94% of consumers surveyed said they would be more loyal to a brand that offers complete transparency“ (IBM, 2023).

Having specialized in “Sourcing and Procurement” as a student at LSM, combined with my personal experience as a consumer, I am deeply intrigued by the potential of blockchain technology to restore trust within the supply chain. Consequently, I am committed to dedicating my time to comprehensively understand this transformative potential and its practical applications.

In this thesis, we will attempt to shed light on blockchain and the impact it has on traceability in the supply chain. We will therefore try to answer the following questions: “How can blockchain improve traceability in the supply chain?”. The main source of information in this thesis is qualitative and is mainly based on scientific content sources or content from companies.

The first part of this thesis is devoted to an extensive review of the literature, exploring the theoretical foundations that frame and clarify the concepts essential to the topic under investigation. The concept and context of supply chain, the notion of trust, the arrival of blockchain and finally its application to supply chain.

In the second part we will compare the theoretical to the practical aspects by focusing on a qualitative approach (semi-define). Indeed, we have selected different people related to blockchain and supply chain to ask them questions and observe what the reality of our subject is, which provides us primary data.

Finally, to draw a conclusion to this thesis, we will talk about the practical analysis' findings, their limitations, and the extra challenges that will need further exploration in future studies.

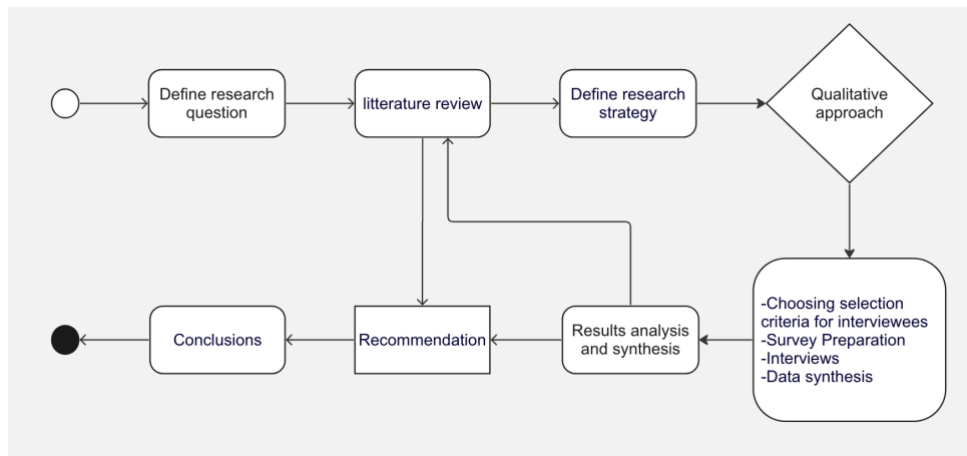


Figure 1: Research workflow.

Our research journey began by scrutinizing a broad range of sources related to blockchain and supply chain management. As we delved deeper into these topics, questions began to surface, eventually leading to the formulation of our research question. In an attempt to propose answers to this question, we embarked on a comprehensive literature review.

Parallely, we charted out our research strategy using a qualitative approach. Given the abundance of resources on blockchain and supply chain, we opted for expert interviews to gather in-depth, precise information. This decision was driven by the intent to make our findings as representative as possible.

One of the challenges we faced was the development of an impartial questionnaire that would successfully harness the unique and diverse expertise of each interviewee. These questions were carefully curated to test the hypotheses that were stated during the literature review.

Following the interviews, we embarked on a thorough analysis of the collected data. We subsequently translated the results into recommendations, which paved the way to formulating our conclusions. This iterative and methodical process, from initial exploration to final analysis, allowed us to gain a comprehensive understanding of the potential of blockchain in enhancing traceability within the retail supply chain.

PART 1: Literature review

1. The supply chain

To develop a more nuanced understanding, we will commence this literature review by elucidating several key concepts. We'll explore the notion of a supply chain, its fundamental roles, the characteristics of the retail sector, the concepts of trust and traceability, the significance of collaboration in supply chain dynamics, and finally, the features of contemporary supply chains.

1.1 Definition and history

According to Mecalux²(2022), the supply chain can be defined as the network of businesses and activities involved in the manufacturing and distribution of a good or service. This covers the acquisition of raw materials, production, movement, storage, distribution, and client delivery. It is composed of lots of steps and companies in a network. Coordination and optimization of these processes are part of supply chain management, which aims to boost productivity, cut costs, and boost customer satisfaction (Mecalux, 2022).

However, the nature of supply chain is far from static. It has continually evolved in response to technological breakthroughs, the forces of globalization, and fluctuating consumer demands. This has, in turn, significantly transformed the way humans procure resources. Key developments that have catalyzed these changes include:

Industrialization: The development of mass manufacturing and assembly line techniques, which significantly boosted efficiency and decreased costs, was a result of the emergence of

² Mecalux is a multinational storage systems company.

industrialization in the 18th and 19th centuries. It led in the 1950s to popularize the concept of supply chain management³ (Huque & Islam, 2007).

Globalization: As communication and transportation technologies advanced, it became possible to acquire raw materials and produce goods in many locations throughout the world. Nations become more interconnected upon one another through the trade of products, services, and ideas. It entails the blending of political, cultural, and economic systems across international boundaries and frequently entails the growing influence of international organizations. Due to this, international supply chains were created in which various production phases were carried out in several nations. At this point, companies started to put their focus on their core competencies and outsource efficiently to optimize their productivity (Chin, Tat, Sulaiman, Long, & Yi, Revisit Supply Chain Management: Evolution, Definition and Benefits, 2019). Globalization has a great impact on how consumers and companies provide themselves. There is now a dependence to international trade and thus the importance of importation/exportation has risen a lot in the world. (**Appendix 1.1:** Figure Import/Export).

Information technology (IT): IT tools have become central as computers and the Internet have become more widely used, real-time data collection and sharing has become available, enabling businesses to coordinate and improve their supply chain operations more effectively (Chin et Al., 2019).

E-commerce and digitalization: The development of e-commerce and digital platforms has made it possible for businesses to communicate directly with customers, cutting out the need for conventional middlemen and boosting the speed and effectiveness of the supply chain. “The introduction of Enterprise resource planning (ERP) in the 1990s, gave a boost to the evolution of the SCM and buyer - supplier relationship” (Mehmeti, 2016).

³ “The management of all activities, information, knowledge and financial resources associated with the flow and transformation of goods and services from the raw materials suppliers, component suppliers and other suppliers in such a way that the expectations of the end-users of the company are met or surpassed.” (Van Weele, 2009, p. 19).

Sustainability and responsible sourcing: As people's knowledge of environmental and social issues grows, sustainable and responsible sourcing practices like cutting carbon emissions, ensuring fair working conditions, and sourcing ethically are being given more attention. It led to the birth of the “Green Supply Chain Management” (Chin et al., 2015).

Geographically, several regions have embraced various business models and technological advancements to compete on the world stage. For instance, nations with lower labor costs tend to focus on production, whereas nations with developed transportation and logistical infrastructure tend to focus on distribution and logistics. Additionally, depending on the amount of technological advancement and investment, different areas use digital technology in the supply chain in different ways. Furthermore, there are demographic changes. In many parts of the world, rising consumer incomes and fundamental shifts in social structures have a significant impact on how customers behave and make purchases. Besides, the shortage of raw materials and energy shape the economical interactions and thus the organization of the market. (E.G: USA’s demand for raw materials is higher than their production of raw materials so they have a high dependence on raw material importations) (**Appendix 1.2:** Figure of global supply and demand for raw materials).

In conclusion, each company's business model across the world specializes on specific tasks, and lets other businesses focus on the remaining tasks to maximize the expertise and productivity of each. This leads to a better productivity of the whole supply chain and makes it more competitive to others. This maximization of supply chain productivity is often done at the expense of ethics because of the high competition and the fact that ethics are not easily monitored due to the wide geographic distribution and the large number of players in the supply chain. This can lead to dangerous situations creating troubles or scandals in the supply chain. We will talk more about this problem later.

1.2 The roles of supply chains

In this section, we will investigate into the significance of supply chains, examining their multifaceted roles and the diverse array of actors involved.

I. Importance

Nowadays, Supply Chain Management (SCM) has become a critical function with a significant influence, becoming a critical competency inside businesses. It plays an important role in the identification and maintenance of supplier relationships, while also providing highly valued specialized expertise to the organization. In many cases, the purchasing department is responsible for allocating more than 50% of all sales revenue, meaning that it is often the biggest source of expenses. Frequently an organization devotes more capital to the purchase of materials and services than to any other expenditure, with service expenditures rapidly increasing (Schuh, Raudabaugh, Kromoser, Strohmer, & Triplat, 2012). This emphasizes the importance of the purchasing function in an organization's economic system.

II. Goals

The primary objective of the supply chain is to ensure a seamless flow of goods, services, and information between suppliers, manufacturers, distributors, and customers. This process is vital for meeting customer needs and expectations, while concurrently maximizing the profitability and effectiveness of business operations (Kshetri, 2018).

There are several specific roles within the SCM that facilitate this aim. For instance, provisioning management ensures the necessary initial materials and finished goods are readily available in appropriate quantities and time frames. Additionally, operational management is responsible for organizing, coordinating, and executing the manufacturing, distribution, and transportation activities in a way that effectively meets customer demands and enhances profitability. On the other hand, logistics management streamlines the movement, storage, and distribution of goods throughout the supply chain, a strategy aimed at reducing costs and improving customer satisfaction. Customer relationship management is also a key focus, with the goal of supplying products and services that align with customer needs regarding quality, price, and delivery time. Lastly, performance management plays a critical role in monitoring and evaluating the supply chain's overall performance, pinpointing opportunities for ongoing improvements and cost savings (Chin et Al., 2019).

In conclusion, the SCM plays a critical role in the creation of value for customers and businesses by ensuring the availability of goods and services, cost optimization, and customer satisfaction.

III. Actors and SC's functions:

Nowadays, the supply chains are widely spread and have numerous roles which brings the need to have a lot of actors participating in all the steps and interactions of the processes, including suppliers, manufacturers, distributors, retailers, logistics providers, regulators, and managers of the supply chain that oversee organizing and streamlining all the chain's operations. Within the same supply chain, their responsibilities may overlap, and several organizations may take on multiple tasks. *“Due to increased competition, globalization and outsourcing, the number of players in a typical supply chain has increased significantly.”* (Kshetri, 2018).

This need/objective to maximize every actor's part in the supply chain is known as "value chain management," all stakeholders in the same value chain are challenged to be the best company's value offer (Van Weele, 2009).

We can note that supply chains are very complex as they contain a lot of actors with many different responsibilities, they all can be used with different combinations depending on different factors. It depends mostly on time and costs efficiency, regulations from the different market or geography, competences, and trust between actors, etc. This complexity makes it necessary to develop professional specialization in the SCM businesses which lead us to define the parallel concepts of procurement, purchasing, sourcing and logistics for more clarity.

Procurement is a strategic function and occurs when a company finds and acquires external goods, services, or work through a competitive bidding or tendering process. It is a key component of supply chain management and includes aspects such as strategic vetting, selection, negotiation, buying, evaluating, and managing supplier performance (Codeless Platforms, 2022).

Purchasing is a subset of procurement. It's the transactional function of procurement that involves the process of ordering goods or services, receiving them, and then paying for them.

It's more operational and routine compared to procurement (Codeless Platforms, 2022) (**Appendix 5.2: Purchasing definition**).

Sourcing is the strategical part of procurement. “*Finding, selecting, contracting and managing the best possible source of supply on a worldwide basis.*” (Van Weele, 2009, p. 9)(**Appendix 5.1: Sourcing definition**).

logistics “*is a branch of supply chain management that focuses on the storage, transportation, and distribution of goods*” (Mecalux, 2022).

Nowadays, we can organize the structure of the procurement process in many ways. It is important to remember that the procurement function encompasses the process of buying. We can organize the different functions of procurement in many ways according to different sources, however two functions commonly referenced are sourcing (strategic) and purchasing (tactical/operational) (**Appendix 1.3: Figure of the main procurement operations**).

1.3 The retail sector and mechanisms

In this thesis, we will delve deeper into the intricate workings of the retail sector, elucidating its characteristics and operations. The importance of the retail sector in the entire supply chain cannot be overstated, as has been highlighted in the previous discussions. As the primary interface between customers and the broader supply chain, the retail sector plays a pivotal role in balancing the often-conflicting needs and desires of consumers and providers.

Moreover, a thorough examination of the retail sector provides a unique opportunity to understand consumer behavior. Since consumers are a mirror reflecting societal consumption patterns, such an analysis can offer invaluable insights into prevailing consumption trends. This exploration not only promises to shed light on the mechanics of the retail industry but also holds the potential to illuminate broader socio-economic dynamics.

1. Definition

“By “retail” we mean the market that includes all those activities that involve the sale of goods or services by a company directly to the consumer that are usually purchased for personal or family use” (Righini, 2023). Retailers can be physical stores such as supermarkets and boutique shops, or online marketplaces like Amazon and Alibaba. These retail outlets are the final link in the supply chain, serving as the direct point of interaction between businesses and consumers.

Characteristics of the retail industry include a focus on consumer service, varied pricing strategies, and inventory management. Retailers often deal with high volumes of different products, rapid inventory turnover, and significant seasonality. The retail sector also places a premium on location for physical stores, and ease of use and accessibility for online platforms (Levy & Weitz, 2020).

II. Importance in the supply chain

The retail industry must be discussed in the context of supply chain management since retailers are the final link in the chain, directly influencing customer satisfaction. The activities and tactics of retailers can have a significant impact on how well manufacturers and distributors function upstream in the supply chain. Demand forecasting, inventory management, and customer service can all have an impact on the overall efficiency and efficacy of the supply chain. In essence, successful retailing may improve the total supply chain performance and raise overall customer happiness (Ailawadi & Farris, 2017).

III. Potential problem

The retail industry faces several potential constraints and issues. Thin profit margins due to fierce competition, high operating costs, over-reliance on consumer spending, and vulnerability to economic downturns are examples. Retailers must also manage complex inventory and forecast consumer demand properly, which is a difficult undertaking given rapidly changing consumer tastes and preferences (Levy & Weitz, 2020).

Another concern is digital disruption, with the advent of e-commerce compelling traditional brick-and-mortar retailers need to adapt or risk collapse. Furthermore, supply chain disruptions

can have a significant impact on retailers, particularly those with low supplier diversification (Ailawadi & Farris, 2017).

IV. The customers' buying behavior

The current retail scene is continually changing, with a variety of factors influencing customers' purchasing behavior and expectations. There are differences in all consumers habits and expectations but here are some of the most relevant factors that define the principal current consumers.

Product quality: Customers want high-quality products that are well-priced. They are becoming more concerned with factors such as product longevity, performance, and even environmental friendliness (Levy & Weitz, 2020).

Price: Price is still a major element influencing purchase decisions. Before making a purchase, consumers compare prices across many platforms (Ailawadi & Farris, 2017).

Convenience: With the introduction of e-commerce, customers have come to value the ease of shopping. This includes purchase convenience (intuitive user interface), product availability, quick shipping alternatives, and hassle-free returns (Ailawadi & Farris, 2017).

Customers demand high-quality service, including quick and effective responses to questions or complaints, as well as individualized assistance. Customer loyalty and happiness can be increased by providing excellent customer service (Ailawadi & Farris, 2017).

Trust is essential. Customers must have confidence that their personal information is secure, and that the things they purchase are as advertised (Schuh et Al., 2012).

Social Proof: Customer reviews and ratings play a vital influence in influencing purchasing decisions. Before making a purchase, consumers frequently look at product ratings and read reviews (Homburg, Jozić, & Kuehn, 2017).

Sustainability: A growing percentage of customers are concerned about the environmental impact of their purchases. They are more likely to buy from brands that show a commitment to sustainability (Ailawadi & Farris, 2017).

Those factors don't have the same weight/importance but vary through people and time, hence the need to determine what are the value criteria for business development.

1.4 Traceability and trust

“Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another.” (Rousseau et al., 1998).

The growing importance of traceability and trust in the supply chain has become an unavoidable trend in the supply chain. Over the years, several scandals have come to light for a variety of reasons that we will see later. Consumers have become more discerning, and regulations have tightened, forcing companies to review certain aspects of their business model by demanding and providing greater transparency within their supply chain.

Knowing where food comes from is very essential according to 52% of customers (IFIC (International Food Information Council), 2019).

1. Problems of trust on the market

As example, we can take numerous famous scandals that happened in the supply chain that marked the world in the past. Those scandals had disastrous consequences which shock the consumers and impacted companies' image and forced them to make radical change most of the time. Due to space constraints, we have opted to highlight four exemplary cases:

Rana Plaza (2013): The Rana Plaza building in Bangladesh collapsed, killing more than 1100 textile workers who were working there. The investigation has brought to light hazardous working conditions in Bangladesh's textile and confection industries as well as business subcontracting and social responsibility practices.

Scandal of horse meat in Europe (2013): a scandal broke out when testing revealed that horse meat had been falsely labeled as beef in prepared dishes sold in several European countries. The investigation uncovered flaws in the traceability of the meat and the supervision of the supply chain.

Scandal of Contaminated Eggs in Europe (2017): In 2017, eggs were contaminated in several European countries by a pesticide that was banned on the continent. The incident brought to light oversight shortcomings in the supply chain and prompted investigations into agricultural practices and food law.

Scandal of Listeria Contamination in Southern Africa (2018): In 2018, a listeria epidemic brought on by tainted meat products claimed the lives of over 200 people in southern Africa. The scandal exposed issues with food safety and oversight shortcomings in the supply chain.

There are many more examples and behind each of these scandals, there are consequences. An illustrative example of the potential consequences would be the 2015 E. coli outbreak at Chipotle Mexican Grill outlets.

“The crisis left 55 customers ill. The company suffered a reputation loss due to negative news stories, restaurant shutdowns, and investigations. Sales reduced dramatically and its share price dropped by 42%. The roots of the problem lie partly in the reliance of Chipotle and other food companies on multiple suppliers to deliver parts and ingredients. There is a severe lack of transparency and accountability across complex supply chains.” (Kshetri, 2018).

Those scandals have all had a significant impact on company procurement practices and social responsibility, highlighting the significance of transparency and traceability throughout the procurement process. Indeed, when the scandal explodes, customers no longer trust the brand and/or don't dare to buy the products concerned, which creates bad publicity, complaints, demonstrations, blockades and, most of the time, lost sales, and therefore lost profits.

II. The firm's societal responsibility

We can see that companies that are directly involved in scandals or accidents are often wrongly held responsible as the unique wrongdoer in this faulty stage of the supply chain. In fact, the

latter are often lacking resources and are unable to make decisions, they mainly respond to demand according to market conditions that are caused by companies that consume the supplied service. In addition, it was possible to observe that some companies were often aware of the questionable conditions that were happening earlier in the supply chain, which leads to questioning the ability of these companies to be able to act to avoid this kind of situation and therefore question their share of responsibility in the existence of these incidents. This then increases the responsibility of the end companies and the tendency to point the finger at those end companies because they interact with the consumer and are responsible for the end-product that arrives at the consumer's basket and the steps that have been taken to bring it to its final state. It is therefore becoming important for companies to have visibility on what is happening upstream in the supply chain, they can no longer turn a blind eye or not care to investigate. We can also notice that this kind of event has its role to play for the arrival of CSR⁴, to integrate environmental and social issues into decision-making but also for the creation of regulations and standards aimed at monitoring and auditing companies to assess their true impact through various factors (Pfajfar, Shoham, Małecka, & Zalaznik, 2022).

One of the notorious standards is the ESG⁵ standards. It is the publication of information on business activities regarding to the environmental, social, and governance aspects of a firm that is evaluated against benchmarks and targets in a report made available for a variety of stakeholders, including investors, employees, and consumers (Courtneil, 2023).

In conclusion, the role of companies in direct contact with consumers obtain a very influential role in the supply chain. given that they supply and attempt to satisfy the consumer directly, they are the main channel of communication between all supply chain actors and consumers. They bring value by providing the final goods that correspond the best to the needs and values of consumers. To prove their efforts, companies find themselves through models and standards such as ESG standards, in parallel then appears the "Green supply chain management."

III. The causes

⁴ Corporate Social Responsibility.

⁵ Environmental, social, and governance.

But what are the reasons that cause the supply chain to create such errors? Here we will show some of the causes that push supply chains to fail in scandals.

Supply chain's length

Nowadays, the principal reason is that supply chains are now very long which make the SCM very hard to control. Each company needs to precisely determine its purchasing objectives and correlate them with the different departments of the company. Then, it needs to select the right suppliers through many layers to match the right criteria which is very complex (Van Weele, 2009). There are 3 points that brings lots of complexities in every procurement management process of companies, called the “3P” (people, paper, process) (Blome & Henke, 2022).

About people, there are many stakeholders, each with their own role in the procurement cycle. They must oversee beginning or authorizing each stage of the procedure. If the roles are not well determined, problems could occur (Blome & Henke, 2022).

About process, different lists of procedures that must be followed while looking over, ordering, acquiring, and paying for products and services. The complexity of the purchase increases the number of checkpoints and processes (Blome & Henke, 2022).

About paper, there are lots of paperwork and documentation engaged in the procurement process at every stage (for reference and auditing reasons). The problems are cost, time, errors, etc. (Blome & Henke, 2022).

The problem does not stop there, as these criteria only concerned intra company aspects. The major problems reside in the fact that each company in the supply chain need to manage those aspects and need to match them with the different companies across the same supply chain and through different layers. Being very long, supply chains imply many differences through culture, norms, values, tools, regulations, objectives, etc. These differences could lead to chaos, loss of control which could lead to supply chains imbalance.

Market condition

Nowadays, markets are becoming very rough for companies because they have very complex conditions.

Indeed, there is an extreme competition on the markets. Now there are rapidly lots of competitors across the world which lead to put pressure on cost, market share, etc. (Schuh, Raudabaugh, Kromoser, Strohmer, & Triplat, 2012, pp. 2-3). In addition, today's markets exhibit extreme volatility. They react swiftly to a wide range of factors including sovereign debt crises, decisions from rating agencies, foreign exchange rates, and regime changes. This frequently leads to change and complicates the acquisitions of required materials. This volatility pushes companies to anticipate those factors but also to formulate effective responses (Schuh, Raudabaugh, Kromoser, Strohmer, & Triplat, 2012, pp. 3-4).

Moreover, in an era of global markets and rapid technological advances, businesses must innovate to stay competitive. Yet, they face shrinking product life cycles and the need to hasten time to market. It leads them to outsource more.

While these market conditions might make “doubtful⁶” suppliers more attractive, it could result in an uncontrolled or a mismanaged supply chain.

The environmental vision

Lastly, the emergence of these scandals can often be attributed to a poorly defined and poorly implemented environmental vision. Historically, corporations were inclined at shifting and manipulating product image through outsourcing of troublesome steps of their production. This was feasible because, for many years, a company's responsibility was predominantly limited to its own production facilities. Hence, an ambiguous understanding of environmental implications often led to unethical practices, subsequently giving rise to scandals.

“The responsibility of a company was largely confined to its production sites. In the 1980s it expanded to include operational environmental protection, and in the 1990s grew further to embrace the concept of corporate social responsibility, largely understood as a company's responsibility to the local community. (This was a time when every company that outsourced had the immediate side benefit of freedom from such responsibility)” (Schuh, Raudabaugh, Kromoser, Strohmer, & Triplat, 2012, p. 4).

⁶ We understand by “doubtful”, suppliers with low switching cost, lower prices, but at higher risk.

1.5 Collaborative supply chains

As we have seen, nowadays, modern supply chains are no longer solitary entities, but rather interconnected networks of companies and institutions. They collaborate to source raw materials, manufacture and assemble products, and distribute them to consumers in a practice known as "Global sourcing"⁷. This method calls for the expertise of various businesses, each specialized in distinct processes. Consequently, every company is tasked with the challenge of identifying the optimal set of partners that align with their business model, thereby creating an ideal supply chain alternative for the end customer's needs. This approach is continually enhancing the efficacy of supply chains.

1. Cooperation

One aspect of actual supply chains is that they need to cooperate a lot. To obtain those productive relationships, companies need to select the right suppliers and establish long-term relationships for supplier development. It is the process of giving your suppliers new skills or competencies (related to performance enhancement) to give your business a competitive edge. The short- and long-term supply needs of the purchasing firm are what the supplier development program seeks to achieve which can lead to common investment (Van Weele, 2009).

This structural change implies that supply chain management optimization and specialization has led to a longer-term view of the supply chain, and the real challenge now is having complementarity with stakeholders around by managing three flows: financial, informational, and physical (Van Weele, 2009).

Finance, the good circulation, and availability of financial resource allows the entire supply chain to have enough budget for working effectively.

⁷ Global sourcing: "*Proactively integrating and coordinating common items and materials, processes, designs, technologies and suppliers across worldwide procurement, engineering and operating locations.*" (Van Weele, 2009, p. 17).

Information, all companies have different information about the market, as they collect them differently and for different reasons. However, those information's could be useful and valuable for others and could be more beneficial if shared with the rest of the supply chain.

Physical, there is a flow of goods and physical input across the supply chain that is needed.

We can observe more details in the following appendix. (**Appendix 1.4:** Figure of “How is the interrelation of financial flows, information flows and product flows benefiting companies?”).

Indeed, to make sure that their supply chain is the best possible, companies require managing those 3 fluxes the best way possible by cooperating with all the stakeholders in the supply chain. Squeezing the supplier isn't the best way anymore (Van Weele, 2009). (**Appendix 1.5:** Figure of the collaborative purchasing behavior).

II. Early supplier Involvement (ESI)

As a result of the increase in collaboration relationship's vision, we observe an ESI⁸. Indeed, suppliers are becoming a more significant source of innovation. ESI brings several advantages such as better production quality, cheaper production costs, a faster development cycle, lower developing expenses, collaborative research initiatives, coordinating technology initiatives and sharing risks, etc. It allows companies to agree on the different aspects of the products. However, it can be difficult for companies to define and agree on the conditions and limits of their cooperation as it is possible to find some conflict of interests (Blome C. , 2022).

1.6 Modern supply chain:

The accelerating pace of technological evolution and the expansion of our economy are driving transformative changes in the equipment we utilize and the methodologies we apply. We will explore the abundant potential that technology provides in the realm of procurement.

⁸ “*Early supplier involvement (ESI) Situation where the supplier is involved by the buyer at an early stage of the new product development process.*” (Van Weele, 2009, p. 18).

This metamorphosis is primarily driven by the digitalization of our commercial and economic infrastructure, compelling organizations to transition towards a predominantly digital environment.

Innovation in procurement focuses on generating or acquiring distinctively superior products and services, as well as introducing novel organizational and business methodologies. This approach aims to offer innovative solutions and responses to emerging needs, enhanced quality, and optimum cost-efficiency.

The key paths to advancement include learning and applying new technology and abilities, as well as cultivating a long-term perspective.

1. Industry 4.0

Industry 4.0 holds significant potential to alleviate issues plaguing supply chains. Indeed, the automation and digitalization of operations can significantly enhance efficiency, reduce errors, and bolster supply chain transparency. This can be realized through technologies such as Internet of Things (IoT) devices, advanced analytics, and enterprise resource planning (ERP) systems, smart contracts, etc. (**Appendix 1.6:** Figures of what will the future look like).

The evolution of industries hinges on technological advancements, and it is when these technologies work in unison that they yield maximum results. Consequently, the interconnectedness inherent in Industry 4.0 proves highly beneficial as all the co-communicating technologies contribute to the amplification of their collective effectiveness. When these technologies interact and collaborate, they become complementary, unlocking new functionalities and capabilities. (**Appendix 1.7:** Figure of IOT and services).

The technological metamorphosis of supply chains is well underway, leaving an indelible imprint on the role and operations of procurement within businesses. Advancements such as digitalization and process automation have already played their part in the transformation journey. Future chapters of this journey may see the incorporation of predictive procurement and virtual assistants. Driven by data analysis and artificial intelligence, these future trends

promise to enable more effective decision-making. Innovations such as predictive analytics, machine learning, blockchain, and chatbots represent the exciting potential of these new developments.

II. Enterprise Resource Planning (ERP)

ERP is an integrated management system that centralizes information from diverse departments of an organization to streamline and automate fundamental business activities. This involves, among other things, sales, purchasing, accounting, human resource management, customer relationship management (CRM), and inventory management (Monk & Wagner, 2012).

When in use, an ERP system acts as a central repository for all business data, allowing for a comprehensive, real-time view of business operations. ERP systems can help businesses to operate more efficiently by decreasing redundancy, enhancing accuracy, and improve decision-making by integrating multiple business operations (Monk & Wagner, 2012).

However, effective ERP adoption is strongly dependent on various elements, including meticulous planning, top-level commitment, and user acceptance. Furthermore, given the variety of processes that an ERP system covers, firms must select an ERP system that corresponds with their specific needs and operational context (Umble, Haft, & Umble, 2003).

III. E-procurement

E-procurement⁹, refers to the use of digital tools and technology to automate and streamline the procurement process from demand to payment. E-procurement systems can handle a variety of procurement tasks, including as e-tendering, e-sourcing, contract administration, catalog management, and more (Panayiotou, Gayialis, & Tatsiopoulos, 2004).

⁹ E-procurement: electronic procurement.

By providing an audit trail of all procurement actions, e-procurement can improve efficiency, cut purchasing costs, improve accuracy, and boost transparency in its operation (Panayiotou, Gayialis, & Tatsiopoulos, 2004).

However, the efficiency of e-procurement is dependent on several elements, including the availability of consistent internet connectivity, user digital literacy, and the capacity to interface the e-procurement system with other business systems (Hawking, Stein, Wyld, & Foster, 2004).

IV. The Interplay between ERP and E-Procurement

While ERP and e-procurement are independent systems with different goals, they are frequently used in tandem to improve business performance. In many circumstances, e-procurement can be thought of as a module within a larger ERP system. E-procurement, on the other hand, can be used as a stand-alone system or as part of a larger procure-to-pay (P2P) solution.

In summary, ERP and e-procurement are both integral components of a modern supply chain. While they serve different functions, their integration can lead to improved business performance and supply chain efficiency. For example, it facilitates effortless data flows between procurement and the rest of the organization, which can increase supply chain visibility, control, and efficiency.

2. The blockchain technology

In this initial section, we will introduce the concept of blockchain, offering a theoretical foundation for understanding its mechanism. Additionally, we will explore the potential benefits that this technology can bring and examine the existing limitations that obstruct widespread adoption by businesses.

2.1 Origin and popularity

Here, we will trace the genesis of blockchain technology, provide a comprehensive definition, and elucidate its operational mechanisms.

I. Context:

The blockchain is a technology that has the potential to completely transform how businesses and organizations manage transactions and data exchanges. The blockchain was created in 2008 when "Bitcoin: A Peer-to-Peer Electronic Currency System" was published by Satoshi Nakamoto¹⁰. The document describes the creation of a decentralized digital currency as the first application of the blockchain technology. With the help of this new system, people can trade the cryptocurrency Bitcoin without needing to go through a financial institution as a reliable intermediary (Nakamoto, 2008). With the creation of Bitcoin in 2008, the blockchain idea gained traction, but its potential quickly went well beyond financial transactions.

In fact, the blockchain makes it possible to store data in a secure, transparent manner without any risk of piracy or fabrication. This makes the technology very appealing to the logistics and supply chain industries since it makes it possible to guarantee the traceability of goods and processes from the point of production to final delivery. Furthermore, by eliminating pointless middlemen from transactions, the blockchain can help to optimize stock management and lower costs (European Parliament, 2020).

To summarize, the blockchain is a promising technology that has the potential to significantly transform how businesses and organizations exchange information and manage their operations. It is not surprising that The Economist referred to blockchain technology as The Trust Machine (The Economist , 2015).

II. Definition:

For more clarity we would like to define the blockchain here, although we are aware that there are many ways to define it. Therefore, for the purpose of providing a comprehensive overview

¹⁰ Pseudonym for the unidentified person or group of people that created Bitcoin.

of how blockchain works from different perspectives, we will choose three definitions. Afterwards, we'll explain how blockchain works.

“The blockchain is a distributed ledger representing a network consensus of every transaction that has ever occurred” (Tapscott & Tapscott, 2016).

“Blockchain is a technology that enables people to do business with each other in a direct - peer to peer- way, even if they are not sure they can trust each other completely.” (Verlinden, 2018).

A technical definition from Imran Bashir, an information security, software development and IT expert would be: *“Blockchain is a peer-to-peer, distributed ledger that is cryptographically secure, append-only, immutable (extremely hard to change), and updateable only via consensus or agreement among peers.”* (Bashir I. , 2018, p. 16).

III. How does it work?

The blockchain is primarily a distributed/peer-to-peer¹¹ database that records transactions in blocks that are connected to one another chronologically, creating a chain of blocks. The blockchain's operation depends on a network of nodes¹² (or computers) that communicate with one another to validate and record transactions. Each transaction is grouped into a block, which is then added to a chain of blocks to create a transaction history (Colin, 2020).

Each block contains a collection of transactions as well as a "hash"¹³ (a cryptographic fingerprint) that enables uniquely identifying the block and linking it to the block before it in the chain. The integrity of the chain of blocks may be guaranteed by verifying these hashes because every change to one block affects the hashes of all subsequent blocks (Colin, 2020).

¹¹ “Relating to, using, or being a network by which computers operated by individuals can share information and resources directly without relying on a dedicated central server” (Merriam-Webster Dictionary, 2023).

¹² “A node is a computer, a participant in the blockchain network that maintains a copy of the blockchain ledger and actively participates in the validation and propagation of transactions.” (Blockchain Council, 2023).

¹³ “A hash is a unique digital fingerprint generated from data using a cryptographic function.” (Frankenfield, 2023).

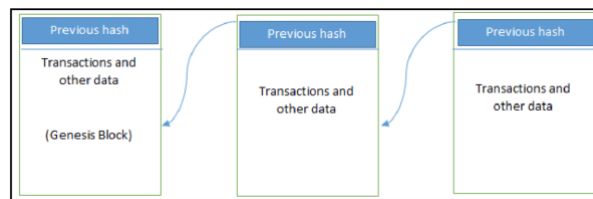


Figure 2: *Generic elements of a blockchain.*

From: (Bashir I. , 2018, p. 20).

Miners have a crucial role in the blockchain system as they validate transactions and add new blocks to the chain. In return for their work, miners receive rewards. Consensus is the process of reaching an agreement among participants in the network to determine the validity of transactions. Different consensus mechanisms exist depending on the specific blockchain protocol used. These mechanisms ensure that transactions are verified and the blockchain remains secure. Miners contribute to the consensus process by actively participating in validating transactions and maintaining the integrity of the blockchain network (Bashir I. , 2018).

Due to the blockchain's decentralization, any participant can access a copy of the chain of blocks and the data is spread over numerous different computers. This enables the security and authenticity of transactions to be guaranteed because majority of network miners must approve a transaction for it to be considered valid (Colin, 2020).

This diagram illustrates the steps in a blockchain transaction that were discussed.

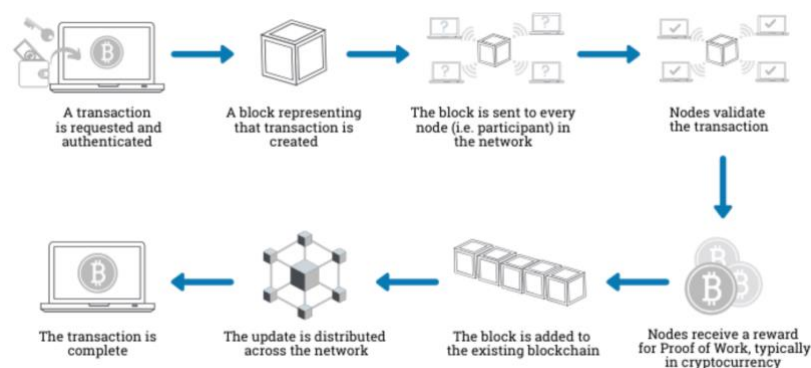


Figure 3: *General functioning of the blockchain.*

From: (Euromoney Learning, n.d.).

2.2 Sort of Consensus:

As said earlier, each time a block is added to the chain of blocks. The nodes that have mined this block receive a reward. These rewards are determined by the consensus¹⁴ that is predefined for each specific blockchain. there are a multitude of different consensus. Here are some examples of them:

The proof of work (PoW) is the most known as it is the original consensus algorithm used by bitcoin. The first miner to successfully solve a challenging mathematical problem has permission to add a new block to the blockchain. The network then validates the response, adds the block, and pays the miner if it is accurate (Nakamoto, 2008). A major downside of the PoW is that it is very energy intensive.

The proof of stake (PoS) is based on the quantity of coins or tokens that a participant is willing to "stake" as collateral. A participant's likelihood of being selected to validate transactions and build new blocks increases with the number of coins they have staked. They are rewarded for accurately validating a block. However, if they behave maliciously their staked coins may be taken. PoS is more energy efficient than PoW, and because participants run the risk of losing their staked coins, PoS encourages honest behavior (ethereum.org, 2023).

Proof of Authority (PoA): transactions and blocks are validated by approved accounts, known as validators. The process is automated and does not require validators to be constantly connected to the network. This model is optimized for private networks where all validators are known and trusted (Bashir I. , 2022, p. 413).

¹⁴ “A blockchain consensus protocol is a mechanism that allows participants in a blockchain system to agree on a sequence of transactions even in the presence of faults. In other words, consensus algorithms ensure that all parties agree on a single source of truth even if some parties are faulty.” (Bashir I. , 2022, p. 210).

Consensus Mechanism	Advantages	Disadvantages
Proof of Work	Decentralized Structure	High Block Time
	High Levels Of Security	Energy Inefficiency
	Acceptable Levels Of Scalability	Hardware Dependency
Proof of Stake	Fast Block Creation Time	
	High Throughput	Suffers From Centralization
	Energy Efficiency	Lower Cost Of Misbehaving
	Scalability (But Less Than PoW)	
Proof Of Authority	Independence to the Special Hardware	
	Transactional Speed Not Decentralized	
	Tighter Security	Breaks Anonymity

Table 1: Consensus Mechanisms Summary Table.

from: (Fáwólé, 2023).

2.3 Types of blockchain

Considering that each blockchain can be customized with a range of distinct consensus and characteristics to serve diverse applications, we can design and establish a broad variety of blockchain types based on varying needs and requirements. In this study, we will focus on the four most prominent types of blockchain, providing a comprehensive overview of the current blockchain market.

These four primary types of blockchain have evolved to encompass a spectrum of potential uses. They are determined by the access privileges of the participants: who can keep a copy of the ledger, who can write to the database, who can read its contents, who can update the ledger, and the governing rules for these activities.

1. Public blockchain (permissionless¹⁵)

A public blockchain is a decentralized and open network that allows anyone to join and participate in the validation process. It offers complete transparency as all transactions are

¹⁵ Nodes don't need a permission to participate.

visible to every participant in the network and are irrevocable. Because their email addresses do not contain any personal information, users of the public blockchain can choose to maintain their anonymity. The most famous example is the cryptocurrency Bitcoin (Bashir I. , 2018).

II. Private blockchain

A private blockchain is a permissioned and limited network run by a single organization. Only some users are permitted access, visibility, and participation in the validation process. This kind of blockchain, which is frequently used for business applications, provides better speed and scalability (Bashir I. , 2018).

Private blockchains are often used by businesses to increase data security and lower transaction processing costs. It makes it possible to track transactions along their supply chain. Users can access the blockchain to verify transactions and track the status of products (Mann, 2022).

III. Hybrid Blockchain

A hybrid blockchain combines aspects of both public and private blockchains. While keeping certain data decentralized and accessible, it enables operators to manage who can view and access specific information. This maintains a balance between security, control, and openness. It enables businesses to share information with their partners while maintaining certain information's confidentiality (Bashir I. , 2018).

IV. Consortium blockchain (group blockchain)

The consortium blockchain, also known as a “group blockchain”, is a blockchain reserved for a group of business partners who cooperate to increase the effectiveness of the supply chain. Decisions are made collaboratively, and each group member has power over a node in the network. This maintains a compromise between public blockchains' transparency and redundancy and the high level of trust offered by private blockchains (Bashir I. , 2022).

V. Conclusion

The various types of blockchains each have their own benefits and drawbacks in terms of security, confidentiality, and flexibility. So, businesses must pick the blockchain that best suits their requirements and financial constraints. Furthermore, for the blockchain to be implemented correctly, significant technical knowledge and resources are needed.

Here under, we can sum up the characteristics of each type of blockchain:

	Public (permissionless)	Private (permissioned)	Hybrid	Consortium
ADVANTAGES	+ Independence + Transparency + Trust	+ Access control + Performance	+ Access control + Performance + Scalability	+ Access control + Scalability + Security
DISADVANTAGES	- Performance - Scalability - Security	- Trust - Auditability	- Transparency - Upgrading	- Transparency
USE CASES	■ Cryptocurrency ■ Document validation	■ Supply chain ■ Asset ownership	■ Medical records ■ Real estate	■ Banking ■ Research ■ Supply chain

Table 2: *Characteristics of Blockchain types.*

From: (Campbell, 2023).

2.4 Tools of the decentralized economy:

Blockchain technology is expected to power a wide range of complex and revolutionary applications in the future. For the purposes of this research, we will concentrate on three promising and crucial aspects: distributed ledger technology (DLT), smart contracts, and decentralized app (Dapps), and these ideas are expected to fundamentally alter the way that digital transactions and governance are carried out.

“Because the blockchain is a powerful decentralized database, the technology is increasingly recognized as a way to support machine-to-machine communications that will soon emerge from Internet enabled devices that constitute the Internet of Things.” (Wright & Filippi, 2015, p. 8).

I. *Distributed Ledger Technology (DLT)*

DLT is a digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple places at the same time. Unlike traditional databases, DLT have no central data store or administration functionality. This technology allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network nodes (Tapscott & Tapscott, 2016).

The key benefit of a DLT is the absence of a central authority: transaction data is processed by several nodes, each node owning an instance of the ledger and participating in the confirmation of transactions. The ledger is updated in each node independently when a transaction is approved, making it highly resistant to technical failures and malicious attacks (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016).

Blockchain technology is a type of DLT, where data is saved in blocks that are linked together in a chain. While all blockchains function as a distributed ledger, not all distributed ledgers employ a chain of blocks to provide a secure and valid distributed consensus (Zohar, 2015). A distributed ledger can be permissioned¹⁶, or permissionless¹⁷.

DLTs have potential applications in many areas including finance, healthcare, property, and identity verification, amongst others (Tapscott & Tapscott, 2016).

II. Smart contract:

The origin of the smart contract concept dates to 1997, when a cryptographer and computer scientist named Nick Szabo published an article entitled "Smart Contracts: Formalizing and Securing Relationships on Public Networks" (Szabo, 1997). In this article, Szabo presented the idea of smart contracts as an evolution of our traditional understanding of legal contracts. He proposed a system where contractual terms could be embedded in computer code and executed automatically without the need for intermediaries.

¹⁶ Meaning that only a select number of nodes are allowed to participate in the consensus process.

¹⁷ Meaning that any node can join the process.

The term "smart contracts" refers to computer programs that facilitate, verify, or carry out the execution of a contract. They are often built on a blockchain, a distributed ledger technology that makes it possible to store information in a transparent and unchangeable manner.

Smart contract functionality is based on the "if-then" logic. If a predefined condition is satisfied (if), then a certain action is started (then). For instance, the buyer's payment might be the condition in a smart contract for the sale of goods. Once this payment has been confirmed, the contract will next carry out the operation of transferring ownership of the goods to the buyer (Bashir I. , 2018).

Szabo conceived the idea for smart contracts long before the blockchain was developed, but it was the arrival of this technology, particularly with Ethereum in 2015, that made its practical implementation feasible. The smart contracts can operate in a decentralized, transparent, and fraud-resistant manner by utilizing the blockchain as a platform (Tapscott & Tapscott, 2016).

In conclusion, smart contracts are a powerful invention that combines traditional contract with blockchain technology to produce automated, transparent, and reliable contractual systems. This technology would then allow to considerably reduce fraud risks and traditional mediation/transfer costs.

Figure 4 – Smart-contracts concept

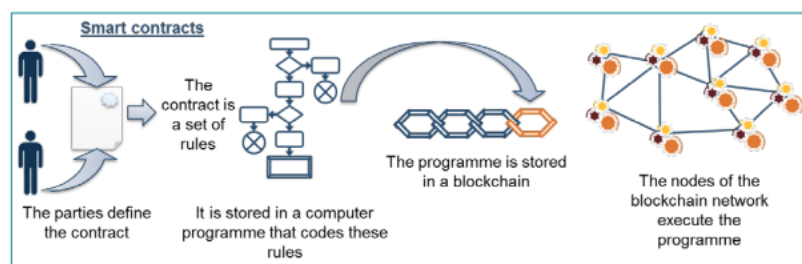


Figure 4: Smart contracts concept.

From: (European Parliament, 2020).

III. Decentralized applications (Dapps)

Applications called DApps, or decentralized applications, operate on blockchain networks like Ethereum and free users from dependence on a central authority. They provide more security

and transparency by dispersing data across the entire network, where each transaction is openly recorded and verifiable (Bashir I. , 2018).

Decentralized Autonomous Organizations is a specific category of DApps. They are governed by blockchain-based smart contracts, autonomous codes that specify how they should operate. These contracts enable advanced automation, where certain tasks are carried out without human interaction, enhancing transparency and effectiveness (Tapscott & Tapscott, 2016).

The potential of DApps extends far beyond these base functionalities. When these decentralized applications are powered by artificial intelligence (AI), they could evolve into autonomous systems capable of self-regulation and adaptation to changing conditions. This synthesis of DApps, blockchain, smart contracts, and AI holds promise for creating more resilient, efficient, and intelligent systems. It might foster new forms of emergent, complex AI-like behaviors (Swan, 2015).

IV. E-procurement and ERP:

Blockchain, ERP¹⁸, and E-Procurement technologies all offer different but complementary benefits to the supply chain. When used together, they can greatly improve the efficiency, transparency, and reliability of supply chain operations.

ERP Technologies allow data consistency by assuring the accuracy and uniformity of the data recorded on the blockchain, eliminating the possibility of conflicts and errors. Moreover, the ERP system can automate the process of recording transactions on the blockchain, resulting in greater efficiency. Finally, the marriage of ERP and blockchain can improve interoperability among various supply chain systems and stakeholders. This occurs because of the blockchain's ability to share data securely and openly from the ERP system (Banerjee, 2018).

E-Procurement Technologies: E-procurement technologies digitalize the procurement process, making it faster, more efficient, and less prone to human error. They can also provide detailed

¹⁸ ERP: Enterprise Resource Planning.

analytics for better decision-making (Van Weele, 2009). When integrated with blockchain, e-procurement can benefit from the transparency, security, and traceability of blockchain, enhancing its ability to prevent fraud and errors.

Integrating blockchain, ERP, and e-procurement technologies can enable the creation of a fully transparent, efficient, and secure digital supply chain. For instance, ERP can automatically record all business transactions into the blockchain ledger, providing real-time, verifiable, and immutable data for all parties in the supply chain (Banerjee, 2018). Similarly, e-procurement can use the blockchain to verify the authenticity of suppliers and products, reducing the risk of fraud.

The integration of these technologies could be a revolutionary step towards creating a fully digital, decentralized, and secure supply chain. However, it should also be noted that this integration would require significant technological expertise, infrastructure, and potentially regulatory compliance.

2.5 Benefits and limitations

We can now make a summary of all the benefits that provides the blockchain.

Transparency: Blockchain encourages accountability and transparency, by giving all parties access to the same information.

Traceability: transactions are visible and accessible for auditing. As a result, it is simpler to follow the flow of assets, which makes fraud more challenging.

Decentralization: Blockchain eliminates the need for a single authority by operating on a decentralized network. Since there is no single point of failure, this improves system resilience.

Security: It is almost impossible to edit or remove data once it has been stored on a blockchain. Because transactions are connected to earlier ones and encrypted, the blockchain is extremely resistant to fraud and hacking.

Efficiency and Cost Savings: By removing intermediaries, minimizing paperwork, and automating trust-based activities, blockchain has the potential to streamline processes. Cost reductions and increased efficiencies may result from this.

As we have seen, a blockchain can have a wide range of qualities. It is crucial to remember, however, that a blockchain's advantages can vary based on the use case and how it is implemented. Moreover, Blockchain does have certain limitations and challenges that need to be addressed for further development. These limitations and challenges include:

Scalability: As the network expands, the blockchain capacity and speed of transaction processing lower. This may make it more difficult for it to efficiently handle a high volume of transactions.

Energy consumption: Some blockchain consensus processes, such as PoW¹⁹, use a lot of computational power, which uses a lot of energy. The potential effects on the environment have raised concerns.

Governance and Regulation: Determining liability, resolving disputes, and establishing standards can be complex. Legal systems must determine how to adapt existing legal principles to this new technology. This includes issues like who bears responsibility for the verification of transactions, how to enforce compliance with law, how to tax transactions, etc.

Adoption barriers: It includes interoperability²⁰ issues, technical challenges, and the requirement for industry-wide cooperation. It might be difficult to integrate new systems with already established infrastructure.

Privacy: The immutability of data on the blockchain makes it difficult or impossible to change or erase information once it has been recorded. It's crucial to find a balance between transparency and privacy.

¹⁹ Proof of work (PoW).

²⁰ "The ability to work together with other systems or pieces of equipment" (Cambridge dictionary, 2023).

3. Blockchain in the supply chain

In the previous chapter, we discussed the functioning and characteristics of blockchain, which has an enormous technological potential and can potentially bring technological improvements in many areas. In this chapter, we'll focus on describing the impact that blockchain could have on the supply chain and the current practice. Therefore, we will start with an historical context, the specific benefits/application that will allow the blockchain in the supply chain and finally a word about technology combination. To better illustrate these aspects, we provide a practical example from the food supply chain (**Appendix 5.3: Food supply chain example**).

3.1 Historical context

The newest technological investment in logistics is blockchain technology, which will speed up and secure information exchange. It improves customer, business, and supplier communication. By 2025, this technology is expected to add more than 176 billion dollars to the industry, according to the American advisory firm Gartner (Mecalux, 2021). Moreover, according to IBM²¹ and Forrester²², blockchain for supply chain is still in the early stages. *“In our study, 63% of respondents indicated their organizations use blockchain today. While, for many, those deployments are still fairly small and often still in the proof-of-concept or pilot phase, nearly three-quarters of those using blockchain today are expanding their implementation, which indicates fairly nascent usage of the technology.”* » (Bennett & Malladi, 2020). In the following figure we can analyze a commissioned study conducted by Forrester Consulting on behalf of IBM, July 2020. About “What are your company’s plans when it comes to utilizing Blockchain/distributed ledger technology (DLT) for your supply network(s)?”

²¹ IBM is an american multinational company active in the fields of computer hardware, software, and services.

²² Forrester Research is an American company that provides its customers with market research on the impact of technology on the business world.

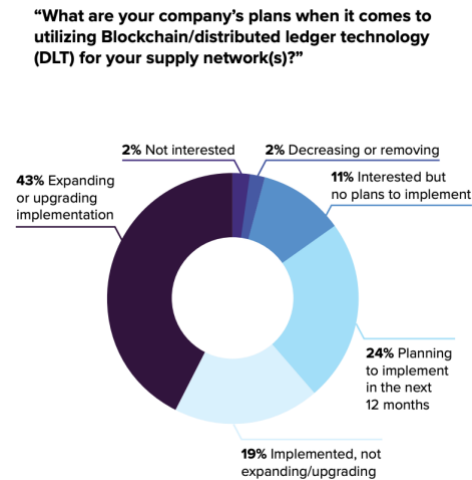


Figure 5: “What are your company’s plans when it comes to utilizing Blockchain/distributed ledger technology (DLT) for your supply network(s)?”

From: (Bennett & Malladi, 2020).

A lot of companies have understood the potential of this technology. In 2017, a significant advancement came when IBM announced a collaboration with Maersk to create a blockchain-based shipment tracking platform. In this program IBM and Maersk claimed that 94 organizations from all around the world were actively involved (port and terminal, authorities, cargo owners, transportation, and logistics companies, etc.) (IBM, 2018). This trend continued as French retailer Carrefour utilized blockchain in 2018 to track its food products (Carrefour, 2019). By 2019, retail giant Walmart, along with several other companies, launched the blockchain-based Food Trust platform for supply chain traceability to improve their food safety control (Sristy, 2021). Moreover, the COVID-19 pandemic in 2020 further highlighted the critical need for supply chain transparency and traceability, leading to an increased interest in blockchain solutions.

3.2 Benefits of Blockchain for supply chain

Here, this section will examine the potential for using blockchain in the supply chain.

1. Traceability and transparency

One of the main benefits of the blockchain is its ability to guarantee complete and transparent transaction traceability. This means that, in the context of the supply chain, every product can be tracked from the point of manufacture to the end consumer. The blockchain allows for the storage of all information related to a particular chain step, resulting in a permanent and unchangeable record. This makes product authentication easier and helps prevent issues related to fraud (Mecalux, 2021).

II. Trust Increase

The transparency that the blockchain provides may help boost consumer confidence. Blockchain reduced the information asymmetry gap letting consumers look up a product's origin, composition, manufacturing date, and other information. Additionally, they can ensure that they purchase authentic goods, which may boost their trust in the brand. According to an IBM and Forrester survey (Bennett & Malladi, 2020), 74% of organizations benefit of a direct improved customer confidence and data quality.

III. Prevention of Fraud

The blockchain may play a significant role in the prevention of fraud due to its immutable and transparent data structure. Because each product can be verified on the blockchain, counterfeit goods are more easily detectable. Additionally, due to the structure of the blockchain, it is very hard or nearly impossible to falsify transaction records (Mecalux, 2021).

IV. Improvement of Efficiency

The need for numerous middlemen in the supply chain may decrease thanks to blockchain, which could lead to an increase in operational efficiencies. The blockchain can also help to prevent delays and errors by automating processes through intelligent smart contracts and by offering complete traceability (Mecalux, 2021). According to (Bennett & Malladi, 2020), it reduces risks, increases flexibility, and improves speed by removing human intervention and it improves data quality.

V. Example of the food industry

Indeed, the blockchain could bring many technical aspects and improvements to many industries. We can now take an example of an industry that could be improved by the blockchain. According to Radocchia (2018) from the Forbes, blockchain could bring 3 improvements to the food industry: “Food recalls”, “product labeling” and “farm and distributor information”.

1. Food Recalls

“Every year, one in 10 people around the world become ill due to foodborne diseases, and approximately 420,000 of them die. Part of the reason we still see statistics like this is because it takes far too long to isolate product recall or contamination issues in the supply chain.” (Radocchia, 2018). Indeed, Walmart’s vice president of food safety ordered his team to identify the origins of a bag of sliced mangoes, it took his team 6 days, 18 hours, and 26 minutes. After implementing a blockchain project with IBM, it took only 2.2 seconds to track (Sristy, 2021).

For this reason, the company started to use blockchain technology. Blockchain allows to keep easily track of the food's journey from farm to table. In case of a food safety issue, stakeholders can quickly identify where in the supply chain the issue occurred, potentially isolating, and solving the problem more swiftly. This can reduce the risk of foodborne illnesses and enhance consumer safety. Mainly, it avoids freezing the entire supply chain for an isolated problem. In the USA, there was a deadly strain of E. Coli in tainted spinach in the past and consumers stopped consuming the product. Frank Yiannas, VP of food safety at Walmart *said* *“Consumers, in general, stopped eating spinach. Restaurants pulled it off the menu”* (Hackett, 2021). Here we see how blockchain could bring traceability and trust by improving the effectiveness of the supply chain.

2. Product Labeling

In today's marketplace, consumers are increasingly seeking detailed information about the products they purchase. Businesses are therefore obliged to respond to this demand by providing products with the right characteristics and adequate product information. Demonstrating their compliance and integrity, however, often poses a twofold problem. Firstly,

the physical limitations of product labels restrict the amount of information that can be shared (Radocchia, 2018). Secondly, the data provided on labels are often difficult for consumers to verify and thus difficult to trust.

This is where the potential of blockchain technology becomes apparent, as it can greatly improve trust and transparency within the food industry. Blockchain allows for the recording of verification data, certifications, and audit reports on an immutable, decentralized ledger, strengthening the validity of marketing claims associated with product labels such as "organic," "cruelty-free," or "sustainable." This technology promotes ethical labeling practices by making good behavior clearly visible and accountable. By simply scanning a QR code, consumers can trace a product's journey from farm to store, leading to confidence in product labeling and the integrity of the food they consume.

3. Farm and Distributor Information

Producers and distributors could also benefit from the blockchain technology. It can democratize access to current market information and commodity prices, boosting farmers' and producers' productivity and competitiveness (Radocchia, 2018). An illustration of this is the collaboration between Block Commodities Ltd. and Global Markets Exchange Group International LLP, which wants to develop a blockchain-based platform connecting farmers in sub-Saharan Africa with buyers and brokers. This platform's goals include securing higher agricultural prices, enabling loans with lower interest rates, and offering insightful data on commodity prices and loan interest rates that is safely stored on the blockchain (GMEX Group, 2020). Farmers and distributors can make their product more inclined with what consumers are looking for, adding an extra value to their business.

3.3 Technology combinations

We have seen that blockchain could be very useful to improve the supply chain operations. However, this potential could still be improved. Indeed, one of the significant blockchain strength is its synergistic potential with other innovative technologies. Its capabilities can be multiplied. As we see with Wright (2015) earlier, as the blockchain is a powerful decentralized

database, the technology could be the way to support machine-to-machine communications and lead to synergistic effects.

Internet of Things (IoT): IoT involves connecting various devices and objects through the internet, allowing for seamless data collection and exchange. When integrated with blockchain, IoT can offer an extensive range of opportunities for enhancing supply chain management (Kshetri, 2018). Machines can communicate with one another and exchange data. For example, in the Warehouse Management System (WMS), we will see autonomous mobile robots, sensors, automation, smart tags, and other devices communicating and functioning autonomously together which can enable increased productivity, reducing errors, saving time and money (Mecalux, 2021). Moreover, as said earlier, we have access to real time traceability, data are available for each step at any time (Kshetri, 2018).

Artificial intelligence (AI): AI allow to create intelligent agent²³ capable of making rational decisions depending on conditions of their environment (Bashir I. , 2018). Compared to humans, AI is more efficient at processing and analyzing enormous amounts of data. Blockchain and AI can work together to analyze the vast amount of data stored there, giving decision-makers insightful information (Tapscott & Tapscott, 2016). Moreover, Bashir said “*A key requirement in AI-based systems is the availability of authentic data that can be used for machine learning and model building. The explosion of data coming out IoT devices, smartphones, and other data acquisition means that AI and machine learning is becoming more and more powerful.*” (Bashir I. , 2018, p. 603).

Big Data: As blockchain will process lots of data, companies will be able to analyze them and utilize them to extract value by using data processing and analysis. Big data with blockchain can provide strong analytics capabilities while keeping them secure (Anand, 2022).

Smart contracts and smart tokens: We have already seen what a smart contract is, but here we want to relate about the automation of payments and transactions between supply chain

²³ Autonomous Agents (AA)

partners that may be made possible using smart contracts and tokens on the blockchain. Here is how that might work:

Token: Tokens are digital assets that can represent a value or a right, such as a currency, an activity, or a product. The use of tokens in the supply chain can be used to represent goods, services, or payments. For instance, a business may produce tokens that stand in for certain products in its supply chain, and these tokens may be exchanged between supply chain partners. Without requiring a third party of trust, such as a bank or a lawyer, the tokens can also be used to carry out payments and transactions between partners (Bashir I. , 2018, p. 22).

Smart contracts²⁴: They can be utilized in the supply chain to automate partner payments and transactional processes. For instance, a smart contract might be made such that when certain circumstances are met, like the delivery of a purchase order or the receipt of products that meet specifications, the payment is automatically initiated. The use of smart contracts can also be used to automatically resolve disputes or legal disputes amongst supply chain partners (Bashir I. , 2018).

Technology combinations can result in supply chains that are more efficient with less errors, predictive analytics for demand and supply, better quality control and autonomy. There are still lots of technologies that could be added in the equation, leading to industry 4.0 (Mecalux, 2021).

Furthermore, hypothetically, in the future, the combinations of these technologies could lead to AIDAO²⁵ that could “*act on behalf of humans to run entire organizations on their own*” (Bashir I. , 2018, p. 604).

²⁴ Smart contracts are computer programs that automatically execute on blockchains in response to predefined criteria.

²⁵ Artificially Intelligent Decentralized autonomous organizations.

PART 2: Practical analysis

1. Problematic and method

In this second part, we will demonstrate the selection of the research question, the research method, and the potential biases of our approach.

1.1 Research question

We successfully contextualized and defined the key theoretical concepts crucial to our research framework, specifically “supply chain”, “trust”, and ultimately “blockchain”. Upon examining the potential advantages of blockchain for the supply chain, we identified traceability as a key advancement. This realization inspired us to investigate this topic more thoroughly, evaluating both the current contributions of blockchain and potential future improvements.

Given the complex and extensive nature of the supply chain, we concluded that the final stage, retail, exerts the most significant influence on its overall operations. Therefore, it is the most appropriate step to test the traceability of a single product. This realization prompted us to not only define and contextualize the "retail sector," but also to narrow the scope of our research to more closely look at this aspect. In the latter part of our study, our goal was to evaluate the impact of traceability and the trust engendered by blockchain on the supply chain, with a special emphasis on the retail sector. This exploration guided us towards our final research question: "How can blockchain enhance trust in the retail supply chain?".

1.2 Research Method

As for our empirical approach that is based on experience and observation rather than theory, we opted for a qualitative method realized by semi-structured interviews as our primary method of data collection. The interviews consist of open-ended and broad questions, allowing for flexible responses and enrichment of the interview guide. As the conversation progresses, the focus can be shifted to more specific topics as needed, enabling the accumulation of important information. We engaged with multiple stakeholders in the supply chain who are using

blockchain technology to gain first-hand insights and contrast the on-the-ground reality with theoretical implications. This enabled us to understand the current market situation, real-world problems, and opportunities, needs, and areas for improvement.

The research was conducted through interviews with six different experts. We carefully selected the interviewees to ensure a diverse range of perspectives and backgrounds, while also ensuring they possessed the competence and qualifications to provide valuable insights into the topic. All interviewees either currently work in areas related to supply chain and blockchain technology or have developed expertise around its development and usage.

1. Our actors:

Prof. Dr. Michael Henke works at the TU Dortmund university of technology and owns his chair of logistics and works at Fraunhofer Institute in Dortmund for material flow and logistics, where he is managing a team of 20 people in blockchain technology research.

Christophe de Coster, the Vice President at EFESO. With a distinguished 22-year career in supply chain management, he has assumed various roles and was previously a Supply Chain Director, with responsibility for strategy, planning, purchasing, logistics, processes, and systems. Christophe brings a wealth of experience to the table, specializing in global supply chain optimization and transformation across a diverse range of industries. His expertise extends from (agro-)chemicals, food and beverage, and consumer products to retail, medical devices, pharmaceuticals, distribution, transport, and logistics.

Mr. “Anonymous”, senior business developer/country manager with an expertise in the fields of luxury goods, energy, banking, IT, blockchain and sustainability. He worked at a company that brings together several entrepreneurs already active in the blockchain field to advance the use of blockchain in Belgium.

Gabrielle Chauvet works at Carrefour Belgium as product manager for the “Filière Qualité Carrefour” (FQC) brand, which is a brand of fresh produce selected to meet the highest

environmental, animal welfare and taste standards, and with a long-term partnership with producers. She is Project Owner for blockchain development here in Belgium.

Tarik Ibnouzahir is a professional based in Paris with a diverse background in business development and entrepreneurial ventures. He has a significant experience of over a decade in business development roles, and earlier in his career, he started as a consultant at Arthur Andersen. He has been part of Tilkal, a traceability platform based in Paris, for over a year and a half. Tarik is focused on helping companies solve problems around compliance and transparency using Tilkal's traceability solutions, which use blockchain technology partially.

Jonathan Fenton is a business analyst consultant at Fujitsu in the innovation/blockchain team. He now primarily focuses on blockchain projects that enhance supply chain traceability. His role is a crucial bridge between clients and developers, translating requirements and simplifying complex terminologies.

The combined strengths and weaknesses of all the interviewees offer a comprehensive perspective on the impact of blockchain on the traceability of supply chains. Globally they all have a high level of education and are professionally diverse, each interviewee presents a unique lens through which to view the topic.

Prof. Dr. Michael Henke and Christophe de Coster offer academic and strategic perspectives. Gabrielle Chauvet and Jonathan Fenton provide hands-on insights, but their perspectives may be restricted by their specific roles. Finally, Mr. "Anonymous" and Tarik Ibnouzahir bring business and compliance considerations to the table. Their collective expertise facilitates a comprehensive understanding of blockchain's potential in supply chain traceability.

However, it is pertinent to acknowledge certain limitations. Our sample size of only six individuals may not accurately cover the entire spectrum of perspectives in the broader field. Additionally, conducting interviews in both French and English could result in the potential dilution of subtle details during translation. An inherent bias might also be present due to the professional affiliations of the interviewees; for instance, those associated with companies promoting blockchain technology might inadvertently overstate its merits while understating

its shortcomings. Lastly, the geographic scope of our study could affect the comprehensiveness of the findings. Since all interviewees are based in similar regions within Western Europe, the insights garnered might not account for the varied use and adoption of blockchain technology for supply chain traceability in different geographical contexts.

II. Hypotheses:

In this empirical section, we will compare the theoretical aspects drawn from our literature review with the practical experiences reported by interviewees in their respective fields. We aim to bridge this gap between theory and practice by formulating a series of hypotheses that were posed and answered through the twelve interview questions. Those interview questions were asked and classed through nine criteria. The hypotheses that we will then try to validate or refute are the following:

- Consumers and companies feel a greater need to trust the supply chains they use through better traceability.
- Blockchain enhances stakeholder and consumer confidence in the supply chain.
- Consumers are willing to pay more when products are from a blockchain-traceable supply chain.
- Supply chains are more efficient when they use blockchain.
- Supply chains are more sustainable when they use blockchain.

III. Recording and analysis:

Each interview²⁶ approximately lasted an hour and was recorded for comprehensive review. The transcriptions are provided in appendix. For the sake of clarity and efficiency, we have meticulously filtered out extraneous "noise" and linguistic redundancies.

²⁶ Interviews available in appendix.

Subsequently, we processed the information furnished by our respondents. This was done by systematically categorizing and comparing responses to each question across all interviewees in a table²⁷.

1.3 Potential bias

When executing semi-structured interviews, there is a potential for various biases to manifest. Minimizing these biases requires cognizance and an effort to counteract or mitigate them. Let's consider some of these biases:

Selection Bias might occur if the selected interviewees do not accurately represent the larger population you aim to investigate. With just six participants, there is a risk that the results might not wholly reflect the broader group. Nonetheless, we've ensured diversity in our selection, including experts from various sectors who can provide insightful and nuanced perspectives.

Confirmation Bias arises when researchers unintentionally pose questions or interpret responses in ways that align with their preconceived notions or hypotheses. It is crucial to maintain impartiality when analyzing responses to counteract this bias.

Respondent Bias, Interviewees may provide desired responses instead of expressing genuine experiences or feelings. Participants were informed that there are no "right" or "wrong" answers, to encourage honesty and authenticity in their responses.

Interviewer Bias, the interviewer's influence on participants' responses, either through the way questions are asked or responses are received, can result in biased data. Moreover, the interviewer's personal opinions or prejudices might influence their interpretation of responses. This necessitates vigilance to personal reactions and conduct throughout the interviews.

²⁷ Table available in appendix.

2. Comparative analysis

In this chapter, we will analyze the data from our interview through nine criteria. This will allow us to discover the reality and opinion of experts in the domain. In the appendices, there is a table that summarizes and categorizes all responses for each question (**Appendices 3.1: Comparative table**). Moreover, alongside these nine criteria, we will provide tables that structure and synthesize the responses to each of these criteria, offering a broader overview.

We will class their answer by the following:

1. “+” Positive.
2. “+/-” Mitigated.
3. “-” Negative.
4. “DNK” Do Not Know.

2.1 Trust: The Perceptions of Businesses and Consumers

In the increasingly interconnected world of global commerce, trust and transparency have become cardinal elements, shaping the landscape of supply chains. As businesses and consumers navigate the fluctuation of supply and demand, a pressing question emerges: “Do businesses and consumers feel a greater need to trust the supply chains through better traceability?”

According to a Label Insight study²⁸, about 73 percent of respondents indicate their readiness to pay a higher price for a product that guarantees full transparency in all its attributes and 94 percent of participants express their likelihood to remain loyal to a brand that provides absolute transparency (Label Insight, 2016).

In this section experts provide insights on trust in the supply chain and the need for improved traceability among companies and consumers.

²⁸ Label Insight, operating as a cloud-oriented platform for the refinement of product data, conducts an analysis on the details that customers seek from brands, their preferred methods of accessing this data, and the influence this information has on buying behavior and loyalty to a brand. The research involved over 2,000 participants (Label Insight, 2016).

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Do businesses and consumers feel a greater need to trust the supply chains they use through better traceability?	+	+	+	+	+	+

Table 3: Trust.

1. The Rising Importance of Traceability in Supply Chains

All the interviewees agreed that the lack of confidence in supply chains exists and is largely due to past fraud, mismanagement, and product recalls. It also comes from investigations and facts revealed in the press about product composition problems and other similar issues.

The increasing significance of traceability in supply chains is grounded in a mix of elements. Gabrielle Chauvet of Carrefour underscores how external influences, such as the advent of QR codes and amplified consumer awareness regarding food sources, have shaped trust and transparency needs. Tarik Ibnouzahir from Tilkal considers that creating a product passport via a QR code provides accessible product information, but it's insufficient due to potential misrepresentations. Without a robust regulatory mechanism to verify the quality of this information, trust is subjective and only extended by those willing to believe. Hence, there must be stringent regulatory frameworks to ensure accuracy, with penalties enforced for non-compliance.

Similarly, Michael Henke, an expert in supply chain management, observes that disruptions and crises, most notably the COVID-19 pandemic, have exposed the lack of trustful connections and the necessity for reliable traceability.

Adding another layer of complexity, Christophe de Coster highlights the escalating requirements for visibility and traceability, noting that businesses now seek greater assurance concerning the origins of their products or materials. Coupled with the strides made in digital innovation, these increased needs for traceability have given rise to a plethora of opportunities for real-time tracking and data gathering. Finally, Mr. anonymous points out that consumers

want to have confidence in the supply chain, but don't want to put the effort into examining the details.

II. The Impact of Traceability on Consumer Confidence

When exploring the implications of traceability on consumer confidence, Gabrielle Chauvet reiterates that consumer expectations are evolving, as they yearn to comprehend the origins and production methods of their purchases. However, skepticism also pervades consumer perceptions, particularly when supermarkets claim sustainability efforts, raising the specter of "greenwashing." *"In the press or even among customers, we immediately sense this mistrust, 'supermarkets, they don't have the legitimacy to have this kind of partnership', it's greenwashing, etc."* [Our translation] (Gabrielle Chauvet). Echoing similar sentiments, Michael Henke points out that younger consumers, aware of sustainability needs, are more inclined to use products from reliable and sustainable supply chains.

III. The Challenges of Full Traceability in Supply Chains

Achieving full traceability in supply chains, while desirable, presents certain challenges. From a consumer perspective, Mr. anonymous suggests that consumers prefer easily digestible information about products. When faced with details that are difficult to understand, consumers may feel overwhelmed and do not attempt to verify the given information. *"But consumers take everything at face value. They're incredulous. Trying to explain to them that you've followed a product from the moment it was created to the moment it's on the shelves is boring, tiring and still of no interest to them."* [our translation] (Mr. anonymous). Consequently, businesses must strike a delicate balance between providing adequate product information and not inundating consumers with overly complex data.

On the business side, Michael Henke underlines the need for a transparent supply chain. While consumers might trust a retailer, the lack of visibility further upstream can jeopardize this trust. This situation necessitates the application of new technologies to enhance transparency, leading to more resilient, sustainable, and flexible supply chains.

IV. Conclusion

In summary, the call for amplified trust in supply chains via enhanced traceability is not just felt but is becoming increasingly critical for both businesses and consumers. This demand is fueled by various factors, such as past supply chain scandals, the spotlight shone by the COVID-19 pandemic, and the growing sustainability awareness of younger consumers. As we navigate through these changes, digital innovations play a pivotal role in meeting these demands by enabling real-time tracking and data gathering.

However, the provision of accessible information, like product passports via QR codes, is merely the first step. Robust regulatory frameworks are required to ensure the authenticity of this information and prevent potential misrepresentations, thereby strengthening consumer trust. While it is crucial to provide comprehensive product information, businesses must also avoid overcomplicating data. The information should be easily digestible, thus avoiding overwhelming consumers with complexity.

Further, trust in retailers is undermined by frequent scandals and a lack of visibility upstream in the supply chain, reinforcing the need for transparency-enhancing technologies. Lastly, skepticism surrounding companies' sustainability claims necessitates sincere, verifiable actions, distancing from mere 'greenwashing'. As we move forward, comprehensive traceability will continue to be vital in fostering trust and transparency in supply chains, shaped by these multifaceted considerations.

2.2 Traceability:

We will discuss the potential impact of blockchain on improving product traceability and increasing stakeholder and consumer trust. In addition, we present here whether consumers would be willing to pay more for products from a blockchain-traceable supply chain.

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Can blockchain improve product traceability, thereby enhancing stakeholder and consumer confidence in the supply chain?	+	+/-	+/-	+	+	+

Are consumers willing to pay more money for products from a blockchain-traceable supply chain?	-	-	-	-	-	-
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Table 4: Traceability.

1. Blockchain's impact on trust

Blockchain technology has emerged as a potential game-changer for traceability in various industries, promising to enhance supply chain transparency, increase stakeholder and consumer trust, and ultimately revolutionize the way we track and verify products' journey from source to end. *“The consumer would have confidence in the product. He would then buy the product excessively and there would be recurring business and all the players in the chain would benefit.”* [Our translation] (Mr. Anonymous). Our interviewees weighed in on the subject, providing insights from diverse perspectives.

Blockchain technology's primary appeal is its ability to provide secure, immutable records that can be viewed by all parties involved in a supply chain. Gabrielle Chauvet from Carrefour commented on the immense credibility blockchain brings, thanks to its external nature, reliability, and resistance to manipulation. This technology can effectively provide consumers with comprehensive information about their purchases, thereby enhancing trust and confidence. Blockchain's potential in this aspect prompted Carrefour to enter a commercial contract with the IBM Food Trust blockchain, aiming to provide transparent, reliable information about its products.

These authors confirmed that blockchain, which is a DLT²⁹, can improve the customers' trust in retailers. *“DLT can affirm customers' trust in retailers' claims, eliminating the need for intermediaries that currently function to verify those claims »* (Grewal, Motyka, & Levy, 2018).

Tarik Ibnouzahir also claims that blockchain is a decentralized technology that allows to create auditability. Once data are in the server, they are locked across the nodes of the network. Data can easily be recorded, shared, and kept as evidence over time in multi actor environment. Moreover, initiating a project with a handful of suppliers and then scaling up to thousands is relatively easy when deploying a network. The process of node deployment for the network

²⁹ Distributed Ledger Technology.

expansion can be efficiently achieved. Both Mr. Anonymous and Jonathan Fenton emphasize that the sharing capabilities and immutability of data within the blockchain encourage participants to input only reliable information.

II. Financial barrier

However, transitioning to blockchain-based traceability is not without challenges. Blockchain technology is still relatively new, and not all companies are ready to share their data, an essential component of effective blockchain use. Furthermore, Mr. Anonymous, points out the cost associated with the adoption of blockchain, which many companies perceive as more significant than the possible return on investment. Companies are often reluctant to invest in a technology they consider a "nice to have" rather than a "must-have." Often companies consider having other priorities to implement or to invest before blockchain, which blocks its integration. Gabrielle Chauvet also thinks that it is a big cost, which pushes them to begin to trace only the high value product "FQC" on which they have a complete vision on the supply chain and a good partnership with the providers.

III. Knowledge and perception barrier

Concerning the blockchain's impact on consumer trust, all interviewees share similar views, believing that most consumers don't understand the underlying technology and won't pay a premium simply because a product is "blockchain-proof." Instead, they suggest that consumers value the assurances that blockchain can offer – such as sustainability, ethical sourcing, and product safety – but not the technology itself directly. Furthermore, Michael Henke holds the view that blockchain creates trust through the network partners' mutual agreement on the correctness of data, thus ensuring transparency and accuracy. However, Mr. Anonymous argues that consumers may not be more confident in one blockchain solution over another due to their lack of understanding of the technology. Additionally, consumers may possibly perceive it as only tracing desirable elements. *“And if he's suspicious, he may say that we've simply traced the elements we wanted to be traced.”* [Our translation] (Mr. Anonymous).

Gabrielle Chauvet explains that the key challenge for effectively communicating to consumers and to value the work that they do with the blockchain, is to keep information simple, user-friendly, and non-technical, even omitting the term "blockchain" from packaging to avoid confusion sometimes. The emphasis is on presenting clear, simple data, avoiding complexity for smoother marketing communication.

Furthermore, not all products need the level of traceability blockchain offers. For some products, like fast-moving consumer goods (FMCG), consumers might not care to know the details of every production and distribution stage. Consumers may not have the time or the will neither to check the veracity of product's information. However, for more impactful purchases, consumers may indeed value such transparency.

“If you buy a chocolate bar in a supermarket because you are hungry between two lectures. Maybe you do not really look at it in detail (...) But if you have enough time and if the products have a higher impact on your working and private life, you are very much interested and even more interested in the future.” (Michael Henke).

Moreover, based on a paper that Michael Henke has written a couple of years ago, investigating different customer behaviors, there was no willing from customers to pay more for a product that uses blockchain solutions. But his opinion is the opposite. *“If in the future a company cannot prove that their supply chain behind the products is sustainable, then they will disappear. They won't stay on the market because we as customers set this as a kind of a prerequisite and just buy if this is sustainable.”* (Michael Henke).

IV. Technological barrier

One major concern is the interoperability of various blockchain solutions or technologies. Not all blockchain frameworks can interact seamlessly with one another, leading to potential issues when connecting different networks, as pointed out by Michael Henke. Hence, the choice of a suitable blockchain framework is a critical factor to consider. *“If you start a blockchain with a genesis block that contains wrong information, then maybe all the further blocks that are added to the blockchain are also wrong”* (Michael Henke).

V. Cultural barrier

To Mr. Anonymous, blockchain technology is advancing in a dissimilar manner across the globe. There are certain locations, like Dubai, Lisbon, and some cities in the U.S., where development activity is particularly vigorous. These hotspots are driven by clusters of visionaries propelling the industry forward. However, in regions like Wallonia, development is less pronounced.

Moreover, there is also the cultural barrier within organizations. Many companies, especially those entrenched in traditional practices, may resist the level of transparency blockchain demands. *“Companies do not really want to give all the transparency to their partners. The people who work are happy about transparency of the financial information of their suppliers because then they can squeeze them even better. But this is not the idea of blockchain. It's transparency in both directions.”* (Michael Henke). Shifting mindsets, therefore, is one of the significant hurdles that need to be overcome. *“The more people leave university with technological education and with socialization, the more we will see the use of blockchain and new business models that are built on data sharing and really working together in terms of cooperation”* (Michael Henke).

As with any technology, the use of blockchain also demands oversight. Regular audits might be necessary to ensure the data's correctness and to evaluate the qualifications of those managing the blockchain network. Despite its inherent security features, the trust placed in blockchain technology should not be blind. As Christophe de Coster puts it, even though blockchain can potentially offer more security than existing tracking methods, it should still be used judiciously. According to Michael Henke it is important to audit the correctness of the data, but it is much more important to control the capabilities of the people who must understand or use the blockchain.

VI. Conclusion

In conclusion, the consensus from the interviewed experts is that blockchain has the potential to improve product traceability and enhance stakeholder and consumer confidence in the supply

chain. However, its implementation requires careful planning and consideration, overcoming technological, financial, and cultural barriers, and the readiness to evolve along with the rapidly advancing landscape of blockchain technology. The question now is not whether blockchain can improve traceability, but rather, how businesses can best leverage this powerful technology to enhance their operations and build both trust and understanding with their stakeholders and consumers.

2.3 Data:

The role of blockchain in the context of companies' data security was a central discussion point in the interviews. We will explore responses regarding potential data security concerns for companies using blockchain. Opinions diverged on the impact of using blockchain on the data security of companies and their customers.

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Are companies using blockchain at greater risk regarding the security of their data and their customers' data?	-	+/-	-	-	-	-

Table 5: Data.

1. Blockchain types

Jonathan Fenton explains that data confidentiality can be ensured through private blockchains, which restrict access to data. Tarik also argues that the type of blockchain employed significantly impacts the functionality and security of the data recorded. Private blockchains, according to him, present issues as they can be controlled by one player, limiting the direct interaction between participants and their data.

He also believes that a public blockchain does not offer sufficient confidentiality for business-to-business manufacturers, who often have confidential relationships with suppliers that they wish to protect.

Therefore, his company has chosen a "permissioned blockchain". This system allows suppliers to directly record their data but requires participants to be authorized to join this network of

nodes. This choice is designed to meet the needs of various industrial companies who wish to share data with their suppliers but are reluctant to make this data accessible to all market players. the design of this network allows new members to join without any one participant dominating, encapsulating the benefits of a blockchain while guaranteeing security and confidentiality.

II. Risks associated with the use of Blockchain for companies.

The use of blockchain technology by companies can pose several risks, particularly in relation to data protection. One of the main challenges is that blockchains are designed to be immutable, meaning that once data is recorded on the blockchain, it cannot easily be modified or deleted. This poses a problem for the GDPR, which requires that personal data be modified or erased where necessary to comply with legal requirements. Another challenge is the lack of clarity around how to define (joint-) controllership in a decentralized system, which makes it difficult to allocate responsibility and accountability for data protection (Poullet & Delforge, 2020).

In addition to these data protection risks, there are also other risks associated with the use of blockchain technology, such as the risk of fraud, hacking, and cyber-attacks. Blockchain technology is not immune to these risks, and companies must take steps to ensure the security and integrity of their blockchain systems (Poullet & Delforge, 2020).

However, Jonathan Fenton believes that blockchains are much safer than a basic database. Additionally, Tarik Ibnouzahir believe that blockchain technology provide a fundamental level of security for data that is quite phenomenal. However, the most significant risk in the rise of blockchain activity is the potential for misinformation or inaccurate data, especially if suppliers aren't held accountable for their data quality.

According to Gabrielle Chauvet, the use of blockchain by companies is well regulated. Each partner signs a legal charter making them responsible for the data, including their entry and quality. This suggests a high level of security and accountability in data management. Indeed, according to a Forrester study, “79% of decision makers reported significant improvements in data quality from using blockchain for supply chain.” (Bennett & Malladi, 2020).

An alternative view was provided by Mr. anonymous, who pointed out that although the blockchain itself is generally secure, the security of the information being inputted into it and the systems used to transfer this information can pose a problem. This suggests that security flaws often lie outside the blockchain itself.

Finally, Christophe de Coster argued that blockchain is safer than other data platforms because users can only see data for which they have the appropriate access rights.

III. Consumer Concerns about Data Privacy

On the question of consumer data privacy, Gabrielle Chauvet indicated that her platform is fully GDPR compliant and cannot collect data without user approval. *“If they don't accept cookies, we can't take any data.”* [Our translation] (Gabriel Chauvet).

However, Michael Henke suggested that consumers typically do not worry about data privacy when conducting online transactions, raising the question of whether the issue of data privacy is overstated in the context of blockchain. *“If we order something online, for example, via Amazon, we don't care neither about our data, right? We give all our personal details about who we are and where we live.”* (Michael Henke).

IV. Blockchain and regulation

GDPR³⁰ rules were also touched upon in the interviews. Chauvet mentioned that their platform signs confidentiality charters with partners to regulate information sharing. *“We make each of the partners sign a legal charter which makes them responsible for the data and therefore for data entry, but also for the quality of the data.”* [Our translation] (Gabrielle Chauvet).

³⁰ General Data Protection Regulation is a European Union regulation that sets out rules for the protection of personal data (Poullet & Delforge, 2020).

On the other hand, Michael Henke referred to the Gaia X³¹ which is a European wide initiative that ensures the security and integrity of stored data. That is their way to ensure that data is safely stored and cannot be manipulated.

Christophe de Coster added that blockchain facilitates GDPR compliance and that both have the same objectives, though full control over the location of data storage may be a challenge. It is maybe difficult because it is basically cloud based and not on your own premises or on your own servers. It's somewhere and you never know.

V. *Conclusion*

In conclusion, the exploration of the role of blockchain in companies' data security through these interviews demonstrates its potential for enhancing data security, but it also illuminates the complexities of its implementation. The type of blockchain employed can drastically affect both functionality and security, with permissioned blockchains emerging as a balanced solution between security and openness, as articulated by Tarik.

There are legitimate risks associated with the use of blockchain, as highlighted by Tarik Ibnouzahir, and the potential for misinformation or inaccurate data is a noteworthy concern. However, the overarching sentiment, as shared by Gabrielle Chauvet and Christophe de Coster, indicates that well-regulated use of blockchain can ensure high levels of security and accountability.

Consumer data privacy and GDPR compliance remain critical factors in this discourse. While Gabrielle Chauvet asserts full GDPR compliance of her platform, Michael Henke's commentary suggests that consumer concerns over data privacy may sometimes be overstated.

³¹ “A Federated and Secure Data Infrastructure (...) Our goal is to establish an ecosystem, whereby data is shared and made available in a trustworthy environment. Our intention is that we give the control back to the users by retaining sovereignty over their data. Our outcome will not be a cloud. It is a federated system linking many cloud service providers and users together in a transparent environment that will drive the European data economy of tomorrow.” (Gaia-X, 2022).

Therefore, the careful and responsible use of blockchain technology seems to be the recommended path, underpinned by robust regulation, user consent and increased attention to data quality and security.

2.4 Regulation:

We assess expectations for positive regulatory developments in supply chain management in relation to the requirement to use technologies such as blockchain to improve traceability.

Several new regulations have emerged in recent years, such as:

The European directive on Waste from Electrical and Electronic Equipment (WEEE):

This regulation mandates manufacturers and importers of electrical and electronic equipment to maintain comprehensive records of their product's raw material supply chains (European Commission, 2023). Blockchain technology can assist in fulfilling these requirements by providing verifiable data on the origin of the materials, their transformation process, and their application in financial products.

The French Corporate Duty of Vigilance Law: Enacted in 2017, this law obliges businesses to routinely monitor their supply chains for possible violations of human and environmental rights (Business & Human Rights Resource Centre, 2023). Blockchain technology can help businesses comply with this law by offering reliable proof of the source and traceability of the raw materials used in their products.

Nowadays, there is a growing debate around the expectation of future regulatory developments, particularly those that might mandate or promote the use of blockchain technology to enhance traceability within supply chain management. The central question that this section seeks to address is: "Do we expect to see more positive regulations in supply chain management, requiring solutions like blockchain to improve traceability?".

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Do we expect to see more positive regulations in supply chain management, requiring solutions like blockchain to improve traceability?	+	+/-	-	+	+	+

Table 6: Regulation.

1. Anticipating Positive Regulations

Gabrielle Chauvet observes that in the current geopolitical climate, including wars and pandemics, the origin of raw materials is being heavily scrutinized. She believes that future laws will require more precise traceability, and thus greater justification for where raw materials originate. This implies an increased need for tools like blockchain that can promote better provenance.

Tarik Ibnouzahir tend to agree and believes that companies will increasingly be required to implement traceability due to regulations. He cites recent laws against deforestation affecting products like cocoa, coffee, soy, and meat as examples. The stakes are high for traceability obligations and it's becoming a necessity to sell certain products. In fact, traceability could become like an authorization to sell on the market in the future.

Jonathan Fenton holds a moderate perspective, believing that regulations won't directly target blockchain. Rather, he views blockchain as a tool for meeting these regulatory requirements. He mentions that there's a significant push in his team to initiate projects related to the Digital Product Passport (DPP³²), which would necessitate the use of blockchain solutions.

Mr. Anonymous makes a distinction between "positive" and "restrictive" legislations. Restrictive legislation imposes prohibitions that can be self-regulated within the supply chain, with penalties for non-compliance. This does not necessarily demand any additional traceability. *"The law applies to everyone, there's no need for a tracking and tracing system. If*

³² The Digital Product Passport (DPP) is a tool aiming to retrace the lifecycle of a product. It is designed to share essential product information, promoting sustainability and circular economy. It enhances efficiency, supports sustainable consumer choices, and ensures legal compliance (European Commission, 2023).

someone is caught using the product, he or she is punished.” [Our translation] (Mr. Anonymous). Positive legislation, on the other hand, incentivizes specific behaviors or actions. For example, the European Green Deal, which encourages companies to reduce CO2 emissions, can be addressed through voluntary transparency or, on a more detailed level, through traceable reports, potentially based on blockchain. Finally, he thinks that we are still early and far from seeing radical change in regulation.

Moreover, Mr. Anonymous believes that blockchain can play a crucial role in contract management, particularly where certain precautions are required. The implementation of blockchain can contribute to stricter enforcement of contractual stipulations and protect companies from liability in the event of a problem. For example, a company purchasing products from a subcontractor may require a specific clause in the contract. This clause would explicitly prohibit the subcontractor from using incorrect components in the product. In addition, the company could insist on regular monitoring and traceability through sample testing. The results of these tests could then be recorded on the blockchain, facilitating more rigorous monitoring of contract compliance. However, while this approach is viable, it entails additional costs and is not a legal requirement.

Michael Henke offers a contrasting perspective. He believes that there are already sufficient regulations in place and is not supportive of introducing more, especially in the context of new technologies like blockchain.

Christophe believes that future regulations might force companies to adopt technologies such as blockchain, providing these regulations guarantee data security. In his view, companies remain hesitant to embrace such technologies due to concerns around data storage and associated liabilities. He perceives this as an ongoing challenge that must be resolved to advance the use of blockchain technology in supply chains.

II. Current Challenges and Blockchain's Potential Role

Mr. Anonymous sees the promotion of blockchain as somewhat idealistic, given the complexity of tracing everything for maximum transparency. He argues that not all parties are interested in

this level of information, and it may not always be beneficial. He also notes the complexity of legal recognition for blockchain-enabled businesses, arguing that without a solid legal framework, companies are unlikely to take the risk of adoption. Infrastructure is not well equipped to understand this technology yet.

Christophe de Coster suggests that blockchain could secure the right application of regulations. While regulations exist in areas like food safety or financial transactions, they often lack concrete enforcement methods. Blockchain, in his view, could be a tool for implementing these regulations, thus promoting their correct and secure application. However, he acknowledges that the wider adoption of this technology would require that the technology is regulated by a body that is independent such as a European government. And it would need the expertise and help of a technology enabler to own the technology knowledge.

III. Conclusion

While there are varying views on the potential for more positive regulations requiring solutions like blockchain, there's a consensus on the potential of blockchain to significantly improve traceability. The key challenge lies in establishing a robust legal framework and addressing data security concerns to encourage broader adoption of blockchain technology.

2.5 Efficiency:

In the landscape of the supply chain, blockchain technology presents interesting possibilities for efficiency improvements and enhancements in data quality. We explore this potential by addressing two central questions: "Does the use of blockchain enable the supply chain to be more efficient?" and "Can the use of blockchain improve data quality in the supply chain?"

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Does the use of blockchain enable the supply chain to be more efficient?	+	+	+	+	+	+
Can the use of blockchain improve data quality in the supply chain?	+	+	+	+	+	+/-

Table 7: Efficiency.

1. The Role of Blockchain in Supply Chain Efficiency

Blockchain technology eliminates intermediaries in SCM³³ by providing a decentralized and secure ledger that allows for direct transactions between parties. This eliminates the need for intermediaries which can reduce transaction costs and increase efficiency. Additionally, blockchain technology can validate transactions almost instantly. This eliminates the need for time-consuming verification processes and reduces the number of process steps, making communication more efficient (Gurtu & Johny, 2019).

When evaluating the ability of blockchain to improve the efficiency of the supply chain, we consider different aspects, such as costs, time, and quality. Gabrielle Chauvet from Carrefour suggests that blockchain is particularly useful in food traceability, providing an efficient information flow for consumers. They've managed to integrate blockchain with their ERP systems, which is adaptable to different sectors and industries, making it efficient for partners to use and enter data. This allows to gain time, information, and clarity.

Mr. Anonymous believes that blockchain can significantly improve efficiency, especially for businesses that lack sophisticated information processing systems. He sees value in smart contracts enabled by blockchain, which could potentially automate the process, saving both time and money.

Echoing this, Michael Henke suggests that the real-time data exchange capability of blockchain can significantly enhance efficiency across the supply chain. By mitigating information asymmetries, blockchain can offer significant benefits, particularly in cross-border transactions. This technology could dramatically reduce the delays associated with the transportation of goods and documentation, especially in customs management.

Tarik Ibnouzahir emphasizes the benefits of using blockchain in identifying and addressing problems or inconsistencies. Blockchain's immutable nature offers indisputable proof of data,

³³ Supply Chain Management.

allowing companies to confront service providers with evidence if any issues arise. He suggests that this creates a level of accountability, making individuals more aware of their actions as their data can be used as a source of evidence.

Overall, blockchain technology can make tracking items and transactions in the supply chain faster and simpler, cutting administrative and logistics timelines in shipping by an estimated 85 percent when used in conjunction with IoT technology (Gurtu & Johny, 2019) .

Lastly, Christophe de Coster acknowledges that while blockchain is not a must-have, it can improve efficiency, particularly in data integrity and information exchange. He asserts that blockchain could accelerate collaboration among different stakeholders in a supply chain. *“Blockchain is more effective when you have different parties needing to contribute on a piece of information.”* (Christophe de Coster).

II. Implementation and Associated Costs of Blockchain in the Supply Chain

Blockchain implementation in the supply chain requires technical expertise, and its cost depends on various factors, including server costs, maintenance, and the development of new channels. Gabrielle Chauvet points out that partnerships, like the one Carrefour has with IBM Food Trust can help manage these aspects.

Mr. Anonymous, however, posits a minimalist approach, where only crucial or potentially contentious information should be encrypted and inserted into the blockchain. This view proposes using conventional information systems as the primary mode, with blockchain serving to enhance data security and integrity.

On the cost aspect, Michael Henke states that while setting up a blockchain node is not very expensive, the associated costs in terms of resources and potentially running a change management project could be substantial. However, he also emphasizes that efficiency gains from blockchain use can quickly compensate for these initial costs. Jonathan Fenton tends to approve, noting that while the initial implementation of blockchain can be expensive, it rapidly yields economies of scale and accelerates information sharing.

III. Measuring the Effectiveness of Blockchain in Supply Chain

To measure the effectiveness of using blockchain throughout the supply chain, Christophe de Coster suggests tracking the reduction in issues and complaints, and the avoidance of potential negative events.

IV. Blockchain's Role in Enhancing Data Quality

On the question of improving data quality, Christophe de Coster and Tarik Ibnouzahir agree that blockchain could significantly enhance data quality, especially in interactions between different stakeholders. The use of blockchain can streamline the process and lead to better data integrity across different stages of the supply chain.

Jonathan Fenton believes that the effect depends on how the technology is used, asserting that blockchain doesn't necessarily improve the data's quality but rather enhances its veracity.

V. Conclusion

In conclusion, the role of blockchain in enhancing supply chain efficiency and improving data quality is clear. Despite some challenges in implementation and associated costs, the potential benefits in terms of real-time information exchange, increased collaboration, and improved data quality make a compelling case for the adoption of blockchain in the supply chain domain.

2.6 Collaboration:

The deployment of blockchain in supply chain processes offers not just the potential for increased efficiency and improved data quality, but also an opportunity for enhanced collaboration between entities and fostering new business models. Hereby, we explore whether the utilization of blockchain promotes collaboration among companies, and how it may inspire new business models, focusing on the key question: "Are companies using blockchain more willing to collaborate with each other?"

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Are companies using blockchain more willing to collaborate with each other	+	+	+	+	-	-

Table 8: *Collaboration.*

I. Blockchain Facilitating Collaboration

The implementation of blockchain technology inherently requires collaboration among involved parties. Gabrielle Chauvet from Carrefour highlights that in France, they have fostered partnerships with national brands to develop blockchain-based solutions to pool this technology. There's a real partnership with Labeyrie, which has really invested in blockchain for smoked salmon. Carrefour has teamed up with Nestlé and IBM Food Trust for Mousline, a 100% French purée, to highlight the expertise of farmers, as well as the sourcing and manufacture of the product.

Similarly, Mr. Anonymous asserts that blockchain can create an extra layer of trust between partners, potentially eliminating the need for traditional contracts and replacing them with blockchain-verified transactions and test results.

Echoing these sentiments, Michael Henke contends that companies using blockchain are generally more willing to collaborate due to the need for transparency. The technology inherently requires parties to cooperate and share data, which promotes collaboration. Christophe de Coster adds that blockchain's effectiveness shines in complex data streams involving multiple parties, which inherently promotes cooperation. *“The more complex the data stream is, the more likely blockchain will be a good option”* (Christophe de Coster).

Jonathan Fenton suggests that although blockchain theoretically fosters collaboration, in practice, due to the individualistic nature of businesses, its implementation often results in selective cooperation, leaving overall dynamics largely similar to pre-blockchain times.

II. Collaboration amidst Competition

When it comes to competition, Christophe de Coster notes that while blockchain is useful for individual companies, competitors are not yet feeling forced to use it merely because others are. That said, there are ongoing tests in sectors such as container freight, indicating the emerging interest in leveraging blockchain for collaboration despite competition.

III. Challenges to Effective Collaboration via Blockchain

However, implementing blockchain for collaboration does not come without challenges. According to Michael Henke, one of the significant hurdles is fostering the right mindset for collaboration and data sharing. Companies need to realize that competition in the domain of blockchain technology can lead to resource wastage, and it is more productive to concentrate resources on areas that differentiate companies from their competitors.

This report from Deloitte tend to agree with this idea.

“The blockchain creates most value for organisations when they work together on areas of shared pain or shared opportunity (...) The problem with many current approaches, though, is that they remain stove-piped: organisations are developing their own blockchains and applications to run on top of them. In any one industry sector, many different chains are therefore being developed by many different organisations to many different standards. This defeats the purpose of distributed ledgers, fails to harness network effects and can be less efficient than current approaches.” (Grewal-Carr & Marshall, 2016).

Additionally, Tarik Ibnouzahir criticizes the development of many blockchain solutions that lack interoperability, which is crucial for the interconnection of various systems, a demand he identifies in the market. He expresses his discomfort with the large number of global players, who create their own blockchain standards for their ecosystem, assuming that they will be adopted by the entire industry. He stresses the need for interoperability, as these companies will inevitably interact with companies in other sectors sharing common products and raw materials. Expressing that there is a need for collaboration and interoperability in the different blockchain solutions.

Gabriel Chauvet adds that Carrefour's blockchain developments are built on strong, long-term partnerships and mutual trust with suppliers. Not all suppliers are ready and want to commit the time and effort needed to input and make data visible. Carrefour noticed that blockchain is an

investment that requires supplier willingness and motivation. Thus, trust, solid relationships, and shared vision are critical to blockchain's implementation, involving strategic decisions on which products to link and significant time investment.

IV. Blockchain-Driven Innovation and Business Model Creation

The collaboration between companies using blockchain can also stimulate innovation and create new business models in the supply chain. Henke elaborates that the usage of blockchain can eliminate the need for intermediaries in transactions, paving the way for innovative business models. For instance, blockchain's combination with other technologies like IoT can lead to the full automation of production processes, which can be a new income source for the companies involved. Indeed, Henke developed a collaborative partnership with a bank and a German telecommunication service provider. This cooperation has advanced to create a solution for automated finance based on the IoT. This innovative solution indicates a new level of inter-industry collaboration in the digital space.

“We combine data that's collected from IoT sensors with the blockchain and the data triggers also payments automatically by the financial institution. Here you can see that a financial institution and a service provider came up with new business models, namely the full automation and in the future automatization of production processes. It's a new business model and income source for the companies that collaborate with each other.” (Michael Henke).

Moreover, as we have already seen in the appendix 5, in today's supply chain, all the players have a vested interest in working together, rather than "squeezing" each other, because it is in their interest to be the best-performing supply chain. So, it is in their best interest to jointly strive for excellence in managing physical, informational, and financial flows to create a top-performing supply chain. Blockchain has the potential to achieve that.

V. Conclusion

In conclusion, blockchain technology offers a promising platform for companies to collaborate more efficiently. While there are challenges related to mindset shifts and the competitive landscape, the potential of blockchain in fostering innovation and creating new business models offers exciting prospects. Despite the varying pace of adoption across sectors, the ongoing

experiments and partnerships highlight the growing recognition of blockchain's transformative potential in the supply chain.

2.7 Interoperability:

Interoperability, referring to the ability of computer systems or software to exchange and make use of information, is a critical factor in evaluating the applicability of blockchain throughout the supply chain. An essential question emerges: “Is the use of blockchain compatible and usable throughout the whole supply chain?”

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Is the use of blockchain compatible/usable throughout the whole supply chain?	+	+/-	+	DNK	+/-	+

Table 9: Interoperability.

Gabrielle Chauvet indicated that the platform from the partnership with IBM Food Trust allows different types of data entry modes to provide to different partners with different needs and level of technical satisfaction, which improves compatibility and usability throughout the supply chain. The flexibility of data entry methods allows different partners to input their data with varying degrees of frequency and quantity. They have distinct ways for data input. For entities like a farmer’s cooperative with minimal and infrequent changes in data, manual entry via a web form is used. However, for industrial operators with large and frequent data, like chicken producers, automated processes are in place. They can upload files to a server, which the blockchain automatically retrieves, eliminating daily manual entries.

Contrarily, Mr. Anonymous acknowledged that although it's theoretically possible to build bridges between different blockchain systems for information exchange, it poses practical challenges including financial costs and security risks. This perspective highlights that while compatibility is conceivable, actual implementation may encounter obstacles. Tarik Ibnouzahir highlights the lack of collaboration and compatibility among companies implementing their own solutions. He emphasizes the importance of adopting common standards for interoperability in supply chains.

Professor Michael Henke claimed that for blockchain to truly fulfill its potential as a decentralized network enabling global collaboration, interoperability is not just desirable but a necessity. Otherwise, it's not possible to use different frameworks across the supply chain, which is contradictory to the original idea of blockchain which is decentralized networks where everyone can work together with everyone else around the world. This requires interoperability. Jonathan Fenton also affirms that despite inherent challenges, blockchain is fully compatible with data systems and operates alongside other technologies like data analytics. He believes that blockchain enhances interoperability, providing added value.

The analysis of these interviews reveals a broad consensus on the importance of interoperability and compatibility in the use of blockchain throughout the supply chain. However, it also highlights the challenges, including technical difficulties, potential security risks, and the necessity of utilizing compatible systems or frameworks for maximum efficiency. As such, for blockchain to effectively revolutionize the supply chain, these challenges need to be thoroughly addressed, and interoperability must be prioritized.

To efficiently address this significant complexity, some companies delegate the responsibility of blockchain implementation to external entities. *“With the current level of maturity of cloud platforms, many companies have started to provide Blockchain as a Service (BaaS)”* (Bashir I., 2018).

2.8 Technology:

Traceability in supply chains is a pivotal aspect that can be significantly improved by the adoption of blockchain. However, for maximum impact, blockchain is often combined with other technologies. This synergy of technologies not only provides enhanced traceability but can also lead to innovative business models and improved operational efficiency. Therefore, we will discuss additional technologies used with blockchain to improve traceability.

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
What technologies are used with blockchain to improve traceability in the supply chain?	DNK	+	+	+	+	DNK

Technologies mentioned	ERP	IoT	All (IoT, IA, etc.)	IoT	Data management	DNK
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Table 10: Technology.

Gabrielle Chauvet thinks that she is not specialized in this matter but knows about possibilities of linking blockchain technologies to ERP systems for an automated and unified exchange of information. In this setup, the supplier's ERP system communicates directly with the blockchain, enabling machine-to-machine communication, which is fast and reduces the chance of human error.

Jonathan Fenton admits his limited knowledge on the convergence of technologies, considering blockchain as a still-emerging technology that has not yet fully tapped into its potential.

Mr. Anonymous emphasizes the synergy between IoT and blockchain. IoT devices can collect real-time data from various points in the supply chain and feed it into a database. A layer of blockchain is then applied on top of this database, which serves to notarize this information, providing a trustworthy record that can be shared efficiently with third parties. The fusion of these two technologies can significantly enhance transparency and traceability in supply chains.

“By combining blockchain and IoT technologies, retailers can track precisely where products are at any moment in the supply chain. If product provenance is important (e.g., wine, coffee), consumers can scan a quick-response code on the packaging and see the entire journey of their coffee beans, from farm to cup” (Conick, 2017) in (Grewal, Motyka, & Levy, 2018).

Michael Henke thinks that blockchain technology is a trust point and that this technology can be combined with many technologies. He focuses on the fact that blockchain technology, combined with IoT and Artificial Intelligence (AI), can be pivotal in creating a circular economy. In this model, the material flow, information flow, and financial flow are interconnected, with blockchain serving as the trusted link between these flows. By enabling a holistic view of the supply chain, blockchain can assist in the move to really put supply chain management on the next level in terms of circular supply chain management. By means of illustration, a practical example is readily available in (**appendix 1.8: Asset tracking case**).

Christophe de Coster also recognizes the relevance of combining IoT with blockchain, particularly by sensors and trackers placed on containers or products. This data is then uploaded to the blockchain, replacing paper-based certificates with digital ones, accessible to all parties in the chain. However, he notes that the transition towards a paperless supply chain, while beneficial, still faces regulatory challenges as most of the governments around the world are rather slow to adapt and recognize this kind of digital documentation.

Tarik Ibnouzahir suggests that the ideal technologies to combine with blockchain are those centered on data analysis and management. Because, initially, the blockchain records raw data without any modification but an added value comes later when layers of artificial intelligence, machine learning, and other forms of analysis are implemented to scrutinize and extract insights from the raw data.

In conclusion, it is apparent that while blockchain is a key technology in improving traceability in supply chains, it does not exist in isolation. The combination of blockchain with other technologies like IoT, AI, and ERP systems not only amplifies its potential but also paves the way for innovative business models and improved efficiency in supply chain management. This multifaceted approach, however, requires careful planning and consideration of regulatory implications, especially in the transition towards digitalization.

2.9 Sustainability:

This chapter explores the environmental impact of blockchain technology and its potential use as a tool for exhibiting corporate environmental responsibility. Through interviews with four professionals in the field, we discuss two key questions: “Does using blockchain have a negative impact on the environment?” and “Is blockchain a tool for demonstrating corporate environmental commitment?”.

	Chauvet	Anonymous	Henke	de Coster	Ibnouzahir	Fenton
Does using blockchain have a negative impact on the environment?	+	+/-	-	+/-	+	+/-
Is blockchain a tool for demonstrating corporate environmental commitment?	+	+/-	+	+/-	+/-	+

Table 11: Sustainability.

1. Promoting Sustainability through Blockchain Technology:

Blockchain technology provides innovative solutions to promote sustainability, especially within supply chain management. Its inherent transparency and accountability present new avenues to enhance working conditions, particularly for laborers in developing nations, and recognize companies making sustainable choices.

Blockchain utilization in supply chain management facilitates the verification of fair and secure work environments. It enables employers to track a wide range of worker data, from wages and working hours to conditions and social compliance certifications. By recording this information on an immutable blockchain, employers can verify their commitment to ethical labor practices (Tapscott & Tapscott, 2016).

This technology is instrumental in combatting various exploitative practices like child labor, forced labor, and discrimination. By promoting accountability and transparency throughout the supply chain, blockchain technology not only combats these issues but also fosters a more equitable relationship between companies and their workers. The resultant effect is a holistic improvement in supply chain sustainability, encouraging fairer partnerships and practices (Tapscott & Tapscott, 2016).

Small businesses, often operating at a disadvantage against larger competitors, can also benefit significantly from blockchain adoption. By minimizing transaction costs and streamlining supply chain processes, blockchain provides them with a competitive edge (Tapscott & Tapscott, 2016). Equipped with these advanced tools and technologies, small businesses can operate on a level playing field with larger counterparts.

Blockchain technology's unique features, such as transparency, immutability, and efficiency, make it an excellent tool to promote sustainability. From improving worker conditions to supporting small businesses and developing nations, blockchain is set to revolutionize sustainability in the global economy.

II. The energy consumption of blockchains

Blockchain's environmental impact primarily comes essentially from the energy required to keep its servers running. Gabrielle Chauvet points out that this is a common issue with all technologies that rely on server-based storage. Mr. Anonymous and Jonathan Fenton adds that the degree of impact can vary depending on the blockchain type and the consensus mechanism used, hinting at the potential for mitigating the environmental impact.

Michael Henke and Tarik Ibnouzahir believe that the energy consumption is a stereotype that is often misapplied to all blockchain applications due to the notorious energy consumption of Bitcoin mining. Indeed, the proof of work consensus of blockchain is very energy intensive. The following quote from Bashir (2018) concurs with this viewpoint:

“It is evident from Bitcoin's blockchain that the PoW mechanism is very inefficient. Of course, this computation secures the Bitcoin network but there is no other benefit of this computation, and it wastes much electrical energy. To reduce this waste, now there is more focus on greener options such as PoS algorithms which do not need enormous resources like Bitcoin's PoW algorithm. This trend is expected to grow, especially with PoS planned for Ethereum.” (Bashir I. , 2018).

Jonathan Fenton also believes that public blockchains, particularly Bitcoin, have a negative environmental impact. However, he also acknowledges that traditional financial systems consume a lot too, so it's not a clear-cut issue.

Henke counters this by noting that energy-efficient frameworks are being developed for B2B blockchain applications. Christophe de Coster considers the carbon footprint of data management in a supply chain to be significant but suggests that it can be counterbalanced by green energy solutions for example. He further suggests that the focus should be on more

impactful areas such as transportation and material use, and that companies and regulations want to tackle those problem first.

Furthermore, Tarik Ibnouzahir asserts that the primary environmental concern lies not in the data itself, but in the hardware and equipment utilized to gather or process this data. *“It is 80% of the impact of carbon emissions through the manufacture of this equipment.” [Our translation] (Tarik Ibnouzahir)*. Thus, he implies that the actual use of data is not the primary environmental concern today, but rather the manufacture and overuse of digital devices.

III. The blockchain as a demonstrating tool of sustainability

In terms of blockchain as a tool for demonstrating corporate environmental commitment, Gabrielle Chauvet presents blockchain as a means to highlight the sustainability efforts of supply chain partners. The technology provides a decentralized platform for these partners to share their sustainability narratives. With a QR code, it is possible to see all the steps. It's no longer possible to cheat and play with words. Sometimes products are labelled as “from Belgium” but, it is just produced in Belgium, and/or you can see that raw material are not from Belgium. That is precisely the advantage of blockchain, you can see all the concrete steps and it is provided by an independent source.

Jonathan Fenton suggests that blockchain guarantees against greenwashing as, at any moment, an external entity can audit the blockchain and confirm or disprove the validity of claims. Consequently, their solution is considered more sustainable than other non-blockchain-based ESG³⁴ platforms.

Mr. Anonymous believes that blockchain can be used for ecological reporting, providing a robust and transparent record of a company's environmental actions. However, he questions the necessity of this level of commitment unless mandated by legislation. Indeed, blockchain is a good tool to demonstrate the validity of information, but it has a cost, it is not mandatory and there are already other solutions. It is just a new philosophy to prove your information.

³⁴ Environmental, Social and Governance standards.

However, Michael Henke argues that blockchain is a prerequisite for achieving ESG compliance in supply chains due to its ability to provide real-time, transparent data on various aspects of the supply chain.

Tarik Ibnouzahir emphasizes that brands and manufacturers must provide proof to back up their claims, whether it's to the authorities or consumers. Blockchain can serve as a proof tool in this process. However, establishing trust extends beyond providing proof; it's a process that develops over time. Trust is reinforced by consistent quality demonstrations from the brand and positive feedback from global suppliers. Ultimately, it is a collective effort of various actions, not a single solution or magical technology, that helps build confidence in brands and their products.

Christophe de Coster agrees that blockchain can facilitate highly detailed sustainability reporting, but notes other platforms exist for this purpose too. He underlines that the real value of blockchain in demonstrating environmental commitment is its potential to connect the dots in the complex supply chain sustainability ecosystem.

IV. Conclusion

In conclusion, the environmental impact of blockchain in supply chain applications is an area of concern, but it is subject to mitigation through appropriate blockchain types, consensus mechanisms, and green energy solutions. Furthermore, blockchain presents a powerful tool for companies to demonstrate their environmental commitments transparently, reliably, and in real-time, though its adoption for this purpose is currently driven more by philosophical alignment than legislative requirement.

Conclusion

Throughout our research, we have conducted an extensive examination of blockchain technology's potential to enhance traceability within the retail supply chain. This investigation, focused on nine pivotal aspects – Trust, Traceability through blockchains, data management,

regulations, efficiency, collaboration, interoperability, associated technologies, and sustainability – paints a compelling picture of blockchain's transformational potential in retail supply chain operations, particularly in bolstering traceability.

Existing studies have correctly articulated the core attributes of blockchain technology – transparency, immutability, and security. These attributes are acknowledged universally as significant catalysts for improving data quality and accuracy, thereby enabling traceability. However, our research offers a more detailed and nuanced perspective, furthering the understanding of blockchain adoption by exploring its practical implementation.

Our research findings corroborate that blockchain implementation is an intricate process requiring thoughtful consideration. Factors such as the choice of consensus mechanism, associated technologies, and their application at different stages of the supply chain are influenced by a plethora of conditions. This indicates that a 'one-size-fits-all' approach to blockchain technology does not suffice. Instead, it demands careful customization to fit specific use-cases, in line with the inherent complexity of retail supply chains.

Our personal recommendation suggests that a permissioned blockchain might be best suited for supply chain contexts. A permissioned blockchain is a closed, secured system where access is limited to specific, identifiable users granted by administrators. This ensures a greater level of security, accountability, and control. Transaction records are kept within the blockchain, providing traceability. These features distinguish permissioned blockchains from public ones, potentially making them more suitable for ensuring a balance of transparency, traceability, and security in supply chain systems.

Complementing this perspective, our research highlights the strategic importance of forming durable, high-quality partnerships with supply chain partners for successful blockchain integration. Achieving alignment on blockchain infrastructure use or ensuring interoperability between diverse systems and technologies is crucial. Equally significant is the consensus on data conformity, security, and value, all of which ensure seamless cooperation among supply chain stakeholders.

Moreover, a unified front among supply chain partners can significantly influence wider market dynamics and government regulations. This can inspire more businesses to adopt blockchain and foster collaboration with regulatory authorities to shape favorable legislation. Such a collective approach not only strengthens the supply chain's resilience but also paves the way for broader blockchain adoption.

Another critical insight from our research is the essential need for user-friendly interfaces to provide valuable information in an accessible and practical manner. This consumer-centric approach greatly enhances the perceived value of blockchain integration, thereby rendering supply chains more transparent and trustworthy to consumers.

Finally, the potential role of blockchain in promoting sustainability is a noteworthy finding of our research. By facilitating secure, transparent, and efficient operations, blockchain technology can encourage better product quality, healthier working conditions, and increased corporate commitment to sustainable practices.

Our research also indicates that blockchain adoption isn't without challenges. The financial implications and governance issues, particularly those surrounding the authority to write, validate, and audit the blockchain, demand clear regulations and consensus mechanisms. This aligns with existing studies but further emphasizes the need for detailed planning and strategic execution to minimize disruption to existing operations and realize the transformative potential of blockchain.

In conclusion, while our findings are in broad agreement with existing literature, this research provides a more in-depth and nuanced understanding of the practical challenges and opportunities associated with blockchain's adoption in supply chain management. We emphasize the importance of a strategic, well-considered, and cooperative approach to integrate blockchain technology successfully into supply chains. Blockchain technology's colossal potential to improve traceability in retail supply chains, combined with its capacity for efficient data management, integration with other cutting-edge technologies, and potential to foster environmental sustainability, make it an invaluable asset for achieving more efficient, transparent, and trustworthy supply chains. Blockchain is not an end in itself, but a powerful

tool to improve traceability, enhance operational efficiency, and deliver more value to consumers and society. The integration of blockchain in retail supply chain management represents a significant shift towards transparency, efficiency, and sustainability.

Further research

In conducting this comprehensive study, we have explored the vast potential of blockchain technology to enhance traceability within the retail supply chain. Our findings provide a rich, detailed perspective on the transformative potential of blockchain technology in retail supply chain operations, particularly concerning improving traceability.

However, it is important to acknowledge that this study is not without limitations. Despite our best efforts to consider various facets of blockchain technology in the retail supply chain, some constraints inherently bound our research. The translation from French to English may have resulted in certain concepts being diluted or less clear. Moreover, the dynamic nature of technology, particularly blockchain, and its rapidly evolving landscape introduces an element of uncertainty into our findings. Technological developments and innovations that have occurred post our study might provide further insights or present additional challenges in blockchain integration.

In terms of blockchain's adoption in the supply chain, one size certainly does not fit all. The research highlighted the fact that the right choice of consensus mechanism, accompanying technologies, and their application across different stages of the supply chain is subject to various conditions. These factors significantly influence the implementation and effectiveness of blockchain, implying that solutions must be bespoke and carefully designed to suit specific contexts. It would be interesting to make further research on these conditions.

Moreover, it would be interesting to make further research on BaaS to observe the role it can have to accelerate and optimize the blockchain integration in supply chains.

Our study, though extensive, is also geographically limited. The dynamics of supply chains can vary greatly across different regions and countries, influenced by factors such as local

regulations, technological infrastructure, and cultural practices. Therefore, the insights and recommendations derived from this study may not be universally applicable. This research was more European oriented, extending this research to include diverse geographical regions more precisely would offer a more holistic view of blockchain's potential in retail supply chains. Additionally, it would be interesting to make an analysis concentrated on the consumers perspective through different demographical conditions to analyze their opinion/perception about the blockchain technology.

We also recognize the limitations in exploring the complex landscape of regulations governing blockchain technology. Regulations are often fluid and are subject to change based on a multitude of factors including, but not limited to, political, social, and economic dynamics. While we have endeavored to present a current view, future changes in regulatory environments could significantly influence the implementation and effectiveness of blockchain technology.

This research raises some open questions and provides ample opportunities for future research. For instance, understanding how retail supply chains can effectively transition from traditional systems to blockchain-based systems without disrupting operations is a critical area that needs more exploration. Moreover, studies can be conducted to quantify the costs and benefits of blockchain adoption in the supply chain to compare them with traditional systems.

Future research could also focus on investigating the interoperability of various blockchain platforms and how they can effectively communicate with other technologies such as AI, IoT, and ERP systems. This could provide further insights into how the combination of these technologies can enhance traceability in the retail supply chain.

Finally, sustainability, being an emerging concern in today's world, presents another area for future research. Further studies could explore how blockchain technology can contribute to the development of environmentally friendly supply chains, the potential of green blockchains, and how they can impact the triple bottom line – people, planet, and profit. It could also be interesting to analyze the differences in impact on energy consumptions of each consensus mechanism.

In conclusion, while we have attempted to provide a comprehensive understanding of blockchain technology's potential to improve traceability in retail supply chains, there is still a vast expanse of uncharted territory in this field. We hope that our research will provide a solid foundation and inspire future studies to investigate deeper into this transformative technology's potential and help to address the challenges associated with its adoption.

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