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Blockchain –

Inventory management's next revolution or just an overdue trend?

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PLAGIARISM STATEMENT

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ABSTRACT

Technology is a major part of our lives and the next big thing that is going to revolutionise how we do business is; *blockchain*. This revolutionary technology has the potential to completely overhaul current systems and could provide inventory management with the necessary transparency and security it so much desires. Every document and transaction would be interlinked and readily accessible for everyone that has access to it. This should be supply chain management's endgame; one methodology to rule them all. Therefore, this paper introduces the challenges of adopting a blockchain-enabled inventory management system in order to provide a clear picture of the potential impact of this dormant technology. In this work, the use of blockchain technology tackles the main issues and uses of inventory management by providing practical use cases and opinions of practitioners' experts. Simply put, this study clears the fog that hangs over a blockchain-enabled inventory management system.

Keywords: blockchain; inventory management; supply chain management; transparency

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LIST OF ABBREVIATIONS

Abbreviations used:

- SCM : *Supply Chain Management*
- EOQ : *Economic Order Quantity*
- MRP : *Materials Resource Planning*

1 INTRODUCTION

Excess inventory, poor service levels, low product turnover, failure to keep track of stock, lack of visibility, and experiencing difficulties when identifying demand patterns. In other words, all inventory management issues, and all challenges that reduce the efficiency of businesses (Scorey, 2018). Since inventory is arguably one of the most crucial parts of any business, it should be managed correctly, effectively, and precisely (Sutter, 2015).

That is, however, easier said than done, and some businesses lack an approach that interconnects every single party into one overarching system. A system that is not only easily accessible by every participant of the supply chain, but also a system that is unified, decentralised, immutable, and records every transaction done by every user. In other words, a radical and state-of-the-art solution that is gaining ground today. Simply put, a solution that is disruptive in almost every single industry, a system called *Blockchain* (Marr, 2018).

Blockchain essentially is a gamechanger for both supply chain management and inventory management due to the simple fact that it gives better security, enhanced transparency, and immutability that is currently severely lacking in inventory management systems (Mitra, 2019). To clarify; imagine a system where every single transaction across the chain, every invoice, every time goods changed hands, every transport document, every inventory level from every supplier, and even every contract, are all intertwined and interlinked in one single system and accessible by everyone that has the rights to do so. That is not only revolutionary, that is the endgame (Brody, 2017).

Having said that, momentarily it is still unclear whether or not the technology is going to be universally adopted, and there are not enough successful practical use cases of a blockchain-enabled inventory management system (Kokane, 2019). There are still tons of challenges and hurdles to overcome before it is going to achieve global acceptance among supply chain and inventory management professionals (Kokane, 2019). Therefore, it can be stated that blockchain is something that is hanging by a thin thread and the opinions are quite divisive. That being said, no matter who is right, one thing is quite clear; it is a revolutionary phenomenon that has been *the* talk of the town in recent years (Matilla, 2016).

Being caught in the middle of all those views is often very difficult and makes forming a clear picture of the possibilities of the technology oftentimes strenuous. Understandably, the essence of the technology can, therefore, remain blurry. Due to that, this report is going to be focussing on a wide variety of papers, articles, and a qualitative study for the literature review in addition to conducting qualitative interviews with experts working in inventory management. This, in order to clear the fog that is hanging around a blockchain-enabled inventory management system and reveal whether or not it is going to require a total overhaul of current systems and processes.

The structure of this report is as follows; Chapter 2 presents the problem statement and the research objective. Therefrom, Chapter 3 lays the theoretical groundwork of blockchain technology by synthesising a wide variety of sources, practical use cases, and quantitative data in order to present the inherent characteristics of a blockchain-enabled inventory management system. Subsequently, Chapter 4 gives an overview of the methodology to be used to assess whether or not the results are in alignment with the literature. Consequently, Chapter 5 presents the results of this research and describes the implications of this. Then, finally, Chapter 6 concludes this work and proposes areas for further research.

2 PROBLEM STATEMENT AND OBJECTIVES

Momentarily, there are a monumental amount of different papers being published on not just blockchain, but also on the possibilities blockchain has for supply chain management. However, academic papers on blockchain-enabled inventory management systems are currently lacking, but they are desired. What is more, there are not enough practical use cases available for this research area and the stances of experts on the work floor are exceptionally hard to come by.

Therefore, it is imperative to gauge whether or not blockchain will be as revolutionary for inventory and supply chain management as some say. Currently, it is hard to say if the technology is going to require a total overhaul of systems and processes due to the simple fact that there is a lack of successful practical examples. Simply put, there is a big gap between articles found online, and actual academic proof that a blockchain-enabled inventory management system would actually reduce costs and be beneficial for businesses.

Due to all of the aforementioned, one can state that blockchain technology has the potential to change the world. Therefore, combining the technology with supply chain management (SCM) – and by extension with inventory management – could potentially be revolutionary, but it is still a relatively new field of study (Zhao, Fan, & Yan, 2016). Therefore, the objective of this research study is *to analyse, through a literature study and a qualitative study, the impact of blockchain technology on inventory management systems, and to establish whether or not blockchain will warrant a total overhaul of existing inventory management systems and business processes.*

On account of the previously stated research objective and in order to fulfil it, several research questions have got to be formulated. First of all, it is important to gain an understanding of how businesses are currently taking care of their inventory management and, subsequently, to find the bottlenecks and issues of doing it like that. This, because an analysis of these current barriers is going to reveal which aspects could be improved upon. Therefrom, it is logically necessary to establish how a revolutionary technology like blockchain could resolve those problems.

However, in order to do that, it is first essential to establish the main idea, the challenges, the characteristics, and several use cases of blockchain technologies. Thereupon, the link between SCM, inventory management, and blockchain, can be made. Having said that, it is finally important to find out how this technology is momentarily revolutionising the inventory management landscape and, thus, assessing what the opinion of businesses towards the technology is right now. Due to the previously stated points, the research questions have been formulated as follows:

1. How are businesses currently taking care of their inventory management and what are the current bottlenecks and issues they are facing?
2. What are the characteristics and challenges of blockchain?

3. How is blockchain currently being used in SCM and inventory management, and what are its benefits and challenges?
4. Has blockchain got the potential to solve the previously found inventory management issues? If so, how?
5. What is the current stance of experts working in inventory management on blockchain and could they accept it as a state-of-the-art technology designed to solve the issues?

3 LITERATURE REVIEW

The purpose of this chapter is to elaborate on a variety of topics that have to be analysed in order to be able to answer the research questions. The aim of this literature study is to define the different terms, definitions, and techniques required to define a *blockchain-enabled inventory management system*. These topics have been chosen in order to get a clear view of the underlying methods and processes: (1) inventory management, (2) blockchain technology, (3) blockchain-enabled supply chain management, and (4) blockchain-enabled inventory management systems.

3.1 Inventory Management

3.1.1 Definitions of Inventory Management

In its most basic form, inventory management is the management of stock. Therefore, it is one of the main and most important aspects of SCM. It includes aspects such as overseeing the ordering of inventory, storage of inventory, the controlling of the amount of products available for sale, and the general controlling of stock (Silver, Pyke, & Peterson, 1998). Additionally, Pontius' (2019) definition aligns with the beforementioned and shows that inventory management is a component of SCM that concerns the supervising of inventory, stock items, and capitalised assets in order to get an efficient flow of goods from manufacturers to warehouses and ultimately to the place of sale.

Research has shown that inventory control is becoming more and more crucial due to the fact that supply chains are globalising and it should, therefore, be front and central for businesses (Marx, 2018). Furthermore, Raviv & Kolka (2013) have shown that inventory management is not only crucial for managing the demand of something as niche as a bike-sharing service, but that it extends further to managing fluctuations in demand. What is more, it has been found that effective inventory management leads to a decrease in shelf time for materials, which in turn ultimately leads to higher returns (Koumanakos, 2008). Finally, it has been found that efficient and effective inventory management leads to higher customer satisfaction levels in the long run and is, therefore, of the utmost importance (Patil & Divekar, 2014). So, in other words, it can be stated that inventory management is one of the most essential aspects in today's SCM.

Henceforth, in order to get a clear grasp of what inventory management entails, it is also crucial to define the main types of strategies that are currently being used. DuBois (2019) proposes the following four:

- **Just-in-Time**
  This inventory management strategy is completely based on customer demand, which means that companies only buy the required materials when there is a need for it (DuBois, 2019). By doing this, companies usually experience increasingly efficient operations and a substantial decrease in costs (Kannan & Tan, 2005).

- **Conventional Manufacturing Strategy**
  With traditional manufacturing or inventory strategies, companies let the assembly line work perpetually. This means that whenever one area or department finishes a step, the output is delivered to the following department without taking into account their current situation. Put differently, whenever something is finished it is passed onto the next station (DuBois, 2019). This approach, however, has a major issue; whenever a bottleneck in the production process occurs, the next station might get overloaded with work or might end up waiting for critical parts (Mills, Platts, & Gregory, 1995).

The aforementioned strategies are the most general strategies employed by companies, but the following two delve deeper into the specifics of inventory management:

- **Economic Order Quantity (EOQ)**
  Research has shown that EOQ is an unmatched strategy for minimising inventory costs and is potentially the most robust and simplest strategy out there (Cárdenas-Barrón, Chung, & Treviño-Garza, 2014). In its most basic terms, EOQ is essentially the amount of units a company has to purchase in order to keep inventories at the desired level after an order has been placed. By doing this, shortage costs, holding costs, and order costs (e.g. inventory costs) are kept as low as possible (Perera, Janakiraman, & Niu, 2017). That being said, Dubois (2019) explains it as the specific reorder point a manufacturer uses in order to avoid overages or shortages.

- **Material Requirement Planning (MRP)**
  MRP is described as a production and inventory planning system that aligns a bill of material with various production schedules in order to calculate purchasing and shipping schedules for specific components and parts (Rouse, 2017). Rouse (2017) describes three primary functions;
  1. It reduces waste due to the fact that businesses are able to maintain a low amount of product levels and in-stock materials,
  2. MRP systems help with the planning of purchasing, delivery schedules, and manufacturing functions,
  3. It helps organisations ensure that appropriate raw materials are available in order to avoid shortages and with ensuring products are available when customers need them.

Simply put, MRP gives companies an insight into the time a part or product is needed, which could be an essential requirement for organisations (Vandaele & De Boeck, 2003). Having said that, it is often incredibly expensive for businesses to implement and smaller businesses, therefore, occasionally opt out of implementing it (Hart, 2018).

3.1.2 Challenges of Inventory Management

All of the aforementioned being said, there are also challenges and issues involved when aiming for an efficient inventory management strategy, such as: excess inventory, poor service levels, low product turnover, failure to keep track of stock, lack of visibility, and experiencing difficulties when identifying demand patterns (Scorey, 2018). However, those are only a few of the issues and challenges of traditional inventory management and it has been found that many of the current challenges are mostly due to poor decision-making, poor execution, and poor communication (Orchestro, 2015). In other words, this means that whenever the management's expectations are not aligned with those of the employees, the inventory will not be organised the way it is supposed to (Inventory Control, 2018). Thus, it has been established that the key challenges of present-day inventory management are a lack of visibility and a misalignment of information (Fernie & Sparks, 2018).This means that, and more often than not, a reactive inventory management system creates imbalances in supply and demand (Soni, 2018). Therefore, an alternative approach should be found to get rid of all these intricacies and challenges. An approach that connects separate parties with one single unified, decentralised, and immutable system that not only records every transaction across the whole chain, but one that is also easily accessible by every party (Karatkevich, 2018). Simply put, it is time to implement a radical and state-of-the-art solution that is momentarily disruptive in a wide variety of industries: *Blockchain* (Marr, 2018).

3.2 Blockchain Technology

Momentarily, blockchain technology is being accepted by organisations more and more and a shift towards blockchain related services, researches, use cases, products, and solution developments can, therefore, be seen (Shrivas & Yeboah, 2018). It simply has the ability and the potential to revolutionise the world's economy due to the simple fact that it has created a new type of internet (Tapscott, 2016). However, what is *blockchain technology* and how is it going to not only revolutionise the world, but how is it specifically going to reform *inventory management*?

3.2.1 The Main Idea of Blockchain Technology

First things first, the main reason why blockchain technology is as disruptive as people say, is because one can trust the authenticity of data without having to rely upon established trusted intermediaries. Anyone can verify and authenticate the data independently without relying on someone else's stamp of approval (Mattila, 2016). In order to fully grasp the scope of this potential change, one simply has to think about the immense amount of trusted intermediators we use in our daily lives; trusting an online vendor with personal information, putting faith in safety icons that have been put on products, or even the keys made by a local locksmith. In other words, the world loves to use and trusts intermediaries, but would just as fast get rid of them when the opportunity arises (Crooks, 2018).

Therefore, it can be established that blockchain technology is unmistakably one of the greatest achievements in recent memory due to the fact that it allows data to be sent but not copied (BlockGeeks, 2019). In technical terms it is essentially a series of time-stamped and immutable records that are managed by individually owned databank computers that are separated from each other – in other words, a decentralized database where everyone in the network owns the data (Twesige, 2015). These records are called blocks and when put together form a *chain* that is transferred to a *distributed ledger* (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). Furthermore, it has been found that blockchain technology has three main pillars: *decentralization, immutability,* and *transparency* (Zheng, Xie, Dai, Chen, & Wang, 2017; Rosic, 2016).

Momentarily, a generally accepted definition of what blockchain technology entails, has not been defined yet (Seebacher & Schüritz, 2017). Even Nakamoto's white paper that was published in 2008 and introduced the world to blockchain technology does not provide a clear definition of the underlying technology. However, he did put in place the foundations for the technology and claimed it is a system that allows for trustworthy direct digital transactions (Nakamoto, 2008). That being said, a clear and concise definition of this revolutionary technology is required, and a peer-reviewed literature study, therefore, has to be carried out.

3.2.2 Definition of Blockchain Technology

Research has shown that a blockchain can either be seen as a decentralised network (Kosba, Miller, Shi, Wen, & Papamanthou, 2016; Bonneau, et al., 2015), or as a distributed database or data structure (Lewenberg, Sompolinsky, & Zohar, 2015; Wang, Chen, & Xu, 2016; Tschorsch & Scheuermann, 2016). It has been found that the blockchain serves as a ledger that documents every activity or transaction within a certain construct (Zhao, Fan, & Yan, 2016; Beck, Stenum Czepluch, Lollike, & Malone, 2016). Within this construct, a sequence of transactions is linked together (Sharples & Domingue, 2016; Böhme, Christin, & Moore, 2015) and after being timestamped (Zyskind, Nathan, Pentland, & A.S., 2015) broadcasted to every participating entity of the shared peer-to-peer network (Zhao, Fan, & Yan, 2016; Wang, Chen, & Xu, 2016). Furthermore, participants verify transactions – which are cryptographically secured through a

public key – for their correctness (Böhme, Christin, & Moore, 2015; Zhao, Fan, & Yan, 2016; Tschorsch & Scheuermann, 2016). Thereafter, a transaction is stored in a block that still needs to be published on the overarching chain. Due to that, it shows that every block is simply a storage unit for transactions that includes a reference to the already verified blocks on the existing chain. That being said, once a block is verified it cannot be altered anymore and can only be appended (Beck, Stenum Czepluch, Lollike, & Malone, 2016; Kraft, 2016; Idelberger, Governatori, Riveret, & Sartor, 2016).

Now, it is possible to synthesise the previous statements in order to find a clear-cut definiton for *blockchain technology* that is going to be used for this research:

"*A blockchain can be defined as a shared and agreed upon distributed database on a peer-to-peer network that consists of a sequence of linked blocks. These blocks hold cryptographically secured timestamped transactions that are verified by the whole network community. Lastly, whenever something is appended on the blockchain, it cannot be altered, which essentially turns the blockchain into an immutable ledger of previous transactions.*"

Having established that, it is also important to make a distinction between private and public blockchains. Private blockchains are used in a setting that wants to limit the contributions of data on the network, whereas public blockchains allow every participant to append the blocks and is, therefore, unrestricted in terms of rights (Sharples & Domingue, 2016).

3.2.3 Basics of Blockchain Technology

Now that the definition of blockchain technology has been established, the basics can be defined. Figure 1 below illustrates a typical example of a blockchain. Nofer, Gomber, Hinz, & Schiereck (2017) explain it as follows; the figure represents a chain of data packages (*blocks*) that together form a complete data set (*blockchain*). Additionally, every separate block is comprised of various *transactions* (TX1-n). Put differently, it represents the complete ledger of any given transaction history. All of these blocks are validated by using cryptographic means on the network and contain the unique *hash value* of the parent block, *timestamps*, and a *nonce* (a randomly generated number to validate the hash). Lastly, the first block – or, the *genenis block* – is used to ensure the integrity of the whole chain and is, therefore, the fundamental block for preventing fraud. This, because of the fact that whenever a block changes value, the hash value itself would also change.

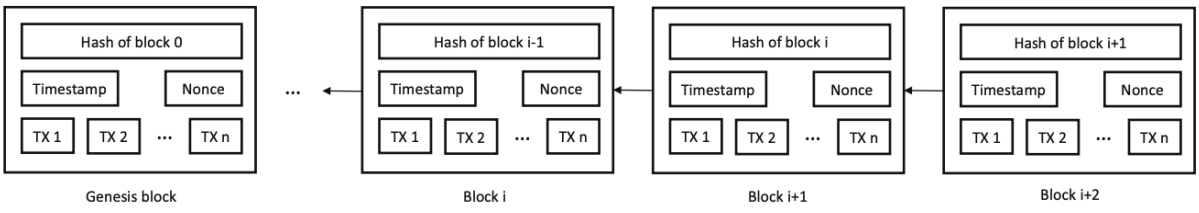


Figure 1, Example of a blockchain (Zheng et al., 2016)

Moreover, there is something called a *consensus mechanism* that is triggered when the majority of the nodes in the network need to check the validity of the transaction. After everything has been verified, the block and transaction will be added to the whole blockchain (Frankenfield, 2018). Put simpler, Swanson (2015) describes the mechanism as a set of procedures and rules between the participating nodes that make sure a coherent set of facts are upheld. Therefore, it can be seen as a process that decides the moment when most of the validators of the network reach an agreement on the state of the ledger. Basically, the mechanism makes sure that not every transaction is immediately transferred to the ledger and stores them in a different block for a certain time (Trummer, 2019).

It has been established now that a blockchain is essentially a growing list of records and can undeniably be considered one of the most ingenious inventions in recent years (Rosic, 2016). The explanations given by Nofer et al. (2016) and Swanson (2015) showcase the technology in more technical terms, but it is also desirable to have an insight into how a single simple transaction works. Scull (2017) summarises this in *Figure 2* below.

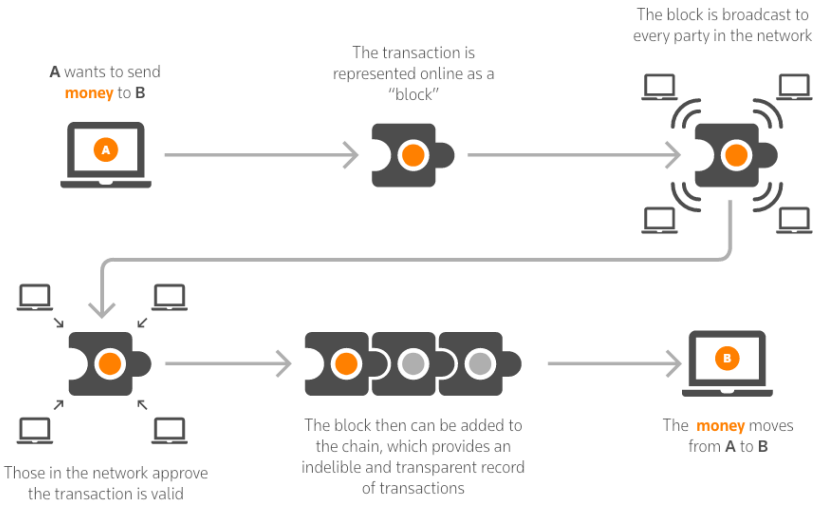


Figure 2, A blockchain transaction, using money as example (Scull, 2017)

The figure basically shows that a transaction is in a way a simple process of passing digital information in an automated and safe way. Therefore, the *transaction costs* are usually non-existent or are considerably lower than the costs of a traditional transaction. This is quite revolutionary because it has the potential to replace all business models and processes that require a small transaction fee (Rosic, 2016). Put differently, this means that due to the peer-to-peer nature of the network, the middle man is cut out of the equation and organisations can, therefore, accept payments without having to pay a merchant processing fee (Heitner, 2018). That being said, transaction costs are also not carved in stone and are actually quite situational (Hartnett, 2019).

So, in other words, when someone wants to do a transaction or transfer money online from one account to another, the banks are involved, and banks keep track of every transaction. However, with blockchain the transaction is almost instantaneously between both parties and can,

therefore, not be tampered with (Siddiqui, 2019). That being said, blockchain technology is bound to revolutionise a wide variety of industries (Ayers, 2018). Therefore, it is crucial to gain an insight into the specific characteristics of the technology and to define its main properties and pros and cons.

3.2.4 Characteristics of Blockchain Technology

Blockchain has been defined as a shared distributed ledger said, Zheng et al. (2017) and Rosic (2016). They proposed three main pillars of the technology: *decentralisation, immutability,* and *transparency*. In addition, Seebacher & Schüritz (2017) consider *trust* and *decentralisation* to be the main characteristics of blockchain technology, which corroborates with Zheng et al. (2017) and Rosic (2016). Due to this, the pillars have to be discussed in detail;

- **Decentralisation**

  It has been touched upon before, but blockchain allows direct interactions between agents without having to go through a third party. This reduces costs and makes sure that there is no core authority that dictates the truth to other users (Lisk, 2019). Simply put, all the network participants have the ability to access the history of past transactions and can individually confirm new transactions. In other words, this makes sure that all the information that has been recorded on the blockchain is impossible to manipulate due to the fact that there are multiple copies available and accessible for every participant (Hamal, 2018; Zheng et al., 2017). The figure below illustrates the differences.

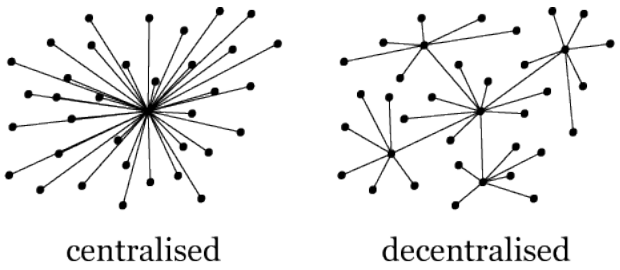
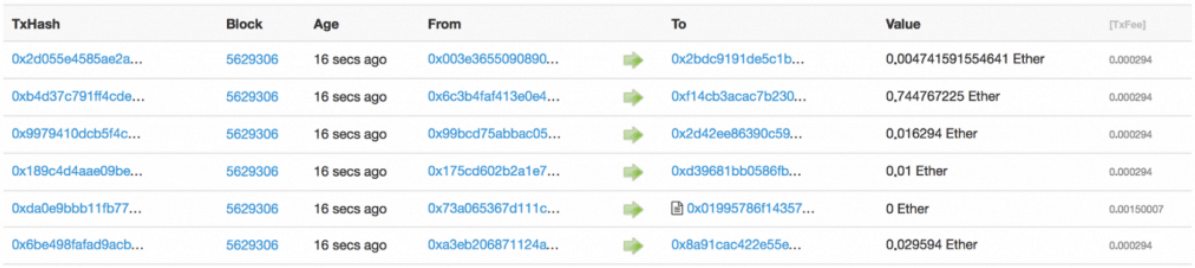


Figure 3, Different types of software systems (Raval, 2016)

  In essence, this figure shows that on a decentralised network every computer can handle their own tasks independently, while on a centralised network everything is controlled by one entity. This makes a decentralised database infinitely better than a centralised one because centralised systems have some vulnerabilities. For example, a software update would halt the entire system, while a shutdown of the system would result in someone being unable to access the data itself. Also, it is an easy target for hackers due to the fact that the data is stored in one spot. Finally, when data gets corrupted the whole system will become compromised (Rosic, 2016). However, it has been found that pitching decentralised systems to the masses has not been as successful as it should be due to the fact that decentralisation mostly only matters to developers instead of the public (Wu, 2019).

- **Immutability**
  In the context of blockchain, when something is immutable, it means that once specific data has been published on the blockchain, it cannot be altered or tampered with (Rosic, 2016; Zheng et al., 2017). In other words, Pilkington (2016) describes it as "*the ability to declare a truth, globally and without a centre of authority, regardless of what anyone else does to change this truth".* These definitions already show that having an indelible, unalterable, and permanent system is one of the crucial benefits of the technology. Having said that, problems could also arise when sensitive personal data is published on the chain. It would essentially become near impossible to delete this data once it is on there, but current blockchain environments have safeguards in place that separates this data from the usual data (Doubleday, 2018).

- **Transparency**
  This is one of the most misunderstood concepts of blockchain; some say the technology gives you privacy while others say it gives you transparency (Rosic, 2016; Zheng et al., 2017). In essence, both are correct. Figure 4 below shows a person's transaction history and shows that while someone's real identity is secure, their public address that they used for their transactions is still visible. Therefore, if one were to know the public address of a specific company or person, they would simply have to pop it into a search engine and they would discover all the transactions they have engaged in (Rosic, 2016). Basically, this forces those agents to be honest and open about all their dealings done on a blockchain. It is highly unlikely that big corporations will start using crypto transactions for all their dealings (Rosic, 2016) but it might have exceptionally great possibilities for improving supply chain visibility (Francisco & Swanson, 2018).



TxHash	Block	Age	From		To	Value	[TxFee]
0x2d055e4585ae2a...	5629306	16 secs ago	0x003e3655090890...		0x2bdc9191de5c1b...	0,004741591554641 Ether	0.000294
0xb4d37c791ff4cde...	5629306	16 secs ago	0x6c3b4faf413e0e4...		0xf14cb3acac7b230...	0,744767225 Ether	0.000294
0x9979410dcb5f4c...	5629306	16 secs ago	0x99bcd75abbac05...		0x2d42ee86390c59...	0,016294 Ether	0.000294
0x189c4d4aae09be...	5629306	16 secs ago	0x175cd602b2a1e7...		0xd39681bb0586fb...	0,01 Ether	0.000294
0xda0e9bbb11fb77...	5629306	16 secs ago	0x73a065367d111c...		0x01995786f14357...	0 Ether	0.00150007
0x6be498fafad9acb...	5629306	16 secs ago	0xa3eb206871124a...		0x8a91cac422e55e...	0,029594 Ether	0.000294

Figure 4, Example of Ethereum transactions (Rosic, 2016)

Henceforth, it can be established that blockchain technology has quite a few reasons why businesses seem to flock towards the technology. Nevertheless, all of these findings correlate with the findings of Seebacher & Schüritz (2017), who have discovered that the main characteristics are trust and decentralisations and have neatly summarised them in *Figure 5*.

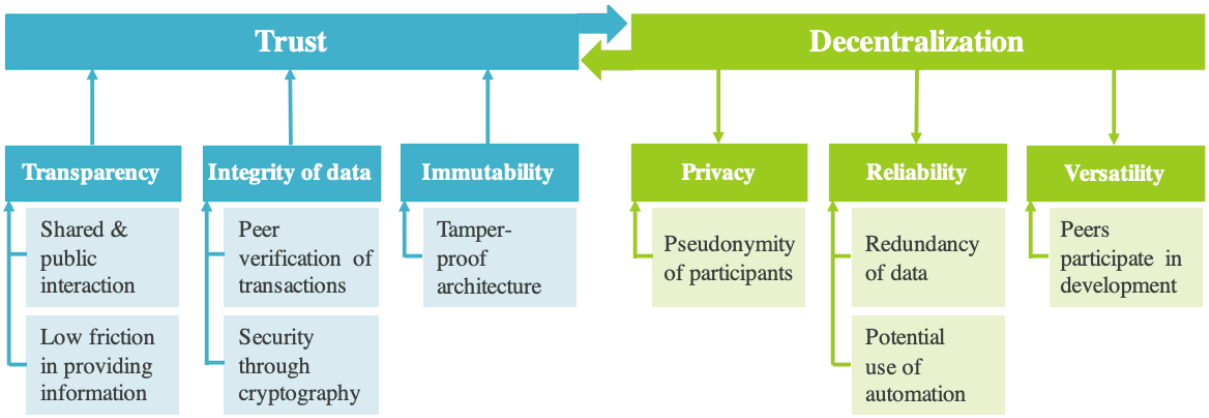


Figure 5, Characteristics of blockchain technology (Seebacher & Schüritz, 2017)

Due to all the aforementioned, blockchain technology sounds like it is going to solve all the world's problems, but there are obviously also challenges that arise with it (Mattila, 2016). These will be discussed below.

3.2.5 The Challenges of Blockchain Technology

Momentarily, it is still unclear whether or not the technology is going to be globally accepted and understood in order to attract a sufficient number of developers, entrepreneurs, and customers to be economically viable. At point of writing, there are only a mere thousand companies or start-ups focusing blockchain-related innovations and, therefore, it simply cannot be established if it will be as disruptive as everyone claims it is going to be (Mattila, 2016). Simply put, the technology is far from being universally adopted. Furthermore, Mattila (2016) mentions that there a wide variety of factors that could potentially disrupt the attraction to the technology in capricious ways, such as changes in regulation or a new different innovative technology. What is more, it has been pointed out that building successful and viable platforms is difficult even in the best of times due to the fact that fostering network effects is like walking a tightrope – in other words, a delicate balancing act (Mattila, 2016; Hagiu, 2014).

Moreover, a different survey by Zheng, Xie, Dai, Chen & Wang (2018) found that *scalability* is one of the main challenges blockchain technology has got to face, which is in alignment with the findings of Blenkinsop (2018). Their research describes the problem as follows: the *blockchain scalability problem* refers to the fact that the technology is limited to frequency and size. For instance, Bitcoin can only handle 7 transactions per second at the moment, which is incredibly low and unacceptable for the majority of business applications. The fact that a blockchain is everlasting due to the fact that every transaction is stored within refers to the size issue. That is, a blockchain can become a very huge data file, which – in turn – slows down the whole network. Having said that, there is a substantial amount of additional kinds of research that point out the scalability is going to be a tough challenge moving forward (Zheng et al., 2018;

Puthal, Malik, Mohanty, Kougianos, & Das, 2018; Karame, 2016; Benkinsop 2018), but it has been found that research also exists that tackles this problem:

- *Optimising the storage capacity of the blockchain*: Bruce (2014) proposed a new blockchain technology scheme that aims to remove old transactions in order to create room for newer ones. This essentially means that nodes no longer have to store every transaction to verify the others. On the other hand, van den Hooff, Kaashoek, & Zeldovich (2014) proposed to introduce an innovative lightweight client that validates the transactions by using different lightweight clients from multiple servers. By doing this, all the transactions are not stored on the same client, which creates more space for new ones.

Scalability is not the only big issue of the technology, and research has shown that – in spite of blockchain creating more immutability and transparency (Rosic, 2016; Zheng et al., 2016) – there could be a potential *privacy leakage* (Zheng et al., 2018). Their research found that while every transaction has a unique key, it cannot be guaranteed that they are hidden to the public eye. Bitcoin transactions, for instance, can be linked to a user's information and could even be linked with IP addresses. So, even though it is private by appearance, the origin of every transaction can still be discovered. In other words, this means that blockchain does not increase the visibility of transactions as good as is promised. However, there are some methods that have been introduced to tackle this anonymity problem;

- *Mixing*: Mixing is an approach that makes sure that the inputs and outputs of transactions are combined with different inputs and outputs of other transactions (Sun, 2018). This means that every input and output has got to be interchangeable, which – in turn – means that every unit has to be considered the same for the input or output. However, this requires the use of intermediaries due to the fact that the transaction uses different transaction of someone else, which is worrisome for the technology because cutting out intermediaries is one of the unique selling points of blockchain technologies (Zheng et al., 2018).
- *Anonymous*: Miers, Garman, Green, & Rubin (2013) introduced a new system of animosity that essentially allows transactions to be validated by a list of valid transactions, as opposed to requiring the participants to validate a transaction. Simply put, they do not link personal payment information to the origin of a transaction and is, therefore, entirely anonymous.

Finally, integration of systems is going to be a major problem for supply chains and financial institutions alike moving forward. Failing to properly and efficiently integrate various systems could potentially become a big hurdle that leads to inaccuracy and instability in the whole chain (Robinson, 2019). Rodriquez (2019) desribes this problem as a communication problem. It is said the blockchain application could pottentially result in a misalignment of systems due to bad communication between the systems. However, Rodriquez (2019) also proposes several technologies that could be helpful in solving this problem;

- *Oraclize*: this is a tool that focusses on connecting different blockchains and interlinking them with existing systems.
- *Rhombus*: similar to Oraclize, this tool provides an elegant model that connects blockchain-based technology to existent external data systems.

In summary, table 1 below provides a clear overview of the main challenges and solutions described above.

Challenge	**The Problem**	**Solution**
Scalability	Blockchain is everlasting and every transaction that occurred is saved on it. Transactions can therefore become slower and slower.	Optimising the storage space of the underlying blockchain system.
Privacy leaking	The origin of a transaction can be found through various means, which is not anonymous at all.	Mixing (changing the transaction origins) or introducing a valid list of transactions.
Integration of systems	Inability to successfully integrate existing systems with revolutionary blockchain technology.	Systems that interlink existing systems with new ones (Oraclize, Rhombus).

Table 1, Challenges of blockchain technology – Source: own elaboration

It has now been demonstrated what blockchain technology really is, what its characteristics are, and what its challenges are. However, in order to gain an all-encompassing insight into this technology, it is required to present some use cases of practical examples of the technology.

3.2.6 Blockchain Applications and Use Cases

In April 2019 Walmart faced an issue with a bad batch of melons – it contained salmonella. Therefore, they quickly recalled it and advised consumers and stores to check the packaging in order to determine whether or not it contained the disease (Beach, 2019). Having said that, another such instance happened in 2018. Back then Walmart had to recall more than 200 million eggs that supposedly caused another salmonella outbreak (Taylor, 2018). It was the latter instance that made Walmart join IBM's *Food Trust Blockchain*, which is a blockchain aimed at tracking food through entire supply chains globally (Sharma, 2018).

Case: *IBM's Food Trust Blockchain*

The Food Trust Blockchain is a system developed by IBM that in real-time captures data from several food companies – which include Dole Food Co., Nestlé SA, Unilever, Walmart, and several others – to identity issues involving food recalls. The main goal is to swiftly identify issues and potential diseases regarding foods in order to trace outbreaks and, thus ultimately, reduce customer risk (IBM, 2019). In other words, it's a *solution-as-a-service* cloud platform that gives everyone using it a collaborative insight into the sourcing of certified and fresh

products. This essentially gives companies an unprecedented veracity and visibility into foods never seen before in food supply chains (Stanley, 2018).

Henceforth, IBM (2019) describes it as the ultimate solution for users to find actionable food supply chain data – from field to store and eventually the customer. The current location and the complete history of any food item in addition to all its accompanying information (e.g. test data, certifications, temperature data) is readily available to everyone in seconds. Put differently, it is a solution that gives participants the ability to controlled sharing of information and convenient data publishing by delivering a shared and permission-based view of the food ecosystem. In order to achieve this goal, the tool only allows access to data that specific participants are permissioned to view. This is done to make sure the encrypted blockchain data remains in the hands of the enabled participants. By doing so, the organisation that owns the data, also maintains the full control over who can or who cannot access it on the network.

So, in summary, the Food Trust Blockchain solution allows users to swiftly locate products from the supply chain in real time. In turn, this gives organisations the capabilities to ensure longer product shelf lives, faster traceability, safer food, better access to shared data, and a reduction in waste. Thus, empowering companies to meet the new higher standards for trust and transparency (IBM, 2019).

Having said all of that, the technology does not only have applications within supply chains of the food industry, but the distributed and immutable nature of the technology can also be used for digital identification management. By having an online digital identity service based on blockchain, the need for trusted third parties is eliminated. Everyone's information is simply stored online and cannot be tampered with. This essentially results in the ability to identify complete strangers and trust them because all their information is immutably documented online (Atzori, 2016). One of the companies working on this is *Bitnation.*

Case: *Bitnation*

The company behind Bitnation call themselves a *governance 2.0* service. This means that they use blockchain technology to provide traditional government services on a globally distributed scale. By doing this, they allow users to dispute settlements, validate identities, offer notarisations, and much more on one shared and secure platform (Bitnation, 2019).

Since some time ago, the company has been collaborating with the Estonian government and by doing so have been offering public notary services to the e-Residents of Estonia. The inhabitants of the country simply have to log in with their online ID and they can simply notarise testaments, land titles, birth certificates, marriage arrangements, etc. from all over the world. Essentially, this has resulted in a safer and faster governmental environment.

So, in conclusion, blockchain technology gained worldwide popularity as a platform that manages the digital cryptocurrency called Bitcoin (Nakamoto, 2008). Nowadays, it is used for not only tracking food across the globe (IBM, 2019), but it is even being used as a new type of

governance tool (Bitnation, 2019). However, apart from enabling a digital currency and allowing more traceability, the technology has created a new type of internet (Tapscott, 2016) that makes sure businesses can – in real-time – easily access a single unified, decentralised, and immutable system that records every transaction across the whole supply chain (Karatkevich, 2018). In other words, the technology is going to have broad and massive implications for logistics and SCM (Saberi, Kouhizadeh, Sarkis, & Shen, 2019). This last bit is the notion that is going to be adopted for the remainder of this thesis.

3.3 Blockchain-Enabled Supply Chain Management

Now that it has been established what blockchain technology entails and what its current challenges and characteristics are, it can now be linked with SCM – and by extension with inventory management. In simple terms, blockchain technology has the potential to bring massive improvements to SCM by providing customers and businesses an insight into an impeccably detailed and immutable list of records on the product level (Mattila, 2016). This could be huge for value chains all over the world.

Mattila (2016) mentions the following practical example to illustrate what the technology could do for SCM: *"A customer wanting to purchase a frozen meal of fish curry could scan a QR code on the item to see where the ingredients came from, how much was paid to each producer and whether or not the product has been maintained within the proper sub-zero temperature range throughout its logistical journey".* This could be huge for SCM due to the fact that it will enhance product safety. Customers could simply see where and when it was certified, for example. What is more, customers are empowered to find out who the bad actors are on the chain and can vote for a different product with their wallet accordingly.

Due to all the aforementioned it can be assumed that blockchain could disrupt SCM considerably, but it is still unclear in what way. Having said that, Saberi, Kouhizadeh, Sarkis, & Shen (2019) remarkably illustrate and summarise this in *Figure 6* below.

It can immediately be noted in the figure that everything is interlinked and intertwined, which means that businesses now finally have the means to trust one another due to the fact that the information is immutable and traceable. For example, the wholesalers can immediately check if the products the manufacturer used were ISO-certified – while standard organisations (e.g. ISO) can see whether or not the whole process of the manufacturer is actually certifiable. In other words, the figure by Saberi et al. (2019) has shown that as opposed to having a *linear step-by-step* supply chain, blockchain technology, can transform a supply chain into one *interconnected system* that is accessible by every actor operating on it.

Furthermore, Pratap's (2018) research explains the pros a little differently; it is shown that blockchain is incredibly beneficial for SCM due to the fact that it allows for data to be more *interoperable*. This is in alignment with *Figure 6* and Saberi's et al. (2019) findings. It simply

becomes easier for organisations to share data and information with vendors, suppliers, and manufacturers. Simply put, this transparency prevents goods from being stuck in the supply chain and, therefore, reduces the number of disputes and delays. Essentially, every product can be tracked in real-time and this causes misplacements to become rare.

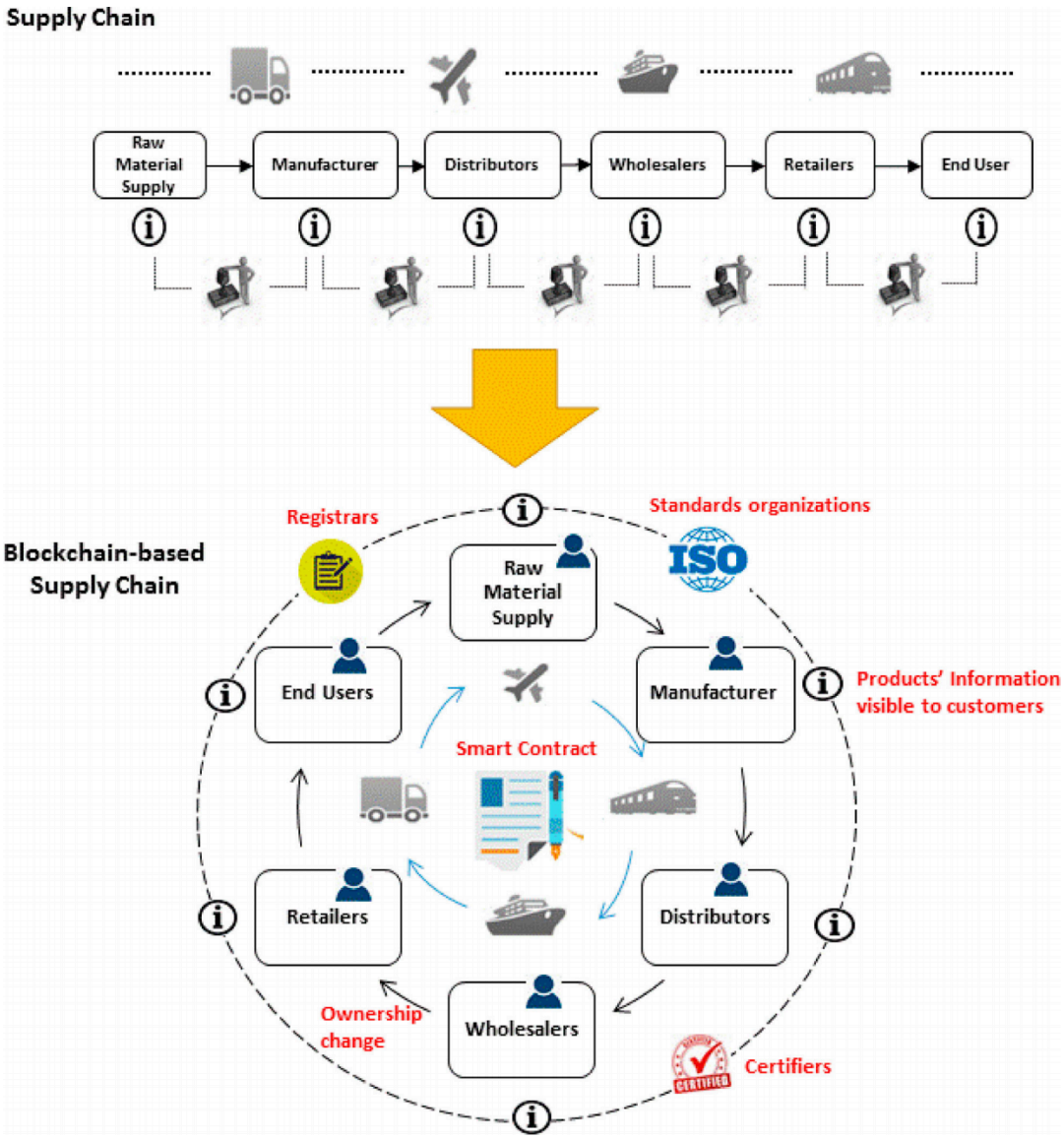


Figure 6, SCM Transformation - Based on blockchain (Saberi et al., 2019)

Additionally, a report by Deloitte (2017) perfectly summarises the practical situation of how blockchain could potentially mitigate some of the operational risks companies face nowadays. Table 2 below presents the summary (Deloitte, 2017);

Stakeholder	*Now*	*Future*
Producer: Ultimately produces the end-product, but also adds value to raw materials.	Is momentarily limited in controlling and verifying the incoming flows from suppliers (i.e. the compliance to standards).	A blockchain-enabled system allows producers to keep track of production and to control inflows in real-time.
Freight handler: Simply transports the products and materials to different stakeholders.	Currently using a reliable yet one-sided tracking system where it is difficult to certify code of conducts and quite complex to track the goods that are being shipped.	One shared data system allows for distributors to see if the goods are certified and allows the client of the products to check if the goods are being transported in the right timing and conditions.
Broker: Acts as the intermediary between various stakeholders.	Due to a lack of visibility, is often unable to verify the path and origin of the goods that they sold and bought.	The blockchain makes sure they can – at any time – check the path, the transformation, and origin of the goods. Thus, always being certain about the provenance and authenticity of the goods.
Consumer: The final user of the product.	For the consumer it is difficult to check the origin, composition, and compliance of the goods they bought, as well.	Same as before; the consumer also has the ability to verify all the specifics of the goods on the blockchain and thus creating more certainty.

Table 2, Practical uses of blockchain technology in SCM – Source: own elaboration

In summary, it has become apparent that blockchain's main characteristics – which are *decentralisation*, *immutability*, and *transparency* – are exceptionally applicable to SCM, as well. This results in the following additional benefits:

- Eliminate or reduce the amount of errors, fraud, or delays due to a greater connectivity across the supply chain network. In other words, everything becomes traceable and transparent across the whole chain (Pratap, 2018; McKendrick, 2018; Battrick, 2018).
- Increases the trust of partners and consumers because everyone has got an insight into where the parts or products originate from or if they are certified or not (Pratap, 2018; McKendrick, 2018; Badoc, 2017).
- Blockchain technology makes sure the system becomes more secure than a standard record-keeping system. This, because every transaction is linked and encrypted after it is approved. Therefore, hackers will be going to have an incredibly hard time to compromise the data (Hooper, 2018).
- Finally, it has the potential to take inventory management to the next level (Pratap, 2018; Wins, 2018).

This last benefit is going to be the focus from here on onwards. Wins (2018) describes the main benefits for using blockchain technology for inventory management as follows: every user on the network has the ability to add, inspect, or access the data, but is not allowed to tamper with it. The whole system, therefore, becomes a considerable amount more safe, secure, and translucent. That being said, all the research that has been consolidated in this literature review of this thesis has made it apparent that blockchains have a wide variety of advantages. For inventory management, these include: reducing costs, decreasing the amount of time delays, visibility into origins of parts and products, simple record keeping across the chain, and much, much more (Wins, 2018; DHL, 2018). These facts and benefits simply prompt one to look more into the details of the implications that blockchain technology could have on inventory management by considering the effects of the technology.

3.4 Blockchain-Enabled Inventory Management Systems

Back in *Chapter 3.2.3* the challenges of inventory management had been described. There, it had been shown that the biggest challenge of present-day inventory management is the fact that various companies lack a certain amount of visibility, which – in turn – causes a misalignment of information (Fernie & Sparks, 2018). Moreover, Scorey's (2018) findings are in corroboration with Fernie & Sparks (2018) and – as such – had found that failing to keep track of stock in addition to having poor visibility of the whole supply chain leads to ineffective inventory management. Consequently, those findings might show that the expectations of the actors on the supply chain are mismatched, as well. In turn, this results in weak control of one's inventories (Inventory Control, 2018). A system like blockchain could, due to that, take inventory to the desired next level (Wins, 2018).

Every inventory management and/or supply chain professional can tell you the same thing; companies selling physical goods always run into the same kind of inventory management problems (Kulkarni, 2018). Kulkarni (2019) puts it as follows: *"Every time a product order comes in, companies have to fulfil the order, send an invoice, and ship the product. Then they wait for the invoice to be paid. At the same time, they're also receiving shipments of raw materials, parts, or other products from upstream partners".* This sounds like a very costly and time-consuming process due to the fact that the current enterprise resource planning (ERP) systems simply have too much limitations compared to blockchain-enabled systems. What is more, according to Jones (2018), the problems surrounding inventory management are: stock-outs, storage costs, spoilage, employee errors, etc. This simply takes too much time and effort to manage, and more often than not, products are also misplaced due to bad data (Jones, 2018).

Francis (2019) describes the above-mentioned phenomenon as the *document mirroring effect* and the figure below summarises this. In essence, this phenomenon occurs when documents are exchanged between different parties. Thus, effectively creating a duplicate of the document that had been shared. This creates a certain inventory in the systems of the participants of the supply chain and, therefore, the whole supply chain becomes increasingly complex (Mearian, 2018).

According to Mearian (2018) the supply chain world is lacking a certain system that has the ability to view all of it in real-time and blockchain could be the one to solve this issue.

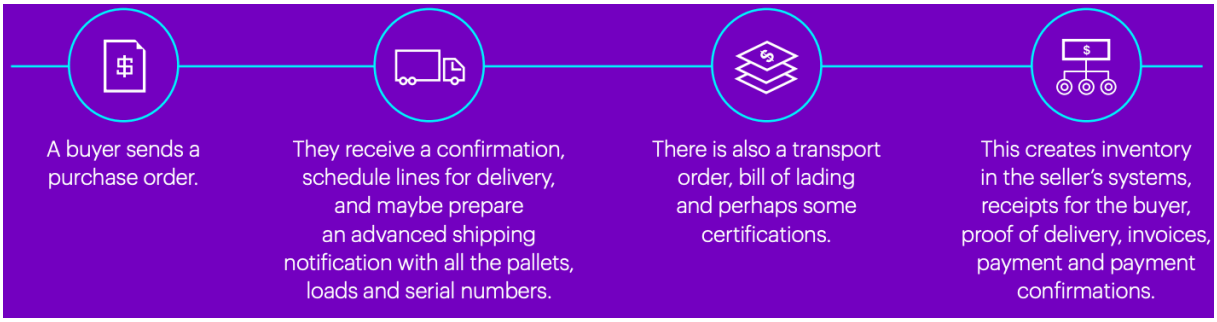


Figure 7, The document mirroring effect (Francis, 2019)

Henceforth, Jones (2018) goes on to explain that the main solutions for the previously mentioned problems is a blockchain-enabled inventory management system. The following advantages are described: real-time inventory management, competitive edge, transparency, business effectiveness, better risk management, and keeping track of sales and production in real time. In other words, when a business has blockchain in place, it will become considerably easier to track the exact path and origin of an item, which – in turn – provides all involved parties a certain degree of trust. By seeing everything in real-time, employees have an easier time clearing stock, managing excess inventory and stock outs, and thus effectively reducing employee errors (Jones, 2018). This means that eventually costs will be reduced due to the fact that inaccuracies can be calculated and ultimately get rid of. Put differently, Jones (2018) is trying to say here that when inventory is managed on a blockchain, businesses can plan necessary implementations and changes by simply looking at what is happening on the work floor in real-time.

So, one could state that blockchain is going to make sure inventory management is moving away from multiple channels, and into *one single system* (Francis, 2019). However, what steps should a company follow should they wish to make a blockchain-enabled inventory management system work?

3.4.1 Blockchain Deployment Process for Inventory Management

In essence, it is not necessary to think of exotic ways of doing business in order to benefit from blockchain systems. One simply has to align the technology with the needs of the business. Logistics Bureau (2018) describes the following steps:

- *Step 1: Identifying expected benefits:*
  The linking between customer satisfaction and improved profitability has to be clear. With reference to blockchain this then means that multiple extra steps are required to find a product in the warehouse could be cut out. Thus, delivering the product faster and ultimately increasing satisfaction, which increases profits and cuts costs.

- *Step 2: Choosing the correct blockchain consensus method:*
  It has been stated before that every user of the blockchain have to agree that a new block is allowed to be added to the chain. Choosing the method how this should be done for an inventory management system is an essential step. Not every user should, for example, have the same kind of rights as other participants.
- *Step 3: Picking the right platform:*
  After the benefits have been defined and the consensus method has been chosen, it is important to establish what platform to use. Most of the blockchain platforms on the market momentarily are open source and thus free to use. Costs will most likely be incurred due to the necessity of hiring engineering resources.
- *Step 4: Configuring the platform:*
  It has been found that blockchain solutions are becoming more and more easy to use, but the technology embedded inside is still quite complex. Having said that, usually this embedded technology can be configured and accessed through simple user interfaces specifically designed for administrators.
- *Step 5: Designing a suitable user interface:*
  Due to the fact that the users of the system do not necessarily have to be technically minded, an engineer could, for instance, design the whole new platform in much the same way the current ERP system of a business is configured. A web interface can, therefore, significantly simplify entering transaction requests or updating inventories. If all of this is then combined with *Smart Contracts*[1], companies have the ability to immediately link incoterms, certificates, supplier information, payment terms, shipping information, etc. with every participant of the blockchain. Thus, effectively creating a transparent and cost-effective supply chain. Having said all that, creating smart contracts is likely to be the most difficult and time-consuming step of transforming a normal inventory management system to a blockchain-enabled one.

Hereafter, Logistics Bureau (2018) goes on to explain a use-case for a blockchain deployment process, which will be discussed below. It is very similar to how one would tackle this adventure for an inventory-based blockchain deployment process.

3.4.2 Use Cases of Enabled Systems

Back in 2017, IBM released an article of how it is starting to use blockchain for their own supply chain (Venkataraman, Vridhachalam, Rosen, & Arthur, 2017). As stated previously, Logistics Bureau (2018) describes the deployment process of this, which is presented below.

Case: *IBM adopting blockchain for enterprise asset management*

IBM tackled the abovementioned steps in the following way:

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[1] Definition of *Smart Contracts: "Smart contracts are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network."* - (Frankenfield, 2019)

- *Step 1: Determining business benefits and needs:*
  IBM was witnessing that several issues were having a large impact on their supply chain. Goods were damaged in transit or the wrong product was being put into an order. All of these issues could closely be related to poor inventory management. Due to the time-consuming effort of aligning all different systems, the customer satisfaction went down, and revenues were ultimately delayed. IBM, therefore, went to look for a solution and found blockchain, which could track all the inventories all the way to the end consumer.
- *Step 2: Figuring out how much blockchain to use:*
  At first, blockchain would only be used for a pre-determined set of inventories and two critical sub-processes of those products; one was *inventory capture and logistics*, and the other *financial management and hardware tracking*. What is more, IBM opted to develop the solution with the absolute minimum number of required features a system needs to be impactful.
- *Step 3: Choosing the consensus method:*
  IBM's blockchain system would basically become one *version of the truth*, which means that it would become a system where everything is automatically tracked throughout the entirety of the supply chain. The design criteria, therefore, were transparency, audibility, and trustworthiness. A data model of interest to all participants was defined and it covered all supply chain and inventory management activities like product serialization, receiving, capitalization, and storing. Every user was securely identified and subsequently giving certain rights and permissions to enter the blockchain network.
- *Step 4: Drafting the smart contracts:*
  The smart contracts were written on an *application programming interface* called *Hyperledger Fabric.* This is essentially a platform that simplifies drafting smart contracts on the blockchain driver. IBM designed the contracts to include business supply chain rules. For instance, this meant that shippers could not create a serial number mismatch, but a receiver could. Thus, effectively creating only unique products in the inventory.
- *Step 5: Developing the interface:*
  In order to simplify the use of the technology, IBM built a client interface that allows users to effortlessly enter events and transactions, like product purchases or installations. For this, the business used Hyperledger Fabric, but Multichain or Ethereum could have been used, as well.

Having said all that, IBM is not the only one that is revolutionising SCM and inventory management. It has been found that there are a wide variety of different start-ups that are helping to increase the veracity of logistics data and increasing the interoperability of already existing data on the huge amount of different platforms (Mire, 2018). Some of these will now be discussed in the case study below.

Case: ***Start-ups revolutionising inventory - and supply chain management***

The start-ups mentioned before are the following ones (Mire, 2018):

- *Eximchain:*
  This is a public blockchain network that not only provides security, privacy, and scalability for the supply chain, but specifically for inventory management, as well. Their blockchain allows enterprises to share, transact, and connect information with every participant in an efficient and secure fashion.
- *OriginTrail:*
  OriginTrail is a supply chain protocol built on blockchain technology and is designed to increase the veracity and integrity of inventory data. By doing this, they are closely working together with supply chain leaders and IT providers in order to give inventory management professionals the necessary and required data insights that are advantageous in multi-organisational environments.
- *T-Mining:*
  This company greatly simplifies the use of smart contracts. They do this by using a ready-made library of proprietary smart contracts specifically designed for logistics, inventory management, and governance toolkits for blockchain networks in order to raise the interoperability and to integrate the new technology with existing software.
- *Peer Ledger:*
  Peer Ledger is a supply chain track-and-trace system that has the ability to track everything – from inventories to shipping details. It has been named one of the most responsible sourcing business by the company themselves.

There are a wide variety of additional start-ups working to improve supply chain – and inventory management with blockchain, but these were the most applicable to this thesis.

Nevertheless, it sounds like blockchain is going to revolutionise inventory management, but it is also crucial to find out what the general opinion of the technology momentarily is. An attempt of knowing it is the online survey by Hackius & Petersen (2017).

3.4.3 Quantitative Data

Hackius & Petersen's (2017) survey collected data from 152 participants who worked for small and medium-sized companies that had an annual turnover of less than $50M and a headcount of under 250 people. Most of their participants are German, and the rest of the participants ranged from the US, France, and Switzerland. Finally, the majority of the survey participants worked in supply chain or inventory management jobs. The findings will now be discussed below.

Figure 8 below starts by showing how many companies have already adopted blockchain technology into their current operations. It has been found that *more than half* of the participants have already implemented it or are investigating potential use cases. Only sixteen percent have

replied that they are currently not looking into implementing blockchain technology. Therefore, it can be concluded once again that blockchain is gaining ground in the world of inventory management. What is more, *figure 9* analyses the existing use cases and it is shown that a large majority of the participants find that the technology is going to be beneficial for the *ease of paperwork processing*, to *identify counterfeit products*, and to *facilitate origin tracking*. However, the chance of adopting blockchain technology for the previously-mentioned cases is slightly lower, but still very much acceptable.

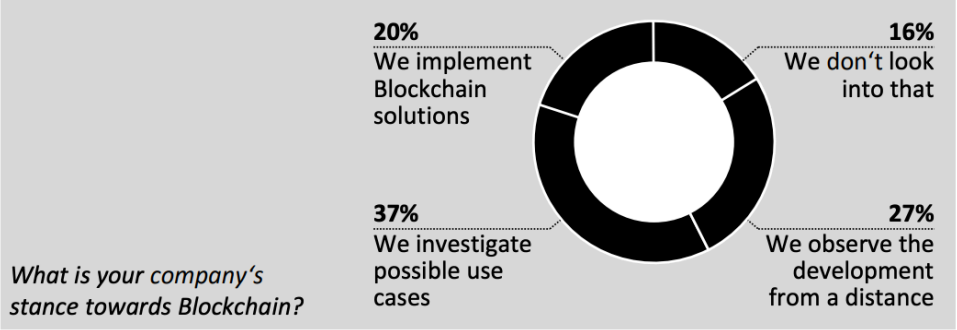

Figure 8, Company's Stance towards blockchain (Hackius & Petersen, 2017)

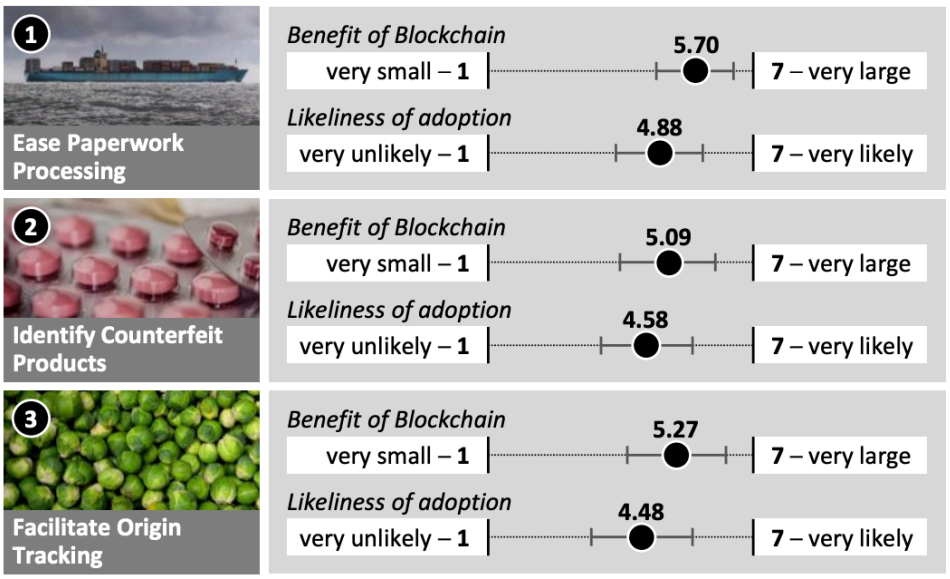

Figure 9, Evaluation of possible practical uses (Hackius & Petersen, 2017)

Moreover, *Figure 10* shows that a colossal 80%, 76%, and 74%, of the logistics service providers, senders, and receivers, respectively find blockchain beneficial in an inventory management context. Having said that, the same respondents had also found several barriers with regards to blockchain adoption. *Figure 11* shows that the most common ones were the following: *regulatory uncertainty, aligning multiple parties, lack of technology maturity and acceptance in the industry, and data security concerns.* Due to these points, it can be concluded that the benefits of adopting blockchain are not yet clearly defined for inventory management systems and only half of the companies are, therefore, only adopting it or looking into it as of now.

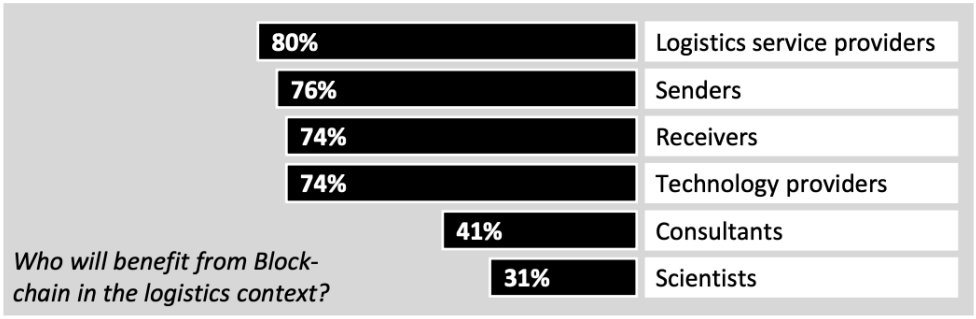

Figure 10, The beneficiaries of blockchain (Hackius & Petersen, 2017)

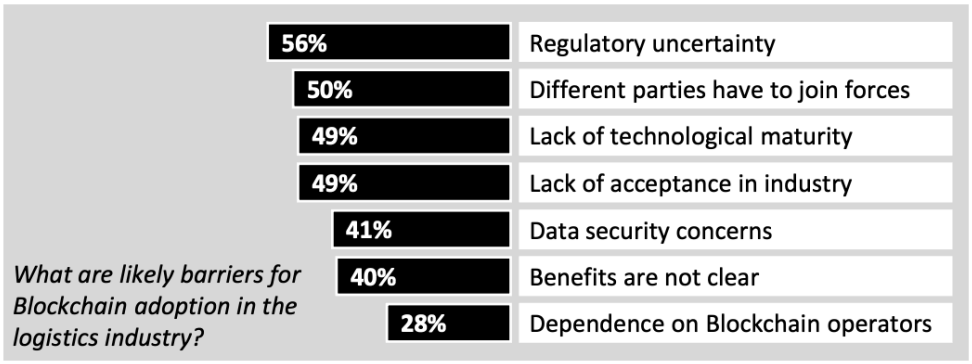

Figure 11, The barriers of adopting blockchain (Hackius & Petersen, 2017)

Then, finally, *figure 12* shows the effect on business models and processes should blockchain be widely adopted in SCM and inventory management. Hackius & Petersen (2017) show that about 70% of all respondents find that blockchain will radically transform their businesses when it is widely implemented. This is quite an important statistic and shows that more use-cases have to be found in order to transition enterprises in a correct manner (Hackius & Petersen, 2017).

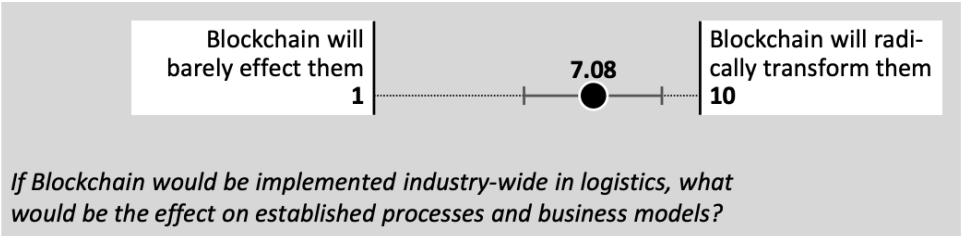

Figure 12, The effect on business models and processes (Hackius & Petersen, 2017)

4 METHODOLOGY

Blockchain in combination with SCM – and by extension inventory management – is still a relatively new field of study. Most publications have, therefore, based their research on available practitioner-oriented sources, such as articles and related forums, and on available white papers (Zhao, Fan, & Yan, 2016). However, a rising academic interest has been found and a tremendous amount of publications that ensure scientific rigor have been surfacing as of late. Consequently, this work had been focussing on a wide variety of papers and articles for the literature study. In essence, this means that all the analysed data for the literature study has either been theoretical, or quantitative/qualitative empirical.

That being said, the focus from here on out is going to be on qualitative interviews. This, because it is essential to compare the findings of online sources with real life practical examples. In other words, as a means to uncover the wide variety of different characteristics of blockchain technology applied to inventory management, professionals have got to be interviewed to get a clear grasp of the potential barriers and benefits of adopting the technology into current systems. Therefore, this document employs a qualitative methodology based on interviews because this ascertains whether or not blockchain will have a positive effect on inventory management systems in practical ways. In order to achieve this goal, two interviews will be held at companies that have not yet implemented blockchain.

The first interview is with Luc Altorf, who is a young professional working as a *Procurement Officer* at *Vlisco Netherlands.* He is responsible for keeping track of inventory levels in order to procure the necessary materials to make sure their clients receive what they requested in a timely manner. In turn, Vlisco is a medium-sized African fabrics manufacturing and designing company that uses honoured methods and materials loved by African women (Vlisco, 2019). A wide variety of their designs have become cultural treasures that have been bestowed with special meanings and names by merchants all over Africa. Therefrom, the second interview is with Mike van Dongen, who is another supply chain professional currently employed at *Mars, Incorporated* as a *Strategic Operations Buyer Business Services*. In that role he manages inventory by implementing new sourcing strategies and purchasing business services in order to keep both suppliers and customers happy. Having said that, Mars is one of the biggest food processing companies operating in the world today and is most well-known for selling *Mars bars, Milky Way bars, Twix bars, Skittles,* etc. (Taylor, 2017).

The aforementioned interviewees have both been contacted by phone and the interviews themselves have not been recorded. During the interviews, notes were written down to make sure that the most important and significant points could be referred to at a later stage of this research. Additionally, these interviews, which both lasted one hour, ensure that the current inventory management issues will be analysed at two different companies of different sizes that have not implemented blockchain technology as of yet. Opting for these companies determines the difference on the stance of implementing blockchain systems between medium-sized and large corporations. In other words, by doing this it allows this study to identify whether or not

blockchain technology is generally a viable option for untangling the previously found issues in SCM and inventory management.

Henceforth, the questions to be asked to the interviewees and the justification for asking them, have been summarised in the table below.

	Question	**Justification**
1	How are your inventories being managed momentarily and what are the bottlenecks and issues you are facing due to doing it like that?	This first question is going to assess the current bottlenecks the interviewees are facing regarding inventory management at their respective companies and will, therefore, lay the groundwork for applying blockchain to these issues.
2	Do you have an idea of what blockchain could possibly do for SCM and inventory management? And if so, how do you think it is going to solve those issues?	Logically following the previous question, this one will attempt to assess the interviewees knowledge and act according to that. The question is going to be answering whether or not blockchain could be seen as a viable option for solving inventory management's issues. Having said that, should the interviewee only have a basic knowledge of the technology, the characteristics and benefits of using blockchain will be explained briefly.
3	Do you think it is going to require a total overhaul of current business processes and models? And if so, what are the barriers that have to be overcome in order to successfully implement a blockchain system?	The previous questions have established the inventory management issues and whether or not blockchain could potentially untangle these. In consequence, it is then important to find out if it is going to require a total overhaul of current processes and what the barriers of doing so would be. Ergo, this question will establish how hard it will be for implementing a blockchain-enabled system.
4	What is your own personal stance on using a blockchain-enabled inventory management system?	The final question is going to be answering whether or not the interviewees opinion on using blockchain in a SCM or inventory management setting is in alignment with what the literature has shown. It might, therefore, be the most essential question due to the fact that it tests if blockchain is a celebrated solution for current inventory management issues.

Table 3, Justification of interview questions – Source: own elaboration

Finally, the discussion and implications of this study reflect on the potential benefits and barriers of implementing a blockchain-enabled inventory management that have been identified in the interviews and, subsequently, compare if they are consistent with the current literature and quantitative data on the same topic.

5 RESULTS

This chapter is going to focus on the two qualitative interviews that have been undertaken with the aforementioned supply chain professionals: Luc Altorf and Mike van Dongen. By doing this the stance on blockchain by experts within an inventory management setting on the work floor can be described and compared.

5.1 Interview Luc Altorf – Procurement Officer at Vlisco Netherlands

As stated before, Luc Altorf has to keep track of inventory levels in order to keep customers happy. He explained this is done by using the *Economic Order Quantity* (EOQ) inventory management method. This essentially means that products and inventories are being purchased whenever they go below a certain level. Luc Altorf described the biggest issue they are facing as follows:

> *On occasion we want to purchase more than the supplier can deliver and not having an insight into those supply levels is sometimes troublesome due to the fact that we cannot produce what we want to produce and, therefore, periodically run into production delays.*

In summary, the aforementioned means that the biggest issue they are facing is a lack of visibility across the chain in terms of inventory levels. Having said that, the interview took a turn towards applying blockchain to those issues. He elucidated that momentarily a lot of the communication is being handled over email and a lack of one overarching system that is accessible by all parties is something to be desired. However, Altorf then went on to say:

> *At the moment I essentially don't see enough issues with the current processes for blockchain to be effective. In other words, blockchain could solve the issues we found, but there are several cheaper, more effective options available that could do the trick, as well.*

Therefrom, the third question was discussed, and the interviewee explained more about the reasons why blockchain would momentarily be ineffective for Vlisco:

> *Due to the fact that the different players do not really know the benefits of blockchain, implementing it is also going to be extremely difficult. There is simply too much resistance from several parties operating on the chain and just implementing it for Vlisco's own inventory management system is going to be too much of a hassle.*

So, to put it briefly, there is not enough urgency to implement a blockchain-enabled system due to the fact that the benefits are not favourable enough. This also relates to Altorf's own stance on using blockchain-enabled inventory management system:

> *Having an insight into everyone's transactions and stock levels immensely helps in terms of transparency and efficiency, but at the moment it does not have enough added value to implement it. It simply costs too much effort to do it.*

In addition, he explained that there are not enough successful practical examples of where the technology really made a difference as of yet. However, whenever it is more widely adopted and accepted, and when businesses no longer have the ability to work around it, then it will be implemented more often. To sum up, he describes the technology as; *"Blockchain is something dubious and equivocal right now and the real potential is still only revealing itself to us."*

5.2 Interview Mike van Dongen – Strategic Buyer at Mars Netherlands

As a Strategic Buyer at Mars Netherlands, Mike van Dongen is responsible for the indirect purchases. In essence, this means that his core tasks involve hiring temporary employees, making travel arrangements for employees, and organising transport for special goods like the pumps required for the factory. This is a different kind of inventory management, because you have to keep track of the availability of the aforementioned employees and transporters. Basically, this means that he has to make sure all different players are in alignment in order to make sure there is no downtime on the factory floor.

Van Dongen started the interview by describing one of the biggest issues Mars faced during his time being employed there. Strictly speaking Van Dongen said the following:

> *Most of the employees from the purchasing department did not feel responsible for the master data of the various SKUs. Due to the fact that some prices had not been updated for the past 10 years, we ran into heaps of issues. We simply did not know how much stock we had of some items due to never updating the master data.*

Essentially, this means that a lot of the data was archaic. So, whenever new stock had to be bought based on a purchase order from the past, every specific supplier had to be contacted for not only a price, but also for a new *unit of measure* and even delivery periods. This resulted in a few unpaid invoices and unhappy suppliers. Long story short, it can be stated that Mars had somewhat of a big issue in terms of inventory and master data management. Having identified that issue, the interviewee had been asked whether or not blockchain technology could have prevented this. Therefrom, he elucidated the following:

> *Should we have had a blockchain-enabled inventory system, then we would have been able to allow our suppliers to update prices in real-time. This would have resulted in a*

considerable amount of less work and we could, therefore, have focussed on other projects. That being said, it would still have required a lot of manual work due to the fact that we needed to build a form that every supplier could fill in.

Consequently, he had been asked if implementing a blockchain-enabled system would have required a total overhaul of systems, but he did not see any big hurdles. However, when asked about if Mars actually would have done it Van Dongen described the following:

Implementing an inventory management system based on a blockchain does not have any urgency as of yet at Mars. In essence, the benefits do not necessarily outweigh the issues. Nonetheless, a blockchain system is basically a way of communicating data, which means that it does not have to be difficult to implement as long as every specific supplier can only see that which they are allowed to see.

In summary, it can be established that like Altorf before him, Van Dongen also sees blockchain as a state-of-the-art technology with a lot of potential yet without any urgency to implement. Ergo, this also shows in his stance on using the technology in general:

In order to implement blockchain, you also have to trust it, but as of now, a huge majority of the supply chain world does not trust it yet or does not see any benefits for using it. I myself am also a bit sceptical to use it. It simply is not widely adopted enough yet.

However, both qualitative interviews have now been transcribed and the opinions of both have been identified, but a cross analysis of both is going to provide an overview that can be compared with the literature. This analysis can be found below.

5.3 Cross-Analysis

The table below summarises the main points that have been ascertained from conducting the aforementioned qualitative interviews. The first row in the table is showing the biggest inventory management issues currently seen at a medium-sized and a large company. Therefrom, the potential of blockchain to solve those issues according to the experts is analysed in the second row, while the third row shows how this would have to be done and if whether or not it will be done. Finally, the personal stance from both experts is described.

	Altorf	Van Dongen
1) Biggest inventory management issue	Lack of insight into inventory/supplier data	Lack of insight into inventory/supplier data; outdated master data that has not been updated
2) Blockchain as a solution	Blockchain would work; cheaper solutions available	Blockchain would work; provides real-time updating; still a lot of work to do
3) Changes required to current systems	Employees do not know the benefits; there is no urgency; difficult to implement	Employees do not know the benefits; there is no urgency; not too difficult to implement
4) Personal stance	Blockchain provides transparency/insight; not enough added value or trust yet; not enough successful examples	Blockchain provides transparency/insight; not enough added value or trust yet; not enough successful examples

Table 4, Cross-Analysis of interviews – Source: own elaboration

Having established the aforementioned key points of the qualitative interviews, it is now imperative to compare it with the quantitative data found by Hackius & Petersen's (2017). This will make sure a generalised opinion can be compared with the stance of using the technology by experts on the work floor.

5.3.1 Discussion and implications

Firstly, it has been found that the inventory management issues elucidated by Altorf and Van Dongen are in alignment with the findings of Scorey (2018), Orchestro (2015), and Fernie & Sparks (2018). All of them describe that a lack of visibility and insight, a misalignment of data and information, and poor communication often results in inventory management problems.

Secondly, the qualitative interviews revealed valuable insights about how blockchain could be adopted in an inventory management context, while Hackius & Petersen's (2017) survey ascertained generalised insights of how that can be done. The quantitative survey revealed that more than half of the respondents are working at companies where blockchain has either already been implemented or are thinking about implementing it. Notwithstanding that, Altorf and Van Dongen's responses contradict that and this would place them in the smaller 16% group that do not want to adopt the technology momentarily. This would suggest that logisticians on the work floor have a harder time seeing the clear benefits of adopting the technology, while the respondents from the survey that are either scientists or consultants worry more about the actual technological issues of implementation. Simply put, everyone sees benefits, but the data insinuates that the urgency of implementing it is not quite present right now.

This is further proven by the fact that the survey and the interviews showcase that the vast majority sees blockchain as beneficial for inventory management, but that the benefits still have to be clearly defined in order to achieve wide adoption. Essentially, this underlines the importance of describing and finding more practical successful use cases. This, because people from the conservative supply chain and inventory management industry – like Altorf and Van Dongen – simply do not get too excited enough about something new if the old systems are still working more than alright. Furthermore, both the qualitative and the quantitative studies describe the same barriers, e.g., being unable to align parties and having a lack of acceptance across the board. The studies have also found that having access to more use cases would increase the likelihood of implementing the technology. This would once again allude to the fact that there is a lack of knowledge of blockchain across the industry.

Thirdly, Hackius & Petersen's (2017) survey and the qualitative interviews with Altorf and Van Dongen both describe the same barriers. The most common ones are the following: *not enough acceptance in the industry* and *aligning different parties is difficult*. Additionally, Altorf (2019) and Hackius & Peterson (2017) also both suggest that adopting the technology will require a radical overhaul of current systems, whilst Van Dongen (2019) does not see too many issues. Considering the former two studies were based on medium-sized companies, this implies that larger companies have a more straightforward way of adopting blockchain.

Finally, the survey indicates that the more experienced the respondents are with blockchain (e.g. those that could provide use cases as opposed to those that only see developments in the industry), the more positively they view blockchain. This signifies once again that effective blockchain-enabled inventory management systems exist, but that they are not quite well-known enough yet.

Having said all of that, one thing is certain though, the vast majority of the respondents of the survey and the two interviewees see blockchain as something that could potentially revolutionise inventory management, but momentarily there simply is a lack of successful examples.

6 CONCLUSIONS

In order to discuss the research objective – which is: *to analyse the impact of blockchain technology on inventory management systems, and to establish whether or not blockchain will warrant a total overhaul of existing inventory management systems and business processes* – a literature review and qualitative interviews have been performed. Consequently, this work has been focussing on a wide variety of papers, articles, and a quantitative study for the literature review in addition to conducting qualitative interviews with experts working in inventory management.

Thereby, the characteristics and challenges of a blockchain-enabled inventory management system have been revealed. In essence, it has been found that blockchain technology creates a collaborative, trustworthy, and decentralised system that is transparent in nature for all the participants of the chain. However, it is currently not seen as the ultimate solution for solving inventory management's current issues (e.g. a lack of visibility and insight, and a misalignment of data and information). This, due to the fact that logisticians currently only see the potential of the technology, but not the actual practical uses of it. What is more, this work has revealed that presently, there is a lack of successful use cases. Therefore, it can be stated that blockchain technology is not going to require a total overhaul of current inventory management systems and processes, but that it is expected to have an impact if it keeps developing itself and, thus, helps with the formation of new systems. That being said, the literature is not aligned with the view of the people actually using current inventory management systems. This, because there simply is not yet enough urgency for widespread adoption at the company level due to the fact that employees do not see the benefits, whilst the literature emphasises a great deal of benefits that cannot be ignored.

What is more, based on the results of this work, the managerial implications also point to the fact that blockchain might not be the leading solution for inventory management's current issues. In other words, as long as there are no successful practical use cases, looking for another workaround or solution could prove to be more useful. Essentially, this means that as of today a blockchain-enabled inventory management system solely sounds good on paper, and should, thus, only be used when businesses can no longer operate without it.

This research has contributed to the available literature on blockchain-enabled inventory management systems by providing a synthesised review on current articles and papers in addition to providing expert opinions on using the technology. The current literature only provides theoretical studies for the most part, yet this empirical work will give an insight into the view of experts currently working with more traditional systems. This is a research area that is currently lacking papers and articles.

This work is limited in the sense that it is a lacking a qualitative interview with an expert employed at a business where they have successfully implemented a blockchain-enabled inventory management system. This would have resulted in the ability to compare successful use cases

with those that do not see the benefits. What is more, momentarily, academic research is lacking on blockchain-enabled inventory management systems, which entails that a substantial amount of the references are based on articles found online. Furthermore, this work also had a time constraint, which means that it is limited in doing more qualitative interviews and quantitative surveys to achieve a broader picture of how blockchain could be applied to current inventory management systems.

Finally, as for further research, it would be of interest to assess the uses of blockchain technology in an inventory management setting. This, to provide more successful use cases that contribute to the widespread adoption of the technology. Hence, large-scale empirical studies should be conducted on existing applications areas in order to generate more insights into blockchain-enabled systems.

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